Project Summary

Purpose

In response to the U.S. Food and Drug Administration Model Ordinance under the National Shellfish Sanitation Plan, we propose a smart deterrent system to mitigate bird roosting impacts on oyster aquaculture, specifically targeting surface oyster farms. This initiative integrates a camera-based roosting bird detector, a flexible deterrent delivery system, an intelligent learning system, and an advisory service, aiming to develop a commercially viable and environmentally friendly solution that adheres to regulations without overburdening farmers.

[1]

This project's purpose is to address the challenges posed by bird droppings in oyster aquaculture through developing a smart, cost-effective deterrent system. This system is designed to be adaptive and sensitive to farm-specific and species-specific conditions, promoting sustainable aquaculture practices while ensuring compliance with regulatory requirements.

[1] A rendering of the integrated avian deterrence system. This includes the use of existing technology: cameras, a deployed sonic-net, the use of a semi-autonomous unmanned boat, and an artificial intelligent bird behavior model to detect and dispatch deterrence strategies.

Activities to be Performed

Year 1: System Development and Initial Deployment

- Construction of the smart deterrent system, including the roosting bird detector and the flexible delivery mechanism.
- Installation of the system in several surface oyster farms for preliminary testing, focusing on "Sonic Net" deterrents and a water spray mechanism.
- Introduction of a semi-autonomous unmanned boat as a mobile delivery mechanism for further evaluation.

Year 2: Optimization, Evaluation, and Advisory Service Implementation

- Optimization of the deterrent system based on initial feedback, incorporating the intelligent learning system for adaptive deterrent deployment.
- Development of an evaluative framework to assess the effectiveness of the mitigation strategies in conjunction with environmental factors and operational practices of the farms.
- Establishment of an advisory service and community board to partner farmers with experts for system calibration and selection of suitable deterrents.

Expected Outcomes

This project is expected to yield a scalable and effective deterrent system that reduces the incidence of bird droppings in oyster farms, thus enhancing water quality and shellfish health. By providing a commercially viable solution that compares favorably with the cost of standard farming equipment, we aim to support the sustainable growth of the aquaculture industry.

Intended Beneficiaries

- Aquaculture Farmers: Operators of surface oyster farms will benefit directly from access to innovative bird deterrent technologies, improving their environmental management capabilities.
- The Wider Aquaculture Industry: Adoption of this smart deterrent system will promote more efficient, productive, and sustainable aquaculture practices.
- Environmental Researchers and Policymakers: The project will provide valuable insights into effective wildlife management strategies, supporting evidence-based policymaking for sustainable aquaculture development.

Subrecipient Activities

Virginia Institute of Marine Science

VIMS will play a crucial role in data collection and analysis, particularly through the Commercial Shellfish Aquaculture Lab, which will provide specialized knowledge in shellfish aquaculture practices and environmental interactions.

Old Dominion University

The Office of Enterprise Research and Innovation will contribute to technology development, artificial intelligent training, focusing on the integration of autonomous systems and image recognition technologies for bird deterrent applications.

William and Mary

The Institute for Integrative Conservation at William & Mary is contributing avian ecology subject matter expertise. The institute will contribute consultation on establishing the requirements for the Sonic-Net and help establish behavior tagged observations from video data collected in the field.

Harmonizing Technology, Ecology, and Aquaculture: Multi-Partner Innovations for Bird Deterrence on Oyster Farms

Type of Project

This initiative represents a collaborative multi-partner effort.

Investigators and Subject Matter Experts

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Collaborative Partners

- Old Dominion University (ODU)
    - Office of Enterprise Research and Innovation (OERI)
    - Virginia Institute for Spaceflight and Autonomy (VISA)
    - Virginia Digital Maritime Center (VDMC)
    - Virginia Innovation Partnership Corporation (VIPC)
- Virginia Institute of Marine Science (VIMS)
    - Commercial Shellfish Aquaculture Lab & Team (C-SALT)
- William and Mary (W&M)
    - Institute for Integrative Conservation

Estimated Budget

	ODU	VIMS	W&M	**Totals**
Year 1 Sponsor	$428,418	$96,209	$37,423	$562,050
Match $	$164,698	$48,104	$38,326	$251,128
Year 1 Total	*$593,116*	*$144,313*	*$75,749*	*$813,178*
Year 2 Sponsor	$260,269	$109,654	$39,200	$409,123
Match $	$139,391	$54,827	$40,243	$234,462
Year 2 Total	*$399,660*	*$164,481*	*$79,443*	*$643,585*
Sponsor Total	$688,687	$205,863	$76,623	**$971,173**
Match Total	$304,089	$102,931	$78,569	**$485,590**
Grand Total	**$992,776**	**$308,794**	**$155,192**	**$1,456,762**

Project Summary

The goal of this project is to develop and implement a comprehensive, integrated avian deterrent system that meets the National Shellfish Sanitation Plan (NSSP) requirements set forth by the U.S. Food and Drug Administration (FDA), addressing critical environmental challenges in shellfish farming with innovative, sustainable solutions. This initiative brings together the expertise of aquaculture specialists from VIMS, technological innovations from OERI, bird ecology insights from the Institute for Integrative Conservation at W&M, and educational outreach initiatives through VDMC. By synthesizing these areas of expertise, the project participants are committed to creating a model for environmentally responsible aquaculture that aligns with regulatory guidelines and advances the industry's sustainability.

