Application for installation of a short-term experimental Integrated Multi Trophic Aquaculture (IMTA) steelhead trout (*Oncorhynchus mykiss*) project in North Falmouth, MA

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Executive summary:

Daniel Ward currently holds licenses issued by the Falmouth Board of Selectmen and Permits from the Division of Marine Fisheries to culture oysters (*Crassostrea virginica*), hard clams (*Mercenaria mercenaria*), and bay scallops (*Argopecten irradians*) on 10.0 acres in Outer Megansett Harbor, North Falmouth, MA (lease number A11-05), as well as an adjacent associated licensed and permitted nursery location for the same species in Fiddler's Cove Marina, North Falmouth, MA. Dr. Ward, in conjunction with the University of Massachusetts, Dartmouth, secured 2019 USDA SBIR funding for an experimental short-term (6 months) ocean-based IMTA (Integrated Multi-Trophic Aquaculture) steelhead trout (*Oncorhynchus mykiss*) research project.

The goal of this project is to produce steelhead trout, eastern oysters, bay scallops and sugar kelp in an integrated multi-trophic production system within existing marina infrastructure. Specific objectives include:

1. Investigate optimal multi-trophic production techniques for steelhead trout, eastern oysters, bay scallops and sugar kelp within an integrated system.

2. Evaluate the economic viability of two intermediate grow-out strategies; direct from the hatchery vs. intermediate growout in a recirculation system.

3. Evaluate environmental impact through comprehensive water quality and benthic sampling.

The project plans calls for the stocking of a maximum of 2,000 steelhead trout from December 1, 2019 through no later than March 15, 2020, as well as marine algae sugar kelp (*Saccharina latissima*), to be farmed along with the oysters and bay scallops in a multi-trophic manner that will be mutually beneficial to all of the cultured species. The proposed project outlined in this document seeks to raise steelhead trout in two net pens and in the same site as the currently permitted site for shellfish nursery operations in Fiddler's Cove Marina. Dr. Ward would like to additionally farm algae as well as fish to remediate any potential negative impacts of adding feed, and therefore additional nitrogen, to the ecosystem.

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1) Detailed site plan including latitude and longitude of corners:

The proposed experimental farming site is located within Fiddler's Cove Marina, North Falmouth, MA. (Fig. 1). The marina is a year-round facility, and currently Ward Aquafarms, LLC operates nursery systems in the marina, and in the summer, accesses their growout sites in outer Megansett Harbor utilizing boats from rented slips in the marina. In the off season (October-May), empty slips are also used to store processing floats and other nursery equipment in the water. At low tide, the depth ranges from less than 1 foot of depth around the edges of the rock riprap, to 10 feet at the deepest section where the net pens are to be located (Fig. 1) Latitude and longitude coordinates can be found below Figure 1.

Figure 1. The entire image is of Megansett Harbor, with Fiddler's Cove being a small inlet to the south bounded by the red box. The enlarged inset image is of the marina with boats (in the summer season), and the red box at the end of the main pier is the proposed location in the area of deepest water.

41°38'51.64"N 70°38'11.39"W NE	*41°38'51.23"N 70°38'11.22"W SE*
41°38'51.45"N 70°38'12.22"W NW	*41°38'51.01"N 70°38'11.99"W SW*

2) Geophysical site characteristics

The site is comprised entirely of fine silty mud, on flat bottom. There are several large rocks (less than 2 ft^3 in volume) throughout, with various natural types of seaweed found throughout.

3) Benthic habitat conditions

Prior to authorization by the Falmouth Board of Selectmen, Massachusetts Division of Marine Fisheries performed a site survey to document benthic conditions of the nursery area at the base of the main dock. The survey found no eelgrass, no additional shellfish of commercial importance were found on the entire site, and therefore the permit was granted to Dr. Ward in 2013. The benthic habitat throughout the confines of the marina is comprised of essentially the same barren flat mud, with occasional seaweed and common slipper snails (*Crepidula)* shells throughout.

4) Proposed species, quantities and densities

Shellfish

Oysters and bay scallops will be stocked at 2 locations in October 2019: 1) directly adjacent to the trout netpens in the same or adjacent slip; and 2) in outer Megansett at the farm growout site. In October, approximately 10,000 oysters (< 2") will be stocked into replicate 5-level, 21 mm monofilament lantern nets at commonly accepted commercial levels (1/3 surface area), and 10,000 bay scallops (< 2") will be stocked into replicate lantern nets, at 20 per ft^2. Half of the animals will be deployed directly adjacent to the netpens, and half of the animals will be deployed on the Megansett growout site. Twenty-five oysters or bay scallops will be sampled from 3 bags or lantern nets bi-monthly, enumerated for percent survival, and measured (shell height) to evaluate differential growth rates between sites. A one-way analysis of variance (ANOVA) will be employed to evaluate the effect of different sites on growth and survival. Tukey's HSD test will be employed for comparison of various sites for the significance of difference at $P < 0.05$.

