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Impact financing and aquaculture: Maryland oyster aquaculture profitability

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Abstract

Aquaculture production of oysters has occurred in the state of Maryland since the 1890s, with limited success due to restrictive regulations and opposition from the commercial wild industry. After revision of the aquaculture leasing regulations in 2009, the Maryland oyster aquaculture industry expanded more than 10-fold. In 2010, Maryland Agricultural & Resource Based Industry Development Corporation (MARBIDCO) started the Maryland Shellfish Aquaculture Loan fund, which features a below-market interest rate, interest-only repayment period and partial-principle forgiveness. This study evaluated differences in farm-accounting metrics when comparing self-financed operations, conventionally-funded operations, and operations with MARBIDCO funding on water-column and bottom-culture oyster aquaculture operations in Maryland. Bottom-culture and water-column operations had significantly higher net present value and internal rates of return when they were MARBIDCO-financed compared to other sources of capital. This research suggests oyster aquaculture operations that make use of MARBIDCO financing or similar options should have the best chance of success and highest financial return. The research also suggests, if significant funds could be identified or obtained (i.e., federal, provincial, or private company disaster payments), establishing programs similar to the MARBIDCO Shellfish Aquaculture Loan Fund can help improve financial profitability of aquaculture operations in other areas of the world.

Keywords: aquaculture, debt finance, economics, Maryland, oyster, profitability, shellfish

Significance Statement: This study was the first to compare different sources of capital on the profitability of oyster aquaculture operations in the state of Maryland. The study shows that the unique mix of grants and low interest loans results in greater profitability when compared to the use of traditional debt financing or self-financed operations.

1. INTRODUCTION

One of the primary species harvested from the Maryland portion of Chesapeake Bay has been the eastern oyster (*Crassostrea virginica*). Harvesting reached its peak in the late 1800s and declined rapidly since (NOAA, n.d.). Through overharvesting and disease, wild-oyster harvests from the Maryland portion of the Chesapeake Bay have continued to decline to a fraction of those historic harvests (Kennedy et al., 2011; Kingsley-Smith et al., 2009; Paynter & Burreson, 1991; Webster, 2009). Aquaculture of oysters has also been practiced in the Chesapeake Bay since the 1890s, however, due, in part, to restrictive regulations and opposition from Maryland commercial watermen, aquaculture has not prospered in Maryland (Webster, 2009).

Currently there are two production methods employed in Maryland for oyster aquaculture. The most common production method is spat-on-shell bottom-culture. In this production method, oyster larvae set on oyster shell in large tanks. This results in multiple juvenile oysters (spat) on each oyster shell. These shells are planted directly on the seafloor and allowed to grow to market size. Oysters from bottom-culture operations are harvested using traditional commercial oyster harvest methods. The majority of growers utilize an oyster dredge pulled behind a boat. This non-selective harvest method has been suggested to increase mortality as smaller oysters may be harmed as the dredge breaks oysters off the seafloor. The majority of oysters from bottom-culture operations are sold to shucking houses for processing with some percentage of the harvest from some operations sold as single oysters.

The second form of oyster production in Maryland is water-column oyster production. Oysters produced in this method are containerized and grown in the water column. Containers may be cages, supported off the bottom with feet, bags or cages suspended from lines in the water column or cages or bags at the surface suspended with floats. Single oyster larvae are generally set on tiny oyster shell fragments. This method produces single oysters, rather than clustered oysters, which are suitable for the half-shell market. Mortality in water-column operations tends to be less than that of bottom-culture operations since oysters are better protected in the container, than when laid on the sea floor. Oysters are harvested by removing the containers from the lease. Oysters can then be graded and sorted by hand or equipment for different markets. Oysters which have not reached market size can be returned to the lease for futher growth.

Since state oyster aquaculture regulations were re-written in 2009, there has been an increase in Maryland oyster aquaculture (Maryland Department of Natural Resources, 2017; Wheeler, 2009). According to Maryland Aquaculture Coordinating Council reports, in 2012, there were 1,472 acres of bottom-culture leases and 175 acres water-column leases in the state of

Maryland (Maryland Aquaculture Coordinating Council, 2013). Production in 2012, total of farmed oyster production in Maryland was 3,340 bushels (Maryland Aquaculture Coordinating Council, 2018). In July 2018, there were 6,420 acres of bottom-culture leases and 383 acres of water-column leases (Maryland Aquaculture Coordinating Council, 2018). In 2017, the total farmed oyster production in Maryland exceeded 74,000 bushels[1] (Maryland Aquaculture Coordinating Council, 2018) In 2008, Maryland Department of Natural Resources (MDNR) applied to the National Marine Fisheries Service to declare a disaster in the wild-caught blue crab fishery and was awarded $15 million (Holzer, Depiper, & Lipton, 2017). While some of the disaster funds were used to buy back crab fishing licenses, over $4.37 million was transferred to the Maryland Agriculture and Resource Based Industry Development Corporation (MARBIDCO) to provide impact financing for oyster aquaculture to promote alternative income streams for affected watermen (Holzer et al., 2017).

