Phase 2, National Science Foundation, Industry/University Cooperative Research Center

Annual report for the period 03/01/2019 - 02/29/2020

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Accomplishments

*** What are the major goals of the project?**

The Science Center for Marine Fisheries, SCeMFiS, will provide academic research products essential for the sustainable management of shellfish and finfish resources. SCeMFiS seeks to simultaneously achieve the goals of sustainable fish and shellfish stocks and sustainable fish and shellfish fisheries. A multi-decaldal evolution in fisheries management in the U.S. has formalized the criteria for sustainability and developed sophisticated modeling tools to achieve this goal; but success is limited by insufficient information on the finfish and shellfish stocks and fisheries and insufficient development of numerical applications to surmount the modeling challenges posed by these sustainability goals. Rapid climate change continues to expose the limitations of present-day data resources and assessment, exacerbating the gap between data resource availability and data resource needs. Increasingly complex management requirements continue to reveal limitations in data resources, data analysis, and model construction, thereby limiting the attainment of maximum sustainable yield.

The attainment of the dual goals of sustainable fish stocks and sustainable fishing industries requires a dual focus on (a) the assessment process that determines the status of the stock and (b) the regulatory process that provides the vehicle by which the fishery is managed to optimize stock status while supporting a robust industry. SCeMFiS supports an academic research program encompassing both components of the management process. SCeMFiS' capabilities encompass the range of oceanographic, fisheries, and marine biological disciplines essential for addressing the data resource and analytical challenges faced by modern-day fisheries management.

*** What was accomplished under these goals?**

Major Activities:

Ongoing projects and projects completed in 2019 include the following:

1. *Biostatistical and fishery-dependent sampling of Atlantic chub mackerel*: This project examines the life-history characteristics of Atlantic Chub Mackerel, including length-at-age and weight-at-length relationships and the catch history of the commercial fishery.
2. *A meta-analysis of the impact of forage fish abundance on predator productivity:* This project evaluates the empirical link between forage fish abundance and predator productivity.
3. *Design of a cooperative winter pelagic survey for Atlantic menhaden in the Mid-Atlantic:* This project will design a cooperative winter pelagic survey for Atlantic menhaden in the Mid-Atlantic region to provide estimates of trends in abundance for the northern portion of the stock inhabiting midshelf waters during winter and early spring.
4. *Evaluation of alternative approaches to risk-based catch advice*: Time series of catch advice, implied fishing mortality limit or target, realized catch, and realized fishing mortality will be used to derive forecast error and the performance of alternative methods for risk based catch advice. Atlantic surfclam and summer flounder will be the focus of this research program.
5. *Evaluation of sampling adequacy for Atlantic menhaden fisheries*: Biological samples collected from commercial menhaden fisheries characterize the age distribution of the catch, track year classes, and estimate fishing mortality and fleet selectivity at age. This biological sampling program will be statistically evaluated to determine sampling adequacy.
6. *Ocean quahog population dynamics: validation of estimation procedures for an age-at-length key:*The range of ages at length, the skewed distribution of the number of individuals at age at length, and the variation between sites in these metrics constrain development of an age-at-length key for ocean quahogs. This project will acquire a a sufficient number of ages at length to permit creation of a standard key to develop methods of estimation from the sparse dataset that will be required for routine age-length key specification.
7. Industry profile and economic impacts associated with the commercial fishery for longfin squid (*Doryteuthis pealeii)*:This work will characterize the commercial fishing industry for longfin squid in the northwest Atlantic, occurring primarily from southern Georges Bank to Cape Hatteras.

8. *Evaluation of sampling adequacy for the Gulf of Mexico commercial menhaden reduction fishery:* Biological samples collected from commercial menhaden fisheries characterize the age distribution of the catch, track year classes, and estimate fishing mortality and fleet selectivity at age. This biological sampling program has not been statistically evaluated to determine sampling adequacy.
9. *Reproductive Biology and Fecundity of Atlantic Menhaden:*The objective of this investigation is to generate a contemporary evaluation of Atlantic menhaden reproductive biology that represents their full spatiotemporal spawning range, and yield updated estimates of fecundity.
10. *Workshop on "MSE and Statutory Objectives for Marine Mammals":*Dissemination of the recent MSE work to scientists, managers and others is needed to identify key issues and challenges for future research. The venue will be a 1-day workshop aimed at scientists, managers, and NGOs involved in marine mammal assessments and management.
11. *The influence of global warming on the Atlantic surfclam and the ocean quahog:*Recent analysis of the NEFSC ancillary database and ocean quahog age frequencies has identified issues that should be addressed related to the continued shift in range of these two clam species. Dating of shells in regions not presently inhabited will permit determination of timing of previous occupation and provide a record of historical range shifts.
12. *Analysis of dredge efficiency for ocean quahog and surfclam commercial/survey dredges:* Reliability of the stock abundance estimate is dependent on the reliability of the dredge efficiency estimate. This project will provide a focused analysis of the many depletion experiments to improve reliability of the estimates.
13. *Evaluation of gray seal-fishery interactions in US waters of the western North Atlantic*: This project will develop a cross-jurisdictional model for the purpose of allowing NMFS to better evaluate the nature and magnitude of gray seal-fishery interactions in the western North Atlantic, and recommend specific research priorities, including sample size and cost-benefit tradeoffs to improve management of gray seals in US waters.
14. *Mid-Atlantic discards analysis*: This project will develop tools in the commercial fishery to reduce bycatch and to promote understanding by the industry of the characteristics of the fishers (gear and sectors) and fishing activity (spatial and temporal patterns) that impact bycatch, focused on scup, *Loligo*, black sea bass, and summer flounder fisheries.
15. *Atlantic menhaden stock assessment review*: This project will review the ASMFC stock assessment and provide recommendations to the IAB for research.
16. *Modeling safety risks arising from offshore wind development*: Intensive offshore wind development is picking up in the Northeast Atlantic without a framework to evaluate risk to vessel operations. This project will combine spatial data sets tracking commercial fishing and shipping vessels to estimate these risks and develop a status-quo model of baseline hazards.
17. *Economic impacts of reduced uncertainty associated with fishery management actions with flounder*: A current economic impact assessment for the mid-Atlantic summer flounder fishery is not available. The objective of this proposal is to provide an economic assessment for the commercial sector of the fishery by employing modeling approaches developed previously with SCeMFiS support

for economic activity along the market chain for surfclams, ocean quahogs, and scup.

18. *Retrospective analysis of age and growth rates in Atlantic surfclams*: The moving footprint of the range of exploited surfclams in the mid-Atlantic and Georges Bank is well documented. This project proposes to develop a 33-year retrospective spatially-explicit time series of growth rates in surfclams over the surveyed range to document the changes in population productivity and to provide an explicit forward projection of future productivity.
19. *Understanding the utility of archived tag-recapture data for evaluation of movement and mortality estimation*: Because of the power of tag and recapture studies for understanding stock dynamics, the Gulf Menhaden Stock Assessment recommended replicating tagging work from 1969 to 1985. Such a study is cost prohibitive, but re-analysis of the previously collected data can provide new insights. This project will provide digital data from these tagging studies for analysis.
20. *Ocean quahog population dynamics: development of a dataset supporting use of age compositions in the assessment*: SCeMFiS supported acquisition of the first population age frequencies for ocean quahogs in the northwest Atlantic. The differential in age-frequencies among the 4 sites has spawned concern about the degree to which any site can be extrapolated regionally. This proposal will address the issue and focus on NJ because the influence of MAB warming is greatest there.
21. *Evaluation of the degree of co-occurrence of surfclams and ocean quahogs at fishable concentrations*: Warming of the Mid-Atlantic continental shelf has initiated a range shift such that an ecotone now exists over much of the offshore range of the surfclam and ocean quahog wherein both are jointly found. Regulations prohibit the landing of the two species simultaneously. Fishingin these areas may unduly increase discards and increase the cost of fishing. The extent of the problem needs to be specified before potential mechanisms to address the present joint-species landing prohibition can be sought.