Macroalgae

Sugar kelp seed string will be purchased from one of the locally available seed string suppliers (Greenwave, CT; Walrus and Carpenter, RI; Cottage City Oysters, MA; Springtide Seaweed ME) in October of 2019. Five, identical 20' lines of sugar kelp will be installed adjacent to the trout netpens, and five identical lines will also be installed at the current Megansett Harbor oyster farm. The lines will be installed starting at the northwest corner, leading from north to south, spaced 25' apart. Following the nursery period, the 1mm nylon string will be brought to the site, and wrapped around the 20' 3/8" rope and connected with cable ties at either end. The line will then be sunk to 7', and checked bi-monthly and adjusted as necessary to remain at 7' depth. five kelp longlines will be brought to the surface bi-monthly from initial set (October) through final harvest (February) to check for biofouling. During the routine inspection for biofouling, once per month each line will be sampled to quantify growth and plant attachment. Three locations will be randomly chosen on each of the five lines, and the number of plants attached in a 12" section will be counted. During this process 15 random plants within each 12" section will be measured for total length.

Finfish

During the fall/winter grow-out, two different grow-out strategies would be employed. The first would be to stock fish at a relatively low density, allow them to grow through the season and harvest during a limited window in the spring. The second strategy would be to stock at a high density and sequentially harvest fish throughout the season. The first strategy would involve lower effort and labor cost but would presumably also result in lower net production. The opposite would be true of the latter strategy. To investigate the differences in terms of net production between those two conflicting strategies, two different methods of stocking will be evaluated: 1) direct from the hatchery, or 2) pre-growing in recirculating tanks (Obj. 3). In October one net pen will be stocked at a high density (15 kg/m^3; 1,000 steelhead trout at 1,000g each from a recirculating pre-stocking tank) while the other will be stocked at a low density (5 kg/m^3; 1,000 steelhead trout at 500g each from a local hatchery; Blue Stream Aquaculture, Barnstable, MA).

5) Proposed physical structures

Shellfish
In October, approximately 10,000 oysters (< 2”) will be stocked into replicate 5-level, 21 mm monofilament lantern nets at commonly accepted commercial levels (1/3 surface area), and 10,000 bay scallops (< 2”) will be stocked into replicate lantern nets, at 20 per ft^2. Half of the animals will be deployed directly adjacent to the netpens, and half of the animals will be deployed on the Megansett growout site.

Macroalgae
Five, identical 20’ lines of sugar kelp will be installed adjacent to the trout netpens, and five identical lines will also be installed at the current Megansett Harbor oyster farm. The lines will be installed starting at the northwest corner, leading from north to south, spaced 25’ apart. Following the nursery period, the 1mm nylon string will be brought to the site, and wrapped around the 20’ 3/8” rope and connected with cable ties at either end. The line will then be sunk to 7’, and checked bi-monthly and adjusted as necessary to remain at 7’ depth.

Finfish
The two identical Dyneema 50 mm square mesh surface net pens (4m x 6m x 3m; custom nets from Reidar’s Nets, New Bedford, MA), will be hung from existing finger piers, utilizing existing flotation and cleats.

6) Detailed operational plan (species, density, feeding rates, etc.)

The goal of the proposed project is to investigate the biological, economic and logistical issues facing finfish aquaculture in New England, and to provide new, scientifically proven guidelines for cultivating a high-valued, “off-season” crop for aquaculture operations. Locally raised steelhead trout could significantly increase domestic finfish production in a short time period, once the concept has been proven economically feasible, given existing marina infrastructure, and transferable knowledge to shellfish farmers in the region. The questions facing finfish farming in coastal waters include biological, economic, regulatory and logistical, of which this proposal addresses them all. The impact of stocking density on the growth and health of these animals must be investigated, in conjunction with a harvest strategy that will work for a farmer economically.

The goal of this project is to produce steelhead trout, eastern oysters, bay scallops and sugar kelp in an integrated multi-trophic production system within existing marina infrastructure. Specific objectives include:

1. Investigate optimal multi-trophic production techniques for steelhead trout, eastern oysters, bay scallops and sugar kelp within an integrated system.

2. Evaluate the economic viability of two intermediate grow-out strategies; direct from the hatchery vs. intermediate growout in a recirculation system.

