VIMS | William & Mary
Virginia Institute of Marine Science

SHELLFISH AQUACULTURE PROGRAM

A GUIDE TO SHELLFISH AQUACULTURE RESEARCH AT VIMS - FALL 2024

MADELINE PITSENBARGER & KAREN HUDSON

SHELLFISH AQUACULTURE PROGRAM

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Mission

The overarching mission of VIMS' Shellfish Aquaculture Program is to advance and support a thriving sustainable shellfish aquaculture community in Virginia and the United States, through globally relevant shellfish aquaculture science, outreach, and education.

Who We Are

The SAP serves as an organic collaboration of the many VIMS faculty, staff, and students conducting research, outreach, and advisory services in support of shellfish aquaculture. SAP has no formal hierarchy, but the collaboration is coordinated by Bill Walton.

Four integrated goals:

- Support prosperous and sustainable shellfish aquaculture production
- Produce highly capable individuals skilled in and knowledgeable about aquaculture production
- Engage and empower communities with the best available shellfish aquaculture science

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MARINE ADVISORY PROGRAM (MAP)

Virginia Sea Grant Marine Extension Program

Dave Rudders, Associate Director, Marine Advisory Program | rudders@vims.edu

Karen Hudson, Shellfish Aquaculture

Shelby White, Marine Business

Lisa Lawrence and Celia Cackowski, Marine Education

About our Program

The MAP is unique in that it is home to scientists whose major focus is on advisory programs that benefit the citizenry, marine industries, and government of the Commonwealth. We actively engage with stakeholders and respond with solutions to emerging issues through research, education, and advisory service to marine and coastal communities in the broad areas of aquaculture, commercial and sport fishing, marine education, and marine business. Marine extension services are provided with Virginia Sea Grant's Marine Extension Program, administered through National Oceanic and Atmospheric Administration (NOAA).

MAP activities related to Shellfish Aquaculture include a team of shellfish aquaculture, marine education and marine business specialists focused on support for sustainable growth of Virginia's shellfish aquaculture industry. Highlighted deliverables include:

- Statewide advisory program that addresses industry questions and concerns and partners to find solutions that advance the shellfish aquaculture industry.
- Coordinated responses to shellfish production failures in Virginia hatcheries and field grow out.
- Coastal Economic Reports
- Workforce Development initiatives focusing on local youth

CORE SHELLFISH AQUACULTURE PROGRAM GROUPS

ACUFF CENTER FOR AQUACULTURE (ACA)

Bill Walton, ACA Director | walton@vims.edu | 804.684.7238

Lauren Gregg, Aquaculture Facility Manager

Haley Uliasz, Aquaculture Algologist

Meghan Capps, Aquaculture Support Specialist

About

The Acuff Center for Aquaculture is a 20,000-square-foot facility that supports the work of several collaborative research, education, and advisory teams within VIMS' Shellfish Aquaculture Program. State-of-the-art seawater filtration and climate-control systems maintain optimal conditions for ripening broodstock, culturing shellfish larvae, and growing large volumes of microalgae for feeding. Flexible lab spaces and an assortment of husbandry and monitoring equipment also support training, demonstration, and academic programs at VIMS.

Each year, in addition to serving as the base of hatchery operations for the Aquaculture Genetics and Breeding Technology Center (ABC) oyster breeding program, the Acuff Center and shellfish nursery pad host a new selection of research projects and collaborations based on the latest interests in shellfish production. Research colleagues, students, industry partners, outreach groups, and public programs can work side-by-side and utilize shared resources as they approach these questions together.

Current Focus

On average, the Acuff Center has hosted 12-16 funded research projects, student projects, and pilot studies in both the 2023 and 2024 production seasons. The majority of this work has been with Crassostrea virginica, which has a long history in VIMS aquaculture facilities, but effective spawning and production techniques are currently being developed for soft-shell clams (Mya arenaria) and ribbed mussels (Geukensia demissa) as well. Conscious efforts are made to include a balance of tried-and-true hatchery equipment and concepts alongside state-of-the-art systems and new technology. Keeping this balance will remain a priority for the facility into the future.

In the 2023 production season, faculty and staff from all three VIMS sections formed the 'AquaGuard Initiative,' a monitoring program that takes advantage of new and abundant sampling opportunities throughout the facility. This program provides valuable feedback about the function of various systems and their maintenance routines and will help form a more complete picture of seasonal water chemistry trends and effects on larval and algal performance, which will be shared with industry members.

CORE SHELLFISH AQUACULTURE PROGRAM GROUPS

AQUACULTURE GENETICS AND BREEDING TECHNOLOGY CENTER (ABC)

Jessica Small, ABC Director | jamoss@vims.edu | 804.684.7955

Formed from a Legislative Initiative in 1997, ABC has grown into one of the world's leading oyster breeding programs. Our general operations can be divided into three major categories.

1. Breeding program in support of the Virginia industry, both growers and hatcheries. Our selection program focuses on breeding lines, both diploid and tetraploid, appropriate for the entire salinity range found in Chesapeake Bay (thus quickly growing to serve Virginia and Maryland). Furthermore, it turns out that some of the lines we produce have utility outside of the Chesapeake Bay area, so our hatcheries benefit from the program by widening their sales of seed and eyed larvae accordingly. The hallmark of ABC's activity is the distribution of fast-growing, disease resistant adult broodstock to hatcheries in Virginia and, now, several East Coast states.

Recent brood stock developments:

- Diploid family lines – Longstanding lines like "Deby" remain ever-popular, but are now accompanied by newer lines updated annually; "Lily" and "Hnry."
- Tetraploid lines – our original GEN line has been refreshed with new genes and hatcheries can now choose from GNL or NGN lines.
- Tetraploid family selection has allowed us to create another new 4N line for hatcheries – FYR.

2. Training and research arm for the industry. Through our Oyster Aquaculture Training (OAT) program, we aspire to train young professionals in the commercial aspects of oyster aquaculture. We have dozens of former OAT trainees dispersed in companies locally and even nationally. Through the years, a number of PhD scientists, post-doctoral scientists, and graduate students have studied questions pertaining to advancing oyster aquaculture and emerging industry challenges. The infrastructure we have built in support of the breeding program increasingly serves as a foundation for collaborative studies in shellfish aquaculture with national partners. Results from all of these benefit our understanding of breeding better oysters.

3. We have been increasingly sought as a source of expertise for other similar programs. We maintain collaborative relationships with the USDA Agricultural Research Service based at the University of Rhode Island, Taylor Shellfish in Washington State, as well as several private companies.

CORE SHELLFISH AQUACULTURE PROGRAM GROUPS

EASTERN SHORE LABORATORY (ESL)

Richard Snyder, ESL Director | rsnyder@vims.edu | 757.787.5834

About

The Eastern Shore Laboratory (ESL) serves as a field station supporting research and teaching and a site for resident research in coastal ecology and aquaculture. By virtue of its access to unique coastal habitats, excellent water quality, and an extensive seawater laboratory, the ESL affords educational and research opportunities not available elsewhere within the region. Over its 40-year history, the laboratory has become internationally recognized for shellfish research, with important contributions to molluscan ecology and culture.

Focal Areas

- The modernized Castagna Shellfish Research Hatchery & Nursery conducts research on native shellfish species, Bay Scallops and Hard Clams, important to the Eastern Shore of Virginia (ESVA) economy and ecology.
- ESL is now the home base for the Krueger-Hadfield Evolutionary Ecology lab. The lab integrates approaches from population genetics, physiology, and population and community ecology in marine, freshwater, and alpine micro- and macroalgae, with the occasional invertebrate thrown in, to resolve one of the great paradoxes in biology – the evolution of sex. The central thread of research has direct implications for understanding biodiversity, transcending taxonomic designations. To learn more about our research, visit the Krueger-Hadfield lab webpage.
- Ecological Monitoring Program which provides status and trend information on the local environment to stakeholders, scientific context for research, and as an education tool for local classrooms.
- Launched fixed-sensor water quality monitoring stations on the seaside and bayside of the ESVA to provide real-time and archived data beneficial to local shellfish industry partners as well as research. Data summaries and more information about ESL's water quality mission can be found in the following reports: Ecological Monitoring Program at VIMS ESL Annual Reports 2018-Current.