Specific Objectives:

The objective of this project is to expand an I/UCRC center focused on marine fisheries, the Science Center for Marine Fisheries or SCeMFiS, and to fulfill the mission and goals of that center. The bylaws establish the mission under which the IAB operates.

Vision Statement: SCeMFiS will provide academic research products essential for the sustainable management of shellfish and finfish resources. SCeMFiS seeks to simultaneously achieve the goals of sustainable fish and shellfish stocks and sustainable fish and shellfish fisheries. A multi-decadal evolution in fisheries management in the U.S. has formalized the criteria for sustainability and developed sophisticated modeling tools to achieve this goal; but success is limited by insufficient information on the finfish and shellfish stocks and fisheries and insufficient development of numerical applications to surmount the modeling challenges posed by these sustainability goals. Rapid climate change continues to expose the limitations of present-day data resources and assessment, exacerbating the gap between data resource availability and data resource needs. Increasingly complex management requirements continue to reveal limitations in data resources, data analysis, and model construction, thereby limiting the attainment of maximum sustainable yield. The attainment of the dual goals of sustainable fish stocks and sustainable fishing industries requires a dual focus on (a) the assessment process that determines the status of the

stock and (b) the regulatory process that provides the vehicle by which the fishery is managed to optimize stock status while supporting a robust industry. SCeMFiS supports an academic research program encompassing both components of the management process. SCeMFiS' capabilities encompass the range of oceanographic, fisheries, and marine biological disciplines essential for addressing the data resource and analytical challenges faced by modern-day fisheries management.

Mission Statement: SCeMFiS utilizes academic, recreational and commercial fishery resources to address urgent and emerging scientific problems that could limit sustainable fisheries. SCeMFiS provides academic research products with a goal of enhancing efficient management of shellfish and finfish resources. SCeMFiS provides scientific research products essential in enhancing awareness of the health benefits of sustainable seafood as well as increasing opportunities for valued growth within seafood business sectors.

Research Focus: The science agenda of SCeMFiS includes the development of essential biological data on fish stocks, including fecundity, age structure, and sources of mortality; support for cooperative surveys and survey augmentation needs; improved models of sampling design, population dynamics, habitat, and fishery performance; evaluation of geographic and depth variations in stock structure and how these relate to the genetics, physiology and sexual dimorphism of species; improved approaches to fishing to limit discard reduction through gear innovation, but also through modifications in fleet deployment consistent with oceanographic processes; development of improved sustainability criteria and evaluation of sustainability; improved assessment model formulations to better integrate available data; and refined approaches to establishing biological reference points.

Significant Results: A status report for selected funded projects follows.

1. *Biostatistical and fishery-dependent sampling of Atlantic chub mackerel*: Data were collected from all companies landing these fish over the last four years. Analyses of length at age and other demographic data were collected. SCeMFiS scientists participated in a 2017 international inter-calibration exercise for ageing chub mackerel. In addition, historical data from the companies and from NMFS were obtained.
2. *A meta-analysis of the impact of forage fish abundance on predator productivity:* Diet information has been assembled for predators to identify key forage fish prey species for each predator. Time series data of forage fish biomass and predator surplus production have been obtained and fit to a hierarchical Bayesian surplus production model with a forage fish term to determine the impact of forage fish on predator productivity.
3. *MSE of fishery management for US marine mammal conservation;*MSE results show that the ability to achieve conservation goals depends on the demographics of the species being managed. The error rates for identifying a stock as strategic were low, but may result from the assumption "once strategic, always strategic". The errors classifying fisheries may be high, particularly for borderline cases. Simulations suggest such errors are mainly between categories I-II that trigger equivalent management actions.
4. *Design of a cooperative winter pelagic survey for Atlantic menhaden in the Mid-Atlantic:*A survey design simulator was developed. Root mean square error (RMSE) estimation of simulated biomass shows that, in general, as the number of

transects goes up, error goes down. The more menhaden schools on the landscape, the smaller the population variance and smaller resulting RMSE. A traditional systematic survey design-based estimator was compared to a ratio estimator that considered the unequal lengths of the transects (and thus the corresponding survey area). The ratio estimator performed better.

5. *Evaluation of alternative approaches to risk-based catch advice*: The surfclam assessment dataset has been implemented in the newest version of Stock Synthesis and a series of simulations run to provide an evaluation of the risk of overfishing and the generation of an overfished stock under a series of management options. Work is beginning on the summer flounder assessment model which will also be implemented using Stock Synthesis.
6. *Evaluation of sampling adequacy for Atlantic menhaden fisheries*: Bait fishery sampling is adequate to characterize mean weight. For the reduction fishery, sampling is also adequate. CVs are lower than for the bait fishery, and reasonable for ages 1-2; Age 4 fish are better sampled by the bait fishery. Analyses have been provided to the NMFS stock assessment team.
7. *Ocean quahog population dynamics: validation of estimation procedures for an age-at-length key:*Field collection occurred in August 2017 with ship time supported by NEFSC. About 2,000 clams have been aged. A age-length key simulator has been developed to examine options for assessing new locations using a much sparser dataset. Substantial differences have been observed in the size at age for males and females, indicating the need to generate sex-specific keys
8. *Industry profile and economic impacts associated with the commercial fishery for longfin squid (Doryteuthis pealeii):*All data have been gathered and economic analysis completed and sent out for peer review.
9. *Evaluation of sampling adequacy for the Gulf of Mexico commercial menhaden reduction fishery:* Current sampling has proven to be adequate for ages 1 and 2. Sampling is adequate for age 3 at two sites. Age 4s are highly uncertain. In general sampling is adequate to characterize mean weight.
10. *Reproductive Biology and Fecundity of Atlantic Menhaden:*This project has been completed. A final report is listed on the SCeMFiS website.
11. *Workshop on "MSE and Statutory Objectives for Marine Mammals":*The workshop was held in Warwick, RI in October 2018. 25 participated including those from NEFSC, GARFO, Atlantic SRG, Marine Mammal Commission, DFO. A series of research recommendations was made. Participants rated the workshop as highly useful.
12. *The influence of global warming on the Atlantic surfclam and the ocean quahog:*In August, sampling was conducted inshore of the present range of the ocean quahog from New Jersey to Delmarva and "fossil" ocean quahogs were collected at a number of stations. A selection of these have been submitted for C-14 dating to determine the time-since-death of these clams.
13. *Analysis of dredge efficiency for ocean quahog and surfclam commercial/survey dredges:*All depletion datasets have been acquired. The Patch model has been updated and a simulation model implemented in R. Final simulation results have been used to evaluate the adequacy of in-field depletion experiments. About one-third have been found wanting As a result, estimated dredge efficiency has been raised to about 70%, as most questionable experiments provided low efficiency estimates.
14. *Evaluation of gray seal-fishery interactions in US waters of the western North Atlantic*: This project is new.

15. *Mid-Atlantic discards analysis*: This project is new.
16. *Atlantic menhaden stock assessment review*: This project review is complete and the report posted on the SCeMFiS website.
17. *Modeling safety risks arising from offshore wind development*: This project is new.
18. *Economic impacts of reduced uncertainty associated with fishery management actions with flounder*: This project is new.
19. *Retrospective analysis of age and growth rates in Atlantic surfclams*: The entire dataset of aged surfclams has been obtained from the NEFSC. A reader inter-calibration exercise has been undertaken. Initial estimates of growth rates show changes over time consistent with Mid-Atlantic warming and its effect on surfclam physiology.
20. *Understanding the utility of archived tag-recapture data for evaluation of movement and mortality estimation*: This project is new.
21. *Ocean quahog population dynamics: development of a dataset supporting use of age compositions in the assessment*: More than 1,500 ocean quahogs have been acquired from two locations on the New Jersey continental shelf. These animals have been shucked and sexed. Preparation for ageing is underway.
22. *Evaluation of the degree of co-occurrence of surfclams and ocean quahogs at fishable concentrations*: The NEFSC survey database has been analyzed to obtain locations where the survey vessel caught significant numbers of both species in the 2016-2019 period. Maps of these locations have been produced and are being used in interviews of clam fishery vessel captains in order to expand the footprint for a survey planned for July 2020.