Our project’s overall solution is to leverage and integrate existing technologies. We aim to address the challenge of bird interactions with floating oyster cages by using a semi-autonomous unmanned boat (SAUB), a deployed Sonic-Net, an artificial intelligence (AI) deterrence behavior system, and a set of cameras. Our methodology adopts a randomized, time-based treatment approach to evaluate the effectiveness of these deterrent strategies, focusing on reducing bird roosting behaviors which will decrease guano in/near around the cages, thereby enhancing environmental stewardship and operational efficiency in shellfish farming. The cost of this system for a farmer will not exceed the cost of a small outboard boat motor—an expense familiar to all farmers. Through collaborations with extension agents from state Sea Grant agencies, we will further test the system on commercial farms in Delaware, Maryland, Virginia, and North

Carolina to evaluate key elements necessary for successful integration into daily farming workflows.

We plan to disseminate our findings through a multi-faceted approach. This includes publishing, presenting at conferences, and conducting workshops for aquaculture stakeholders. We are establishing an advisory service and a community board with partnerships with local farms and C-SALT through VIMS. In parallel, we are investigating the commercial viability of our integrated avian deterrent system with VIPC, VISA, and Sea Grant. Our goal is to set a new standard in aquaculture avian deterrence that balances environmental and economic sustainability.

Introduction/background/justification

The dynamic between oyster aquaculture that uses floating culture methods (e.g., cages, bags) and avian species presents a complex challenge that sits at the crossroads of environmental conservation and the safety of commercial food production. Core to this challenge are the interactions between floating oyster farms and birds, which frequently result in disruptions to protected wildlife (Maslo et al, 2020) and substantial water contamination due to bird droppings (Gomez, 2024; Hudson, 2024; Matvey, 2024). These interactions not only endanger the health and output of oyster farming operations but also necessitate the formulation and implementation of management strategies compliant with the NSSP, as mandated by the FDA (Rheault, 2021).Despite this regulatory mandate, traditional mitigation tactics have proven to be ineffective over time and often interfere with day-to-day farm operations, underscoring an urgent demand for innovative, adaptable solutions that can effectively address these issues without inflicting harm on bird populations or the marine environment (Noble, 2024; O'Keefe, 2024; Rheault, 2024).

To this end, increasing the aquaculture industry's collective knowledge on effective avian deterrent strategies is both a priority and a necessity. Stakeholders across the sector have expressed a desire for new insights and tools to navigate these challenges more effectively. Through this project, we aim to fill this critical knowledge gap, providing evidence-based solutions and fostering an industry-wide shift towards more sustainable and harmonious practices that ensure the safety of both commercial food production and our natural ecosystems.

Recent dialogues facilitated by the USDA's Wildlife Services and key stakeholders in the aquaculture sector have emphasized the limitations of conventional approaches and the critical need for novel solutions for bird mitigation (Rheault, 2021). This discourse and others reveal a significant knowledge gap within the industry regarding the potential and

practicality of advanced technological interventions (Rheault, 2021; Rheault, 2023; Rheault, 2024).

[1]

In response to these complex challenges, and in alignment with farmers' budgets, we have positioned our solution to come in at around the cost of an out-board motor – something that all farms are used to expensing. We aim for our solution to utilize this transdisciplinary knowledge to leverage existing technology solutions packaged in a way to not interfere with on-going operations and still meet the needs of the regulator agencies. (Schiano, 2021; Heo, 2023; Arablouei, 2023) to 1) effectively mitigate bird interactions 2) seamlessly integrate into established oyster farming operations and, 3) ensure no harm to avian populations or the surrounding ecosystem. This approach is informed by the amended guidelines of the NSSP, which mandate the development of management plans for farms attracting birds or mammals, emphasizing the need for strategies that mitigate their impact on water quality. Insights from the "Bird Interactions with Shellfish Aquaculture" online seminar further illuminate the complexity of this issue, from the nuanced impacts of oyster farms on avian foraging behaviors to the challenges of implementing cost-effective deterrents that do not adversely affect protected species or farm operations.