CORE SHELLFISH AQUACULTURE PROGRAM GROUPS

SHELLFISH PATHOLOGY LABORATORY

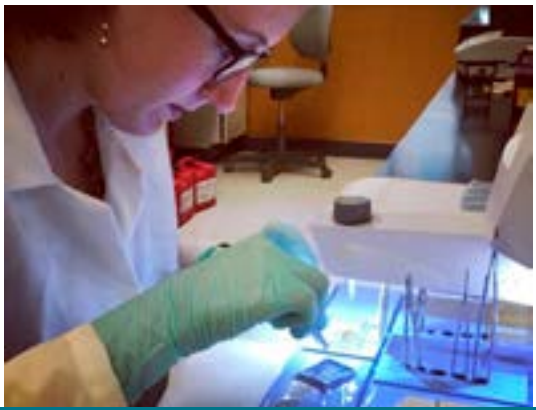
Ryan Carnegie | carnegie@vims.edu | 804.684.7713

The Carnegie Lab continues shellfish health research, education and advisory service that began under Jay Andrews in the 1950s and continued under Gene Burreson's direction from the 1980s-2000s. Central to lab activity is an annual monitoring program that has four elements. Three of these comprise a targeted surveillance program for endemic and emerging pathogens and diseases of aquaculture relevance, and include:

1. A James Quarterly Survey (extending the Fall Survey to January, April and July for four James River reefs)
2. An annual Fall Survey of oyster diseases on 32 Virginia oyster reefs
3. Spring Imports disease sentinel oysters deployed to the York River (monitored from May-November)
4. Samples from industry, which now exceed 150 annually, that represent passive surveillance for known and potentially emerging clam and oyster pathogens. Among other benefits, these activities collectively provide a firm scientific foundation for informing decisions related to interstate transfers, typically to the benefit of Virginia producers.

Additional program activities:

- Ongoing efforts to streamline regulation of shellfish transfers on the U.S. East Coast, with Karen Hudson and colleagues from Rutgers University, the ECSGA, and numerous collaborators from industry, regulation and the academic community;
- Research on the ecology of shellfish diseases, including disease interactions between aquaculture farms and wild shellfish populations. Our most recent paper, "Intensive oyster aquaculture can reduce disease impacts to sympatric wild oysters", highlights work in this area (Aquaculture Environment Interactions, in press; lead author Tal Ben-Horin);
- National and international efforts to promote resilience of shellfish industries to emerging pathogens, in collaboration with USDA and NOAA colleagues and through work on the ICES Working Group for Pathology and Diseases of Marine Organisms.



CORE SHELLFISH AQUACULTURE PROGRAM GROUPS

COMMERCIAL SHELLFISH AQUACULTURE LAB & TEAM (C-SALT)

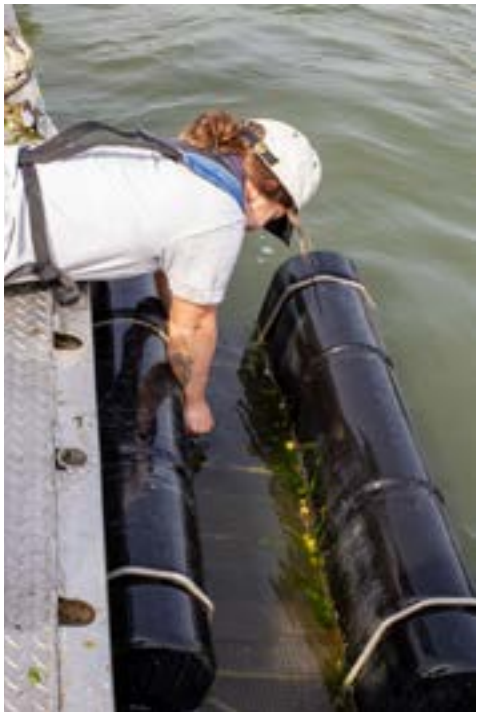
William Walton | walton@vims.edu | 804.684.7238

Our team is dedicated to the VIMS' Shellfish Aquaculture Program mission to advance and support a thriving sustainable shellfish aquaculture community in Virginia and the United States, through globally relevant shellfish aquaculture science, outreach and education.

To contribute to this mission, our team strives to achieve three integrated research goals, while also working to develop highly capable individuals skilled in and knowledgeable about shellfish aquaculture production:

- Improve shellfish aquaculture production, quality, profitability and environmental sustainability
- Increase resilience of the shellfish aquaculture industry through innovation, diversification and adaptation
- Assess factors that affect consumer demand for shellfish

One way our team achieves these goals is through the C-SALT Research Farm. The 1-acre shellfish lease is designed to facilitate applied research, serve as demonstration for the industry, and be a center for workforce development. The farm has a capacity to grow 100,000 oysters/year and utilizes 3 types of aquaculture gear (bottom cage, floating cage, and FlipFarm) to have a good representation of industry practices. For more information or to visit, contact the farm manager, Madeline Pitsenbarger, mkburgess@vims.edu.



CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

AQUACULTURE & ENVIRONMENTAL INTERACTIONS

Bivalve aquaculture such as Virginia's dominant hard clam and oyster sectors involve direct interaction with the surrounding environment. For example, gear used in oyster aquaculture, provides structure that helps maintain important habitats, slows shoreline erosion rates, and provides surface for species to adhere to and seek refuge in, increasing biodiversity both within and surrounding an aquaculture operation. Understanding the ecological impacts of aquaculture on the surrounding ecosystem will help minimize or avoid potential negative effects as the industry expands.

Primary production monitoring to inform shellfish aquaculture
Principal Investigator: Mark Brush | 804.684.7402 | brush@vims.edu
VIMS Collaborators: Sara Blachman
Funding source: VIMS

The expansion of shellfish aquaculture in Virginia has generated an important source of revenue and jobs, provided a local source of quality seafood, and supported the economy and culture of local communities. Sustaining the current industry and enabling future expansion are dependent on an adequate food supply for the shellfish. This supply comes primarily in the form of phytoplankton primary production, but local measurements of this vital rate are scarce.

We have instituted a monitoring program to measure phytoplankton primary production in shallow tributaries around the lower Chesapeake Bay to enable calculation of food availability for cultured bivalves. We are currently collecting our fourth year of monthly monitoring data in Cherrystone Inlet, and our second year of data in Mobjack Bay and its tributaries. Measurements are being combined with modeled rates of bivalve feeding to estimate the number of hard clams and oysters that can be supported by local phytoplankton productivity.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

AQUACULTURE & ENVIRONMENTAL INTERACTIONS

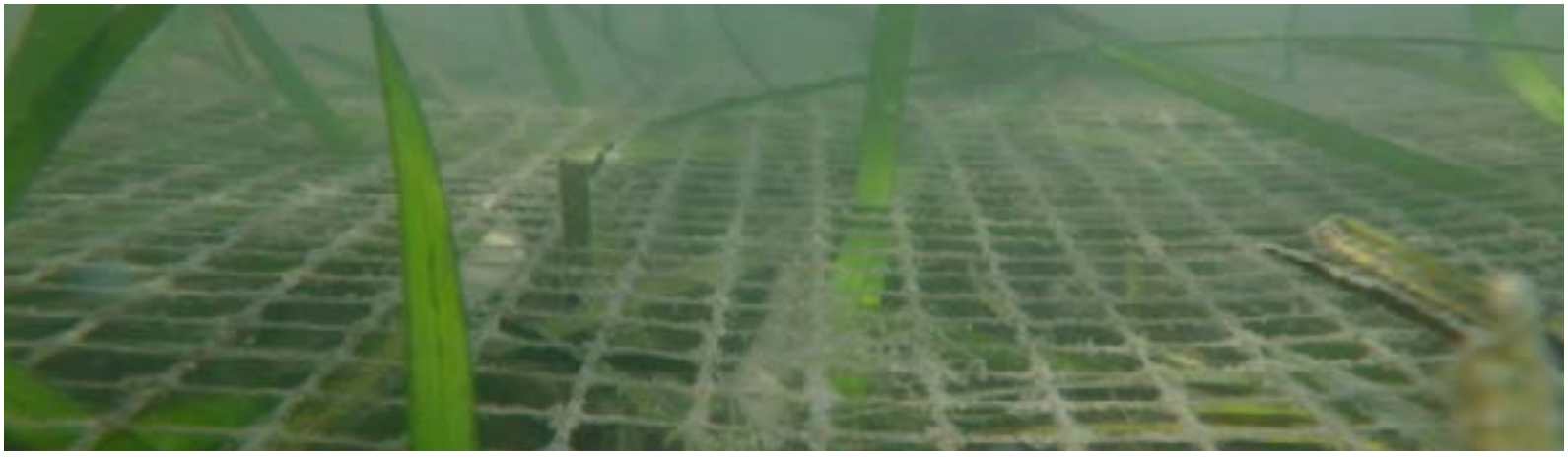
Modeling shellfish production capacity and ecosystem services

Principal Investigator: Mark Brush | 804.684.7402 | brush@vims.edu
VIMS Collaborators: Chris Patrick and Sara Blachman
Funding source: Commonwealth of Virginia

The expansion of shellfish aquaculture in Virginia has created unique "agro-ecosystems" in which cultured bivalves are an integral part of the local marine environment. These bivalves play an important role in ecosystem processes in these systems and provide a number of ecosystem services (e.g., water filtration, nutrient removal), and are simultaneously influenced by the surrounding system (e.g., water quality, long-term change). We are utilizing our predictive ecosystem modeling capabilities to explore these interactions at the ecosystem level, focused primarily on the Virginia Eastern Shore (VAES) in the following projects:

1. Cherrystone Inlet Ecosystem Model: Previous VIMS graduate student Michael Kuschner developed an ecosystem model including hard clam aquaculture in Cherrystone Inlet in 2015. The model was used to quantify clam growth and harvest biomass as a function of stocking density, food sources supporting clam growth, the influence of cultured clams on water quality, and potential impacts of climate change. We have recently updated the model to include cultured oysters and are simulating growth and harvest biomass of both species in the system.

