ABSTRACT

Title of Dissertation: EFFECTS OF DIFFERENT CAPITAL SOURCES ON MARYLAND OYSTER AQUACULTURE OPERATIONS

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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 an interest-only period and partial-principle forgiveness. Loans taken through this

program typically have a 3%, three-year, interest only period. If all interest only payments are made on time 40% of principle of the first loan is forgiven. Remaining principle is amortized at a rate of 5% over the remaining term of the loan. Any subsequent loans feature the same interest only period, however only 25% of the loan principle is forgiven. This study evaluated if there is any difference 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. Bottom-culture and water-column operations had significantly higher net present value (NPV), internal rates of return (IRR), and accounting profit values when they were MARBIDCO-financed compared other sources of capital. Significant economies of scale were found in both bottom-culture and water-column operations, with larger operations having lower break-even costs. The effect of receiving payments for nutrient credits was evaluated for effects on farm accounting metrics. Operations that received nutrient payments had higher NPV, and IRR values, and accounting profit than those operations that did not receive nutrient payments. Nutrient credit payments, however, were unlikely to contribute substantially to operational success since they represent a small percentage of overall revenue. Successful operations were generally successful without nutrient credit payments; therefore, the decision to start an oyster-aquaculture operation should not be based on receiving nutrient credit payments. This research suggests oyster aquaculture operations that use MARBIDCO financing in the State of Maryland will have the best chance of success and highest financial return.

EFFECTS OF DIFFERENT CAPITAL SOURCES ON MARYLAND OYSTER AQUACULTURE OPERATIONS

by

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Dedication

I would like to dedicate this dissertation to my wife, Carie Mellies, son, Broughton Mellies-Parker, and daughter, Azilee Mellies-Parker for their undying support and understanding that allowed me to complete this degree.

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I would like to acknowledge, my committee, Mr. Don Webster, Dr. Don Meritt, Dr. Bob Tjaden, Dr. Suzanne Bricker, MARBIDCO, University of Maryland Extension, and University of Maryland Sea Grant for their support and assistance with completing this dissertation. In addition, I would like to thank the Maryland shellfish aquaculture industry for providing me with guidance and information when needed to make a more realistic model. I would also like to thank those who reviewed countless drafts in preparation of this document. I would like thank Dr. Carole Engle for her guidance and expertise in finding errors in my model and providing general feedback.

Table of Contents

List of Tables

List of Figures

List of Equations

Chapter 1: Background

Introduction

The state of Maryland has a long history of harvesting seafood from the Chesapeake Bay. One of the primary species harvested has been the Eastern Oyster (*Crassostrea virginica)*. Harvesting reached its peak in the late 1800s and declined rapidly since (Figure 1; 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; Webster, 2009; Paynter and Burreson, 1991). Aquaculture of oysters has also been practiced in the Chesapeake Bay since the 1890s, however, due to restrictive regulations and opposition from Maryland commercial watermen, aquaculture did not prosper in Maryland (Webster, 2009).

There has been an increase in Maryland oyster aquaculture since oyster aquaculture regulations for the state of Maryland were rewritten in 2009 (Maryland Deptartment of Natural Resources, 2017; Wheeler, 2009). At the same time, Maryland Department of Natural Resources (MDNR) applied to the National Marine Fisheries Service to declare a disaster in the blue crab fishery and was awarded $15 million. While some of the disaster funds were used to buy back crab fishing licenses, $4,237,360 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). MARBIDCO created a Shellfish Aquaculture Loan fund to help private aquaculture businesses obtain capital needed to start their operations (Maryland Department of Agriculture, 2010a).