Bird Interaction Mitigation

The justification for this project is that it is deeply adaptable in the understanding that the dynamics of avian deterrence necessitate a flexible and intelligent strategy—one that can evolve in response to the adaptive behaviors of birds. One of the perennial bugbears of current avian deterrence methods on oyster farms (and elsewhere) is the birds' habituation

[1] Left: pelicans roosting on farm equipment at VIMS. Middle: Cormorants taking off from farm equipment at VIMS. Right: black floating oyster cages covered in bird guano

to a deterrent. Traditional static deterrents trialed in oyster aquaculture have demonstrated short term effectiveness but fail to sustain their efficacy in the long-term (Comeau et al, 2009; Rheault, 2021). If there are no real consequences associated with long-term exposure to a putative deterrent stimulus then the birds will learn to associate the stimulus with a lack of consequences (Swaddle, 2016). Even in the cases where the stimulus startles the birds (e.g., loud noises, bright lights) the deterrence effectiveness will wear off over time with repeated exposures.

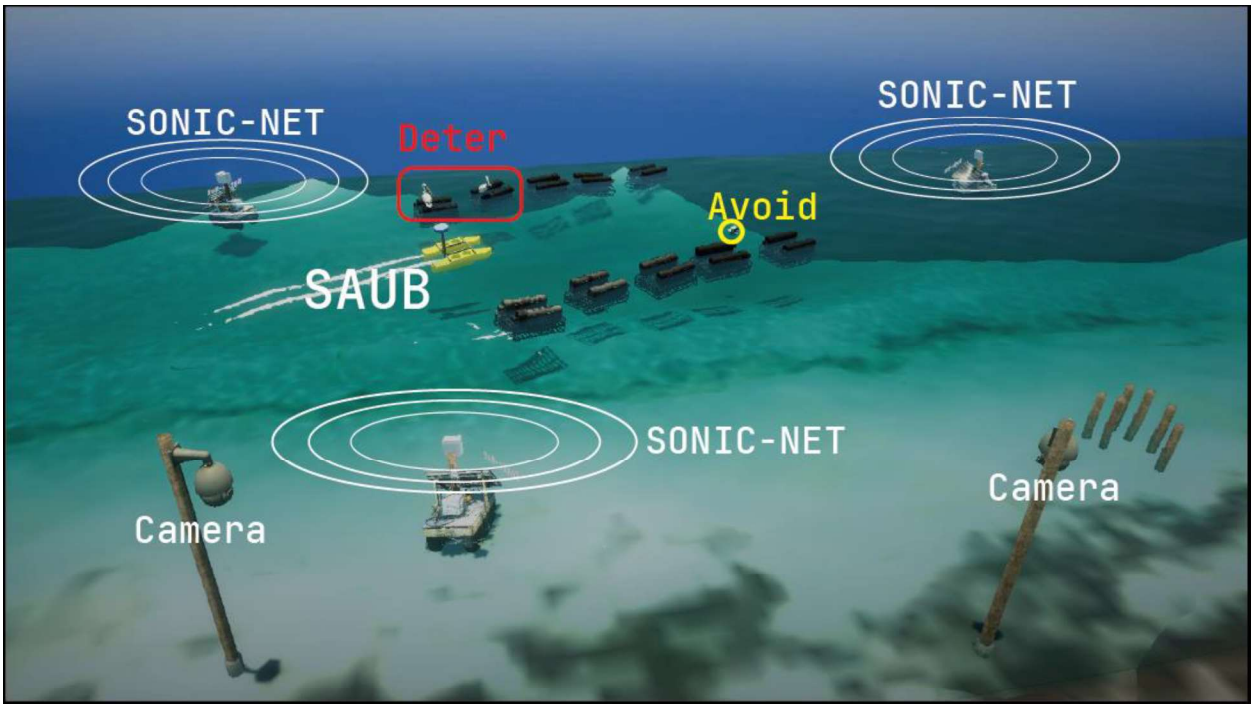
Here, we tackle these issues head-on in two ways. First, we alternate deterrent stimuli so that opportunities to habituate to any one cue are lower. Within our system, we can examine bird responses to cues and make sure they are switched before there are behavioral indicators of habituation. Second, we build in real consequences in some of the cues that we will use. For example, the Sonic Net stimulus is designed to mask acoustic communication (i.e., hearing) for the birds. If they cannot listen out for the real threats that exist on the landscape, the birds will move somewhere else where the Sonic Net sound is not present (Swaddle, 2016; Mahjoub, 2015). By leveraging the capabilities of an AI-driven platform that can adapt its deterrent strategies based on real-time data and changing behavioral patterns, we aim to introduce a sustainable solution that aligns with the operational realities of shellfish farming and the ecological imperatives of bird conservation (Cruz, 2020).