2. SAV-Clam Aquaculture Interactions (with Chris Patrick and Blachman): VIMS received funding from the Commonwealth of Virginia in 2021 to explore the interactions between hard clam aquaculture and submerged aquatic vegetation (SAV) on the seaside of the VAES. We are combining existing and new data with our previously developed models of VAES watershed loading, lagoon ecosystem response, hard clams, and eelgrass to quantify the ecosystem services provided by both habitats.



CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

AQUACULTURE & ENVIRONMENTAL INTERACTIONS

Oyster Bottom Restoration through Aquaculture

VIMS Partner: Karen Hudson | 804-684-7742 | khudson@vims.edu | VA NRCS Aquaculture Program

External Collaborator: Andrew Button, Virginia Marine Resources Commission (VMRC)

Funding Source: USDA - Virginia Natural Resources Conservation Service (NRCS) - Regional Conservation Partnership Program (RCPP)

NRCS has a longstanding partnership with VMRC and VIMS to help oyster growers improve water quality and increase oyster habitat in the Chesapeake Bay and its tidal tributaries. The NRCS funding to date has supported the restoration of more than 200 acres of private oyster ground and the planting of approximately 75,000 bushels of spat on shell.

VMRC and VIMS provide conservation cost-share program education and outreach to private ground leaseholders, technical assistance to program participants on practice planning and implementation, as well as verification of cost-share implementation. The current project will continue to 2027, funding approximately 15 projects a year.

FINANCIAL DETAILS

NRCS financial assistance covers the preparation/restoration of the leased bottom. Depending on the approved plan, the producer either shares in financing the restoration of the bottom or finances the production and deployment of the living overlay of spat on shell, including the cost of larvae and shells for settlement.

NEW OPTIONS FOR FISCAL YEAR 2024

Table 1. Overview of restoration options based on the lease location

	Natural oyster strike at lease area		
Restoration options:	**Poor**	**Moderate**	**High[1]**
Restore or enhance bed - **shell base only**	No	Maybe	Yes
Restore or enhance bed - **stone[2] base only**	No	Maybe	Yes
Restore or enhance bed - **shell base and spat on shell**	Yes	Yes	No
Restore or enhance bed - **stone[3] base and spat on shell**	Yes	Yes	No

[1] These areas include the Piankatank River, the Great Wicomico River and tributaries, the James River and tributaries, and the mouths of the Eastern Shore of Virginia.
[2] Requires Joint Permit and must meet VMRC standards of size, etc.
[3] Requires Joint Permit and must meet VMRC standards of size, etc.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

GENETIC IMPROVEMENT

Genetic techniques can be used for both short-term and long-term genetic improvement in aquaculture species. Genetic improvements are critical for the resiliency of the shellfish industry to produce incremental gains such as faster growth and preparing for future threats in a changing climate. The aquaculture genetics & breeding technology center (abc) provides legacy oyster breeding and research resulting in improved broodstock for the commercial industry. This work continues to evolve. Additional collaborations across sap have expanded genetic technology application to the characterization of hard clams and other species under commercial development which are critical for the development of genetic tools.

Comparing gene expression in response to low salinity among hard clam lines

Student Investigator: Leslie S. Youtsey | lgspeight@vims.edu
Faculty Investigators: Jan McDowell | mcdowell@vims.edu & Kimberly S. Reece | kreece@vims.edu
Funding source: VIMS and Virginia Agricultural Council

Virginia's hard clam industry is primarily limited to higher salinity habitats on the seaside of the Eastern Shore of Virginia or lower Chesapeake Bay. Although the hard clam can be found in lower salinity habitats, they do not grow or survive at rates that are practical for productive aquaculture. In the spring of 2019 and 2021, clam lines were created at the VIMS Eastern Shore Laboratory. Salinity exposures were conducted in the summer of 2021 with eight clam lines at four different salinities (35, 20, 15 and 12 ppt). RNA sequencing data of exposed clams at 35 and 15 ppt were used to assess the transcriptomic response to low salinity stress.

This study found genes in adults and juveniles that were significantly differentially expressed between 15 and 35 ppt. Some clam lines from the same population had large differences in which genes were expressed in response to low salinity and some from different populations showed minimal differences. The observed difference between lines could indicate different tolerance to low salinity and adapted molecular approaches to combat osmotic stress, which could benefit the aquaculture industry and lead to strategic breeding

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

GENETIC IMPROVEMENT

From Sequence to Consequence: Genomic selection to expand and improve selective breeding for the eastern oyster

VIMS Investigator: Jessica Small, 804.684.7955 | jamoss@vims.edu
External Investigators: Eastern Oyster Breeding Consortium Partners
Funding source: NOAA/Atlantic States Marine Fisheries Commission - Eastern Oyster Breeding Consortium

The goal of this research is to accelerate and expand selective breeding of C. virginica for all growing regions on the East Coast by developing, testing, and verifying genome-based breeding. This research will provide proof-of-principle for the application of genome-based tools to existing Eastern oyster breeding programs and will outline standard procedures for the expansion of breeding to fulfill the needs of a diverse industry. This project will:

1. Develop an efficient genotyping platform for C. virginica. Development and evaluation of high-density SNP arrays for the eastern oyster. Marine Biotechnology doi.org/10.1007/s10126-022-10191-3
2. Use the genotyping platform to characterize selected lines and establish associations between phenotype and genotype for important production traits.
3. Apply estimated genotype/phenotype associations to breeding through genomic selection (GS).
4. Evaluate traditional and genomic-based breeding and identify high performance lines across growing regions (ME, RI, NY, NJ, MD, VA, NC).

ABC's specific role is to examine the potential for using genomic selection (GS) in eastern oysters and then applying it to ABC's family breeding program. The application of genomic selection could then be transferred to the commercial oyster industry via newly improved ABC broodstock lines.

Through combined efforts of the Breeding Consortium members, a 66K single nucleotide polymorphism (SNP) array has been developed specifically for east coast oyster populations. ABC has utilized this tool to genotype oysters from 4 years of family production. In spring 2023, GS was used for the first time to calculate genomic estimated breeding values (GEBV) on broodstock candidate oysters. To test G, spawns were executed at VIMS using individually-genotyped oysters to create high salinity, low salinity and low-ranked GEBV families. Field trials of seed from these families, deployed in spring 2024 will be assessed in fall 2024. This information will be the first step in lidation of realized gains associated with genomic selection.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

GENETIC IMPROVEMENT

Production of pedigree families for research on disease resistance and correlation of resistance with field traits

VIMS Investigator: Jessica Small | 804.684.7955 | jamoss@vims.edu

External Investigators: External Investigator: Dina Proestou (USDA ARS National Coldwater Marine Aquaculture Center)

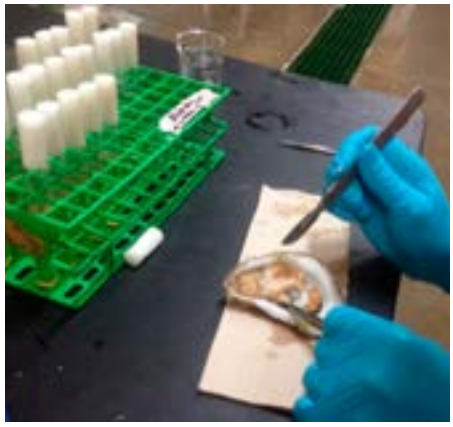
Researchers at ABC and USDA ARS at URI have been examining the genetic parameters associated with Dermo resistance through laboratory-based exposure over the past three years. This has included three large lab challenges performed at University of Rhode Island using over 100 diploid ABC families. It is the intention of this research to understand results of a Dermo lab challenge should be incorporated as a trait into the family-selection breeding models at ABC to improve breeding for Dermo resistance.

When survival of the same laboratory-challenged families deployed by ABC in a local high disease environment, the York River, VA, was compared to the laboratory survival, however, there was little to no genetic correlation between the two. It is known that Dermo as well as the parasite MSX are endemic to the York River and it is likely that multiple parasites and other environmental challenges could be influencing survival at that location.

In order to understand the relationship between survival in Dermo laboratory challenges and survival to Dermo exposure in a field setting, especially as it relates to breeding disease-resistant stocks, it is necessary to conduct further experiments that assess parasite prevalence in field-exposed families and closely monitor them over time for survival and Dermo infection during a Dermo disease exposure window. A follow-on project to this effect is underway at VIMS with spawns completed in late May 2024 led by PI Small, Robin Varney, Shelley Katsuki and Taylor Dolan (graduate student).