Typically, when someone wants to start an aquaculture operation, there are two primary sources of capital available to start the operation. One is to self-finance the operation through personal savings or investments. The other is to use conventional-debt financing through a lending source such as Farm Service Administration (FSA), the Farm Credit System, or conventional lending institutions. FSA loans are often aimed at existing small operators and potential entrants who do not qualify for conventional lending and are used for land, livestock, seed, and other farming inputs (Srnec, Vyborna, & Harvland, 2009) and have the ultimate goal of

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[1] In Maryland a bushel is equal to 0.459 cubic meters (2,800.9 cubic inches), or 1.0194 times the US standard bushel (Maryland Department of Natural Resources, n.d.)

helping borrowers build credit and eventually obtain credit from a commercial lender (USDA Farm Service Agency, 2012)

Much like the FSA, MARBIDCO makes loans of various sizes to agricultural entities in the state of Maryland. For example, MARBIDCO has developed a specialty-lending program in collaboration with MDNR to help expand the Maryland shellfish aquaculture industry (Maryland Department of Agriculture, 2010). A key characteristic of this specialty loan is an interest-only period and partial forgiveness of the loan principle, if all interest only payments are made on time (Maryland Agricultural & Resource Based Industry Development Corporation, 2017). MARBIDCO has approved over 50 shellfish aquaculture loans in its program since 2011, totaling over $3 million (Maryland Agricultural & Resource Based Industry Development Corporation, n.d.). However, until now, there have been no attempts to assess the impact of the loan fund on farm-level profitability. As wild-oyster harvests in Maryland are predicted to continue to decline and oyster aquaculture expected to grow, a clear need has emerged to evaluate and compare the impact of the MARBIDCO funding program, conventional lending, and self-financing will have on the profitability of oyster farms in Maryland. This analysis will help potential entrants to the industry make better business decisions to help ensure farm profitability.

2. MATERIALS AND METHODS

This study modeled the potential profitability of bottom-culture, spat-on-shell oyster operations and water-column oyster operations in Maryland over a 10-year period, and evaluated the differences when the operation is 1) self-financed 2) financed by MARBIDCO, and 3) funded by conventional-lending sources. Due to the length of time it takes oysters to reach market size, and the resulting lack of revenue in the first few years of an operation, a 10-year period was chosen to allow multiple crops to be produced during the study simulation. Due to the relatively young Maryland oyster aquaculture industry, the authors felt the assumptions needed for oyster prices, costs, and technology used for oyster production would be too unrealistic to support a longer simulation period. Despite the length of time for oysters to reach marker size in Maryland, both bottom-culture and water-column operations will have a minimum of seven cohorts reach market size in a 10-year simulation providing time for farms to reach full production and realize a steady state of cash flows.

When possible, public agency reports (i.e. unpublished data from Maryland Department of Natural Resources annual grower survey and Maryland Aquaculture Coordinating Council annual reports) were used to develop the summary of the bottom-culture and water-column culture portions of the Maryland aquaculture industry. Unless otherwise noted, industry information described within was gathered through informal interviews and discussions with state agency personnel, industry experts, owners of active aquaculture operations, the authors' experiences working in the industry, and attendees from University of Maryland Extension (UME) Aquaculture Workshops. Sources of data used in the analysis are included in the tables associated with each section in the text.

In order to compare the impacts of different financing options on oyster-operation profitability, capital-budgeting analyses published by UME (Parker, Dill, Webster, & Meritt, 2013, 2015) were modified for use in this study in order to account for different sources of capital used to start and operate the oyster aquaculture farms. Specifically, bottom-culture analysis was modified to allow production to be driven by the bottom-culture lease size, with a specified planting rate per acre, rather than production quantities, reflecting how aquaculture operations are described by industry members. Modifications to water-column production analysis included the ability to estimate harvests during operation start-up. Estimates of labor were based on production levels for water-column oyster culture. Finally, the water-column production analysis was modified to base production on the number of individual oysters to be harvested once a farm reached full production, again, reflecting how farms are described by industry members.

A section for three financing options: 1) self-financed, 2) financed by MARBIDCO, and 3) financed by conventional-lending sources was added to each budget. The financing modifications allowed up to three loans from MARBIDCO with financing terms of an interest-only period and partial principle forgiveness corresponding to the MARBIDCO loan fund options. For comparison, three loans were included from conventional financing agencies without the interest-only period or partial principle-forgiveness terms with the same loan amounts as the MARBIDCO scenarios.

Annual cash-flow statements and ten-year enterprise budgets were incorporated into the capital budgeting analysis for each source of financing for each production system budget. The cash-flow statements and enterprise budgets were constructed so that all model inputs (costs, survival, prices, etc) would be the same for each source of capital in each simulation iteration. Each simulation yielded three unique data sets to afford comparisons between funding sources.

Simulations of the effects of different funding sources over a ten-year period were performed using the @Risk version 7.6 (Palisade Corporation, 2018) Microsoft Excel add-in. Each simulation utilized Monte Carlo sampling techniques with 5,000 iterations. Statistical analyses were performed using the StatTools version 7.6 add-in that is part of the @Risk software package.

2.1 Model description

The model is a spreadsheet workbook containing annual cash-flow calculations and enterprise budgets, which estimate average profits per firm using calculated input costs and expected production. Enterprise budgeting and annual cash-flow predictions are commonly used when evaluating aquaculture practices since aquaculture is still a relatively new enterprise in the Western hemisphere (Engle, 2010). Monte Carlo simulations were used to input a range of cost and production estimates on business performance over a 10-year period based on constructed risk distributions. Ten-year net present value (NPV) and ten-year modified internal rate of return (MIRR) were calculated for each iteration of the model. Annual enterprise budgets, representing annualized costs of inputs and value of the outputs, were developed to calculate the total costs and revenue over a ten-year period. Annual enterprise budgets were then summed to create a ten-year enterprise budget for each source of financing.

The length of time it takes oysters to grow to market size (76.2 mm) in Maryland varies based on environmental factors, the use of triploid vs diploid oysters, and production method. Growers in Maryland generally report oysters grown using bottom-culture methods take 2-4 years to reach market size. Those grown using gear in the water-column are reported to grow to market size in 12-36 months.

Additionally, industry participants indicated a concern over the impacts of a catastrophic mortality event occurring at least once within the 10-year modeled simulation. To account for this possibility, a 100% mortality event was randomly incorporated between Year 1 and Year 10 by using the random number function in Microsoft Excel for each model iteration. After the catastrophic event, it was assumed the farm would replant, and it would take 18-36 months, depending on production practice, for the farm to reach harvestable production once again.