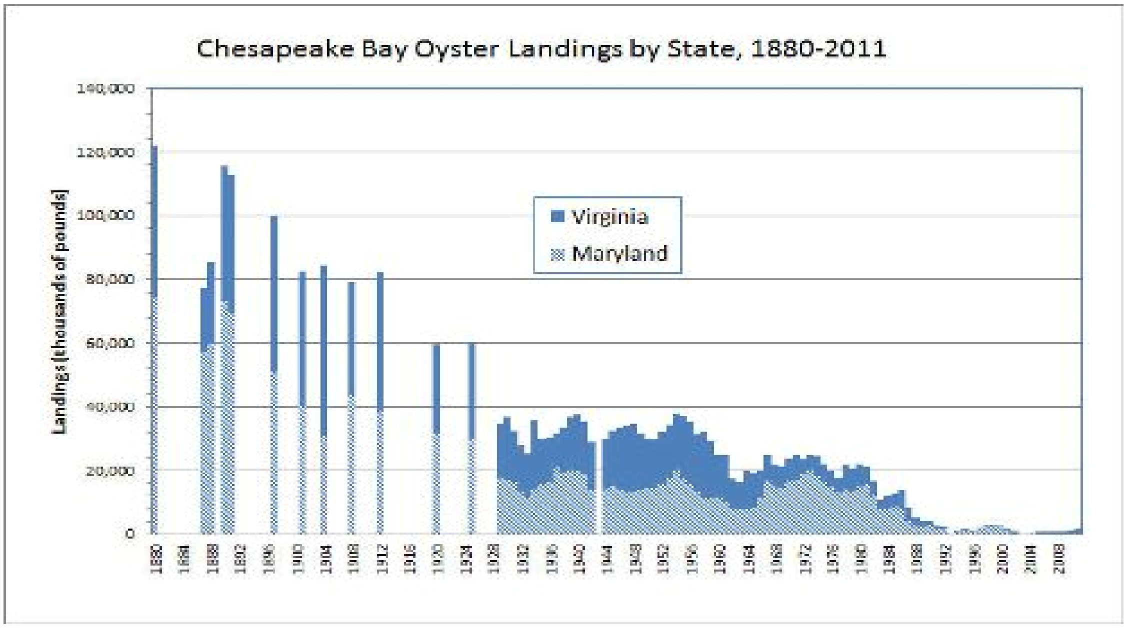


Figure 1. Historic commercially harvested reported oyster landings in the Chesapeake Bay. (NOAA, n.d.)

Coupled with the decreased in the number of oyster in the Chesapeake Bay, the increases in population and industry in the watershed led to a degradation in the water quality of the Chesapeake Bay. In 2010, to address concerns of water-quality degradation, the United States Environmental Protection Agency (USEPA) established the Chesapeake Bay Total Maximum Daily Load (TMDL) requirements limiting inputs of nitrogen, phosphorus and sediment, in order to restore clean water to the Chesapeake Bay and its watershed (United State Environmental Protection Agency, 2017). At the same time, an increased interest in the ability of oysters to remove nutrients from the water column through normal feeding processes led many to believe oyster aquaculture could contribute toward helping Maryland accomplish its required TMDL goals (Bricker et al., 2014; Kellogg et al., 2014; Rose et al., 2014a). Maryland established a nutrient-trading program (Maryland Department of Agriculture, 2010b) in 2010 and set of specific regulations from trades in 2018 (COMAR 26.08.11) without success (Jones et al., 2017). While considered promising, oyster aquaculture operations were not able to participate in the program (Jones et al., 2010) since nutrients removed by oysters had not been evaluated and approved by the Environmental Protection Agency (EPA) Chesapeake Bay Program.

To evaluate the potential for oyster industry or restoration to generate nutrient credits, the Oyster Recovery Partnership (ORP), a non-profit organization, formed an expert panel with the EPA Chesapeake Bay Program (Chesapeake Bay Program Water Quality Goal Implementation Team, 2015) to evaluate net nutrient removal of aquacultured or oyster restoration to be classified as a Best Management Practice (BMP) within the Chesapeake Bay Partnership. Once a practice is approved by the EPA as a BMP, nutrient reduction generated by the BMP may be credited toward achieving required TMDL goals. Aquaculture production has now been approved as a BMP, a first step in enabling producers to sell nutrient credits and generate income from those sales.

Oysters and Aquaculture in Chesapeake Bay Maryland

Oyster harvesting has occurred in the Chesapeake Bay since before Maryland was founded; as oysters were an integral part of Native American diets and were a food source for early colonists (MacKenzie Jr., 1996; Ingersoll, 1881). As the population of the United States grew, so did the amount of oysters harvested from the Chesapeake Bay. When oysters were known to have reached their peak population densities in the late 1800s, it is estimated they were so plentiful they could filter the entire water column of the Chesapeake Bay every three to six days in the summer, compared with requiring over 300 days in 1988 (Newell, 1988). Oyster bars were so plentiful and large that they represented navigational hazards (Newell, 1988; Kennedy and Breisch, 1983). As the country's population expanded, oysters were considered a working class street food (De Voe, 1862). Harvests reached their peak in the late 1800s (Figure 1) before the wild fishery began to collapse (NOAA, n.d.). At their peak, oysters harvest were shipped from Baltimore inland at a rate of 30-40 full train-cars per day (Ingersoll, 1881). Due to this intense harvest pressure, the fishery began to collapse (Rothschild et al., 1994; Paynter and Burreson, 1991). Later, introduction of disease due to moving shell and oysters from infected areas into other areas around the Chesapeake Bay for shell repletion efforts, further decreased the wild-oyster population (Carnegie and Burreson, 2011; Newell, 1988). During the 1985-86 harvest season, 1.5 million bushels of oysters were reported harvested, which dropped to 383,534 bushels during the 2015-16 season (Tarnowski, 2017).