Two publications are in development surrounding this work with tentative titles and authorship are below:

- Direct measurement and genetic parameter estimation of Dermo resistance traits in an eastern oyster breeding population. Dina A. Proestou, Thomas A. Delomas, and Jessica Moss Small
- Evaluation of genomic selection to improve survival of eastern oysters infected with Perkinsus marinus. Thomas A. Delomas, Dina A. Proestou, Jessica M. Small



CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

GENETIC IMPROVEMENT

Assessing the genetic health of ABC's selected lines of diploid oysters

VIMS Investigator: Jessica Small | 804.684.7955 | jamoss@vims.edu
VIMS Collaborators: Robin Varney, Shelley Katsuki
External Collaborators: Katie Lotterhos (Northeastern University)

The Aquaculture Genetics and Breeding Technology Center (ABC) has been engaged in family breeding of eastern oysters since 2004. The ABC oyster breeding program is now responsible for generating elite eastern oyster broodstock that is made available and distributed to the US East Coast oyster aquaculture industry through commercial hatcheries. ABC currently produces five diploid selected lines of oysters (DEBY, XB, LOLA, LILY, HNRY) all with a specific selection history and with precise genetic makeup. The ABC breeding program seeks to improve genetic gains in performance traits, while balancing selection intensity to keep inbreeding low.

To examine the current genetic health of ABC's five diploid selected lines, we compared levels of genetic diversity and inbreeding among the selected lines with first generation oysters spawned from individuals collected from wild populations in Texas, Louisiana, Florida, and Virginia, as well as wild oysters collected from Wachapreague, VA. Samples from each group were genotyped using a high-density SNP array (66,000 single nucleotide polymorphisms) specifically designed for genetic analysis of C. virginica. We examined genetic diversity, inbreeding and genetic differentiation among the groups.

Measures of diversity indicate ABC's five selected diploid lines contain high levels of genetic diversity, with similar levels of genetic diversity observed among ABC's selected lines and slightly higher levels of diversity than among the groups sourced from wild populations. We observed low levels of inbreeding in the five selected lines. Levels of genetic differentiation varied among the groups, with significant differentiation observed among ABC's selected lines as well as those sourced from wild populations. Overall, ABC's five diploid selected lines of oysters appear to be genetically healthy. Our efforts to minimize inbreeding within the lines, as well as maintain genetic differentiation among the lines, have been successful.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

GENETIC IMPROVEMENT

Polyploid Breeding Strategies for Crassostrea virginica

VIMS Investigator: Jessica Small |804.684.7955 | jamoss@vims.edu
External Collaborators: Standish K. Allen (Emeritus Professor, VIMS), Peter Kube (Center for Aquaculture Technologies)

With the overwhelming popularity of triploids in the mid-Atlantic and southward, ABC has expanded its focus into the genetic improvement in tetraploids. Polyploid breeding in oysters represents a new frontier. For example, there is now information to indicate which tetraploid traits would produce better triploids. Moreover, the tetraploid sire, putatively, has twice the influence over traits in triploids than the diploid dam. After more than a decade of producing tetraploid families for analysis and compiling data on traits such as DNA content, chromosome content stability, survival, and growth in different environments, ABC now operates a parallel, family-based tetraploid breeding program, selecting for traits designed to yield chromosomally-stable, high performing tetraploids. Genetic linkages that exist between pedigreed tetraploid sires, pedigreed diploid dams, and the triploid families created with them provides a powerful approach to tetraploid breeding. Bivariate analyses of triploid and tetraploid data indicate that the genetic correlation between triploid and tetraploid survival is 0.84 while the correlation between triploid and tetraploid total weight is 0.58. The correlation between triploid and tetraploid traits allows ABC to utilize triploid and tetraploid data, simultaneously, to breed tetraploids specifically programmed for optimal triploid performance. A result of this breeding strategy is ABC's FYR line, available yearly as part of ABC's broodstock portfolio.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

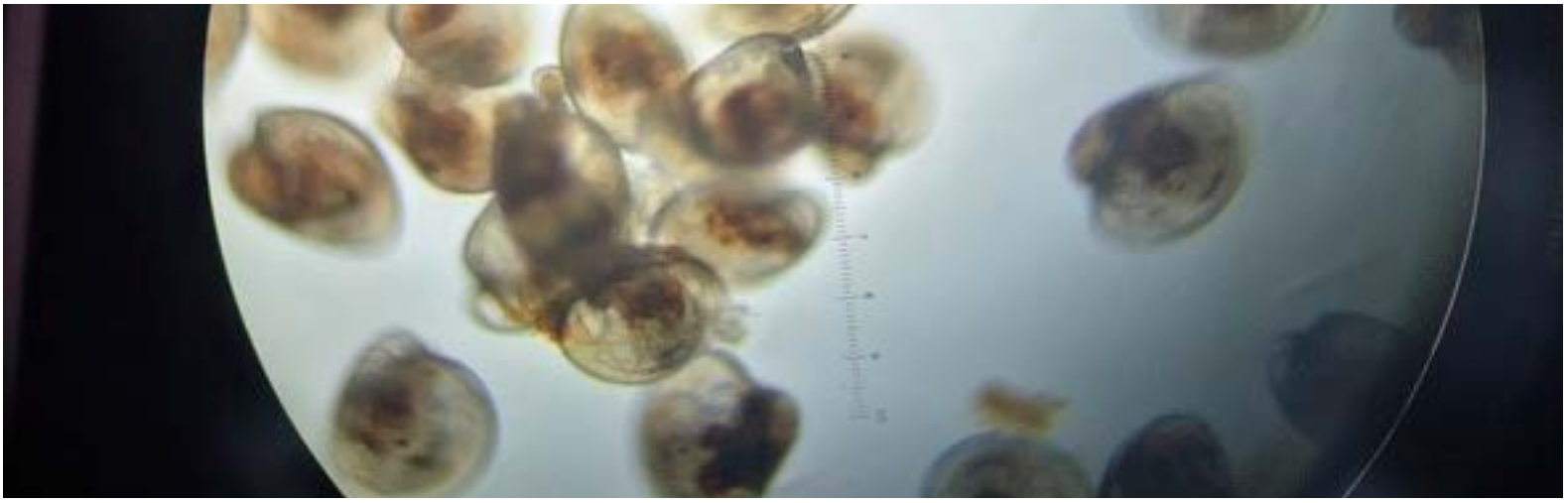
GENETIC IMPROVEMENT

CAREER: Evaluation of machine learning algorithms for understanding and predicting adaptation to multivariate environments with a Model Validation Program (MVP)

VIMS Investigator: Jessica Small | 804.684.7955 | jamoss@vims.edu
External Investigator: Katie Lotterhos, Northeastern University

Predicting organisms' vulnerabilities to rapid and multivariate climate change is a major scientific challenge. A hurdle to addressing this challenge arises from non-intuitive interactions among multiple stressors and evolutionary processes. Understanding the genetic architecture of adaptation to the environment is a key aspect of overcoming this hurdle. Models that seek to understand this genetic architecture, however, assume linear relationships between genetic signatures at the DNA level and the environment. This research will, among other things (all objectives not described here), demonstrate that adaptation of quantitative traits in multivariate environments does not result in linear relationships associated with causal genetic signals in the oyster's DNA, illustrating the need for new approaches to understand and predict adaptation in multivariate environments. To address this need, this project will integrate research and education with a Model Validation Program (MVP). The research will develop and evaluate Machine Learning Algorithms (MLAs) for understanding and predicting adaptation of organisms to multivariate environments from single nucleotide polymorphisms (SNPs). The goal of this research is to evaluate if MLAs, which can model non-linearities, can be used to understand and predict adaptation to multivariate environments under a wide range of scenarios.

At ABC, wild populations of oysters from Maine, New Hampshire, Massachusetts, Chesapeake Bay, Atlantic Florida, Texas and Louisiana, as well as DEBY and LOLA lines, were conditioned, spawned and deployed in a common garden project at two field locations (Coan River, York River). Monitoring of survival and growth of these populations, also using individually tagged and genotyped oysters, over the course of two years, will be used to compare to seascape genomic models attempting to predict an individual's fitness in a multivariate (salinity/disease) environment.



CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

ENVIRONMENTAL CHALLENGES

The Chesapeake Bay has been identified as a vulnerable region due to the emergence of multiple environmental stressors. The over-enriching of coastal waters with nutrients like nitrogen and phosphorus causes algae to grow too quickly; disrupting the water chemistry and quality. Heavy precipitation events are predicted with global climate change scenarios, which can result in eutrophication, dead zones, and decreased salinity levels in coastal areas. The success of the Virginia shellfish aquaculture industry partially relies on understanding how these cultured species react to these emerging environmental challenges.