Key outcomes or Other achievements:

- SCeMFiS was funded for Phase II.
- The Industry Advisory Board (IAB) of SCeMFiS met twice, in April and in November 2019, and convened by conference call in January and July, 2010.
- SCeMFiS scientists participated in the assessment of Atlantic menhaden and provided important new information on sampling sufficiency and reproductive biology in support of the ASMFC and GSMFC assessments for Atlantic and Gulf menhaden, respectively.
- SCeMFiS scientists participated in a review of the new surfclam and ocean quahog stock survey. This new survey design development was partially supported by SCeMFiS funding. The review included provision of new information developed by SCeMFiS scientists on the relationship of broodstock and recruitment in surfclams and the age frequency of ocean quahogs.
- Presentations on SCeMFiS research were given at meetings of the National Shellfisheries Association, the American Fisheries Society, the ICES Symposia, the Eastern Pacific Ocean Conference, CERF, the Fifth International Sclerochronology Conference, and at a number of Federal Council and Committee venues, a total of 12 presentations in all. Eight papers were published in peer-review journals. In addition, SCeMFiS organized a workshop to consider the use of MSE in marine mammal assessments attended by a wide range of academic, federal, and non-profit scientists and administrators.
- The IAB developed the science agenda for Year 1 of Phase II at its April and October meetings. All projects are currently underway with final reports expected in 2020. These projects expanded SCeMFiS funding footprint with collaborating scientists from University of Washington, University of Massachusetts-Dartmouth, Rutgers University, University of Maryland, University of Rhode Island, and three U.S. and one Canadian private organizations.
- In 2019, SCeMFiS supported 22 research projects. Of these, over half (12) were

collaborative and involved researchers from more than one research institution.

- In addition to membership fees, SCeMFiS scientists received three REU supplements, 1 VRS supplement, and 2 Non-Academic Research Internships for Graduate Students.
- For the second year in a row, a SCeMFiS graduate student won a prestigious Knauss Fellowship. The NOAA Sea Grant Knauss Fellowship provides a unique educational and professional experience to graduate students who have an interest in ocean, coastal and Great Lakes resources and in the national policy decisions affecting those resources. The Fellowship matches highly qualified graduate students with "hosts" in the legislative and executive branch of government located in the Washington, D.C. area for a one year paid fellowship. This application was supported by IAB members.
- SCeMFiS co-PIs include 4 members of NMFS Scientific and Statistical Committees. Their service on these committees extends the reach of the center's research and enhances the center's ability to act strategically in response to changes in fisheries policy.
- SCeMFiS scientists and collaborators received $500,000 from BOEM to study the influence of wind energy development off the U.S. east coast on the surfclam fishery. This project will use SEFES (Spatially-explicit Fishery Economics Simulator), a model developed through SCeMFiS funding.
- SCeMFiS compiled the following Public Relations Report for 2019
  - 2019 marked the first full year that SCeMFiS included a public relations element into its operations. The goals were to introduce SCeMFiS to a wider audience and to highlight the unique work being done by Center-funded scientists.
  - The first press release of the year announced the Phase II partnership between NSF and SCeMFiS. This release provided an opportunity to explain the unique structure of the Center and to promote the support from NSF as a component of the legitimacy of SCeMFiS-funded research.

Science Center for Marine Fisheries Continues Work with New National Science Foundation Grant (January 23, 2019)

- SCeMFiS members' participation in Seafood Expo North America – a major trade show held annually in Boston, MA – provided a news hook to once again explain SCeMFiS, its work, and its foundation as a partnership between industry and science.

SCeMFiS Members Attend Seafood Expo North America Following Second National Science Foundation Grant (March 15, 2019)

- The biggest press hit of the year came from promoting a recently completed report from the University of Southern Mississippi and the Virginia Institute of Marine Science which concluded that surfclams were adapting to rising ocean temperatures in a way that was previously unknown. Due to increased public interest in climate issues, the report was picked up by several media outlets, including National Fisherman and Seafood News.

New Study Finds Surfclams Uniquely Resilient in Face of Climate Change (June 19, 2019)

- SCeMFiS also used the awarding of two prestigious research internships to Center researchers as another opportunity to highlight the partnership with NSF.

National Science Foundation Awards two Prestigious Research Internships to SCeMFiS Graduate Students (August 22, 2019)

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

Nine graduate students and 4 undergraduates participated in SCeMFiS projects. Thesis/dissertation research is being conducted on chub mackerel and other forage fish as part of the forage fish research focus, ageing of ocean quahogs to provide data for the age-length key development project,surfclam and ocean quahog dredge calibration and surfclam/summer flounder risk assessment, both intensive modeling projects in support of improved NMFS assessments, the influence of global warming on surfclam growth rates, and the reproductive physiology of black sea bass. Four REU/VRSs were obtained, two to work on the effects of global warming on surfclam and ocean quahog growth and distribution, one to work on menhaden projects, and one to work on the chub mackerel project. Two Non-Academic Research Internships for Graduate Students were obtained. Both graduate students will begin working at the NEFSC in 2020.

*** How have the results been disseminated to communities of interest?**

Participation in NMFS working groups has provided venues for dissemination to the management and regulatory communities encompassed by the NMFS-NEFSC and MAFMC (Mid-Atlantic Fisheries Management Council). Four SCeMFiS scientists serve on Council Scientific and Statistical Committees (SSC), providing additional entrée of data into the management process. Presentations at meetings of the American Fisheries Society, the National Shellfisheries Association, ICES, CERF, and other meetings, as well as to assessment staff of the NEFSC, ASMFC, and GSMFC provide outreach to a range of academic and federal scientists. SCeMFiS updated its webpage providing public access to all final reports and links to all publications. SCeMFiS continued a relationship with Stove Boat, a fisheries-targeted public relations firm to increase dissemination of SCeMFiS findings to the public at large, with an emphasis on those associated with commercial fisheries and its management. A summary of Stove Boat’s activities is found in a preceding portion of this report. Finally, the IAB assigned an IAB liaison to each project to provide frequent contact and information transfer between the PIs and the IAB. In addition, project status has been discussed frequently via emails and conference calls between the IAB and the PIs. Members of the IAB have met frequently with SCeMFiS scientists.

Upon approval from the IAB, work began in spring 2019 for the SCeMFiS website to receive a major architectural revision. SCeMFiS.org was originally built on an html platform and appeared dated. It also did not provide a responsive design for popular handheld devices such as tablets or smartphones. Responsive design applies flexible layouts that detect the visitor's screen size and orientation and changes the layout according to the device being used. In addition, the html platform did not support a dual private login for IAB members as well as a separate private login page for researchers. After investigating various platforms and designs, extensive work was completed internally to convert the site to a Word Press platform. This correspondingly included training the webmaster in Word Press development via online tutorials. Making modifications internally saved SCeMFiS from hiring an external web design firm that would have charged several thousand dollars to design a new site. Currently, review is underway for minor adjustments to content, link paths, improvements in loading speed and search engine optimization. The new site will be formally introduced to the IAB during the January 27, 2020 conference call. Costs associated with SCeMFiS.org should also decrease because Word Press exclusive hosting is less expensive and revisions are not dependent upon web design software. SCeMFiS.org now has a modern look, provides better functionality, and can be modified anywhere there is an internet connection.