3. Evaluate environmental impact through comprehensive water quality and benthic sampling.

Objective 1: Investigate optimal multi-trophic production techniques for steelhead trout, eastern oysters, bay scallops and sugar kelp within an integrated system.

Shellfish:

Oysters and bay scallops will be stocked at 2 locations in October 2019: 1) directly adjacent to the trout netpens in the same or adjacent slip; and 2) in outer Megansett at the farm growout site. In October, approximately 10,000 oysters (< 2") will be stocked into replicate 5-level, 21 mm monofilament lantern nets at commonly accepted commercial levels (1/3 surface area), and 10,000 bay scallops (< 2") will be stocked into replicate lantern nets, at 20 per ft2. Half of the animals will be deployed directly adjacent to the netpens, and half of the animals will be deployed on the Megansett growout site (Fig. 1). Twenty-five oysters or bay scallops will be sampled from 3 bags or lantern nets bi-monthly, enumerated for percent survival, and measured (shell height) to evaluate differential growth rates between sites. A one-way analysis of variance (ANOVA) will be employed to evaluate the effect of different sites on growth and survival. Tukey's HSD test will be employed for comparison of various sites for the significance of difference at $P < 0.05$. 12 2019 Ward Aquafarms, LLC

Macroalgae:

Sugar kelp seed string will be purchased from one of the locally available seed string suppliers (Greenwave, CT; Walrus and Carpenter, RI; Cottage City Oysters, MA; Springtide Seaweed ME) in October of 2019. Five, identical 20' lines of sugar kelp will be installed adjacent to the trout netpens, and five identical lines will also be installed at the current Megansett Harbor oyster farm. The lines will be installed starting at the northwest corner, leading from north to south, spaced 25' apart. Following the nursery period, the 1mm nylon string will be brought to the site, and wrapped around the 20' 3/8" rope and connected with cable ties at either end. The line will then be sunk to 7', and checked bi-monthly and adjusted as necessary to remain at 7' depth. All five kelp longlines will be brought to the surface bi-monthly from initial set (October) through final harvest (March) to check for biofouling. During the routine inspection for biofouling, once per month each line will be sampled to quantify growth and plant attachment. Three locations will be randomly chosen on each of the five lines, and the number of plants attached in a 12" section will be counted. During this process 15 random plants within each 12" section will be measured for total length.

Finfish:

Two netpens will be installed into two identical slips at Fiddler's Cove Marina, North Falmouth, MA (Fig. 1) in October of 2019. Ward Aquafarms already utilizes two other slips for float storage from October-May, and boat use throughout the year. Marinas are frequently used by shellfish farms for nursery and boat operations. By placing the net pens adjacent to an existing shellfish farm operation, additional labor costs will be reduced, and integration into standard farm operations will be more efficient. The two identical surface net pens (4m x 6m x 3m; custom nets from Reidar's Nets, New Bedford, MA), will be hung from existing finger piers, utilizing existing flotation and cleats. Young-of-the-year Steelhead trout will be purchased from a local hatchery (12 months old, approximately 400g, 20-25 cm), stocked into each net pen in late fall (November), when summer water temperatures have declined below 20°C.

The fish will be fed ~3% BW per day split between hourly feedings via autofeeder. An underwater video system will be deployed on each cage, with live data feeds integrated via local wifi connections. Feeding events will be monitored and feed rates will be adjusted to minimize feed waste. Total weight and total length measurements will be sampled monthly to evaluate growth. The desired maximum stocking density for all trials will be 20 kg/m3, and each netpen will be sampled monthly to determine stocking density and adjust as needed. All netpens will be inspected for holes and mortalities daily, and all mortalities will be removed, tallied and disposed of. The harvest will be completed, with all fish being harvested by late mid-March. It is estimated that total production will be approximately 2,000 kg per cage.

During the fall/winter grow-out, two different grow-out strategies could be employed by growers. The first would be to stock fish at a relatively low density, allow them to grow through the season and harvest during a limited window in the spring. The second strategy would be to stock at a high density and sequentially harvest fish throughout the season. The first strategy would involve lower effort and labor cost but would presumably also result in lower net production. The opposite would be true of the latter strategy.

To investigate the differences in terms of net production between those two conflicting strategies, two different methods of stocking will be evaluated: 1) direct from the hatchery, or 2) pre-growing in recirculating tanks (Obj. 3). In October one net pen will be stocked at a high density (15 kg/m3; 1,000 steelhead trout at 1,000g each from a recirculating pre-stocking tank) while the other will be stocked at a low density (5 kg/m3; 1,000 steelhead trout at 500g each from a local hatchery; Blue Stream Aquaculture, Barnstable, MA). Sequential harvest from the high-density net will start in December and will continue throughout the spring to evaluate market demand and maintain a stocking density no higher than 20 kg/m3. Any and all fish harvested will be sampled for length and weight, and all sales will be noted including location of sale, price per unit, and final disposition. Harvest from the low-density net will also begin in December as well with all fish harvested by mid-March 2020.