2.2 Common model assumptions for bottom-culture and water-column culture operations

Although separate models for bottom-culture and water-column culture methods were developed, some data and model assumptions are common to both types of operations (Table 1). Assumptions specific to a given production method are discussed below. Production and analysis are discussed in terms of bushels for bottom-culture operations and single oysters for water-column aquaculture due to the prevalence of that terminology in the industry. An estimate of 275, 76.2 mm market-size (3-inch) oysters per bushel (Meritt & Webster, 2014b) was used to convert single oyster production to bushel equivalents and vice versa.

Retail containers for oysters produced for the half-shell market are assumed as plain, 100-count, waxed boxes based on their prevalence in the Maryland industry. According to industry experts, basic retail boxes are priced at $1.00 per box. It was assumed there was no customization of retail boxes (logos, colors, brand names, etc.) that would increase cost.

Wage rates were established based on discussions with industry participants. A wage rate estimate of $12.50 per hour for all general labor was used based on discussions with attendees at UME business planning workshops in 2016. A wage of $20.00 per hour is estimated for a owner/supervisor. Costs associated with employees beyond wages are included in Table 1.

Business insurance costs are calculated based on shellfish aquaculture industry insurance estimates (Bankers Insurance, 2016). These rates are $1,000 per $150,000 in sales for general liability insurance, $683 per automobile per year, and $600 per boat per year. Crop insurance is not included since it is generally not available for shellfish production. Operations may choose to participate in the United States Department of Agriculture (USDA) Non-Insured Crop Disaster Assistance Program (NAP), which waives fees for basic coverage for participants who have been in operation less than 10 years, and therefore not included in the model.

2.3 Specific assumptions of bottom-culture oyster aquaculture operations

Specific assumptions about bottom-culture production and costs were made based on discussions with current bottom-culture operators in Maryland and other regional industry experts (Table 2). Key assumptions included annual-planting rate, overall survival from planting to harvest, labor required, and associated costs. Discussions about the sources of the assumptions are included below. Data obtained from MDNR in May 2017 show the mean size for bottom leases was 7.49 hectares, the median was 3.70 hectares, and the mode was 2.02 hectares. Therefore, to estimate profitability and returns for common-lease sizes in Maryland, four production levels were simulated 2.02 hectares (5 acres), 4.04 hectares (10 acres), 8.09 hectares (20 acres), 40.47 hectares (100 acres).

Bottom condition is an important factor in the siting of shellfish bottom-culture leases (Webster & Meritt, 1988). It is rare to have a lease with 100% of the bottom suitable for oyster culture. Consequently, spatial patchiness is problematic, difficult to determine, and hard to monitor with regard to anticipated total production capability (Meritt & Webster, 2014a). Furthermore, to minimize the amount of oysters that are outside leased areas, a buffer space is often left along the outside edges of the lease. Oysters outside the leased area may be harvested by others, reducing overall production from the lease. Eighty percent of total bottom-space available was used to allow for unsuitable areas within their lease.

To maximize annual market-size product availability a "crop rotation" method of annual seeding of oyster leases was incorporated into the model with one-third of each lease harvested annually to account for the 36-month growth-to-harvest size of 76.2 mm. After the annual harvest, the harvested area was re-seeded with spat-on-shell oysters the following year. For example, a 2.02-hectare lease with 80% suitable bottom will harvest and seed approximately 0.53 hectares annually [2.02 ha x 0.80 x 0.33=0.53 ha planted and harvested per year].

Bottom-culture operations are planted with diploid, spat-on-shell, oyster seed annually at an equivalent rate of approximately 4.94 million spat-on-shell seed oysters per hectare based on the upper range reported in Meritt and Webster (2014a). Diploid oysters are similar to wild oysters genetically and are available in bulk from the University of Maryland Center for Environmental Science (UMCES), Horn Point Oyster Hatchery. Spat-on-shell oysters are used for bottom-culture to prevent excess mortality of small oysters from crabs, cownose rays, and other predators.

Survival from planting to harvest was estimated at 15% based on available literature for the survival of bottom-cultured oysters in the Chesapeake Bay (Abbe, Mccollough, Barker, & Dungan, 2010; Congrove, 2008; Kingsley-Smith et al., 2009). While Congrove (2008) suggested 20% survival to market size in the state of Virginia, Abbe et al. (2010) estimated survival at 17% in the Patuxent River, Maryland. A more conservative 15% was used as a base survival rate in this calculation due to the potential variations between sites and lack of studies in this area. Since producers decide how many spat-on-shell oysters are planted on a per-acre basis, they do not purchase additional spat-on-shell oyster to account for mortality.

As any other live animal crop produced, individual oysters grow at different rates. Even though it was assumed it would take an average of 36 months for spat-on-shell oysters to reach market size, it is possible some reach market size sooner. Based on information presented by Congrove (2008) none of the oysters planted will reach market size in the first year of operation, 37% of oysters will reach market size in the second year, and 100% of oysters will reach market size by the third year.

Conversations with industry producers suggested an operation with a vessel previously used for wild harvest of oysters could harvest 60.70 hectares (150 acres) per year per boat. Currently, it is an industry practice to contract other individuals using their own fishing boats to harvest oysters from bottom leases over 60 hectares. Since none of the simulations in this study exceeded the 60+-hectare lease-size threshold, it was assumed the operator used their own boat with hired workers. Typically, there are two deck hands operating per boat during the harvest.

