Grants and Education to Advance Innovations in Sustainable Agriculture

Design and construction of a low-impact amphibious vehicle for efficient and sustainable oyster farming

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FNE15-821
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Farmer/Rancher Project
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Region: Northeast
State: New Jersey
Coordinators:

Gustavo and Lisa Calvo
Email
Sweet Amalia Oyster Farm
485 Columbia Ave
Newfield, NJ 08344

Participants:
David Bosco
Consultant
Bosco Architects
Dr. Daphne Munroe
Assistant Professor
Rutgers University

Final Report

Summary

Near shore intertidal environments often present ideal conditions for cultivating shellfish, providing both the appropriate environmental conditions and reducing travel time and costs to access farms. However, the dynamic topographies of alternating sand bars and sloughs, tide-dependent work windows, and environmentally sensitive habitats characteristic of intertidal locations also present challenges to developing environmentally sound, optimal and efficient farm operations. Focusing their efforts during the low tide, many oyster farmers who operate intertidal farms have at best two hours on either side of a low tide to carry out daily husbandry and harvest tasks. This limited period heightens the need for equipment and practices that maximize efficiency while minimizing environmental impacts. A critical problem is the lack of a low impact versatile vehicle that allow oyster growers to efficiently transport oysters and gear to and from, and within the farm, and provide a platform for production activities, such as harvesting and sorting stocks. The purpose of this project was to design, build, and evaluate an Amphibious Farm Vehicle (AFV) customized for working an intertidal oyster farm. Central to the design was the desire for the vehicle to be low impact—quiet and

environmentally friendly. The resultant manually operated AFV has increased the efficiency of farm operations, while minimizing environmental impacts on a small scale oyster farm in the lower Delaware Bay, NJ.

Using it were able to maximize our work time on the farm, increasing our typical field season workday by 25-30%. This resulted in decreasing the number of days we needed to be on the farm greatly saving in labor costs and travel time and costs associated with driving to and from the farm site, an estimated savings of $4,176 per year ($54 travel savings and $120 labor savings per week for 24 weeks). The work platform (deck mounted surface and removable table) provided ample and comfortable work surface for up to six workers.

A formal outreach presentation and demonstration was conducted on December 21, 2015 at the Rutgers Cape Shore Laboratory as part of the University's Shellfish Growers' Forum program.

Introduction

Many oyster farms in the United States are located in inter-tidal zone, near shore areas that are covered at high tide and exposed at low tide. While offering benefits, such areas also provide many challenges for the oyster farmer. Dynamic topographies of alternating sand bars and sloughs, tide-dependent work windows, and environmentally sensitive habitats create challenges when developing environmentally sound, optimal and efficient farm operations. Focusing their efforts during the low tide, oyster farmers who operate intertidal farms have at best two hours on either side of a low tide to carry out daily husbandry and harvest tasks. This limited period heightens the need for equipment and practices that maximize efficiencies while minimizing environmental impacts. A critical problem is the lack of a low impact versatile vehicle that allow oyster growers to efficiently transport oysters and gear to and from, and within the farm, and provide a platform for production activities, such as harvesting and sorting stocks.

Inter-tidal oyster aquaculture represents an important segment of the oyster industry in New Jersey, Massachusetts and elsewhere. In New Jersey the nucleus of a growing oyster aquaculture industry is situated on the extensive intertidal areas of the lower Delaware Bay (Cape Shore).

The intertidal oyster farms are situated in sloughs and on sandbars. Some growers, particularly those operating larger scale farms, use all terrain vehicles (ATV's) to pull small wagons to transport aquaculture gear and oysters. Smaller and entry-level farmers tend to use wheel barrels and/or small-size shallow drafted flat bottom boats. These existing methods were not designed for the purpose of oyster farming and have several disadvantages. ATV's are expensive, subject to rapid corrosion and decay in the marine environment, having only a 2-5 year usable life span and potentially adversely effect the environmental via noise, fuel consumption and potential for spillage, and relatively heavy trampling on benthic estuarine habitat and organisms. Moreover, the potential disturbance of threatened migratory shore birds and their critical habitats by aquaculture has risen as a principal concern for federal and state regulators who are charged with permitting aquaculture activities. The recent Endangered Species listing of the Red Knot, Calidris canutus,whose migratory pathway overlaps with Delaware Bay farm areas, has called into question ATV use and elevates the need to minimize potential impacts of farm vehicles on migratory shorebirds and their habitats. Operation of wheel barrels and small boats has low environmental impact but is cumbersome, requiring multiple trips from shore due to limited haul capacity, and as such are only suited for very small operations. Furthermore, desired transit times driven by daylight and variable tides may be mismatched with water level, resulting in the need to drag boats across sand bars or float destabilized wheel barrels.