Farmer Integration

In addition to questions of long-term efficacy, current bird deterrents in oyster aquaculture are not practical for most shellfish farms due to cost, interference with operations, and/or concerns with reactions from neighbors. (Comeau et al, 2009; Rheault, 2021). Most piloted deterrent systems require farmers to install and maintain individual deterrents on each unit of grow-out gear in the water (Comeau et al, 2009; Cunningham et al, 2023; Matvey, 2024). Because floating oyster aquaculture is characterized by ample growing equipment, with bags and cages often in the thousands of units per farm, installing and maintaining units that are subject to break is labor intensive, hindering the daily workflow of the farm, and decreasing the already slim profits that exist (Rheault, 2021).

The proposed solution circumvents these issues by deterring birds through an ‘on-demand' configuration. Instead of farmers battling to maintain an abundance of additional gear that indefinitely exists in various states of effectiveness, we remove the deterrence device from the daily farming workflow altogether. Deterrents that rely on physical contact with birds are subjected to the daily rigors of oyster farming and are a potential source of pollution (Rheault, 2021). Thus, single systems that are external to the oyster farming

process with contactless deterrence measures allow for greater control on minimizing impacts to the avian community and surrounding aquatic environment.



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Bird and Ecosystem Conservation

In the Chesapeake Bay, oyster aquaculture is recognized as a best management practice for the ecosystem services it provides, such as water filtration and creation of habitat, and commercial farming practices and values have developed to reinforce these inherent environmental benefits (Duarte et al, 2009; Chesapeake Bay Program, 2016; Alleway et al, 2019). Deterrence solutions must continue to strengthen, and not subtract from, the sustainable values of oyster aquaculture (Rheault, 2021). As a new area of study, research on bird deterrence in near-shore coastal environments requires us to think innovatively about functional deterrence techniques that avoid negative avian and environmental impacts.

Our project represents a proactive and innovative response to these articulated needs, offering a scalable and environmentally sensitive model for mitigating the impacts of bird interactions on shellfish aquaculture. Additionally, this initiative seeks to redefine the industry's engagement with technology, advocating for a harmonious balance between environmental stewardship and aquaculture productivity. Through this initiative, we aspire

[2] Components of the Integrated Avian Deterrence System, the use of SAUB, Sonic-Net, Cameras, and depicted model behavior outcome to activate a deterrence strategy.

to bridge the existing knowledge gap, demonstrating the feasibility, efficacy, and economic viability of advanced technological solutions in addressing the longstanding challenges faced by the aquaculture industry.

Project Objectives

1. Development and Deployment of Avian Monitoring and Deterrent System

- Install the integrated avian deterrent system at the VIMS research farm: Integrate existing machine learning systems with an on-site camera system that detects and dispatches various deterrent strategies.
- Engage the industry advisory committee to incorporate farmers' experience and concerns (emphasizing adaptability to different bird species and environmental conditions) to ensure deterrents are practical.
- Optimize Deterrent Deployment Through Intelligent Learning at the VIMS research farm: Utilize existing deep-learning AI to fine-tune train those functioning systems to meet the needs of our deterrent strategies, including a Sonic-Net, the SAUB system itself, SAUB as a platform with deterrence mechanisms like water spraying, and a real-time bird behavior camera system that can identify species and alter strategies from prior knowledge; enhancing the precision and effectiveness of interventions.
- Explore Commercialization and Technology Transfer: Outline a strategy for the commercialization of the integrated deterrent system, ensuring scalability, affordability, and accessibility for wider adoption in the aquaculture industry. Leverage partnerships with VISA and VIPC to start working closely with Sea Grant. VISA has existing relationships with high-tech autonomy industries. That network can be leveraged to help increase knowledge of existing systems for farmers.

2. Evaluation of Deterrent Effectiveness and Model Metrics

- Assess the Effectiveness of Deterrent Mechanisms: Establish a comprehensive Deterrence Evaluation Framework at the VIMS research farm to experimentally quantify the impact of various deterrents, including an intelligent Sonic-Net, the use of SAUBs, and existing deterrents on reducing bird presence.
- Enhance Data Collection and System Responsiveness: Leverage data collection tools to gather bird activity data, supporting the continuous refinement of deterrent strategies.
- Bridge Environmental Gaps with Synthetic Data: Explore employing synthetic data to reconcile environmental and operational differences between the VIMS research farm and partner sites, enhancing the system's adaptability and performance across varied conditions.