*** What do you plan to do during the next reporting period to accomplish the goals?**

SCeMFiS is working well. A proposed expansion of the SCeMFiS mission to include product development has been submitted to NSF for review by the IAB, and has been approved. This should result in increased project financing and increased membership in 2020.

Journals or Juried Conference Papers

View all journal publications currently available in the NSF Public Access Repository for this award.

The results in the NSF Public Access Repository will include a comprehensive listing of all journal publications recorded to date that are associated with this award.

Daley, Taylor T. and R.T. Leaf. (2019). Age and growth of Atlantic chub mackerel (*Scomber colias*) in the Northwest Atlantic. *Journal of Northwest Atlantic fishery science*. 50 1-12. Status = Deposited in NSF-PAR doi:doi:10.2960/J.v50.m717 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Kuykendall, Kelsey M., E.N. Powell, J.M. Klinck, P.T. Moreno, and R.T. Leaf (2019). The effect of abundance changes on a management strategy evaluation for the Atlantic surfclam (*Spisula solidissima*) using a spatially explicit, vessel- based fisheries model. *Ocean and coastal management*. 169 68-85. Status = Deposited in NSF-PAR doi:https://doi.org/10.1016/j.ocecoaman.2018.11.008 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Liang, Dong, G.M. Nesslage, and M.J. Wilberg. (2020). A spatial simulation approach to hydroacoustic survey design: A case study for Atlantic menhaden. *Fisheries research*. 222 105402. Status = Deposited in NSF-PAR doi:https://doi.org/10.1016/j.fishres.2019.105402 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Timbs, J.R., E.N. Powell, and R. Mann. (2019). Changes in the spatial distribution and anatomy of a range shift for the Atlantic surfclam *Spisula solidissima* in the Mid-Atlantic Bight and on Georges Bank. *Marine ecology*. 620 77-97. Status = Deposited in NSF-PAR doi:https://doi.org/10.3354/meps12964 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Powell, Eric N. (2019). The intermingling of benthic macroinvertebrate communities during a period of shifting range: The “East of Nantucket” Atlantic Surfclam Survey and the existence of transient multiple stable states. *Marine ecology*. Status = Deposited in NSF-PAR doi:DOI: 10.1111/maec.12546 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Cadrin, Steven X. (2019). "So, where do you come from?" The impact of assumed spatial population structure on estimates of recruitment. *Fisheries research*. 217 156-186. Status = Deposited in NSF-PAR doi:https://doi:10.1016/j.fishres.2018.11.030 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Leaf, Robert T. (2019). Construction and evaluation of a robust trophic network model for the northern Gulf of Mexico ecosystem. *Ecological informatics*. 50 13-23. Status = Deposited in NSF-PAR doi:https://doi.org/10.1016/j.ecoinf.2018.12.005 ; Federal Government's License = Acknowledged. (Completed by Mann, Roger on 03/01/2020) Full text Citation details

Other Conference Presentations / Papers

Mann, R., E.N. Powell, J.M. Klinck, S. Pace, C.M. Long, T. Redmond, and K. Russell. (2019). "*A 250 year chronology of Arctica islandica in the Mid-Atlantic region of the US continental shelf.*" 5th sclerochronology conference. Split, Croatia. Status = OTHER; Acknowledgement of Federal Support = Yes

Long, M.C., S. Pace, R. Mann, E.N. Powell, and T. Redmond. (2019). "*A multi-decade record of increasing growth rates in a Mid-Atlantic population of ocean quahogs.*" 5th sclerochronology conference. Split, Croatia. Status = OTHER; Acknowledgement of Federal Support = Yes

Russell, K., M.C. Long, T. Redmond, S. Pace, R. Mann, and E.N. Powell. (2019). "*Can we discern major meteorological and environmental events in the growth record of the long lived clam Arctica islandica?*" National Shellfisheries Association. New Orleans LA. Status = OTHER; Acknowledgement of Federal Support = Yes

Long, M.C., and R. Mann. (2019). "*Collections of Young Ocean Quahogs: Lessons learned from from the Newest Recruits of the World's Longest-Living Metazoan*." National Shellfisheries Association. New Orleans LA. Status = OTHER; Acknowledgement of Federal Support = Yes

Hemeon, K.M., E. N. Powell, R. Mann, and M.C. Long. (2019). "*Ocean Quahog Population Age-Frequency Estimates Through Region Specific Age-Length Key probabilities and Model Simulation*." National Shellfisheries Association. New Orleans LA. Status = OTHER; Acknowledgement of Federal Support = Yes

Poussard, L., E. Powell, and D. Hennen. (2019). *"An analysis of dredge efficiency for ocean quahog and surfclam commercial dredges."*. CERF 2019. Mobile AL. Status = OTHER; Acknowledgement of Federal Support = Yes

Poussard, L., E. Powell, and D. Hennen. (2019). *"Analysis of dredge efficiency for ocean quahog and surfclam commercial dredges."* Aquaculture 2019. New Orleans, LA. Status = OTHER; Acknowledgement of Federal Support = Yes

Solinger, L., C. Friedman, E. Hofmann, E. Powell, J. Klinck, L. Poussard, and K. Hemeon. (2019). "*Development of a generalized transmission and proliferation model for withering syndrome for species of farmed and wild abalone.*" Eastern Pacific Ocean Conference. Lake Tahoe, Nevada. Status = OTHER; Acknowledgement of Federal Support = Yes

Hemeon, K., E. Powell, R. Mann, T. Redmond, and S. Pace. (2019). *"First data-rich age-frequency distributions for the ocean quahog and optimized sample-size delection using age-frequency simulator."* CERF 2019. Mobile AL. Status = OTHER; Acknowledgement of Federal Support = Yes

Powell, E.N., K.M. Kuykendall, R. Mann, and S.M. Pace. (2019). *"The warming of the northwest Atlantic as recorded by the ocean quahog Arctica islandica and the Atlantic surfclams Spisula solidissima."* Aquaculture 2019. New Orleans, LA. Status = OTHER; Acknowledgement of Federal Support = Yes

Solinger, L., E. Powell, D. Hennen, and S. Cadrin. (2019). *"Using simulation testing to guide risk-based management of Atlantic surfclam (Spisula solidissima)."* CERF 2019. Mobile, AL. Status = OTHER; Acknowledgement of Federal Support = Yes

Powell, E., R. Mann, and S. Pace. (2019). *"Warming of the northwest Atlantic as recorded by ocean quahogs and Atlantic surfclams."* CERF 219. Mobile AL. Status = OTHER; Acknowledgement of Federal Support = Yes

Technologies or Techniques

SCeMFiS scientists produced the first population age frequencies for ocean quahogs in the northwest Atlantic more than doubling the number available worldwide. Ocean quahogs are the oldest living non-colonial animals with ages often exceeding 250 years. They are also a biomass dominant and support one of the largest shellfish fisheries. Understanding age frequency and thus recruitment dynamics is critical for managing this remarkable resource. In order to accomplish this, SCeMFiS scientists have developed an improved method for ageing clams. SCeMFiS has submitted this project for an NSF Breakthrough Award. The hinge region of each clam is photographed using a high-definition Olympus DP73 digital microscope camera using the Olympus CellSens microscope imaging software. This software permits photographs of the hinge region to be captured at a resolution high enough to distinguish annual growth lines without the use of a stain or acetate peel. The individual images are then stitched together automatically by the imaging software and each annual growth

line recorded using the ObjectJ plugin in the software ImageJ. As a consequence, SCeMFiS has now aged more ocean quahogs than the cumulative number aged by all previous researchers, U.S. and foreign.