Modeling the influence of multiple stressors on shellfish aquaculture
VIMS Investigators: Mark Brush, Emily Rivest, Marjorie Friedrichs
VIMS collaborators: Pierre St-Laurent, Karen Hudson, and Sara Blachman
Funding source: NOAA

Cultured shellfish are subject to a myriad of stressors including fluctuations in temperature and salinity, elevated total suspended solids, low dissolved oxygen, and declining pH. These stressors will likely become increasingly detrimental with ongoing climate change. To address the impact of these stressors on Eastern oysters the Brush lab's EcoOyster, a model that simulates the growth of oyster tissue and shell over daily, seasonal, annual, and multi-annual time scales as a function of local environmental conditions is being applied to the following collaborative projects:

- NOAA Ocean Acidification (OA) Thresholds Project: Rivest used results from a controlled OA experiment to expand EcoOyster to include the impacts of OA on oysters, particularly on shell growth. The model is predicting OA thresholds and other stressors that will result in negative growth and thus be detrimental to the industry. We are also exploring the potential for seagrasses to offset the negative impacts of OA on oysters by coupling EcoOyster to the seagrass model GrassLight.

- NOAA Regional Vulnerability Assessment Project (with Friedrichs, Rivest, St-Laurent, Hudson, Blachman): EcoOyster has been implemented within the high resolution ChesROMS-ECM model to explore the impact of current and future OA on oyster growth. Shellfish Thresholds and Aquaculture Resilience: Chesapeake Bay

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

ENVIRONMENTAL CHALLENGES

A transcriptomic study of the differential stress response between diploid and triploid eastern oyster and its potential involvement in triploid mortality

VIMS Investigator: Hamish Small | 804.684.7745 | hamish@vims.edu
VIMS Collaborators: Ryan Carnegie, Karen Hudson, Jan McDowell, Kimberly Reece, Jessica Small, Bill Walton
Industry partners: Cherrystone Aqua-Farms, Big Island Aquaculture

Elevated mortalities of eastern oysters, Crassostrea virginica, at farms along the United States Atlantic and Gulf of Mexico coasts represents a significant economic impact to affected growers. Mortality events remain enigmatic and typically have occurred in near market-sized oysters in late spring and early summer months (average ~30%, but has approached 50-85% in some cases).

To investigate the differential stress response between diploid and triploid oysters (and whether this plays a role in mortality events) we deployed six lines of diploid and triploid C. virginica at collaborating oyster farms in 2023. Oysters were sampled from March through October to record mortality and growth data, and to collect sub-samples for histopathological analysis and gene expression studies. In addition, the same oyster lines were used in concurrent stress experiments (ex. elevated water temperature and food limitation) within the VIMS Acuff Center for Aquaculture to further explore the influence of these variables upon oyster health and gene expression response. Laboratory experiments were conducted for two months and samples collected for both histopathological analysis and gene expression studies.

Based on the mortality and growth data collected we have identified a panel of samples from both field and laboratory studies and are currently processing these for histopathological analysis prior to gene expression studies. These studies will help to better understand how different oysters (diploid and triploid) respond to stressors and whether this contributes to cryptic mortality events.

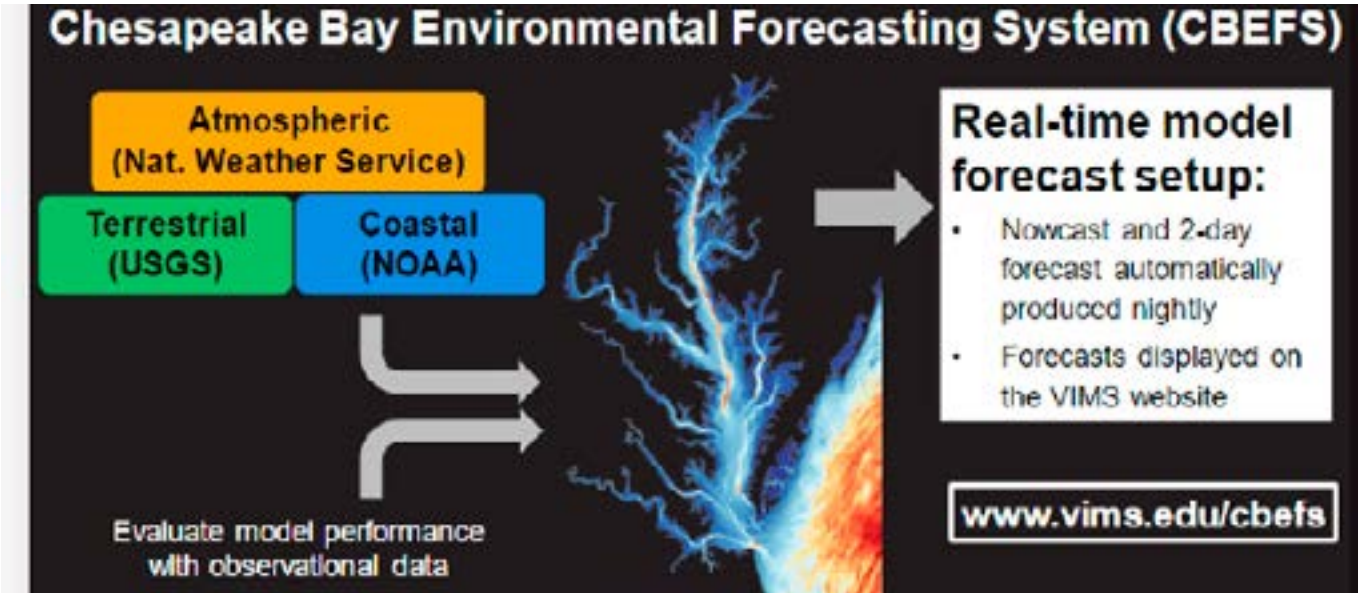
CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

ENVIRONMENTAL CHALLENGES

Chesapeake Bay environmental forecasting system: Accelerating the transition of HAB and pathogen models from research to operations

VIMS Investigator: Marjorie Friedrichs | 804.684.7695 | marjy@vims.edu
VIMS Partners: Pierre St-Laurent, Karen Hudson and Susanna Musick
External P.I.s: Raleigh Hood (UMCES), Christopher Brown (NOAA), Gerhard Kuska (MARACOOS).
External Partners: RPS North America, Anchor QEA
Funding source: NOAA

For many years VIMS' existing CB Environmental Forecasting System (CBEFS) has been providing real-time nowcasts and forecasts of salinity, temperature, hypoxia, and acidification metrics such as pH. Input from Stakeholders has revealed these forecasts to be very useful and indicates interest in additional information including harmful biotic events. Based on this feedback, we are currently adding nowcasts/forecasts of Vibrio as well as Prorocentrum minimum, a harmful algal bloom (HAB). Forecasts of additional HABs such as Microcystis and Karlodinium are also under development. As part of this project we are also establishing a prototype alert system that will send automated alerts when thresholds for the probable occurrence of these noxious organisms are present.



CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

IMPROVING AQUACULTURE PRODUCTION

Virginia leads the nation in hard clam and eastern oyster production. For the industry to continue expanding, it is important to identify methods that increase success and survival in the hatchery, to optimize methods of larval rearing, setting, and field grow-out, and to better understand the effect of domestication and genotype-by-environment interactions. There is also an opportunity to improve efficiency and profitability through innovative techniques and new technology, positioning the industry to thrive and be a national leader. Co-culture of multiple species, multi-trophic aquaculture, and the new species development will further expand Virginia's aquaculture industry.

Culture practices affecting water parameters inside oyster grow-out containers on commercial shellfish aquaculture operations

Student Investigator: Julianne Grenn 804.684.7313 | jmgrenn@vims.edu
Faculty Investigator: William Walton
Funding Source: VASG graduate research fellowship

Numerous studies have reviewed how different husbandry decisions on oyster farms correlate to oyster performance, but not much is understood about how these decisions affect the water parameters inside oyster grow-out containers. Ambient conditions on leases might appear suitable for oyster performance, but different husbandry decisions could potentially affect the environment within the growing containers and cause significant deviation from ambient conditions.

This ongoing project explores if stocking density and total mesh blockage affect water parameters (dissolved oxygen, pH, turbidity, and chlorophyll-a) inside oyster grow-out containers. Paired water samples were collected from May through October of 2022 and 2023 from the inside and less than 0.3 meters outside of oyster-growing containers at 22 farms in North Carolina, Florida, and Virginia across various gear types, salinities, and water temperatures.

Preliminary data analysis shows that the lowest DO, pH, and chlorophyll-a values were observed in bags with greater than 50% stocking density and 70% blockage. Results from this study suggest that farmers can influence the water parameters within their bags through various husbandry decisions.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

IMPROVING AQUACULTURE PRODUCTION

Ulva and Oyster Coculture: A potential climate change mitigation strategy for oyster farmers
Student Investigator: Julianne Grenn 804.684.7313 | jmgrenn@vims.edu
Faculty Investigator: William Walton
Funding Source: VASG graduate research fellowship, TNC SOAR, VIMS

This project explores the feasibility of Eastern oyster and Ulva co-culture with a field experiment deployed at a shellfish farm located on the lower York River, Virginia. We are examining how combinations of oyster stocking density crossed with Ulva density in floating baskets affects

1. water parameters inside baskets (dissolved oxygen, chlorophyll-a, pH, turbidity, and Ωcalcite),
2. oyster growth and performance and
3. shelf life of the oysters.