3. Stakeholder Engagement and Dissemination of Knowledge

- Engage Stakeholders and Disseminate Findings: Work with C-SALT and local aquaculture farmers, industry stakeholders, and educational programs to exchange knowledge, gather feedback, and promote the development and adoption of sustainable deterrent strategies.
- Introduce a community board made up of farmers, community members, and academics to help align our advisory service.
- Utilize the Virginia Digital Maritime Center and the Aquaculture Information Exchange (an online community/portal of aquaculture members) to distribute educational content for public school districts ranging in the 6^{th}-12^{th} grade levels.
- Demonstrate System Integration and Field Efficacy: Highlight the integrated capabilities of the deterrent system through trials at the VIMS research farm and a partner commercial farm, emphasizing its adaptability, scalability, and impact on minimizing bird-related contamination.

Work Plan and Methodology

Our research methodology adopts a randomized, time-based treatment approach, allowing us to systematically assess the effectiveness of our avian deterrent strategies within the constraints of a one-acre research farm. This design will help facilitate a dynamic and responsive assessment of bird roosting behaviors by our associated deterrent strategies and still lets us scale later for trials at a larger farm. This approach leverages the VIMS research farm and gives us an opportunity to develop the deterrence evaluation framework before attempting to scale it up.

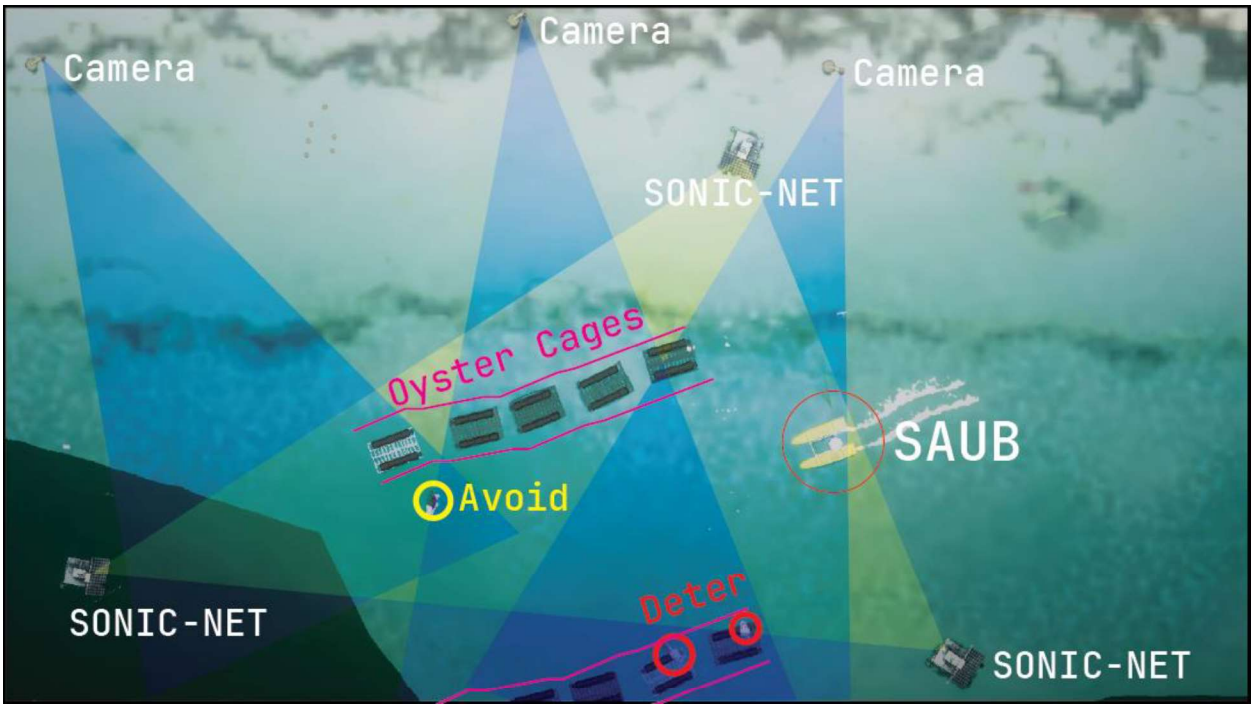
Research Design

Treatment Assignment: At the beginning of the study, each week is randomly designated as either a deterrent-deployed or non-deterrent-deployed week. This ensures that deterrent effects are assessed across the varying environmental conditions and bird behavior patterns over the study period.

Observation Schedule: Observations are scheduled around the deterrent deployment to capture both immediate and short-term effects. On Mondays and Tuesdays, pre-treatment observations will establish a weekly baseline behavior and environmental conditions. The deterrent strategy is then deployed (or not, in control weeks) on Wednesdays. Depending upon the deterrent strategy, which might have us on-site observing or off-site remote monitoring, will commence on Thursdays and Fridays.

Phased Implementation: to account for seasonal variation in bird behavior and environmental factors, we intend to start in Q3 of Year 1 and continue through Q2 of Year 2 to account for a full year of performing the study at the VIMS research farm.