The project was a collaborative effort of Gustavo and Lisa Calvo, Sweet Amalia Oyster Farm; David Bosco, Bosco Architects; Dan Dutra, Dutra Sheet Metal Co.. Daphne Munroe, Haskin Shellfish Research Laboratory of Rutgers University served as the project's Technical Advisor.

Architect and builder David Bosco, Newfield, NJ specializes in design/build project delivery methods in addition to full architectural design services for the commercial, industrial and residential markets. For additional information see http://boscoarchitects.com

Fabricator Dan Dutra, Dutra Sheet Metal, Co. (DSM) of Vineland, NJ offers a wide range of services to a diverse clientele. In addition to fabricating ductwork for the commercial construction industry, he has experience designing and constructing equipment for the many local farms, glass houses and food processing plants. The projects range from one of a kind prototyping, modifications to existing equipment systems, as well as design and construction of new and innovative equipment.

Dr. Daphne Munroe is an Assistant Professor at the Haskin Shellfish Research Laboratory, Rutgers University. An expert in the area of marine biology, Dr Munroe has 14 years of experience conducting research on shellfish aquaculture and benthic ecology.

Sweet Amalia oyster farm is a small family farm established on the Cape May Peninsula in 2012. The farm with a target annual production of 200,000 oysters per year employs rack and bag grow out system, producing half shell market oysters for direct delivery. The farm originated in Mobjack Bay, Virginia where it operated from 1999-2004. Environmentally responsible and sustainable farm practices are at the heart of the farm's business model.

Initial collaboration began at examining our farm's day-to-day operations and means of equipment/gear organization and available modes of transportation. Recognizing that there was a vast potential for improvements, the team developed a criteria to design and build an innovative, nimble, versatile, and low impact amphibious module to serve as transport and working platform with a goal to establish a more sustainable and efficient operations of inter-tidal and shallow sub-tidal oyster farming.

Objectives/Performance Targets

Objectives

1. To design and build a specialized amphibious farm vehicle to improve farm operation efficiency and minimize environmental impacts.
2. To optimize vehicle design through an iterative process of trial and modification.
3. To demonstrate the amphibious farm vehicle to local and regional shellfish growers through various outreach initiatives.

Performance Targets

1. Design and build one amphibious farm vehicle.
2. Improve efficiency of typical farm practices via implementation of an amphibious farm vehicle there by reducing operational costs by a minimum of $500/month.

Methods

Design. The project team consisting of oyster farmer (Gustavo Calvo, Sweet Amalia Oyster Farm), architect (David Bosco, Bosco Architects), and steel fabricator (Dan Dutra, Dutra Sheet Metal Co.) met in early May 2015 to develop plans for the prototype AFV. Factors such as function, efficiency, material compatibility, and life cycle costs were carefully considered. Design criteria were as follows:

- One person should be able to move and operate the module by him/herself
- Stable, lightweight, and easy to move over water, sandflats, mud sluices and irregular terrain
- Low environmental impact
- Easy to maneuver between rows of racks
- Fits in an eight foot bed of a pick-up truck
- Easy and rapid to anchor/release
- The module shall provide enough space to serve as a working station for sorting/grading by up to 4 workers
- The module shall provide space for carrying loads of oysters (20 bags of market oysters/2500 oysters)

- Space for bundles of mesh bags and floating cages
- Space/load for 10-15 racks
- Easy to load onto a truck or trailer
- Ability to lock it for storage