Harvest records submitted to MDNR indicate the majority of bottom-culture, spat–on-shell oyster harvest occurs only from March until October. Thus, a good estimate of labor assumes two employees working 40 hours per week for 30 weeks per year. Supervisory labor was assumed 40 weeks per year for each operation. To accommodate the time from start-up to full production, general labor was reduced in the first two years of the operation to account for the time needed for oysters to reach market size. Therefore, labor in the first year was estimated to be 25% of the calculated amount for a full-production operation. Labor in the second year increased to 50% of the calculated amount. Full-labor costs are expected by the third year of operation. The owner-supervisory labor was estimated at the full amount each year. It is assumed the owner used the time in the first two years of the operation to acquire materials, attend educational workshops, and find buyers for the oysters produced from the lease.

2.4 Specific assumptions water-column oyster aquaculture operations

Specific assumptions about water-column production and costs were made based on discussion with current oyster operations in Maryland and regional industry experts (Table 3). Key assumptions included overall survival from planting to harvest, labor required and associated costs, and the percentage of oysters reaching market size in years one and two. Discussion about the sources of the model assumptions are included below. There were four production-level models, based in information from the industry and amounts indicated on MARBIDCO loan fund applications (500,000 oysters per year, 1 million oysters per year, 2 million oysters per year, 2.5 million oysters per year).

It was assumed that, double-stack “Virginia tray style” cages, measuring 0.91 meters (3 ft.) by 1.22 meters (4 ft.), are deployed containing 1,200 76.2 mm oysters per cage at harvest. The total number of cages required for the farm to reach full production level was determined based on this capacity. Six plastic mesh “bags” are inserted into each cage to prevent seed from falling out of cages until oysters reach a size where they will not fall through the cage. Mesh bags cost $6.00 each.

The lease size for all farming operations is assumed 2.02 hectares (5 acres). Based on data obtained from MDNR in May of 2017, the mean water-column lease size was 1.90 hectares, the median lease size as 1.66 hectares. The modal water-column lease size was 2.02 hectares.

The number of cages per hectare varies in the Maryland industry based on owner preference, lease configuration, and production goals. The theoretical maximum, assuming two-dimensional spacing, number of cages that could be put on a 2.02-hectare lease is 18,150 cages based on cages taking up 1.11 square meter per cage. The 2.5 million oyster per year simulation requires only 4,168 cages. Thus, a 2.02-hectare lease size assumption gives ample room for all cages and production levels analyzed.

Fifty percent of each lease is harvested per year based on two-year average growth to a market size of 76.2 mm. This harvest strategy allows a crop rotation to be established to ensure product availability each year once the farm reaches full operating capacity. The stocking of additional seed will occur each year to meet production goals.

Predicted survival from seed to market size is 50%. Literature review shows oyster survival in containers is highly variable in the Chesapeake Bay with ranges of 8% to over 70% mortality (Callum, 2013; Calvo, Luckenbach, & Burreson, 1999; Hudson, Kaufman, Murray, & Solomon, 2012; Paynter et al., 2008; Paynter, Mallonee, & Shriver, 1992; Proestou et al., 2016; Wieland, 2007). Fifty percent mortality was selected as a medium level of mortality based on the published data and discussions with commercial operations. Unlike in bottom-culture operations, water-column operations are targeting a specific production level. Additional seed oysters are purchased to account for mortality. For example, if a producer expects 50% mortality and would like to harvest 1,000,000 oysters per year, they would purchase 2,000,000 seed oysters for each cohort.

Some oysters grow faster than others do, which can be due to normal variation in individual oysters or driven by site-specific factors such as on local oxygen levels, salinity, and food availability. It is assumed that 25% of oysters stocked at farm start-up were harvested in the first year. Seventy-five percent of oysters stocked at farm start-up were harvested in the second year. The farm will reach steady state of oyster harvests in subsequent years. Based on consultation with industry participants, currently all oysters harvested from water-column operations in the state of Maryland are sold to the half-shell market.

Oyster seed is purchased for $17.00 per 1,000 for 5-10 mm triploid, disease-resistant seed from UMCES Horn Point Oyster Hatchery (Horn Point Oyster Hatchery, 2018a) based on prevalence in the industry (Maryland Aquaculture Coordinating Council, 2018). Triploid oysters are specially bred to add an additional set of chromosomes, which prevents them from reproducing. Since the triploid oysters do not produce reproductive organs, more energy is devoted to growth resulting in better meat quality year round. Studies have shown that triploid oysters have the potential to grow faster than diploid oysters (Dégremont, Garcia, Frank-Lawale, & Allen, 2012; Maryland Aquaculture Coordinating Council, 2018; Wadsworth, Wilson, & Walton, 2019; Walton et al., 2013).

Labor for water-column operations was calculated based on regression analysis (FIGURE 1) of data available from Virginia operations (Hudson et al., 2012), which also included supervisory labor in their estimates. General labor in the current analysis included office labor, which was not included in Hudson et al. (2012). Labor estimates in the Virginia study were based off of four years of grower surveys and included full- and part-time employees (Hudson et al., 2012). Supervisory labor in this analysis is assumed owner labor and is accounted for separately.

To accommodate the time from start-up to full production, general labor in the first year of each simulation is estimated to be 50% of the calculated value and the full value in subsequent years. Supervisory-owner labor is assumed 2,080 hours per year.

2.5 Risk analysis

Every oyster aquaculture operation has different infrastructure, production, marketing, and financing; however, many bottom-culture and water-column culture operations share the same sources of uncertainty. The uncertainty associated with oyster production creates a certain amount of risk that can be estimated based on historical production data and conversations with other growers or industry experts. While operations can plan and project production levels and incomes from year to year, the associated assumptions (costs of inputs, price received for oysters, survival, disease impacts) may be unknown and can vary each year. For example, there may be environmental factors such as drought or excess rain that affect oyster growth or survival. Likewise, differences in spat-on-shell or seed quality occur from year to year. A difference also exists for the amount of investment each operation undertakes regarding equipment needed for production. Risks common to bottom-culture and water-column culture, along with their expected values, are presented in Table 4. Discussions of the key assumption values are presented below.