Larger Farm Expansion: Our initial methodology is tailored around the size of the one-acre research farm, but we can still utilize this design for a larger farm trial as this approach lets us simultaneously run deterrent strategies and non-deterrent strategies if we have access to a larger farm.



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Objective 1: Development and Deployment of Avian Monitoring and Deterrent System

Phase 1.1: Data Setup and Avian Monitoring Installation

- Year 1 Q1-Q2: Procurement and installation of hardware and equipment to support the study. Placement of battery operated 'trail cameras' on the VIMS research farm to archive video footage before the permanent system is installed.
- Year 1 Q2-Q3: Focus on engineering activities to integrate the solution for bird detection and deterrence mechanisms. Finalize development and begin testing of the roosting bird detector and modular deterrent system at the VIMS research farm.

[3] Top-down representation of the system: the upper portion of the image has 3 cameras looking towards the floating cages. Middle of the image: the Sonic-Nets form a triangular net of the farm equipment, and a SAUB is on patrol. Towards the bottom are identified birds to run a strategy against while another (in yellow) is set to avoid.

- Year 1 Q3: Begin running the system and collecting data towards the study.

Phase 1.2: Integration of Deterrent Strategies

- Year 1 Q2: Deploy SAUB system for internal control study to assess adaptability and responsiveness of SAUB at the VIMS research farm. Installation of Sonic-Net platform at VIMS research farm
- Year 1 Q3: Begin rotation of random time-based deterrent strategies towards the study.
- Objective 2: Phases of Testing, Evaluation and Optimization of Monitoring and Deterrence Strategies.

Objective 2: Performing the Study and Evaluation of Avian Monitoring and Deterrence Strategies

Phase 2.1: Generation of tagged video/image data

- Year 1 Q3-Year 2, Q2: Implementation of the time-based treatment study.
- Year 1 Q3– Year 2, Q2: Continuous tagging of existing data to build training data set for 'segment-anything' fine tuning by species detection and roosting behavior models.
- Year 2 Q3-Q4: Data collection and full use of the fine-tuned Avian Monitoring System with deterrent strategies at partner farm location(s).

Phase 2.2: Assess the Effectiveness of Deterrent Mechanisms

- Year 1 Q1-Q2: Establishment of estimates of bird counts based on VIMS research farm observations while working the farm and review of archived 'trail camera' video data for obtaining baseline counts.
- Year 1 Q3- Year 2, Q2: Continuous analytical updates on past 30-days of collected data.
- Year 2 Q2-Q4: Conduct ongoing evaluation of deterrent strategies at partner farm location(s), building an understanding of metrics for the Deterrence Evaluation Framework.

Phase 2.3: Optimize Deterrent Deployment through Integration of Synthetic Data

- Year 1 Q4 – Year 2, Q1: Identify missing training data between VIMS research farm and partner farm locations.
- Year 2 Q2: Utilize synthetic data generation to help prepare the model for the differences between the research farm and the partner farm locations.

- Year 2 Q2: Isolate a subset of training data with and without synthetic data, compare results to establish a metric of performance in variation between the model before synthetic data and after.
- Year 2 Q3-Q4: Evaluate synthetic data model with deterrence strategies at partner farm(s).

Objective 3: Stakeholder Community Building and Knowledge Dissemination

Phase 3.1: Build a community board representing farmers and educators

- Year 1 Q3-Q4: Begin engaging with stakeholders by hosting listening sessions through VIMS, Aquaculture Information Exchange, and Virginia Digital Maritime Center.
- Year 2 Q1: Establish community board from stakeholder sessions.
- Year 2 Q2-Q4: Conduct workshops and training sessions for farmers and community stakeholders, culminating in the dissemination of findings and best practices through a final stakeholder meeting and educational outreach.

Phase 3.2: Technological Innovation and Sustainability

- Year 1 Q3-Q4: Coordinate with Intellectual Property requirements across partner networks at ODU, VIMS, and William and Mary.
- Year 2 Q2-Q4: Evaluate the commercialization pathway for the deterrent system, focusing on cost-effectiveness and market potential through our partners at VISA and VIPC.
- Year 2 Q3: Process software through the partners Intellectual Property disclosure process with ODU, VIMS, and William and Mary.