The team selected the core components for the vehicle, which included a 10-foot Jon Boat (Model 1032, G3 Boats, Lebanon Mo.) and 19.3" x 9" polyurethane low-pressure balloon wheel/axle kits (Wheel Axle Kit 49UC, Wheeleez, Inc, Benicia, CA). The pre-manufactured, readily available Jon Boat was selected due to its shape/size, affordability, weight, and material, which could withstand the harsh marine environment. The volume of the vessel allowed ample space for programed/transient storage. For the wheel assembly, the team selected four fixed axel wheels that could be secured to the Jon Boat. The commercially available low-pressure polyurethane wheels are designed for the marine environment and are proven to transport large loads across sand and irregular beach terrain. The vehicle design also included a work surface, shading, pump-station cradle, and miscellaneous storage bins. The work surfaces were designed to accommodate multiple workers/tasks. Marine grade aluminum (5052 series) was chosen as the construction material for its resistance to the harsh environment as well as its ability to be easily machined and adapted.

Fabrication of Prototype. Fabrication began in mid-May with the construction of a temporary structural frame connected to the vessel. The frame was developed to accommodate the wheel mounts in a manner to allow adjustment of spacing between axles enabling determination of the optimal distance, in respect to weight distribution and the ability to load on an eight foot bed pick up truck. Vessel components were constructed and mocked up out of a combination of light gauge steel, aluminum, and wood. Their final construction was of marine grade (5052 series) aluminum. Design goal was to have the vehicle best address the oyster farmer's day-to-day operations with the ability to accommodate additional projected tasks. Some task are less frequent but just as critical in the overall scheme of the farm's production and maintenance, such as the task of power-washing the mud packed oyster bags or the transportation of the (10') ten foot long steel support racks. Construction was guided by field-testing. See attached design description/specifications.

Field-testing. Field tests were conducted on June 5 and 14, 2015. Vehicle maneuverability was evaluated with an eye to optimize wheel span, wheel mounting height, and the handle/steering component. The work surface configuration was also evaluated to inform storage layout with an overall goal to improve task ergonomics. The vehicle on and off loaded efficiently into a standard pick up truck bed, easily rolling on and off using store bought aluminum ramps. The vehicle rolled well on sand surfaces, across mud bottom, and floated adequately at depth of less than 2'. The vessel was easily pulled while floating with a lead line affixed to the bow. A temporary bi-level push bar was mounted to the stern to identify best height for pushing. The field test indicated that both bar heights were useful allowing adaptable leverage for pushing on dunes and in water. An optimal table height and position was identified to ensure that several workers could comfortably work around the table at the same time. Finally the pump cradle was evaluated at multiple heights to ensure that the height did not exceed the distance from which the pump could draw water and to ensure stability on the craft. Overall the vehicle was found to function very well. Weaknesses were identified to be a limited ability to turn, which was anticipated and some difficulty in pushing across mud and up dune inclines. Though somewhat challenging under some conditions, the vehicle was still maneuvered by a single individual. See attached design description/specifications.

Prototype Modification and Refinement. Modification and redesign occurred as a result to the field-testing. This process involved physically altering some of the key components to accommodate structural integrity and additional functions and flexibility. An interlocking table design was developed so that two table surfaces would be on the vessel, one could be removed and set up on standard plastic saw horses while the second could remain attached on the vessel platform. The stationary table was mounted on a frame structure that was latched to the vehicle with rubber clip mounts, enabling complete frame removal for transit of large loads (ie. racks and large numbers of oysters/grow out bags). Optimal positions for the wheel axles were determined, the temporary mounting frame was removed, and axle brackets were mounted directly to the jon boat with water tight stainless steel pop rivets. Once the key components were identified, storage cubbies were equipped to maximize space with in the vessel. Hose mounts were welded to the pump-carrying frame to add capacity and ease transport of the pump and accessories on and off the vessel. Final fabrication was completed and the vehicle was delivered to the farm on July 23, 2015. See attached design description/specifications.

Application. During the period of July 2015-February 2016, the remaining term of the project the vehicle was routinely used and exceeded expectations in respect to enhancing farm efficiencies. The vehicle supported gear and oyster transport, provided an oyster sorting and harvesting station, and served as a mobile platform for power washing the oyster racks. See attached design description/specifications.