Risk distributions for individual model inputs, based on triangular distributions, were used to model the uncertainty in certain input values that can change from year to year, and were constructed by designating the minimum value, most likely value, and the maximum value for an input (Fairchild, Misra, & Shi, 2016; Johnson, 1997). For the risk analysis an expected price of $55.00 per bushel with a range of $35.00-65.00 per bushel is used, which is consistent with prices seen in the Virginia extensive spat-on-shell oyster industry (Hudson, 2018).

Fuel costs are variable based on market conditions and the size and type of vessel, as well as fuel prices. Fuel costs are estimated to range from $1,000-6,000 per year with an expected value of $3,000 per year.

Every oyster operation modeled included one vehicle devoted to aquaculture operation use. As operations increase in scale, there may be a need for additional vehicles. Vehicle use varies by operation and includes transporting equipment and oysters, and general business use. Vehicle purchase costs are estimated to range from $0-30,000 per vehicle with the most likely value estimated at $15,000.

2.6 Bottom-culture aquaculture risks

While there are several risks in common between bottom-culture and water-column oyster production in Maryland, there are unique challenges for each production system. For example, there may be differences in yearly survival and the amount of equipment needed. Inputs that represent uncertainties in bottom-culture are presented in Table 5.

Some percentage of oysters harvested from bottom-culture operations are suitable for sale to the single, half-shell market, and this percentage can be increased if the bottom is “worked” from time-to-time to break up clusters of oysters. The expected volume of production sold as single oysters is 10% of production with a range of 0% to 25%. The remaining volume of oysters sold as bushels are calculated automatically based on the volume determined for single-oyster sales.

The price for half-shell oysters varies on the quality of the product and the desired market. While the average price for single oysters raised in Virginia has been $0.41 per oyster (Hudson, 2018), an expected average price of $0.50 per oyster with a range of $0.35-0.55 per oyster is based on input from producers.

Each oyster operation is assumed to employ one boat devoted to the aquaculture operation with equipment to harvest such as a dredge. In some cases, these boats were previously owned by the operation owner and converted to aquaculture uses. In other cases, a boat must be purchased. The per-boat cost ranges from $0-55,000 with the most likely value being estimated at $20,000. As with vehicles, as production scales increase beyond levels modeled in this analysis, there may be a need for additional boats.

Marketing expenses are highly variable between firms and much lower in bottom-culture of spat-on-shell oysters than in the water-column production of oysters because most bottom-culture oysters are destined for the shucked meat market. A range of $0-1,000 per year for marketing expenses was estimated with the most likely value being $200. These expenses include, but are not limited to, branding, transportation, samples, and promotional marketing materials to gain market access to restaurants and distributors.

Monitoring costs (health, growth, and theft prevention) vary among operations. Some operations plant spat-on-shell oysters and wait to harvest them in several years, while others monitor growth and health more frequently. A range of $0-1,000 per year was estimated for monitoring with most likely value being $300 per year.

While the same survival factor was used to plan production for each year in the model simulation, to account for the realistic variability in survival from year to year, an environmental effect factor was incorporated for each year in the model simulation. This factor calculates survival in a range of 25-120% of the predicted 15% overall survival and changes each year. Using these examples, Year three survival may be 25% of the predicted 15% survival resulting in 3.75% survival of seed from planting to market size for that crop. Survival below the predicted value could be attributed to less than optimal environmental conditions such as an abnormally low salinity, increased mortality from disease, predation, or other factors such as low oxygen levels or theft. Survival rates higher than the 15% levels are possible if there is a natural recruitment of oysters in the growing area. For example, in Year 6 survival may be 120% of the 15% predicted survival resulting in 18% overall survival for that crop.

"Other" equipment needed may also vary from operation to operation. Equipment could include, but is not limited to, items such as a dredge, tables to sort and cull, equipment to break-up clusters of oysters, and harvest baskets on the boats, land-based refrigeration equipment, or materials handling equipment to transfer spat-on-shell oysters to the boat for planting. The range of values used is $1,500-$30,000 with $5,000 being the most likely value.

2.7 Water-column aquaculture risks

Like bottom-culture, there are uncertainties in production that are unique to water-column production of oysters. As with bottom culture, environmental factors will affect oyster growth or survival. There may also be differences in seed quality from year to year, hatchery used, or the genetic lines or families obtained.

Single oysters grown in the water column are reported to demand a higher price than those grown on the bottom because of shell configuration and amount of meat available in comparison to a similar-sized oyster from bottom-culture. Therefore, a higher maximum price was used when compared to bottom-culture for single oyster sales. This price difference could also be attributed to increased marketing through the creation of brand names for oysters. An expected average price of $0.50 per oyster with a range of $0.35-0.60 per oyster was based on input from producers.

Double-stack tray cages vary in price depending on supplier. Ketcham Supply Company (New Bedford MA) charges $101.40 per cage (2018 price). In contrast Hooper's Island Aquaculture Company charges $87 for a kit and $137 for an assembled cage (Hoopers Island Oyster Company, n.d.). A range of $87-137 per cage was used in the model. Fifty percent of the required cages were purchased before farm start-up. The remaining cages were purchased in year one.

As with bottom-culture, every oyster operation employs a boat with equipment to harvest water-column oysters. The model assumes one boat per farm. Some operations use traditional commercial fishing boats, while others use small skiffs. The model uses an average boat cost per firm, but since the type of boat varies, the estimated cost of the boat ranges from $0-55,000 per boat with the most likely value being $20,000, allowing for cases where boats were already owned and did not have to be purchased. All boats include equipment to hoist cages from the water in order to harvest and sort oysters.