Phase 3.3: Release of Deterrence Evaluation Framework

- Year 1 Q3-Q4: establish parameters and some baseline metrics for roosting, counts of species, and time between various avian events.
- Year 2 Q1-Q2: initial version of the Deterrence Evaluation Framework is established and written up with help from the community board and partners.
- Year 2 Q4: Creative Commons publication and release of Deterrence Evaluation Framework

Sub-Objective 3.4: Release and Distribute Training Data

- Year 2 Q3: Make all training data publicly available for live data
- Year 2 Q3: Make all training data publicly available for synthetic data
- Year 2 Q4: Open-Source Synthetic Data Libraries

- Year 2 Q4: Creative Commons and Open Science Framework projects are connected and established with existing publicly available data

Anticipated Outcomes and Deliverables

Bird Detection System with In-Field Setup of a Sonic-Net

- Deliverable 1: Development and deployment of a state-of-the-art bird detection system, integrated with a responsive Sonic-Net, designed to adaptively deter specific bird species from aquaculture areas without causing harm. This system will employ advanced algorithms to identify bird species and adjust deterrent sounds, accordingly, enhancing the precision of avian management strategies and providing a record of effectiveness for farmers and regulators.
- Outcome 1: A measurable decrease in bird roosting incidents near oyster farms. This outcome will be supported by comparative analysis of bird activity patterns before and after the system's implementation, demonstrating the effectiveness of species-specific deterrent strategies.

Development, Implementation, and Release of Deterrent Evaluation Framework

- Deliverable 2: A deterrence evaluation framework that outlines standardized methodologies for assessing the effectiveness of avian deterrent strategies. This framework will focus on metrics by deterrent strategies and impacts on timing between various bird behaviors. This will include incident expected counts by deterrent strategy by farm setup/parameters. For example: *85% reduction in Roosting behavior of Brown Pelicans by using a Sonic-Net during calm morning days on floating cages*.
- Outcome 2: Enhanced understanding of deterrent strategy effectiveness, informed by data-driven insights collected through the deterrence evaluation framework. This will include documentation of the system's ability to adapt to different bird species and behaviors, contributing to best practices in avian deterrence within aquaculture settings.

Autonomous SAUB Platform Introduction

- Deliverable 3: A report on the introduction and integration of a SAUB platform, equipped with capabilities for deploying deterrent measures, collecting data, and performing site surveillance. The SAUB will demonstrate advanced autonomy in navigating aquaculture sites and executing targeted deterrent actions as informed by the bird detection system.

- Outcome 3: Increased operational efficiency and scalability of avian deterrence measures. This outcome will highlight the platform's ability to potentially reduce manual labor requirements and enhance the precision of deterrent deployments, marking a significant advancement in technology-driven aquaculture management and reducing costs to deploy deterrence strategies.
- Outcome 4: A broader acceptance and interest in autonomous and intelligent systems among aquaculture stakeholders. This shift in perception will pave the way for future innovations and applications of autonomous technologies in the aquaculture industry.

Open Science Framework Data from Avian Monitoring System

- Deliverable 4: A dataset containing actions/event data on bird species, bird counts, roosting behavior events/counts, and interactions around the VIMS research farm. This dataset will be derived from the output of the trained monitoring system
- Deliverable 5: A dataset of live training data consisting of video segments, tagged image data, and corresponding image masks.
- Deliverable 6: Vector weights for trained segment anything model from live training data.
- Deliverable 7: A dataset of synthetic training data consisting of tagged image data, image masked data, and synthetic environment parameters.
- Outcome 5: Enhanced understanding of bird-aquaculture interactions, providing the industry and research communities with insights into bird behavior patterns around floating oyster cages.
- Outcome 6: Through the release and distribution of training data, we are encouraging others to generate and utilize the data from this project into other use cases across other instances of agriculture and aquaculture.

Dissemination of Project Findings and Scientific Content for Hampton Roads Public School System

- Deliverable 8: Comprehensive materials including reports, publications, and workshop content, summarizing our findings, methods, and best practices for the aquaculture community. Contents will cover SAUB, deterrence strategies, evaluation frameworks, data outcomes, and model statistics for bird identification.
- Outcome 7: Strengthened collaboration and knowledge exchange within the aquaculture sector, promoting the adoption of innovative solutions for environmental management and sustainable farming practices. The project aims to

empower farmers and industry stakeholders to make informed data-driven decisions.

Development of an Online Repository and Resource Website

- Deliverable 9: Create an online website dedicated to linking all previously mentioned data sources and digital content under one registered domain. This digital resource will serve as the central hub for disseminating the information generated by the project. This site will be available for 5 years post project funding and backed up indefinitely with ODU Library under the Creative Commons.

Outreach and Technology Transfer Plan with Commercial Implications

Our project is dedicated to the principles of diversity, equity, and inclusion, ensuring that the advancements in bird deterrent technologies and sustainable aquaculture practices reach a broad and diverse audience within the aquaculture industry and the local community. This commitment is reflected in our comprehensive Outreach and Technology Transfer Plan, which is designed to disseminate project findings and technologies effectively to all sectors of the aquaculture community, with a particular focus on underrepresented groups and communities.