Since its beginning in the 19th Century, Maryland aquaculturists have faced many challenges that prevented efforts from becoming a successful industry, which ranged from theft to laws prohibiting aquaculture in certain areas due to pressure from commercial fishermen who assumed there was a competitive conflict with wild harvesting (Webster, 2009; Wieland, 2007). Despite these challenges, interest in aquaculture persisted in Maryland due to the success of aquaculture in other east coast states including Virginia.

In 2009, oyster-leasing laws were amended at the state level to make the business of aquaculture easier to start. Leasing laws were reformed and a "use it or lose it" clause was implemented to prevent leases from being acquired but not used (Maryland Department of Natural Resources, 2016; Webster, 2009). In 2011, the oyster-leasing process was streamlined and consolidated into the MDNR (Maryland Department of Natural Resources, 2016), thus creating a “one stop shop” for acquiring oyster-aquaculture leases. The regulatory changes led to a greater than 10-fold increase in the harvest of aquacultured oysters from 2012-2017 (Figure 2; Maryland Aquaculture Coordinating Council, 2018). The increase in shellfish aquaculture in Maryland is aligned directly with the United States Department of Commerce Aquaculture Policy, National Oceanic Atmospheric Administration (NOAA) Aquaculture Policy and the National Shellfish Initiative (National Oceanic & Atmospheric Administration, 2011b, 2011a; US Dept. of Commerce, 2011).

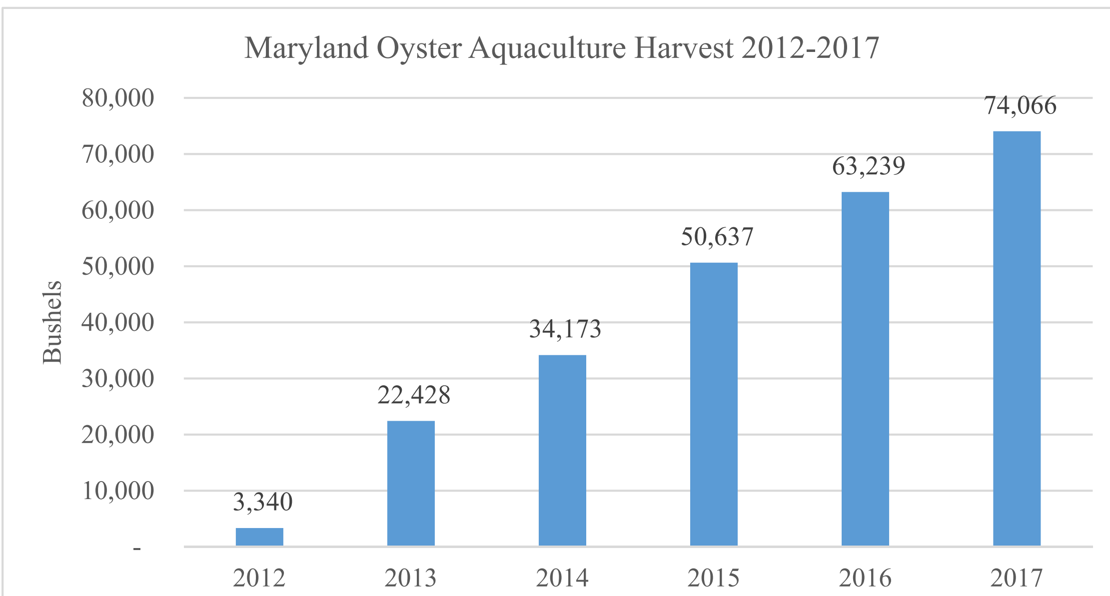


Figure 2. Total Reported Maryland Oyster Aquaculture Harvest 2012-2017 (Maryland Aquaculture Coordinating Council, 2018).