As mentioned previously, marketing expenses are highly variable among operations and are much lower in bottom-culture of spat-on-shell oysters than in the water-column production of oysters. A range of $0-5,500 per year for marketing expenses is estimated with the most likely value being $4,000. These expenses include, but are not limited to, transportation, branding, providing samples, and marketing materials to promote product and gain market access to restaurants and distributors.

Monitoring costs (health, growth, and theft prevention) vary among farms. A range of $0-2,000 per year is estimated with most likely value being $1,000 per year.

As with bottom-culture, there is annual variability in survival in water-column culture of oysters despite what is assumed when planning yearly production. An environmental effect factor was incorporated for each year in the water-column model simulation. This factor calculates survival in a range of 25-125% of the predicted 50% overall survival and changes each year. Using these estimates, year three survival may be 25% of the predicted 50% survival resulting in 12.5% survival of seed from planting to market size for that crop. Survival below the predicted value could be attributed to less than optimal environmental conditions such as an abnormally low level of salinity or other factors such as disease, theft, or low seed quality. Survival rates higher than the 50% levels may be achieved if growing conditions are optimum for a longer period in the year or if higher quality of seed is purchased. For example, survival of previously planted oysters scheduled for harvest in Year 6 may be 125% of the 50% predicted survival resulting in 62.5% overall survival. The upper end of the environmental effect is higher than that of bottom-culture operations since oysters are better protected from predators.

Also like bottom-culture, “other” equipment is needed and varies from operation to operation. Such equipment may include, but is not limited to, items such as a davit, tables to sort and cull oysters on shore, harvest baskets, land-based refrigeration equipment, or mechanized sorting and tumbling equipment. The range of values used is $15,000-40,000 with $30,000 being the most likely value.

2.8 Financing scenarios modeled

Each production level is modeled with three financing scenarios. The first scenario uses personal funds for investment without any support from debt financing. This approach served as the base model for comparison. The second scenario uses financing from the MARBIDCO Shellfish Aquaculture Loan Fund program, and was constructed to allow for up to three separate loans, which afford model flexibility. In general, the MARBIDCO program features an interest-only period, historically three years, and partial principle forgiveness if all interest-only payments are made on time. Currently the first loan taken from MARBIDCO features 40% partial principle forgiveness, while any subsequent loans are granted 25% principle forgiveness. The remaining principle is amortized over the remaining term of the loan at a higher interest rate. The third scenario modeled used funds from a conventional-lending source. The scenario is set up to allow three loans from conventional sources. All loans are taken at the end of the year indicated. Loans assumed in Year 0 are considered part of the initial capital investment to start the operation. MARBIDCO limits any single loan to a maximum of $100,000. Multiple loans may be taken over time with an aggregate maximum of $300,000.

MARBIDCO bottom-culture loans in the simulation overlap and are taken in Year 0, one, and two and feature a three-year, interest-only period at a rate of 3.0%. For the first loan from MARBIDCO, 40% of the original principle was forgiven after the interest-only period, with the remaining principle amortized over two years at an interest rate of 5.0%. For subsequent MARBIDCO loans, 25% of the original principle was forgiven, with the remaining principle amortized over two years at an interest rate of 5.0%. Conventional loans overlap and are taken in Years 0, one, and two, and feature an interest rate of 7.0% amortized over six years. Loan amounts for bottom-culture operations are presented in Table 7.

Loan terms obtained for water-column operations from MARBIDCO vary based on purposes of the loan. For this analysis for water-column operations, the first loan is taken from MARBIDCO in Year 0 and the second loan taken in Year 1, which includes production equipment, has a three-year interest-only period with a rate of 3.0%. Forty percent of the principle for the first loan and 25% of the principle of the second loan are forgiven. The remaining principle is amortized over a three-year period at a rate of 5.0%. The third MARBIDCO water-column operating loan, taken in Year 2, which can include the purchase of seed oysters, features a three-year interest-only period with a rate of 3.0%. Twenty-five percent of the principle is forgiven and the remaining principle is amortized over two years at a rate of 5.0%. Conventional loan terms for water-column operations are the same as those for bottom-culture operations. Loan amounts for MARBIDCO and conventional loans are shown in Table 7 for water-column operations.

2.9 Metrics to Measure Success of Oyster Aquaculture Operations in Simulations

To assess if an operation is successful using a given financing mechanism, this analysis focuses on accounting financial indicators rather than economic financial ones. Based on conversations with industry, non-cash items, such as opportunity costs and depreciation, did not seem to be factors used in operator decision making to start the operation. Additionally, based on consultation with colleagues, many new aquaculture operations are primarily concerned with cash-related items, such as the cost of equipment and seed, and accounting profit rather than an economic profit (Carole Engle, Engle-Stone Aquatic$ LLC, personal communication). Further, non-cash expenses would increase the total costs over time for each operation. Overall trends expressed by examining accounting financial indicators should be representative of the trends seen when examining economic costs.

Due to the variety between and complexity of determining federal, state, and local tax payments for an individual operation, all metrics described below are calculated before taxes.

The NPV is a method used to calculate the current value of a stream of future cash flows (Ruiz Campo & Zuniga-Jara, 2017). NPV is calculated on the predicted cash flows over the first 10 years of operation for each iteration and used as an indicator of operation value and profitability. A discount rate of 8.07% for mollusks operations in developed countries based on articles published in the Web of Science, Scopus (by Elsevier) and ScienceDirect over the last 25 years (Ruiz Campo & Zuniga-Jara, 2017), was used in NPV calculations. Loan principle forgiveness was subtracted from the initial capital investment and subsequent operating loans at the time of issuance to reflect the discounted afforded by this practice. Additionally, the MIRR (Yoon & Choi, 2002) was calculated to provide an indication of sensitivity to changes in the discount rate. A cost of capital rate of 8.07% (Ruiz Campo & Zuniga-Jara, 2017) and a reinvestment rate equal to the 10-yr treasury bond rate (2.88% on Aug. 14, 2018) was used in the MIRR calculation.