Educational Outreach with Virginia Digital Maritime Center

In partnership with the VDMC, we will extend our research through the educational outreach efforts of many educational programming managed through the center. For example, there is an educational programming project that provides educational content and resources that deal with maritime industries across most middle school programs in the greater Hampton Roads area. Through the partnership, we will provide research insight to the VDMC team and guide their content creation efforts. This initiative will expose students from diverse backgrounds to marine science and environmental conservation and introduce other aspects of the greater maritime industry by incorporating aquaculture information.

Dissemination of Findings and Technology Transfer

We will utilize a variety of platforms and formats to ensure wide accessibility and engagement.

- Direct engagement with field tests at commercial farms, working with industry members to demonstrate and test the deterrent system.

- Workshops and Webinars: Conducting educational sessions that cater to a diverse audience, including those from underrepresented communities, to share knowledge and best practices in bird deterrence and aquaculture management.
- Regional and National Aquaculture Meetings: Presenting at the Chesapeake Bay Oyster Symposium in the first year, which is a grower and academic-oriented conference, and moderating a session with a panel discussion about 'Innovations in Bird Deterrents for Aquaculture' at the United State Aquaculture Society's Aquaculture America.
- Involvement of Sea Grant Extension Personnel: Sea Grant extension personnel will play a crucial role in our outreach and technology transfer efforts, facilitating connections with aquaculture stakeholders in four Mid-Atlantic states, including underserved groups within our project region.
- Facilitate Broad Commercial Adoption and Collaboration: Partner with VIPC to enhance our solution's market reach. Engage with VISA to leverage their extensive network within high-tech autonomy sectors which will foster integrative opportunities across government, industry, and academia. This alliance aims to streamline technology transfer, amplifying our solution's impact and utility in diverse settings.
- Publication of work in Journals related to Deep Learning Networks, Aquaculture, and Avian Ecology.
- Online Resources: Deploying a website that offers easy access to project resources, training materials, and the latest research findings.
- Use of Open-Source Software Standards in releasing software libraries.

Through this Outreach and Technology Transfer Plan, we aim to not only disseminate project outcomes broadly but also ensure that the benefits of our research and development efforts are equitably shared. Our goal is to foster a more diverse, inclusive, and skilled aquaculture workforce, thereby contributing to the sustainability and profitability of the industry.

Diversity Statement

This project embraces NOAA's commitment to diversity, equity, and inclusion by actively involving and benefiting underrepresented groups in our scientific activities. To achieve this, we will build upon our successful collaboration with VDMC, which delivers enriching educational resources and activities to every middle school student in the Hampton Roads area. This initiative underscores our commitment to educational outreach, specifically tailored to serve underrepresented communities who live in and/around the Chesapeake Bay. This approach not only broadens the scope of environmental education but also

fosters an inclusive space where students from diverse backgrounds can envision themselves as future marine scientists and environmental protectors.

Expanding our efforts beyond educational outreach, we are using Sea Grant to help partner with workforce development teams to engage current and aspiring oyster farmers in the region. This collaboration aims to enhance content for workforce development agencies by providing our results in a more accessible form. We will have video footage of the SAUB being deployed from high-quality cameras and our deterrence evaluation framework. Our team understands how important conveying the use of advanced technology can bring overall appeal to a specific industry. This is to help provide more resources for partner programs who can decide if they want to incorporate said content into the existing programs. By focusing on solutions and the integration of technology we hope to bring the barrier for entry down and convey that these technology solutions can be implemented by farmers right now. We aim to empower and excite farmers within our region to help motivate individuals from all groups to consider pursuing careers in aquaculture, thereby contributing to the diversification of the industry.

In partnership with VIPC and through other groups like the Virginia Small Business and Supplier Diversity (SBSD), we aim to engage Virginia's Small-Women and Minority Owned (SWaM-certified) agriculture entities, expanding their horizons towards aquaculture. Through targeted workshops, we'll explore aquaculture opportunities, leveraging our project's solutions to encourage diverse agricultural ventures across the Commonwealth. For existing oyster farmers, our project will offer advanced workshop sessions at regional conferences demonstrating the innovative deterrent technologies and how they can contribute to sustainable farming practices, ensuring they have the tools and knowledge to improve their operations and environmental impact.

By weaving diversity, inclusion, and small business efforts into every aspect of our project—from educational outreach content to workforce development content—we not only align with NOAA’s vision but also contribute to a more equitable and inclusive future in marine science and aquaculture. Our comprehensive approach ensures that the benefits of our research and development efforts are accessible to all, promoting equity in environmental services and creating opportunities for meaningful participation and advancement within the aquaculture sector.

Letters of Support

See the attached letters of support from our confirmed partnerships.