

1) Proposed Research Focus: Biotechnology Approaches to Seafood Security in a Changing Ocean

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4) Intellectual Merit: (the research focus)

A. Need: More than 10% of Maine’s employees are involved in the ocean sector, despite only 25 of the 3500 miles of Maine coastline classified as working waterfront. Seafood processing and lobster landings alone bring >\$300M to the state each year. But increased privatization of waterfront property limiting access to the shoreline, paired with multiple climate-related and land-based stressors that impact water quality in the greater Gulf of Maine (GoM) ecosystem threaten to erode the fabric of Maine’s seafaring culture. It’s difficult to tease apart the relative importance of each stressor and their synergistic effects and to predict how fisheries will fare in rapidly changing ocean. Further, the US is slow to adopt technological tools to improve fisheries yield, safety, and resilience that exist, but are not yet well-explored in the context of aquaculture.

Currently, Maine’s fisheries portfolio is based on very few commodities, making Maine’s seafood system highly vulnerable. The aquaculture industry is poised to diversify seafood production lines and make significant contributions to the state economy, but faces 1) the same water quality challenges as wild-caught fisheries that could limit yield and compromise safety of product for human consumption and 2) infrastructure limitations to conduct cutting-edge research and development and generate new jobs. **Seafood security depends on understanding the environmental and ecological drivers of the GoM ecosystem and the bottlenecks to industry growth; only then can we assess risk and make informed decisions about how best to increase fisheries capacity in the state, as well as make our current operations more sustainable.**

B. Research Goal & Objectives: The overall goal of our project is to capitalize on the pioneering and innovative spirit of Mainers and build a cross-sector collaborative of working waterfront industry members, the growing local food sector, biotechnology, marine scientists and educators, and state policy-makers to build a more secure, responsive, and reliable seafood system in a changing ocean. We propose three key focus areas:

- 1) Conditions in the GoM are changing more rapidly than almost anywhere else on earth and its imperative that we identify the critical drivers of change for effective management and adaptation strategies. But understanding how one driver operates in isolation is insufficient – **we must strive to understand how multiple stressors (e.g., warming, coastal acidification, increased precipitation, hypoxia and eutrophication) interact synergistically to impact fisheries production and sustainability.** Armed with this information, we seek to develop indices of ocean health and risk assessment for stakeholders as they decide whether and where to invest capital or when to diversify fisheries portfolios.
- 2) Increasingly we are aware of threats to human health and biosecurity of aquacultured products that reduced ocean water quality can pose, but seafood is also a natural resource for critical dietary needs (e.g., omega-3s, iodine, etc.). **The proposed Maine Marine Biotechnology Hub (MMBH) will provide the infrastructure and resources needed to assess the sources and probability of danger for human safety (heavy-metal contaminants, biotoxins, and pathogens) and biosecurity (fisheries pathogens) placed in a global context and balanced with a quantification of nutritional value will give consumers more confidence in buying Maine-based seafood products.** Developments in the biotechnology sector can enable us to create and help implement rapid detection tools for policy-makers and generate new and/or value-added seafood products adapted to anticipated water quality changes (from focus area 1) with improved culturing and processing technology.
- 3) The prior two focus areas are each components of building a more resilient working waterfront in Maine. **The final**

component would be a robust workforce development training program, including continuing education for the existing working waterfront population and introduction to sustainable fisheries science and biotechnology at the high school stage, to realize and retain potential economic growth within Maine informed by scientific knowledge gained and using the proposed MMBH. These programs would be in addition to traditional undergraduate and graduate training programs. Support for new approaches is inexorably tied with education of the general public and workforce development.

C. Research Actions:

- Installing a **Research and Industry-compatible Monitoring Network** that will be used to:
 - Attribute measurable ecological/ecosystem change (particularly for commercially important species) to physio-chemical oceanographic drivers and define scope for species adaptation
 - Detect early and systematically warn of extreme events (e.g., precipitation driven acidification, rapid warming, or harmful algal blooms) and
 - Create predictive power for ecosystem and economic forecasting and development of risk assessment tools
 - Leverage existing monitoring programs to reduce capital costs and citizen-science approaches to more deeply engage the general public
 - Design elegant process-based field and laboratory studies to formally test compelling hypotheses
- Build state-of-the-art **Maine Marine Biotechnology Hub** to:
 - Create and operate formal, FDA-approved testing centers for various human health concerns that broaden existing state public health testing programs and allow for targeted management actions
 - Develop genetic systems for guiding selective breeding of commercial aquatic species of interest
 - Generate new intervention strategies to prevent/ameliorate the effect of pathogens/changing ocean conditions (e.g., with genetic modification or virus therapy)
 - Develop of cheap, quick diagnostics (using biomolecules, genetics, etc.) to expand the scope of testing programs for biosecurity for aquaculturists
 - Bioprospect for marine natural products (e.g., explore the utility of seaweed extracts as anti-disease agents in aquaculture, or as value added consumer products)
- **Workforce development** (including training for continuing education and grade schools)/STEM
 - Incorporate hands-on programs in sequencing, bioinformatics, and genetics for undergraduate and graduate programs
 - Participation of high-school students and undergraduates on iGEM, an international program for developing critical thinking and problem solving using genetic engineering
 - Provide the scientific and cultural environment to retain trained workforce and attract new companies to Maine
 - Raise caliber of training and tech transfer for existing waterfront workforce
 - Providing experiential training courses/workshops and forums for resource managers and stakeholders engaged in seafood security issues

D. Priority: The proposed project addresses several NSF program priorities, including investing in the development of human capital and infrastructure. We also address three of seven Maine targeted technology sectors, including biotechnology, environmental technologies, and marine technology and aquaculture.

5) Broader Impacts: (related to the research focus)

E. Societal Benefit Impacts:

- Generation of new opportunities in the seafood sector that allow for retention of working waterfront jobs
- Resistance of the 'Maine brand' of seafood to human safety and biosecurity concerns, and resiliency to fluctuations in fisheries production
- Development of a landmark statewide monitoring program (with early warning markers), stakeholder-relevant indices, and forecasting and risk assessment tools to help achieve outcomes.
- Creation of a marine biotechnology center to facilitate research and development of applied solutions

F. Economic Development Impacts:

- High-tech monitoring and biotech infrastructure, and the jobs to maintain that infrastructure
- Improved understanding of the ecological and physical drivers of coastal food webs = better possibility of restoring once lucrative fisheries (or exploiting new sources best suited to cope with future change)
- New aquaculture products (e.g., value added) = expansion of current efforts and job diversification
- Provide incubators and attract start-ups to Maine by providing a trained workforce

G. Workforce Development Impacts: While hiring of faculty and research scientists and training of postdocs, graduate, and undergraduate students continues to be an important component of workforce development, there are two underserved populations in Maine this proposal is targeting: high school students (vocational and experiential training) and members of the working waterfront seeking to diversify (continuing education). By coupling scientists with industry members and students directly, we will help increase stakeholder knowledge base, and equip them with new tool kits for improved decision making, risk assessment, and business development.

H. R&D and Education Infrastructure Impacts: We seek to develop water quality monitoring network, to develop a marine biotechnology center, and to establish industry incubators for accelerating innovation, each which can contain training components or facilities for education and outreach