2.10 Statistical analysis

The model was constructed in such a way where each simulation resulted in an individual output data set for each source of financing using the same input values. As a result, a single mean for the NPV and IRR was calculated for each financing scenario. To determine if there was a significant difference ($p<0.05$) between financing scenarios mean NPV and mean IRR were compared via one-way ANOVA. Significant differences ($P<0.05$) between different pairs of financing scenarios were determined by Tukey's pairwise comparison method using the Microsoft Excel add-in StatTools version 7.6 (Keller & Warrack, 2003; Palisade Corporation, 2018).

3.0 RESULTS

3.1 Bottom-culture results

Bottom-culture results for all sources of capital and operating scales for mean NPV, mean IRR and percentage of negative NPV and IRR are shown in Tables 8, 9 and 10, respectively.

The mean NPV and IRR were negative for 100% of the 2.02-hectare bottom-culture operations. The 4.04-hectare operations also had negative mean NPV and IRR, but the probability of having both a negative NPV and IRR ranged from 76% (MARBIDCO financing) to 92% (conventional financing). The larger 8.09 and 40.47-hectare bottom-culture operations had positive mean NPV and IRR. The probability of having both a negative NPV and IRR fell to between 6% (MARBIDCO financing) and 24% (conventional financing) for the 8.09 hectare operation, but was 0% for all forms of financing for the largest scale operations of 40.47 hectares .

The randomized year of catastrophic loss also influenced the NPV and IRR of operations in the simulation. Using the 40.47 hectare bottom-culture simulation as an example, farms experiencing a catastrophic loss had the lowest NPV when the catastrophic loss occurred in year 3 and the lowest IRR when the catastrophic loss occurred in year 2 (Table 11).

3.2 Water-column culture results

When describing their operations, water-column oyster owner-operators in Maryland primarily produce and sell single oysters to the half-shell markets, and commonly refer to the number of oysters they harvest each year rather than the number of bushels. Therefore, water-column operations in this study are discussed in terms of the number of oysters they are predicted to harvest each year based on the model assumptions previously described before the environmental factor was incorporated.

The water-column production model suggested the mean NPV for five-hundred thousand and one million oysters per year water-column culture operations would be negative for all sources of capital. The mean NPV for all other water-column oyster aquaculture operations were positive for all sources of capital (Table 12).

The model also suggested the mean IRR for five-hundred thousand oysters per year water-column culture operation would be negative for all sources of capital. The mean IRR for all other water-column oyster aquaculture operations were positive for all sources of capital (Table 13). Last, model results suggested all five-hundred thousand water-column operations would have a negative mean NPV and negative mean IRR for all sources of capital.

In comparison, with the one-million and two-million oysters per year operations, the model suggests MARBIDCO-financed firms had the lowest percentage of negative NPV and negative IRR and operations while conventional financing had the highest percentage of operations with a negative NPV and negative IRR (Table 14). All simulations showed positive NPVs and positive IRRs for the two-million five-hundred thousand oyster per year operations.

As with bottom-culture simulations, the randomized year of catastrophic loss also influenced the NPV and IRR of water-column operations. Using the 2-million oysters harvested per year simulation as an example, farms experiencing a catastrophic loss had the lowest NPV when the catastrophic loss occurred in year 3 and the lowest IRR when the catastrophic loss occurred in year 2 (Table 15).

4.0 DISCUSSION

As with other types of production agriculture, producing aquacultured oysters is financially risky. Risks may be associated with production such as survival and disease, or possibly financial, such as changes in price, sales, and input costs. Even with the results presented herein, one should always verify input costs and assumptions as each operation is unique and physical conditions may be different given that growing areas perform differently and all operations have unique financial needs and challenges. Given these risks, this analysis examined the effect of difference sources of capital on the success of oyster aquaculture operations in Maryland.

The interest-only and partial principle forgiveness features of the MARBIDCO Loan Program make it an attractive source of funds when compared to using conventional loans or using personal funds to finance a business. In all simulations, at all production scales, using the model inputs assumptions from this study, firms were more financially successful when MARBIDCO financing was used to fund and operate the oyster aquaculture operation rather than when personal funds or conventional financing was used due to the substantially lower cost of lending.

When comparing sources of debt financing, operations with MARBIDCO financing resulted in higher NPVs and IRRS when calculated over a 10-year period compared with those that financed with conventional-lending sources. The interest-only period of the MARBIDCO loan program reduces costs in the early years of the operation while businesses are incurring substantial start-up and operational costs but not yet able to sell most of their oysters since they have not reached market size. In contrast, the conventional-lending programs require principle and interest payments be made during the period before oyster sales begin and any income is received. The partial principle forgiveness feature also increases a MARBIDCO-funded operation's likelihood of success because it lowers the overall costs of debt service. It should be noted, however, obtaining a loan from MARBIDCO does not guarantee success if poor husbandry, poor original assumptions, or costs of production exceed sales prices

One drawback of the MARBIDCO program, expressed by some operators, is the large principle and interest payments once the interest-only period has expired. The large principle payments have the potential to place a financial burden on the owner's cash flow, however with proper planning; these payments can be anticipated and managed. Additionally, in recent years, MARBDICO has begun to address the issue of large principle payments by extending the amortization period for loans with large equipment purchases resulting in lower principle payments. Furthermore, they have been willing to negotiate loan terms with borrowers should environmental factors result in lower than expected production (Steve McHenry, MARBIDCO, personal communication).