We will also survey restaurants that purchase oysters to quantify market interest in this product and understand Ulva's potential uses in the food industry.

This project explores if Ulva, a common occurrence on oyster farms, can impact Ωcalcite values inside oyster bags and baskets. If Ulva raises Ωcalcite values inside grow-out containers, this research could help farmers immediately mitigate climate change using an easily accessible and cost-effective solution. This study can also inform farmers on if there is a market for Ulva and what those end uses might be in a restaurant setting. Farmers could leverage this knowledge to expand production to include a new product if chefs and restaurants indicate interest. This study encourages growers to adopt best-rearing practices that improve the long-term sustainability and resiliency of oyster farms in the face of this changing climate.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

IMPROVING AQUACULTURE PRODUCTION

Test of the genetic diversity of a hatchery cohort on grow-out performance
VIMS Investigators: William Walton, Jessica Small , and Jan McDowell

In shellfish hatchery production, the effective number of parents in any given cohort can vary widely. In addition, the typical hatchery practices often include culling of slow growers. In combination, these practices may lead to cohorts of seed having very different genetic diversity. We are evaluating the field grow-out performance of five cohorts produced with varying number of effective parents with seed spawned in 2023. We will repeat this work in 2024. Performance is being assessed in terms of growth and survival.

Comparison of bottom and floating cage oyster production
VIMS Investigator: William Walton | 804.684.7238 | walton@vims.edu

Intensive aquaculture is the practice of raising oysters in containers through their life cycle to market. In Virginia, intensive aquaculture is dominated by two basic practices, bottom cages and surface floats. There are costs and tradeoffs in both practices, and the challenge for any new farmer is to determine which practice is cost effective and fits their business model best. The purpose of the project is to compare a series of metrics between oysters raised in floating cages versus those raised in bottom cages to provide growers quantitative data on the differences.

Oysters were raised to market size and underwent normal husbandry practices that include grading and sorting through the life cycle. At the same time, oysters were measured for specific metrics at regular intervals. These metrics can be loosely divided into three categories: 1) Yield (growth and survival); 2) 'Quality' (e.g., shell shape, meatiness, etc.); 3) Consumer Satisfaction. Metrics include, but are not limited to, attributes such as: growth and survival, shell shape, meat fullness, color, cleanliness, shelf life, and willingness to pay; with the latter being assessed once oysters had reached market size later in the study.

The study team is compiling an informational report that will describe the study and the results. This literature will be distributed to various industry organizations and resources for distribution to the aquaculture community of practice. Examples may include sites such as the Shellfish Growers of Virginia, VIMS Marine Advisory Services, the East Coast Shellfish Growers Association, etc.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

IMPROVING AQUACULTURE PRODUCTION

Exploring the use of technology to enable data-driven decision-making in commercial shellfish farm management

Student Investigator: Matthew LaGanke | 508.505.5631 | mjlaganke@vims.edu

Faculty Investigator: William Walton

Funding Source: Chesapeake Bay Trust Oyster Innovation Program, VIMS Internal Funds

Despite the rapid expansion of shellfish aquaculture in the digital age, commercial shellfish farmers predominantly rely on traditional tools for farm management, which force decisions based on less-than-complete information. In an industry constrained by limited labor and slim profit margins, poor decisions can increase the workload exponentially and amplify the economic strain on a company. This four-part research initiative investigates the feasibility and practicality of integrating modern management technology to help track, preserve, and analyze data for the purpose of providing farmers with better insights for production decisions and risk reduction.

1. Evaluate the needs of shellfish farm managers across the US through a nationwide survey toinvestigate the challenges, behaviors, and perceptions of shellfish farm managers as they pertain to daily farm management stressors, inventory management, sudden unusual mortality, and technology adoption.

2. Innovate a new application for Radio Frequency Identification (RFID) technology to digitally track and manage oyster farm inventory. RFID technology is similar to barcode scanning technology, but more robust against biofouling and other environmental challenges.

3. Evaluate the ability of three state-of-the-art models to predict oyster growth. Working closely with an off-bottom oyster farm in Florida who has collected five years of crop growth data, the team will compare whether models based on pattern recognition (machine learning), organism-environment derived relationships (bioenergetic), and farmer-experience (scientific wild guess) are more accurate in predicting year-round oyster growth.

4. Publish resources, including webinars for industry and extension personnel, on the tradeoffs of adopting digital technology in shellfish aquaculture, with a focus on RFID and other cutting-edge technologies.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

IMPROVING AQUACULTURE PRODUCTION

Characterizing the role of toxic phytoplankton byproducts in shellfish hatchery failures
VIMS Investigator: Juliette Smith I 804.684.7289 | jlsmith@vims.edu
VIMS Collaborator: Ryan Carnegie (Co-P.I.)
External Collaborator: Bethanie Edwards, UC Berkeley
Industry Collaborators: Oyster Seed Holdings, Mook Sea Farm, Fishers Island Oyster Farm
Funding source: NOAA-NMFS Saltonstall-Kennedy

This project is expected to promote the sustainability of oyster seed production through mitigation of an emerging disease syndrome on the US East Coast. A troublesome new syndrome presented in young oyster larvae at several regional hatcheries in 2020, resulting in production failures decreasing seed output by over 40%. Moribund, dwarfed, and delayed in development, affected larvae clearly displayed pale digestive glands suggesting failure of digestion despite a stomach full of microalgal food. The signs reappeared in 2021, demonstrating the disease's persistence. Similar signs presented across a wide geography, with reports of seed not digesting their food, and therefore not growing, at hatcheries in Maine, New York, and Virginia. Preliminary work conducted by one of these hatcheries, Mook Sea Farm (Maine), demonstrated a link between the signs and toxic phytoplankton byproducts in the hatchery water. This timely project now builds on this information, expanding the study to include three East Coast hatcheries and experts in disease and lipidomics. Through partnerships between industry and academia, this project strives to understand this new but persistent disease, increase awareness along the East Coast, and identify mitigation technology to avoid or minimize symptoms with the overall goal of improving product yield.

This work addresses three objectives

1. Characterize byproducts and their algal producer(s) in incoming seawater and within hatchery-treated water at three East Coast hatcheries across seasons;
2. Correlate hatchery performance (yield) with pathology and byproduct abundance; and
3. Determine the relative potency of the most abundant byproducts, and identify a water-treatment solution to remove these byproducts.

An informative brochure, webpage, listserve, and presentation at an industry-focused conference will be used to communicate results and application to end users. Outcomes expected from the following activities include an increased awareness of empty-gut syndrome among East Coast hatcheries, and adoption of optimized water treatment step(s).

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

IMPROVING AQUACULTURE PRODUCTION

Economic and environmental feasibility of soft-shell clam aquaculture in Virginia
VIMs Investigator: Rochelle Seitz I 804.684.7698 | seitz@vims.edu
VIMS Collaborators: Andrew Scheld, Rom Lipcius, Lauren Gregg
External Collaborators: Brian Beal, University of Maine; Mike Congrove, Oyster Seed Holdings
Funding source: Saltonstall-Kennedy Grant, NOAA Fisheries

Soft-shell clams (Mya arenaria) are suspension-feeding, infaunal clams ranging from Canada to Georgia. Maine has cultured soft-shell clams for years, and there is market demand for them in Virginia. We have been able to successfully spawn soft-shell clam broodstock with known culture techniques, and this species could enhance and diversify VA aquaculture. Soft-shell clams naturally exist in VA waters, and VA soft-shell clams can add >1 mm shell length/week when grown on-bottom from fall to early summer, whereas growth rates are slower farther north.

Our objectives are to spawn, raise, and grow out soft-shell clams to engage partnering shellfish growers, and to experimentally examine environmental conditions necessary to enhance production of soft-shell clams. A team of researchers and the aquaculture industry are studying the economic and environmental feasibility of soft-shell clam aquaculture in VA. Interviews with industry personnel indicate that there is interest in soft-shell clams, and VA-grown soft-shell clams could be marketed locally and in the Northeast.