For this objective we will evaluate fish, shellfish and algae growth between the two treatments. Net production, effort and cost will also be evaluated. A one-way analysis of variance (ANOVA) will be employed to evaluate the effect of different treatments on the above variables. Tukey's HSD test will be employed for comparison of various treatments for the significance of difference at $P < 0.05$.
Objective 2: Evaluate the economic viability of two intermediate grow-out strategies; direct from the hatchery vs. intermediate growout in a recirculation system.

Spring water feeding the hatcheries in the southern New England region is approximately 10° C, which results in a 20-25 cm, 400-500 g fish in October (12 months post-hatch), which typically sells for $6.00 per fish. However, fish from the same cohort can be purchased in May-July at 10-15 cm, and 140-150 g, for $2.00 per fish. When the rainbow trout are raised at 17° C instead of 10° C for 3 months, the same fish can grow to 1 kg when stocked into the net pens at 12 months as opposed to 400-500g. If the feed conversion ratio (FCR) can be kept low, and the install cost of a recirculating system can be minimized, the difference in stocking size could lead to a significant difference in harvest value, and subsequently economic viability of the enterprise, given the short growing window in New England. The design, build and installation costs are variable and specific to each farm, and therefore will not be evaluated in this project. The intent of this objective is to study the economic impact of "pre-growing" the rainbow trout in recirculating tanks, aside from initial installation consideration. Collaborating with Mr. Rillahan at the University of Massachusetts is ideal, as the school recently constructed a new recirculating seawater facility, which will be utilized for this objective.

If 1,000 fish are purchased at $6.00 in October at 500g per fish, that is 500 kg of fish, for a cost of $6,000. Those fish can then be sold as steelhead trout once they have been in salt water at a minimum of $7.00 per pound ($15.40 per kilo). Survival of the conversion from fresh to salt water is never 100%, and therefore, there will need to be some on growing for the saltwater-adapted fish before the system is worth the initial investment of $6,000. Feed costs are under $1.00 per pound including labor, and if the FCR is near 1.0, the system may be profitable after a short period of time. However, if 1,000 fish are purchased at $2.00 in July at 150g, and then grown to 1 kg in October for the same final cost of $6.00 per fish, the stocked fish in October will be a total of 1,000 kg of fish for the same $6,000 cost. These fish will be immediately worth $15,400 as opposed to the 500g fish which will be immediately worth $6,000 at stocking, though each of the initial purchase costs were $6,000. Given the short time that water temperatures are above 5° C from October – May (generally, October through early December, and then April), in order to promote finfish farming in New England, there may be a need to initiate the growing season on land first, and an anadromous fish like rainbow trout are the ideal fish to grow. The recurring annual cost of intermediate grow-out in tanks to produce a larger fish for net pen stocking, will be compared to purchasing 12 month-old fish direct from a flow-through farm on land. Economic viability of each approach will be compared through final yield and revenue as they relate to input costs for each method.

The first strategy includes purchasing 1,000 fish (20-25 cm, 400-500 g) in late October of 2019 from a local flow-through trout farm in the region (Blue Stream Aquaculture, Barnstable, MA). The fish will be directly transferred from the freshwater farm, into the saltwater net pens, and allowed to acclimate for 48 hrs prior to feeding, identical to Objective 1.

The second strategy includes obtaining young of the year (YOY) rainbow trout from the same local flow-through trout farm in early July 2019 at 140-150 g for $2.00 each. The fish will be transferred to the University of Massachusetts Dartmouth and placed in a heated freshwater recirculating system which will be well aerated and maintained at 17° C. Tanks will be stocked with fingerling rainbow trout stocked at recommended stocking density of ~20 kg/m3 to ensure the proper welfare of the fish (Ashley, 2006; Stevenson, 2007: Person Le-Ruyet et al., 2008). Fish will be fed four times per day using via automated feeding system. Prior to moving fish to the marine netpens the fish will be slowly adapted to saltwater and ambient temperature. This has been shown to increase growth and decrease mortality (Chambers, M., Pers. Comm.). When local water temperature decline below 20° C (October 2019) fish will be transferred to the marine netpens for growout.