In addition to regulatory challenges, the success of oyster aquaculture in Maryland also faces environmental challenges. The ideal salinity range of Eastern oysters is 14-28 ppt for adult survival and growth (NOAA, n.d.). In Maryland, salinity ranges from 18 ppt in the southern areas of the state to less than 5 ppt in the northern portions of the Chesapeake Bay and its tributaries (Schubel and Pritchard, 1986; Chesapeake Bay Program, n.d.). While not a detriment to the oysters themselves, many areas are closed or only conditionally open for harvest for human consumption due to the likelihood of pathogens that could be harmful to human health (Maryland Department of the Environment, n.d.). There are also the challenges of oyster diseases in Maryland influenced by environmental conditions such as temperature and salinity (Ewart and Ford, 1993). For example, in the 1980s, drought conditions over multiple years increased the prevalence of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (dermo) that decreased oyster production in the Chesapeake Bay (Burreson and Andrews, 1988). In addition, there exist restrictions in specific growing areas in order to protect submerged aquatic vegetation (SAV) (Maryland Department of Natural Resources, n.d.).

The most common form of oyster aquaculture in Maryland is spat-on-shell bottom-culture leases, which represents 80% of current leased areas (Maryland Department of Natural Resources, 2018). A major challenge to starting a bottom-culture operation is finding a location with suitable bottom conditions. If the bottom has too much mud, the oysters will sink and suffocate. In addition, the bottom may not be consistent resulting in a "Swiss cheese" effect where an individual may have a one-acre lease with pockets of unusable bottom (Parker et al., 2013). Many aquaculturists will purchase additional oyster shell or other material in order to stabilize the bottom to alleviate the issue of mud on their lease, but this can be cost-prohibitive depending on the volume of material needed and the stabilization material chosen (Webster and Meritt, 1988). Water-column production of oysters helps to somewhat mitigate the issue of bottom quality; however, many water-column producers use cages, which sit on legs on the bottom of the leases. If the depth of the mud in these operations is too deep, the oysters will not survive, or the cages will sink into the mud and become stuck on the bottom.

Despite the regulatory and environmental challenges to oyster aquaculture in Maryland, there is still a considerable interest in starting and expanding current oyster aquaculture operations as indicated by MDNR reports of the 80-100 lease applications under review at any given time over the last several years (Maryland Deptartment of Natural Resources, 2018). The MDNR has developed an Aquaculture Siting Tool to assist interested persons determine where to site their oyster aquaculture operation (Maryland Department of Natural Resources, n.d.). The GIS-based web tool has layers for bottom type, submerged aquatic vegetation locations, current leases, commercial-fishing nets, and other prohibited areas and results in illustration of areas that are suitable and available for leases.

Determining the maximum potential for the aquaculture industry in Maryland has been difficult. Carlozo (2014), using GIS analysis, identified priority areas for oyster aquaculture in Maryland of 38,018 acres for bottom-culture, 88,973 acres for bottom-cage culture, and 313,678 acres for floating cage. In May 2018, there were 6,420 acres of bottom leases and 382 acres of water-column leases reported by MDNR (Maryland Department of Natural Resources, 2018). Current leased acreage represents less than an estimated 20% of available space for bottom-culture and less than 1% for water-column culture is being utilized, and suggests there is room for increased production in the Maryland portion of the Chesapeake Bay (Carlozo, 2014). Through similar analysis, Weber et al. (2018) determined available space for aquaculture operations would not be a limiting factor over the next 15 years.

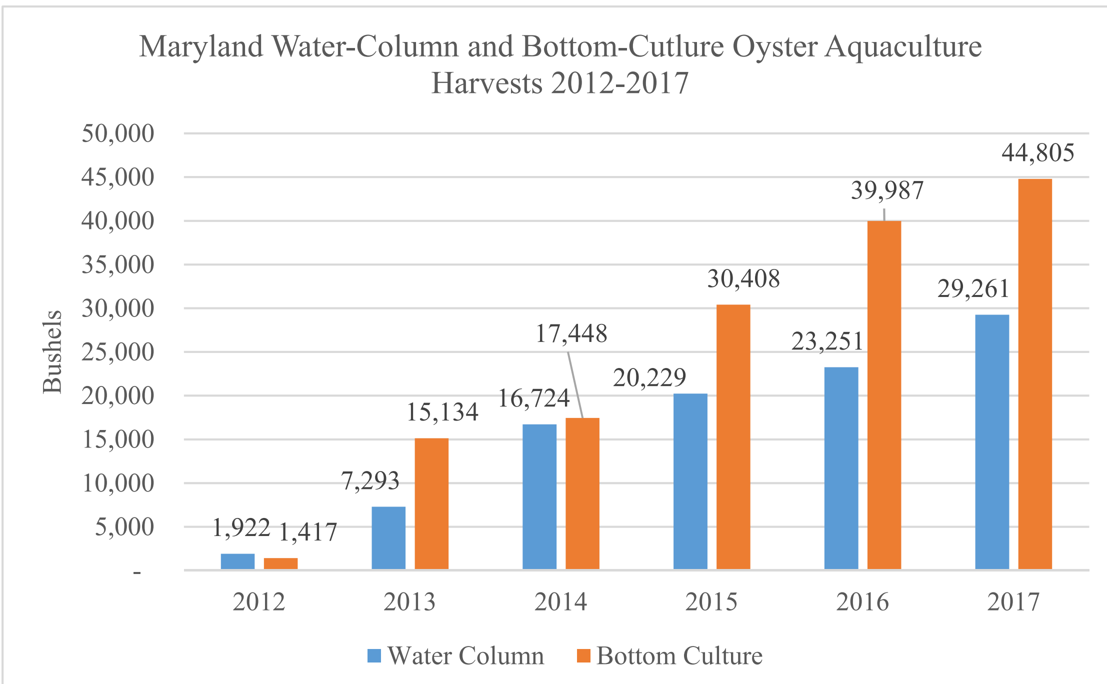
Oyster Aquaculture Industry Expansion in Maryland since 2010