In 2019 SCeMFiS began a series of studies designed to examine the influence of wind energy development on U.S. east-coast fisheries and vessel transit. Among these is the acquisition of $500,000 in support from BOEM based on the application of SEFES, a fisheries simulator developed and originally implemented by SCeMFiS, to the question of wind energy development and its influence on the surfclam fishery. As of this writing, this model has also been chosen by the Sea Scallop Research Set-aside Program for the evaluation of wind energy development on the sea scallop fishery. SEFES (Spatially-explicit Fishery Economics Simulator) is an individual-based model of a temporally and spatially variable stock harvested by a fleet of commercial vessels. The primary model is written in Fortran 90 with postprocessing in MatLab and statistical analysis using SAS (SAS Institute Inc., Cary, NC). SEFES is a unique model in incorporating vessel specific and captain specific behaviors in evaluating fishery performance.

SCeMFiS developed a depletion model simulator to evaluate performance of depletion experiments used to calibrate survey dredges. The Simulation Model allows the dredge with an assigned efficiency to catch clams in its path. These data are fed into a model previously available, the Patch Model, that uses the catch per tow data generated from the simulated depletion experiment to estimate gear efficiency, clam distribution, and clam density in the area. The Simulation Model allows for various inputs to be treated as predictors of model performance by examining the effects of initial stock abundance, distribution, and fishing behavior on stock removal and Patch Model efficiency estimates. The Simulation Model allows for the adjustment of factors some of which are normally unalterable or difficult to evaluate in designing an actual field experiment. Normally, the distribution and density of organisms on the bottom is unknown, for example. Dredge tow paths can be partly, but not completely controlled as tide and wind conditions affect vessel performance. The number of tows required is not known *a priori*. Results will be used to evaluate field experiment performance by comparing descriptive metrics derived from the simulation model and the field experiment.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Mann, Roger	PD/PI	5
Powell, Eric	Co-Investigator	5
Cadrin, Steve	Faculty	1
Jensen, Olaf	Faculty	1
Latour, Rob	Faculty	1
Leaf, Robert	Faculty	1
Scheld, Andrew	Faculty	1

Sproul, Tom	Faculty	1
Weir, Michael	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Pace, Sara	Other Professional	6
Otto, Nathan	Technician	4
Price, Kasea	Technician	6
Redmond, Theresa	Technician	6
Gartland, James	Graduate Student (research assistant)	3
Hemeon, Kathleen	Graduate Student (research assistant)	6
Hollander, Alexis	Graduate Student (research assistant)	6
Poussard, Leanne	Graduate Student (research assistant)	6
Solinger, Laura	Graduate Student (research assistant)	6
DeMaster, Doug	Consultant	1
Moreno, Paula	Consultant	1
Murray, Tom	Consultant	1
Reay, Karen	Consultant	4
Russell, Khalil	Research Experience for Undergraduates (REU) Participant	8

Full details of individuals who have worked on the project:

Roger L Mann
Email: rmann@vims.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 5

Contribution to the Project: Site Director and project PI

Funding Support: Virginia Institute of Marine Science

International Collaboration: No
International Travel: No

Eric Powell
Email: eric.n.powell@usm.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 5

Contribution to the Project: Director, SCeMFiS

Funding Support: USM and NSF

International Collaboration: No
International Travel: No

Steve Cadrin
Email: scadrin@umass.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: PI on fish assessment projects

Funding Support: NSF

International Collaboration: No
International Travel: No

Olaf Jensen
Email: olaf.p.jensen@gmail.com
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: PI and researcher on finish projects

Funding Support: NSF

International Collaboration: No
International Travel: No

Rob Latour
Email: latour@vims.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: PI on mackerel project

Funding Support: NSF and Virginia Institute of Marine Science

International Collaboration: No
International Travel: No

Robert Leaf
Email: Robert.Leaf@usm.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: PI on fish projects

Funding Support: NSF and USM

International Collaboration: No
International Travel: No

Andrew Scheld
Email: scheld@vims.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: PI on squid economics projects

Funding Support: NSF

International Collaboration: No
International Travel: No

Tom Sproul
Email: sproul@uri.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: PI on fish assessment project

Funding Support: NSF

International Collaboration: No
International Travel: No

Michael Weir
Email: mweir@uri.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: working on risk assessment project

Funding Support: NSF and URI

International Collaboration: No
International Travel: No

Sara Pace
Email: Sara.Pace@usm.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 6

Contribution to the Project: project management and clam projects

Funding Support: NSF and USM

International Collaboration: No
International Travel: No

Nathan Otto
Email: nkotto@vims.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 4

Contribution to the Project: technician working on clam age projects

Funding Support: NSF and Virginia Institute of Marine Science

International Collaboration: No
International Travel: No

Kasea Price
Email: Kasea.Price@usm.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 6

Contribution to the Project: working on clam age project

Funding Support: USM and NSF

International Collaboration: No
International Travel: No

Theresa Redmond
Email: terobitaille@vims.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 6

Contribution to the Project: technician on clam projects

Funding Support: NSF and Virginia Institute of Marine Science

International Collaboration: No
International Travel: No

James Gartland
Email: jgartlan@vims.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: graduate student on mackerel project

Funding Support: NSF and Virginia Institute of Marine Science

International Collaboration: No
International Travel: No

Kathleen Hemeon
Email: Kathleen.Hemeon@usm.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: working on clam age model project

Funding Support: USM and NSF

International Collaboration: No
International Travel: No

Alexis Hollander
Email: ahollander@vims.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: graduate student working on surf clam age project

Funding Support: NSF

International Collaboration: No
International Travel: No

Leanne Poussard
Email: Leanne.Possard@usm.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: graduate student working on clam dredge efficiency project

Funding Support: USM and NSF

International Collaboration: No
International Travel: No

Laura Solinger
Email: laura.solinger@usm.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: working on assessment projects

Funding Support: NSF and USM

International Collaboration: No
International Travel: No

Doug DeMaster
Email: doug.demaster@gmail.com
Most Senior Project Role: Consultant
Nearest Person Month Worked: 1

Contribution to the Project: consultant on marine mammal projects

Funding Support: NSF

International Collaboration: No
International Travel: No

Paula Moreno
Email: Paula.Moreno@usm.edu
Most Senior Project Role: Consultant
Nearest Person Month Worked: 1

Contribution to the Project: researcher on marine mammal project

Funding Support: NSF

International Collaboration: No
International Travel: No

Tom Murray
Email: tjm@vims.edu
Most Senior Project Role: Consultant
Nearest Person Month Worked: 1

Contribution to the Project: PI on finish economics project

Funding Support: NSF

International Collaboration: No
International Travel: No

Karen Reay
Email: kreay@vims.edu
Most Senior Project Role: Consultant
Nearest Person Month Worked: 4

Contribution to the Project: web design

Funding Support: NSF

International Collaboration: No
International Travel: No

Khalil Russell
Email: ktrussel@email.wm.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 8

Contribution to the Project: REU working on clam age project

Funding Support: NSF and VIMS

International Collaboration: No
International Travel: No
Year of schooling completed: Sophomore
Home Institution: William & Mary
Government fiscal year(s) was this REU participant supported: 2018

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Atlantic Cape Fisheries, INC	Industrial or Commercial Firms	Cape May, NJ
Bumble Bee Foods	Industrial or Commercial Firms	Cape May NJ
Surfside Seafood	Industrial or Commercial Firms	Port Norris NJ
Town Dock/Seafreeze Ltd	Industrial or Commercial Firms	Narragansett RI & Kingston RI
Garden State Seafood Association	Industrial or Commercial Firms	Washington DC
Lamonica Fine Foods	Industrial or Commercial Firms	Millville NJ
Lunds Fisheries INC	Industrial or Commercial Firms	Cape May NJ
NFI clam committee	Industrial or Commercial Firms	Easton MD

NFI monitoring committee	Industrial or Commercial Firms	Cape May NJ
NMFS-NEFSC	Industrial or Commercial Firms	Woods Hole MA
Omega Protein	Industrial or Commercial Firms	Houston TX
Sea Watch International	Industrial or Commercial Firms	Easton MD