This study will additionally determine the clam's ability to grow and reproduce under various conditions in VA. We will determine how factors such as temperature, salinity, water depth, and predator-exclusion equipment can affect optimal soft-shell clam production in VA. The next step is to involve shellfish growers at multiple locations at varying salinities throughout VA to reveal which conditions are best for growing soft-shell clams. We hope to stimulate interest among commercial growers who can scale-up the field grow-out and sale of this new species in VA. For outreach, we plan to use AIE, workshops, aquaculture meetings, festivals, and marketing to inform the public and engage industry to stimulate a new aquaculture species and enhance industry resilience.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

SHELLFISH HEALTH AND BIOSECURITY

Historically, disease often spread through the transfer of shellfish has had devastating effects on shellfish stocks and aquaculture farms along the East Coast of the United States. It is important to regulate and streamline the transfer of seed between locations to control for disease. Hatchery production is critical to the shellfish aquaculture industry in Virginia and effective management of shellfish pathogens, both endemic and emerging, remains key to sustainable aquaculture development.

Influence of selective breeding on human pathogenic Vibrio spp. in eastern oysters

VIMS Investigator: Corinne Audemard I 804.684.7803 | audemard@vims.edu

VIMS Collaborators: Kimberly Reece, Ryan Carnegie, William Walton, Jessica Small, Robert Latour

Funding source: NOAA-NMFS Saltonstall-Kennedy

The production of oysters safe for human consumption is one key factor for promoting a sustainable oyster aquaculture industry. The threat of human pathogenic Vibrio bacteria naturally associated with oysters is managed through broad measures that fail to account for the wide range of Vibrio spp. concentrations observed among individual oysters within a population. Building upon results from our previous studies, we propose to evaluate the effects of oyster lines and associated oyster health on variations in levels of these pathogens among individual oysters.

We are in the second year of the project. Oyster samples will be collected monthly from May through September. Oysters have been deployed in floating bags at two sites differing in their salinity regime: ~20 psu and ~15 psu. Each oyster sampled will include a measure of 1) total V. vulnificus and total and pathogenic V. parahaemolyticus and 2) general oyster health. Potential influence of oyster line and health status will be analyzed through generalized linear mixed-effects models.

This project will determine whether inclusion of Vibrio spp. levels should be an additional trait controlled through oyster selective breeding programs, and whether using lines that are selected for specific grow-out environments may bring potential benefits with regard to Vibrio spp. abundance and thus control.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

SHELLFISH HEALTH AND BIOSECURITY

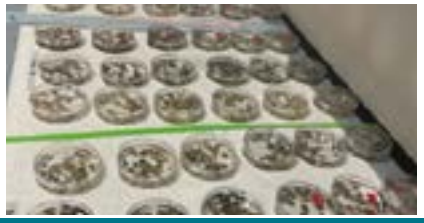
Impact of OsHv-1 microvariants on Crassostrea virginica family lines
VIMS Investigators: Jessica Small & Kimberly Reece
External P.I.: Colleen Burge, California Department of Fish and Wildlife
Funding source: United States Department of Agriculture

Continued growth of the eastern oyster aquaculture industry relies on consistent and increasing hatchery production, availability of disease resilient stocks and the ability to move oysters among leases (following state regulatory structure). The Ostreid herpesvirus 1 (OsHV-1) and its variants, in particular the more pathogenic OsHV-1 microvariants (OsHV-1 µvars), are emerging infectious disease agents of global concern. Though OsHV-1 µvars are primarily known to affect Pacific oysters, there is concern over the potential impacts of the OsHV-1 µvars to the Eastern oyster and hard clam with the possibility of the spread of the virus to the US East and Gulf Coasts. Therefore, the goal of this research is a proactive approach focused on applied solutions, such as selective breeding, in order to limit impact of OsHV-1 µvars on the rapidly growing eastern oyster aquaculture industry.

The objectives of our research are as follows:
1. Conduct laboratory trials to examine differential survival and viral loads of spat and juveniles exposed to OsHV-1 µvar,
2. Perform quantitative genetic analysis based on survival and OsHV-1 viral loads in order to assess the heritability of resistance/tolerance to OsHV-1 in ABC families, and
3. Develop tools for industry preparedness in case of an OsHV-1 µvar introduction.

Two laboratory challenges have been completed. All laboratory trials have been and will continue to occur in a quarantine laboratory in Arizona.
- Mortalities among C. virginica spat ranged from 0-50% with a mean mortality of 15.1±2.5%.
- Juveniles from families showing mortality in the spat challenge were exposed via injection to µvars w/ mortality ranging from 0-86.7% with a mean of 23.3± 6.9%.
- Performance was highly correlated between the spat and juvenile challenges. Viral loads were high in families with higher mortality and low in those with no or very low mortality.

Early results suggest that although some lines and families are susceptible, there is strong evidence for a high degree of genetically-based tolerance in C. virginica. This will be assessed further. These results suggest that selective breeding efforts within C. virginica could play an important role in combatting OsHV-1 should it spread to the East and Gulf Coasts of the US.



CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

SHELLFISH HEALTH AND BIOSECURITY

Virginia coast bay scallops, Argopecten irradians: aquaculture and wild restoration
VIMS Investigator: Richard Snyder & Jan McDowell
757.787.5834 | rsnyder@vimes.edu |
Funding source: NOAA-NMFS Saltonstall-Kennedy

This project is testing the potential of using bay scallops (Argopecten irradians) for both ecological restoration and aquaculture. Restoring the wild population of bay scallops to seaside Eastern Shore of Virginia (ESVA) is focused on increasing genetic diversity. Aquaculture efforts for bays scallops are focusing genetics on traits suitable for culture (fast growth, size, shell color). Both of these goals are using genetic stocks maintained at VIMS ESL from Florida, North Carolina, and New York. Aquaculture efforts also include working with local growers on different techniques, and replicating those at ESL at smaller scale, and developing a plan for a private commercial hatchery.

Education and Training of Veterinary Professionals in Molluscan Hatchery Science and Pathology
VIMS Investigators: Ryan Carnegie, Karen Hudson
Partners and Funding: USDA APHIS Veterinary Services

The Regional Shellfish Seed Biosecurity Program (RSSBP) is a collaboration of Industry, Scientists, Regulators and Extension using the best available science to minimize risks associated with interstate seed transfers of bivalve shellfish. A centerpiece is the Hatchery Compliance Program where hatcheries agree to adopt best practices to minimize disease in hatchery production, regular surveillance for disease and annual physical audits of hatchery facilities to ensure continued compliance with best practices. Given the essential focus on health management, we recognize that incorporating expertise and engagement of the veterinary community in the program would have great benefit, most importantly because it would promote alignment of the RSSBP with the USDA Comprehensive Aquaculture Health Program Standards (CAHPS). Veterinary medical professionals are rarely familiar with shellfish hatchery production methods, and seldom expert in the diseases of molluscs, so there is a clear need to provide training in these areas as a basis for improved engagement with the veterinary community. Specific objectives for the collaboration include:

1. Develop online and in-person training in molluscan shellfish hatchery science
2. Develop online course material on diseases of marine molluscs relevant to hatchery production and aquaculture commerce
3. Conduct an in-person pilot training course to deliver and refine a plan for training that can be used moving forward

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

SOCIOECONOMICS

It is important to understand how society perceives and interacts with the shellfish aquaculture industry for the industry to grow and expand. Societal changes and/or changes in the economic climate may make it difficult for the industry to succeed and action may be necessary to help overcome these obstacles. Furthermore, with increasing production, there may be a need to expand markets and increase consumer demand. Understanding marketing opportunities, consumer attitudes and distribution channels mayincrease in importance.

Feasibility of offshore wind farm areas as multi-use platforms for lower-trophic aquaculture
VIMS Investigators: Andrew Scheld & William Walton
804.684.7160 | scheld@vims.edu
External P.I.s: Elizabeth Andrews (VCPC / W&M Law), Daniel Taylor (Danish Shellfish Center)
Funding source: Atlantic States Marine Fisheries Commission

Over two million acres are presently leased for offshore wind energy development in federal waters of the US Northeast and Mid-Atlantic. The public and federal managers have expressed an interest in maintaining seafood production within these areas. This study investigates the biological, economic, and regulatory feasibility of co-locating lower-trophic aquaculture within offshore wind farms along the US Atlantic coast. Opportunities and barriers for co-location will be identified for a suite of potentially feasible cultured species.

Testing sugar kelp as a winter crop
VIMS Investigator: Richard Snyder I 757.787.5834 | rsnyder@vimes.edu
External Collaborators: Scott Lindell (Woods Hole Oceanographic Institution)
Funding source: Department of Energy's ARPAE MARINER Program

The purpose of this project is to test the commercial potential and temperature tolerance of sugar kelp in Virginia coastal waters. Kelp farming is a young, fast growing, million-dollar industry in Maine and Alaska. A seed string was set out November 2022 and harvested April 2023 with minimal growth, likely due to limited nutrients on seaside ESVA. A second, more promising, trial was run January to April with 1.5 kg/m growth. This has potential for a passive annual winter crop for ESVA Aquaculture. ESL is researching the utilization of other algae species.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

SOCIOECONOMICS

"Who" is Virginia's shellfish aquaculture industry?
VIMS Investigator: Adriane Michaelis | 804.684.7392 | amichaelis@vims.edu
Student Investigator: Zea Smith (REU Student, California Polytechnic University Humboldt)

Demographic data within the US aquaculture industry overall is limited, and this project aims to address that gap in Virginia going beyond basic demographics to describe the individuals and identities that make up Virginia's farmed shellfish industry. Using semi-structured interviews to guide discussions, the research team is meeting with shellfish aquaculturists throughout the state to understand how individual identities shape experiences in aquaculture. Interviews are anonymous, but for interested participants, profiles will be featured on the Communities & Coasts Lab webpage. Interviews began in June 2024 with a focus on women in the industry but will continue through at least 2025 to capture the many perspectives of Virginia's shellfish growers.