Estimated Costs for Vehicle Construction. Costs associated with constructing the prototype, excluding design and test model build follow:

Item	Estimated Cost
Wheels and Axles	$900
Jon Boat	$850
Miscellaneous Supplies	$200
Fabrication and materials	$4,500
Total	$6,450

Ba_AFV_NE SARE Grant_FNE 15-821-29001_Final Report Drawings

Outcomes and Impacts

Through the project we have met our goal of designing and building an innovative, nimble, versatile, and low impact amphibious module to serve as transport and working platform for sustainable and efficient operations of inter-tidal and shallow sub-tidal oyster farms. The vehicle has become a real "work-horse" on the farm, exceeding our expectations and greatly enhancing the execution of farm practices including: harvesting and transport of oysters, transport of gear, serving as a mobile pumping station, and providing a work surface for sorting and grading of oysters. Because the vehicle could be floated out on a falling tide and floated in on a rising tide we were able to maximize our work time on the farm, increasing our typical field season workday by 25-30%. This resulted in decreasing the number of days we needed to be on the farm greatly saving in labor costs and travel time and costs associated with driving to and from the farm site, an estimated savings of $4,176 per year ($54 travel savings and $120 labor savings per week for 24 weeks). The vehicle enabled transport of 12 racks at a time and since we were able to float the racks out, this was accomplished with ease. The work platform (deck mounted surface and removable table) provided ample and comfortable work surface for up to six workers. Smartly situated cubbies provided space for tools and materials enhancing accomplishment of field tasks. Overall the vehicle enabled farm tasks to be more efficiently accomplished and reduced the operational costs of our farm.

Accomplishments

An amphibious farm vehicle was developed. Through the project we have met our goal designing and building an innovative, nimble, versatile, and low impact amphibious module to serve as transport and working platform for sustainable and efficient operations of inter-tidal and shallow sub-tidal oyster farms.

We have received several requests for design specifications suggesting that other farmers are interested in building an AFV.

Potential Contributions

The AFV has greatly enhanced operations at Sweet Amalia Oyster Farm. The prototype AFV serves as a model for other farms to use for construction and adaptation to support their farm transport and work platform needs.

Publications/Outreach

The vehicle was demonstrated to several visiting oyster farmers on an ongoing basis. A formal outreach presentation and demonstration was conducted on December 21, 2015. The presentation was held at the Rutgers Cape Shore Laboratory as part of the University's Shellfish Growers' Forum program. Architect, David Bosco has presented a suite of design drawings (attached). Ba_AFV_NE SARE Grant_FNE 15-821-29001_Final Report Drawings

Future Recommendations

Regardless of the type of innovation, there is always room for improvement. The AFV developed here could be improved in several ways.

1. Ease of turning. The fixed axle design makes turning challenging. The axle system could be modified to allow turning on a smaller radius.
   - Obviously any axle alternative other then fixed would add engineering/fabrication costs as well as add additional moving parts increasing items needing maintenance.
   - Axles could possible be closer together allowing the vehicle to turn sharper, however the trade off would be overall balance of vessel while loaded with gear.
   - Axle configuration also affects the ability for the AFV to be positioned in the bed of a pick up truck/ clear of the truck's wheel well locations.
2. As presently designed the AFV must ne pushed or pulled to move. The possibility of incorporating a power-assisted system should be explored. This would be particularly helpful for moving up inclines such as beach dunes.
   - Such modifications would add engineering/fabrication costs as well as add additional moving parts increasing items needing maintenance
3. Ribs on interior haul of jon boat capture sand blocking water flow when cleaning, this unfortunately is inherent to the jon boats structural design. Design modifications to improve ease of cleaning could be explored base on present efforts.
   - Attention to cleaning was considered when establishing the connection to attach directly to the jon boat. The "stand off" profiles were designed to be minimum in size, to reduce weight, yet its profile is as open as possible to allow for a person's hand and or cleaning brush to pass though.
4. Tumbler/Sorter Attachment. A modular unit for tumbling and sorting product could be designed.