Full details of organizations that have been involved as partners:

Atlantic Cape Fisheries, INC

Organization Type: Industrial or Commercial Firms
Organization Location: Cape May, NJ

Partner's Contribution to the Project:
Financial support
Facilities
Collaborative Research

More Detail on Partner and Contribution:

Bumble Bee Foods

Organization Type: Industrial or Commercial Firms
Organization Location: Cape May NJ

Partner's Contribution to the Project:
Financial support

More Detail on Partner and Contribution: IAB member

Garden State Seafood Association

Organization Type: Industrial or Commercial Firms
Organization Location: Washington DC

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

Lamonica Fine Foods

Organization Type: Industrial or Commercial Firms
Organization Location: Millville NJ

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

Lunds Fisheries INC

Organization Type: Industrial or Commercial Firms
Organization Location: Cape May NJ

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

NFI clam committee

Organization Type: Industrial or Commercial Firms
Organization Location: Easton MD

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

NFI monitoring committee

Organization Type: Industrial or Commercial Firms
Organization Location: Cape May NJ

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

NMFS-NEFSC

Organization Type: Industrial or Commercial Firms
Organization Location: Woods Hole MA

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

Omega Protein

Organization Type: Industrial or Commercial Firms
Organization Location: Houston TX

Partner's Contribution to the Project:
Financial support

More Detail on Partner and Contribution:

Sea Watch International

Organization Type: Industrial or Commercial Firms
Organization Location: Easton MD

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

Surfside Seafood

Organization Type: Industrial or Commercial Firms
Organization Location: Port Norris NJ

Partner's Contribution to the Project:
Financial support
Collaborative Research

More Detail on Partner and Contribution:

Town Dock/Seafreeze Ltd

Organization Type: Industrial or Commercial Firms
Organization Location: Narragansett RI & Kingston RI

Partner's Contribution to the Project:
Financial support

More Detail on Partner and Contribution:

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The project has gelled a unique coalition of academic scientists, federal agencies, and private sector companies and organizations focused on improving the sustainable management of federal finfish and shellfish stocks. The research portfolio for the first six years represents a range of basic and applied research focused on data collection issues, assessment issues, and management issues. This eclectic portfolio is precisely the range of project components envisioned when the Center was established.

SCeMFiS research supported the establishment of a Survey Design Working Group that for the first time provided recommendations for the improvement in the federal surfclam and ocean quahog surveys. As part of this effort, SCeMFiS consultants provided a R statistical package to aid in the evaluation of survey stratification and sample allocation plans. This new survey design was implemented in 2018 and continued forward. This is the first major survey redesign since 1980. The R package has since been used to improve stratification of oyster stock assessment surveys in the Virginia Chesapeake Bay and is being considered for surveys of birds in terrestrial systems

The development of the first age frequencies for ocean quahogs permits evaluation of long-term recruitment trends, thereby addressing the primary concern of the MAFMC Science and Statistical Committee limiting the allowable biological catch for ocean quahogs. A new forage fish emphasis has addressed the perception that forage fish quotas should be reduced to protect ecosystem services provided by these fish. Projects include addressing predator-prey relationships, documenting for the first time basic population dynamics characteristics for chub mackerel, and development of a new survey design for Atlantic menhaden. The menhaden program has expanded to examine the effectiveness of dock-side monitoring of catch for both Atlantic and Gulf menhaden, and under present funding will provide important information on reproductive stage for Atlantic menhaden, menhaden movement and mortality from analysis of tagging data, all data necessary for improved assessment of the species. Recent analysis of long-term data not heretofore examined on the distribution of surfclam and ocean quahog shells and complex habitat provide additional support for species range shifts offshore into deeper water in the Mid-Atlantic region as global warming proceeds. Development of a juvenile growth rate versus birth date for ocean quahogs has demonstrated increasing growth rates since circa 1800 in keeping with Mid-Atlantic warming. Implications include dramatic increases in stock rebuilding potential and the potential use of ocean quahogs as a bottom water proxy.

In 2019, SCeMFiS carried out a re-evaluation of the dredge depletion experiments used to calibrate the NEFSC survey dredge. The catch efficiency correction is a singular source of uncertainty in the surfclam and ocean quahog assessments. Significantly, the NMFS and industry have invested millions of dollars over the 1997-2011 period to develop the present database, but it has not been rigorously evaluated. SCeMFiS scientists developed a depletion model simulator and interfaced it with the Patch model developed by the NEFSC to analyze depletion experiments. This has resulted in identification of a core group of experiments yielding the best estimate of dredge efficiency for use in the assessment of the status of the stock for the two species.

In 2019 SCeMFiS began a series of studies designed to examine the influence of wind energy development on U.S. east-coast fisheries and vessel transit. Among these is the acquisition of $500,000 in support from BOEM based on the application of SEFES, a fisheries simulator developed and originally implemented by SCeMFiS, to the question of wind energy development and its influence on the surfclam fishery. As of this writing, this model has also been chosen by the Sea Scallop Research Set-aside Program for the evaluation of wind energy development on the sea scallop fishery

Detailed instantiations include the following.

The Atlantic and Gulf menhaden have recently been defined to be sustainable by the prestigious Marine Stewardship Council. This species joins other species receiving research support from SCeMFiS, namely Atlantic surfclam, ocean quahog, and longfin squid, that have received MSC certification. Such certifications position SCeMFiS member companies competitively by permitting an MSC label to be used in marketing products.

SCeMFiS provided information on growth rates for ocean quahogs show that growth rates have been increasing consistently since 1800 as the Mid-Atlantic warms. This finding has two important implications. First, the rebuilding capacity for this species has dramatically increased, lessoning the danger posed from overfishing (which is not now occurring). Second, a key problem in modeling climate change is the absence of bottom water temperature information to verify (and parameterize) hydrodynamic models. Good records do not exist prior to the last quarter of the twentieth century. Ocean quahogs provide promise of a unique bottom water proxy for the last ~250 years covering a substantial fraction of the northeastern U.S. continental shelf.

SCeMFiS scientists have developed the first demographic data for the chub mackerel fishery in the western North Atlantic. This fishery is sensitive due to the lack of a fisheries management plan and stock assessment, both resultant from the absence of basic demographic data. This program provided supporting data that permitted the Mid-Atlantic Fishery Management Council to approve an amendment to add Atlantic chub mackerel (*Scomber colias*) to the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan (FMP). Approved measures include catch limits, accountability measures, and other conservation and management measures required for stocks “in the fishery.”

A new menhaden surveywas designed. Patchily distributed pelagic fish species present a challenge to classical approaches to hydroacoustic survey designs. SCeMFiS scientists proposed a spatial simulation approach to designing acoustic surveys and provided a case study in the northern resident stock of Atlantic menhaden *Brevoortia tyrannus*during winter. Recommendations include the use of a combination of down-viewing echosounder and omni-directional sonar to generate biomass estimates. The use of down-viewing echosounder alone generated biomass estimates with poor precision.

The Atlantic surfclam *Spisula solidissima*supports one of the largest fisheries on the US northeast coast. Using ~30 yr of data from surfclam stock surveys, variance-to-mean ratios were calculated to determine the degree of patchiness. These ratios declined from the 1980s to present in all regions (offshore Delmarva, New Jersey, Long Island, Southern New England, Georges Bank). The surfclam’s proclivity for a patchy distribution varied regionally. Regions supporting the bulk of the stock were characterized by significantly higher degrees of patchiness. A species distribution function model corroborated findings of declining patchiness over time, supporting the hypothesis that warming of Mid-Atlantic continental shelf bottom waters is both driving the surfclam into new habitat and extirpating it from nearshore and southern areas. Size-dependent and temporal trends suggest that range expansion is conduced by regional settlement of larvae, followed by biased mortality in suboptimal habitats. This biased mortality ultimately re-establishes the increased patchiness characteristic of larger animals but also predisposes the species to a rapid range shift. This study is being used to define recruitment dynamics in the BOEM implementation of SEFES and supports the NEFSC estimated of 0.95 for steepness.