Improving the messaging from servers to patrons regarding half-shell oysters at restaurants
VIMS Investigator: William Walton and Adriane Michaelis
External Investigators: Thomas Bliss (University of Georgia), Dan Petrolia (Mississippi State University), Jason Rider (Mississippi Department of Marine Resources), Leslie Sturmer (University of Florida), Beth Walton (Oyster South)

Despite the recent expansion of oyster aquaculture in the southern US, lack of knowledge about the quality of these farm-raised oysters and even negative perceptions about southern farm-raised oysters continue to persist, especially in regions outside of the southern US. Over two years, as part of a regional effort in a project led by Oyster South, we are providing trainings to servers in seafood restaurants that serve oysters on the half shell to allow servers to better 'tell the story' of the oysters that are served. We will also conduct formal quantitative and qualitative assessments of the effectiveness of this training program to estimate the causal effect of training on knowledge of and, ultimately, sales of farm-raised oysters.

CURRENT RESEARCH PROJECTS (BY FOCAL AREA)

SOCIOECONOMICS

Addressing labor demand and production efficiency in shellfish aquaculture
Student Investigator: Caela B. Gilsinan
Faculty Investigator Andrew M. Scheld I 804.684.7160 | scheld@vims.edu|
VIMS Collaborators: Adriane Michaelis, Karen Hudson, Bill Walton
External Collaborator: Andrew Ropicki, University of Florida
Funding source: United States Department of Agriculture (USDA)

Virginia and Florida bivalve shellfish aquaculture has rapidly developed however, culturing hard clams and Eastern oysters has high labor requirements due to biofouling control, gear maintenance, and splitting and grading product. Data on labor demands for various production processes and methods are limited. This research will measure labor demands in different types of shellfish culture to assess production efficiencies, evaluate potential technology substitutions, and determine optimal workforce development.

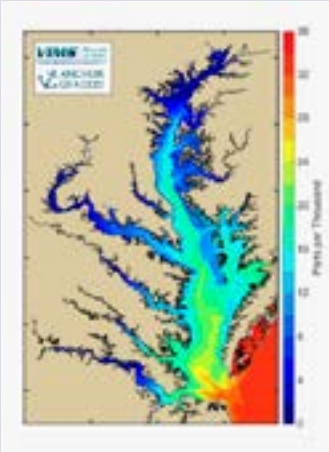
Materials, physical capital, and labor requirements for common oyster and hard clam grow out were assessed through a literature review. Virginia oyster farms were visited to learn more about their operations and grow out methods. After meeting and discussing with members involved in the shellfish industry, two surveys were developed:

- One-time business overview survey which includes background on the business, production equipment, and labor.
- Biweekly farm work report which asks about labor, harvest, workforce management, work intensity, injuries, and challenges.

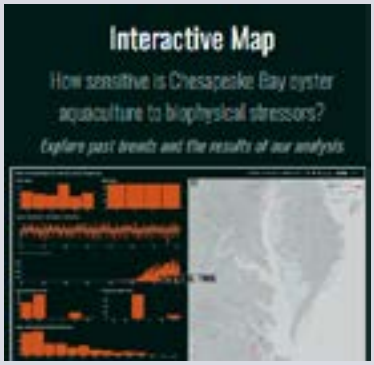
Currently, 10 small-scale farms in VA and FL producing oysters and/or hard clams are participating in the surveys and will provide one year's worth of data. Upcoming employer and employee interviews will be conducted with VA and FL commercial shellfish farmers. Interview topics will focus on labor availability, job satisfaction, stressors on productivity, technology substitutions, and industry growth. This project will provide an improved understanding of labor supply and demand in the bivalve shellfish aquaculture industry so that tools and policies can be developed to improve production efficiency, increase total output, facilitate economic development, and improve sustainability in the sector.

TOOLS AND REPORTS

INTERACTIVE / INFORMATIONAL TOOLS DEVELOPED BY SHELLFISH AQUACULTURE PROGRAM MEMBERS (INDIVDUALLY OR IN COLLABORATION WITH



CB ENVIRONMENTAL FORECASTING SYSTEM (CBEFS)



CB OYSTER VULNERABILITY TO MULTIPLE STRESSORS

REGIONAL SHELLFISH SEED BIOSECURITY PROGRAM

VA OYSTER PRODUCTIITY & INFORMATION

LONG-TERM MONITORING REPORT LINKS

- Ecological Monitoring Program at VIMS ESL Annual Reports 2018-Current.
- Shellfish Pathology Laboratory – Status of the major oyster diseases in Virginia
- Marine Advisory Program – Annual Va Shellfish Aquaculture Situation and Outlook Report
- Submerged Aquatic Vegetation Annual Monitoring Reports – ***Distribution of Submerged Aquatic Vegetation in Chesapeake Bay and Coastal Bays***

WORKFORCE DEVELOPMENT

OYSTER AQUACULTURE TRAINING (OAT) PROGRAM

Jess Small I jamoss@vims.edu I 804.684.7955

The Oyster Aquaculture Training (OAT) program is a five-month hands-on program, focusing on various principles of oyster aquaculture. Located at VIMS in Gloucester Point, Virginia, participants learn and work alongside researchers during our oyster hatchery and spring field season from roughly April to August. To ensure a one-on-one experience, we accept a maximum of two participants each year. During the five-month program, participants will rotate through various stages of oyster aquaculture, including hatchery, nursery, field grow-out operations and laboratory. Working through these rotations will provide a sound understanding of all phases of the oyster life-cycle.

The program offers prospective shellfish aquaculturists an opportunity to learn about all aspects of oyster culture, from hatchery to field operations—essentially, it is oyster culture "boot camp." Many of these trainees have ended up in local businesses, and some have gone far afield. Consideration is afforded to all applicants who demonstrate a desire and aptitude for oyster aquaculture. The program draws from a national pool. The intention is to provide skilled people to the industry, with a priority to Virginia businesses. Companies may contact ABC if they anticipate a need for new employees and could benefit from obtaining a trained individual from the program.

ESL BONNIE SUE INTERNSHIP PROGRAM

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For more than 20 years, VIMS-ESL researchers used grant funding to support 1-2 summer internships for local high school and college students each year. As part of a privately funded initiative, VIMS-ESL has expanded this summer internship program to hire 5 high school and college students from Accomack and Northampton Counties each year. This has been supported by donors to the Bonnie Sue Scholarship Fund.
During the summer that they spend working at ESL, interns primarily assist ESL staff with ongoing research projects. Recent projects have focused on: aquaculture of clams, bay scallops and oysters; habitat needs of juvenile marine fishes; water quality; and general marine ecology and monitoring.

Former ESL summer interns go on to receive undergraduate and advanced degrees in biology and environmental science. Many return to the Eastern Shore after college and find employment in the local aquaculture industry, teaching and research.

WORKFORCE DEVELOPMENT

MARINE ADVISORY PROGRAM WORKFORCE

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The MAP team focus is on supporting local workforce options by ensuring local high school career counselors and students are aware of the variety of career options in aquaculture and related marine trades, and by connecting industry partners to those recent graduates seeking employment. Deliverables include:

Design and pilot of a Marine Trades Career Expo

- Creation of an online directory of industry contacts who are interested in hiring local students for upcoming openings, as well as high school WFD coordinators who may be looking to place students
- Creation of outreach materials highlighting careers in aquaculture and the marine trades for download and distribution
- Creation of a Virginia's Young Fishermen Initiative Listserv

C-SALT APPRENTICE PROGRAM

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The Shellfish Aquaculture Research Farm Apprentice, established as a 3-month pilot program in 2024, assists in all aspects of field project maintenance focused on the C-SALT shellfish research farm at the Gloucester Point Campus. During a 6-month program offered annually (pending funding), there is a dedicated effort to obtain the knowledge and understanding associated with the occupational standards of a commercial shellfish aquaculture crew chief. The apprentice obtains experience with 3 different types of shellfish aquaculture gear, becomes comfortable handling a small vessel, and learns the hard work and dedication required to maintain a shellfish aquaculture farm. The intention of this program is to prepare individuals for success in the shellfish aquaculture workforce.

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WITH SUPPORT FROM - SAP Colleagues
ACKNOWLEDGING - Lexy McCarty for her contributions to the previous document version

UPDATED SEPTEMBER 2024

PUBLICATION NUMBERS