The steelhead trout in strategy one (direct transfer) will be sampled prior to being placed into the netpens. The steelhead trout in strategy two (recirculating system) will be sampled prior to entering the recirculating system, and then every 30 days through the entire tank-based period. The trout from strategy two will also be sampled prior to entering the netpens, and trout in both of the netpens will be sampled every 30 days. Sampling includes randomly selecting 20 trout, measuring for total length and total mass. Total amount of feed per day will be quantified, and any mortality at any point throughout the project will be tallied and noted for date. Survival, growth, condition index and yield per method will be calculated and we will evaluate the differential between treatments. A one-way analysis of variance (ANOVA) will be employed to evaluate the effect of different treatments on above variables. Tukey's HSD test will be employed for comparison of various treatments for the significance of difference at $P < 0.05$.

7) Containment plan to prevent escapees

When deciding what material to construct the net pens from, the typical options are nylon, and various thicknesses and formulations of polypropylene. While very low cost, nets made from these materials are prone to ripping, ultraviolet degradation, and high biofouling load. The net for this project will be constructed entirely out ultra strong and extremely light 50mm square mesh Dyneema. Utilizing Dyneema fiber means farms can use larger and lighter net cages, which are much easier to handle, and as a result, they provide a safer working environment by reducing bodily strain and physical requirements. The extremely strong material is used on fish farms throughout the world, due to less antifouling consumption and excellent bite resistance. Lower weight netting also delivers other benefits for fish farmers. Nets made with Dyneema use 40% less antifouling, compared to nylon,. This not only has a positive environmental impact but also produces significant cost savings.

8) Predator exclusion plan

Dyneema fibers are highly impervious to wear and tear resulting in bite resistance not seen in other materials. This excellent resilience hampers predators like seals, turtles and blue fish from damaging and entering the cages. Even more importantly, it helps protect fish farmers' biggest asset: the fish, since sea bream can't bite their way out of the cage. Over the years Dyneema has become the material of choice for sea bream farming in the Mediterranean. Dyneema is regularly used by the Department of Defense to stop bombs, bullets and other high-speed flying debris without issue, and can be expected to perform in a similar function in an aquaculture setting to deter predator incursions.
9) Anticipated habitat degradation issues and plan to minimize (BMP)
Objective 3: Evaluate environmental impact through comprehensive water quality and benthic sampling.

All environmental monitoring will be conducted by the farm owner (Daniel Ward), with oversight and in accordance with local, state and federal agencies. No antibiotics, sea lice treatment, or any other chemicals will be applied throughout the entire project period.

Extensive sampling prior to adding fish to the ecosystem, as well as throughout the growth cycle will take place to sufficiently demonstrate that there are no adverse environmental impacts from the trout culture. Water temperature and salinity (HOBO Conductivity Data Logger - U24-002) as well as dissolved oxygen (HOBO Dissolved Oxygen Logger - U26-001) are currently continuously recorded at the approved culture site via submerged data loggers. Additional dissolved oxygen loggers will be deployed on the trout cage, and at 10 m to the east and west (tidal direction) from the site to quantify any decrease in dissolved oxygen in the proximity of the cage at the bottom.

Flow rate and direction (SeaHorse Tilt Current Meter; OkeanoLog, North Falmouth, MA) will be measured at the cage, and at the control site. Water samples will be taken at 30 cm from the bottom at the cage location on all four sides (N, S, E, W), and at 15 m away from the netpen in all four directions (N, S, E, W), twice during the growing cycle. First in October (prior to adding fish), in again in May (after all fish have been removed). Sediment grab samples will be taken from the top 5 cm of sediment from identical locations as the water samples, at the same sampling times as noted above. Video transects of the project site and benthos will also be conducted.

All water samples will be assayed for the following parameters by Envirotech Labs, Sandwich, MA: fecal coliform, ammonia, nitrate, nitrite, total nitrogen, organic nitrogen, total phosphorus, organic phosphorus, pH and suspended solids.

All sediment samples will be assayed for the same parameters, except suspended solids in the sediment samples. At the same environmental sampling intervals, identical samples will be taken from four randomly assigned locations within the 10 acre grow-out site, ½ nm west of the netpen site, and will be assayed for the same parameters. All data will be analyzed, evaluated for changes in water and sediment quality and submitted to the required regulatory agencies.

10) Disposal plan for culls and gear

Culls will be bagged, and disposed of through commercial trash removal (dumpsters) as any other seafood waste product. Gear will be removed and transported to the owner's property to be either recycled or stored for future use.

11) Bond

Evidence of performance bond sufficient to remove structures and restore site to its original condition will be provided

12) Evidence of Water Quality Certification and NPDES Permit

Pending