What is the impact on other disciplines?

The ocean quahog ageing study is establishing methodologies for reconstructing life history dynamics from species with life spans exceeding the length of time of scientific surveys; thereby permitting application of modern stock assessment methods to species that otherwise would require decades of data collection in order to support them. Ocean quahogs also record environmental change in their growth rates of centennial time scales, thereby recording climate data pertinent to long-term climate change, including global warming and climate cycles such as the Atlantic Multidecadal Oscillation. The project has described the growth dynamics of the first species studied in which global warming is changing population growth curves during the life span of the individuals. Development of a new growth model is ongoing. In addition, the growth record of ocean quahogs identifies the influence of climate cycles on bottom water temperatures over a period of time when other temperature proxies are not available. In particular, these climate cycles include the Atlantic Multidecadal Oscillation and the North Atlantic Oscillation.

The forage fish project is providing the first comprehensive evaluation of the relationship between prey and predator surplus production to evaluate the importance of resource allocation to the fishery and to higher order consumers. Implications include assessing the resiliency of the continental shelf food web when substantive changes in individual low-order consumers occur. Such changes are ongoing with global warming as differential shifts in species’ range force a restructuring of the continental shelf community and food web.

Global warming is generating movement of benthic dominants on the continental shelf north. The surfclam is a bellwether for this process. SCeMFiS projects have further documented this range shift, across New England and onto the Georges Bank. For the first time, death assemblage data have been used to reconstruct the past history of range shift earlier than the initiation of federal surveys. The historical record so revealed, for example, documents past occupation of the top of Georges Bank and the inshore shelf off Virginia by ocean quahogs, a species that has not been found living in this region since the initiation of federal surveys in 1980.

What is the impact on the development of human resources?

SCeMFiS grants are supporting graduate student and post-doctoral research projects at three separate universities; ten graduate students participated in the research program. In addition, center science teams are establishing national collaborative networks of scientists that will represent unique human resource capabilities. The Center strategically deploys 4 multi-institutional research teams, one for finfish stock assessments, one for shellfish stock assessments, one for marine mammal stock assessments, and a unique one charged with survey design recommendations. The center has been very successful in recruiting scientists outside of the center to lead important research projects. Scientists from the University of Rhode Island, Rutgers University, University of Maryland Center for Environmental Science, University of Washington, and University of Massachusetts at Dartmouth are currently leading projects.

This year, for the second year in a row, a SCeMFiS graduate student won a prestigious Knauss Fellowship. The NOAA Sea Grant Knauss Fellowship provides a unique educational and professional experience to graduate students who have an interest in ocean, coastal and Great Lakes resources and in the national policy decisions affecting those resources. The Fellowship matches highly qualified graduate students with "hosts" in the legislative and executive branch of government located in the Washington, D.C. area for a one year paid fellowship.

The research program at SCeMFiS is highly collaborative. This year, SCeMFiS participated in the Atlantic menhaden assessment and the surfclam survey design review. This continues a substantive involvement of SCeMFiS scientists in the NMFS and ASMFC assessment processes and subsequent quota setting. Widespread influence from the center's scientists on regulatory and other government committees and commissions extends the center's research impact and can have a major positive influence on the financial performance of the center's industry members as well as other industry members throughout the country. PIs and Co-PIs include 4 members of NMFS Scientific and Statistical Committees (SSC). The SSC is charged with evaluating NMFS assessments pursuant to quota determinations. Through this participation, SCeMFiS has significant input in translating science results into fisheries management and, thus, providing economic benefits for the center's members and other members of the industry. Of note, such activities provide opportunities for graduate students to be involved in the federal decision-making process that underpins the regulation of marine fisheries. Graduate student research has been instrumental in the ocean quahog and surfclam benchmark assessments, the MAFMC deliberations on chub mackerel, and the benchmark assessment for summer flounder. This year, two SCeMFiS graduate students were awarded NSF Non-academic Research Internships. Both will begin working at the NEFSC in 2020.

SCeMFiS funding now goes to 11 different PIs at 7 different academic institutions and a number of fisheries consulting groups. Over half of all SCeMFiS projects are collaborative across institutions.

In addition to the assessment team program, six research projects were completed in 2019, two addressing the sampling sufficiency for dock-side monitoring of Gulf and Atlantic menhaden, one on the design of a new menhaden survey, a review of the Atlantic menhaden assessment, one developing new information on the reproductive biology of menhaden, an additional year of monitoring of biological characteristics of chub mackerel as revealed by the fishery, and an economic study of longfin squid. Sixteen additional projects were underway through part or all of 2019. Of these, 7 were affiliated with USM, 4 projects were affiliated with VIMS, and of these 11, 7 were shared jointly between VIMS and USM. Of the remainder, 3 are contracted to other academic institutions or consulting firms. In all, including projects finalized in 2019, 12 of 22 center research projects were collaborative efforts that involve multiple research scientists at multiple institutions. This involvement of researchers from multiple organizations is evidence of successful collaborative leadership and teamwork within SCeMFiS.

What is the impact on physical resources that form infrastructure?

The center was successful this year in leveraging its research budget to obtain research funding from a number of outside organizations and businesses. This included research support from BOEM, and additional NSF support in the form of REU, VRS, and Non-academic Research Internships.

What is the impact on institutional resources that form infrastructure?

SCeMFiS focus is on the expansion of human infrastructure supporting the center beyond that provided by the core academic institutions. To this end, SCeMFiS funding utilizes consultants and other academic institutions as part of its human portfolio, bringing in additional shellfish and finfish expertise, and statistical expertise. This was accomplished through inclusion of additional expertise in the assessment teams, the creation of a new survey design working group, and the expansion of research on risk assessment analysis in fisheries management targeting summer flounder and Atlantic surfclam, and also Gulf menhaden, Atlantic menhaden, and forage fish. SCeMFiS funding also supports undergraduates (REU/VRSs) and graduate students from VIMS and USM.

What is the impact on information resources that form infrastructure?

The SCeMFiS mammal team developed computer code for an MSE model that is open-source, and available via: https://github.com/John-Brandon/PBR-Tier-System. This year, this MSE was expanded as a tool for marine mammal research and presented at a targeted Workshop participated in by a range of federal and state stakeholders.

The surfclam MSE model was finalized in 2015 and published (*Journal of Northwest Atlantic Fisheries Science* 47:1-27). An implementation of this model directed at area management objectives for surfclams was put into practice in 2015 and is ongoing. The results of the MSE modeling supporting this implementation were published in 2017 (*Fishery Bulletin*115:300-325), and a second publication using the MSE model to evaluate the use of area management under a range of future conditions was published in 2019 in *Ocean & Coastal Management*. This model is readily adaptable to any fishery and is unique in describing each fishing vessel independently as it operates within the fleet. No other MSE model has this capability. Significantly, this mode has been chosen for implementation to evaluate the influence of wind energy development off the U.S. east coast for the Atlantic surfclam and sea scallop fisheries. These two fisheries are among the 3 largest U.S. shellfish fisheries and the sea scallop fishery is the second largest fishery in the U.S.

The research program designed to evaluate surfclam habitat on Georges Bank has put into electronic format, for the first time, the ancillary NMFS-NEFSC survey data from 1978-2014 for the southern New England to Georges Bank region, thus providing the basis for routine inclusion of such data in analyses pertinent to that region. An REU obtained from NSF was able to enter the additional data for the entirety of the northeastern U.S. Atlantic coast. This database has now been provided to the NMFS for access by future researchers and has been used to guide survey sampling to reconstruct the history of clam range shifts on the U.S. east-coast continental shelf.