Our modeling assumptions imposed economies-of-scale for the bottom-culture of aquaculture oysters in Maryland. Using the production estimates from the operation sizes analyzed in this study, and examining self-financed operations to remove the influence of debt financing, as the number of bushels harvested from the representative lease size increased the break-even price per bushel decreased (Figure 2). As with the bottom-culture analysis, we also imposed economies-of-scale for water-column production of aquaculture oysters in the Maryland Chesapeake Bay. By examining self-financed operations, as production increased, the break-even price per oyster decreased (Figure 3). The imposition of economies of scale is reasonable based on observations of shellfish aquaculture elsewhere. Similar trends in profitability were seen for small-scale Scottish mussel farming operations and oyster operations in Atlantic Canada (Coffen & Charles, 1991; Poseidon Aquatic Resource Management, 2017). Some operators may feel they can simply increase production in order to decrease the cost of production. Yet, increasing the production level is a “doubled-edged sword” because as production scale increases so does the amount of capital needed. Many potential entrants to the industry may not have the needed capital to start their operation and operate a larger lease site, and thus, have no other choice than to utilize some form of debt financing. When looking at self- and MARBIDCO-financed bottom-culture operations, sensitivity analysis for these operations indicated the risk distributions having the largest impact on NPV and IRR were price received per bushel, the cost of harvest vessels and equipment, the percentage of oysters sold to the half-shell market and survival for all production scales. Sensitivity analysis of risk distributions for self and MARBIDCO-financed water-column operations showed price received per oyster and survival had the highest impact on NPV and IRR for all production scales. However, if a business increases production and is still undercapitalized, it may not reach the scale to achieve profitability, or it may not generate enough income to yield a positive IRR and NPV in a reasonable time-period. Despite the size of the operation or source of funding, operators should carefully consider all factors related to oyster aquaculture to ensure successful operations and underscore the need for sound business planning, even if loans or grants are available.

In addition to the risk distributions modeled, special attention should be paid to the input costs that affect the operational break-even price; especially regarding the amount and type of labor used. Labor in smaller, bottom-culture operations may be overestimated in the study since some operations reportedly only use “unpaid family labor.” Water-column production-labor hour estimates herein were based on a survey of aquaculture producers in the state of Virginia (Hudson et al., 2012). There is, however, no comprehensive information on the amount of labor used in the Maryland aquaculture industry. Some smaller operations may choose to operate with a lower amount of labor than estimates provided in this analysis, or to forgo an owner’s salary if they have other sources of income. One grower told us, “It’s been seven years, and I have yet to draw a salary from my oyster operations. I pay my employees, but luckily have another source of income for now.” To see the impact of labor on the profitability of smaller bottom-culture and water-column culture operations the simulation was performed without the cost of paid labor. The NPV and MIRR of the small operations improved significantly when compared to the simulations which included the original labor assumptions (Table 16). However, any perspective operation should be analyzed individually to see if it could be operated with unpaid labor. Many potential growers mention plans to start small without paid labor and expand their operation in the future. They should consider, at what point they would need paid labor and if the expanded operation would be profitable with the added labor expenses.

While the MARBIDCO Shellfish Loan Program is limited to those operations operating a shellfish farm in the State of Maryland, it could be used as a model to develop programs that help expand shellfish and finfish aquaculture in other areas. Even if principle forgiveness is not part of an aquaculture loan program, the interest-only period could substantially reduce costs during the time the aquaculture crop is growing to market size. The MARBIDCO program, along with other specialty programs, such as the Norwegian Development License Program have been identified as innovative ways to help expand aquaculture development (O’Shea et al., 2019).

While catastrophic losses for oyster operations are unpredictable, their influence on the long-term success of farming operations is relevant. Farms had a higher NPV and IRR when a catastrophic loss occurred later in the simulations. This effect may be attributed to the accumulation of cash reserves from several years of successful production and sales. Interestingly, NPV and IRR were higher if a catastrophic loss occurred for an operation in Year 1 and lower in Years 2 or Year 3. Catastrophic losses occurring in Years 2 or 3 have an impact on market-ready oysters, while losses occurring in Year 1 do not generally affect market-ready oysters, and therefore do not result in lost sales in Year 1. While NPV and IRR were different for bottom-culture and water-column operations, the same trend for NPV and IRR for both culture methods with respect to how a catastrophic loss would affect long-term profitability.

5.0 Conclusion

Overall, the results of this analysis indicate that, MARBIDCO financing improves operation success by increasing financial returns across all levels of production. There was a clear economy-of-scale before break-even profits were realized (Figure 2 & 5). Those operations participating in the MARBIDCO Maryland Shellfish Aquaculture Loan fund would benefit financially when compared to conventional sources of financing due to the lower costs of those loans. Further, many conventional-lending sources may not lend money to aquaculture operations due to the high risk involved, or a lack of understanding of the industry. On a positive note, as the industry has grown, there has been an increased interest in lending to shellfish aquaculture operations from conventional-lending sources (Andrew Rose, MidAtlantic Farm Credit, personal communication). Still, conventional lending for aquaculture is still not as readily available as with traditional land-based agricultural operations.

The MARBIDCO program has and will continue to play an important role in eliminating challenges in obtaining capital for aquaculture operations in Maryland. Clearly, operations in the program are better off financially than those operations obtaining financing from conventional funding sources. In addition the MARBIDCO program can be used as a model in other areas to help spur aquaculture economic development should an appropriate sources of funds be identified (O’Shea et al., 2019). These funds could potentially come from federal disaster grants to the states or from other sources such as the Deepwater Horizon Oil Spill Trust set up by BP in the Gulf of Mexico.

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