The Atlantic and Gulf menhaden projects focusing on sampling sufficiency made recommendations for improved dock-side sampling of menhaden to characterize the weight-at-age relationships in these stocks. These data are critical for the continued sustainability of these resources. SCeMFiS recommendations represent the first updated recommendations for these stocks in the last 30+ years.

In 2019, SCeMFiS carried out a re-evaluation of the dredge depletion experiments used to calibrate the NEFSC survey dredge. SCeMFiS scientists developed a depletion model simulator and interfaced it with the Patch model developed by the NEFSC to analyze depletion experiments. This has resulted in identification of a core group of experiments yielding the best estimate of dredge efficiency for use in the assessment of the status of the stock for the two species.

In 2019, SCeMFiS scientists published a new menhaden survey design. Patchily distributed pelagic fish species present a challenge to classical approaches to hydroacoustic surveys. SCeMFiS scientists proposed a spatial simulation approach to designing acoustic surveys and provided a case study in the northern resident stock of Atlantic menhaden *Brevoortia*

tyrannus during winter. Recommendations included the use of a combination of down-viewing echosounder and omni-directional sonar to generate biomass estimates. The use of down-viewing echosounder alone generated biomass estimates with poor precision. The SCeMFiS approach accounts for the patchy spatial distributions of the survey populations, which leads to more realistic estimates of precision than classical approaches implicitly assuming independence.

What is the impact on technology transfer?

The impact on assessments continue until the next benchmark assessment. SCeMFiS research and support were instrumental in the assessments for Gulf and Atlantic menhaden and the survey design review for surfclam and ocean quahog. Status of the stock estimates permitted an increased quota in both cases, should the industry request it. Potential economic value for ocean quahogs, for example, would be an approximately tripling of the present quota. The ex-vessel value of the fishery today, a highly conservative measure of economic value, is about $10.4 million; thus an additional $20.8 million in catch could be sustained by the present assessment. For surfclams the estimated additional value is $46 million. For black sea bass, the assessment permitted the SSC to set an OFL for the first time in many years. That, plus an increase in estimated biomass permits an increased quota approximately 2 times the present quota. For the commercial sector, this is about $8.8 million in additional ex-vessel value.

Previous work led to a successful benchmark assessment for black sea bass in 2016. The assessment permitted the SSC to set an OFL for the first time in many years. That, plus an increase in estimated biomass permits an increased quota approximately 2 times the present quota. The ex-vessel value of the commercial fishery today, a highly conservative measure of economic value, is about $8.8 million; thus an additional $8.8 million in catch could be sustained by the present assessment. This impact continues today, because the OFL continues to be used as the basis for the yearly quota.

SCeMFiS economic evaluations for scup and *Loligo*squid are being used to educate the lay person and management communities of the importance of these species in providing jobs and economic value to coastal towns and townships.

In 2019, SCeMFiS carried out a re-evaluation of the dredge depletion experiments used to calibrate the NEFSC survey dredge. The catch efficiency correction is a singular source of uncertainty in the surfclam and ocean quahog assessments. SCeMFiS scientists developed a depletion model simulator and interfaced it with the Patch model developed by the NEFSC to analyze depletion experiments and for the first time, evaluate the degree of uncertainty and the sources of uncertainty in these experiments. As the uncertainty about dredge efficiency is an important part of the continuing recommendation by the MAFMC to require a quota well below the OFL, despite the inherent sustainability of the two stocks, this project will further insulate these fisheries from future quota reductions.

SCeMFiS has funded a series of projects aimed at evaluating the influence of global warming on the U.S. east coast fishing industry. The focus has been surfclams and ocean quahogs two of the nations three largest shellfish fisheries. These projects have identified the progress of shifts in range, the mechanisms behind range shifts, the rapidity of such range shifts and the economic and biological conflicts issuing from such range shifts. For the first time, transient multiple stable points have been identified. This research focus will continue into the future as global warming represents a singular threat to the continued success of the shellfish industry.

SCeMFiS has recently supported a “High” priority research need for improving the assessment of Gulf Menhaden: Improving estimates of natural mortality of the stock. Recent research has shown, for Atlantic Menhaden, that natural mortality may be higher than previously estimated. This has import to fishery management because it indicates that the stock may be more productive and thus more resilient to harvest. To begin to understand the mortality dynamics of Gulf Menhaden, the second largest fishery in the United States (by weight), the research group performed exploratory analysis to understand the feasibility of using a comprehensive reanalysis of the tag and recapture data collected during the 1970’s and 1980’s. This was a joint federal and industry effort. This study involved tagging juveniles and adults with internal, individually-numbered ferro-magnetic tags that were recovered on magnets in fish reduction factories. Because of the costs of this tagging work, it is unlikely that such a large-scale tagging study will ever be performed again. However, leaps in the computational power and statistical modeling approaches in recent decades has made re-analysis of the previously collected tagging data a very

worthwhile endeavor.

What is the impact on society beyond science and technology?

The mission of the Center is to “utilize academic, recreational, and commercial fisheries resources to address urgent scientific problems limiting sustainable fisheries.” Improving sustainability will provide long-term support for coastal economies, by maintaining viability of coastal fishing companies, dealers and processors, and a range of other businesses supporting commercial fishing. SCeMFiS research supports businesses from Virginia to Massachusetts and Mississippi and Louisiana in the Gulf of Mexico. Three examples follow. (1) SCeMFiS research and support for the working groups were instrumental in a successful benchmark assessment for ocean quahog. Status of the stock estimates permit an increased quota approximately tripling the present quota. The ex-vessel value of the fishery today, a highly conservative measure of economic value, is about $10.4 million; thus an additional $20.8 million in catch could be sustained by the present assessment. This result directly impacted jobs in New Bedford, MA, Atlantic City, Bivalve, Millville, and Pt. Pleasant, NJ, and Nanticoke and Easton, Md. (2) SCeMFiS research and support for the working groups were instrumental in a successful benchmark assessment for Atlantic surfclam. Status of the stock estimates permit an increased quota approximately 2.5 times the present quota. The ex-vessel value of the fishery today, a highly conservative measure of economic value, is about $30.7 million; thus an additional $46 million in catch could be sustained by the present assessment. This result directly impacted jobs in New Bedford, MA, Atlantic City, Bivalve, Millville, and Pt. Pleasant, NJ, and Nanticoke and Easton, Md. (3) SCeMFiS research and support for the working groups were instrumental in a successful benchmark assessment for black sea bass. The assessment permitted the SSC to set an OFL for the first time in many years. That, plus an increase in estimated biomass permits an increased quota approximately 2 times the present quota. The ex-vessel value of the commercial fishery today, a highly conservative measure of economic value, is about $8.8 million; thus an additional $8.8 million in catch could be sustained by the present assessment. The value of the black sea bass recreational fishery is certainly much greater, but economic numbers are not available. Nonetheless, recreationally and commercially, this result directly impacted jobs at most commercial fishing ports and all ocean-side recreational docks from Virginia to Massachusetts.

In addition, SCeMFiS research addressing sustainable fisheries has aided in the acquisition of approval as sustainable by the prestigious Marine Stewardship Council, this year for Gulf menhaden and Atlantic menhaden, and in the past several years for longfin squid, Atlantic surfclam, and ocean quahog. These fisheries reap financial benefits by being able to display the MSC seal on their products. SCeMFiS continues to emphasize research support for sustainability.

This year, SCeMFiS began a program to look at multiple use conflicts on the continental shelf with a focus of the conflict of fishing and vessel transit with offshore wind energy development. SCeMFiS has directly supported one project and SCeMFiS models of the fishing industry have resulted in a total additional funding of $800,000 in 2019-2021 to address this issue. This conflict, along the impact of global warming, represents the singular challenges to U.S. east-coast fisheries present today.