The Maryland oyster aquaculture industry started to expand in 2010 with the signing of the Code of Maryland Regulation 08.02.23.00 in 2009. The regulation revised shellfish aquaculture leasing laws making it easier to obtain an aquaculture lease for shellfish production. Additionally, MDNR began taking applications for submerged-land leases and water-column leases. Further, permitting was streamlined in 2011 into a "one-stop shop" located in the MDNR Aquaculture Division.

In January 2014, there were 277 bottom-culture leases representing 3,483 acres and 51 water-column leases representing 191 acres of production (Maryland Aquaculture Coordinating Council, 2013). By May 2018, the number of bottom-culture leases had increased to 345 representing 6,420 acres and water-column leases had increased to 75 representing 382 acres of production (Maryland Department of Natural Resources, 2018). Along with increased number of leases and acres under production, harvest from aquaculture also increased. In 2012, there were 1,922 bushels harvested from bottom-culture leases and 1,417 bushels harvested from water-column leases (Maryland Aquaculture Coordinating Council, 2018). In 2017, aquaculture harvest had increased to 44,805 bushels for bottom-culture and 29,261 bushels for water-column production (Figure 3) (Maryland Aquaculture Coordinating Council, 2018). The rapid production increase in the Maryland oyster aquaculture industry is indicative of an early growth stage (Porter, 1980), which is further supported by the continued submission of applications for shellfish leases in Maryland. The MDNR reports that between

September 2010 and January 2018 the state received 502 lease applications and issued 253 new commercial shellfish aquaculture leases totaling about 5,464 acres (Maryland Department of Natural Resources, 2018). Additionally there are 137 new lease applications currently being reviewed (Maryland Department of Natural Resources, 2018).

Figure 3. Reported bottom-culture and water-column oyster aquaculture harvests 2012-2017 (Maryland



Aquaculture Coordinating Council, 2018).

Bottom-Culture Production of Oysters in the Maryland Chesapeake Bay

In Maryland, the most common form of oyster aquaculture is the culture of spat-on-shell oysters on bottom leases, which represents 80% of current leased areas in the state (Maryland Department of Natural Resources, 2018). In 2017 there were 393 leases in operation, totaling 6,186 acres (Maryland Deptartment of Natural Resources, 2017). From 2012 to 2017, aquaculture production from bottom leases increased from 1,417 bushels to 44,805 bushels (Figure 3) due to the increase in bottom leases from 166 to 327 during the same period.

Getting started in the bottom-culture production of oysters has low capital investment requirements. Additionally, those who have previously harvested wild oysters, or other commercial fish or shellfish, already have much of the required equipment needed for oyster aquaculture, with a boat being the single largest investment. Further, those with bottom-culture leases do not have to buy cages because spat-on-shell oysters are planted directly on leased bottom.

Monthly harvest data collected by MDNR since mid-2012 through 2017 shows bottom-culture oysters are, primarily harvested from March to October when the wild-oyster harvest season is closed (Figure 4). The seasonal difference provides evidence that aquaculture does not compete with the wild-oyster harvest.

The per-bushel price for oysters harvested from bottom-culture operations has ranged from $50-$65 in recent years. In comparison, the average 2017 per-bushel price for the wild-oyster fishery was $47 (Tarnowski, 2018) up from approximately $32 per bushel in 2013 (Tarnowski, 2013). The price differential, combined with the timing of reported aquaculture harvests, provides good evidence that many growers are taking advantage of higher prices during the summer.

The MDNR had received applications with 287 Tidal Fisheries License (TFL) holders named on lease applications between 2010 and 2016 (Maryland Deptartment of Natural Resources, 2017). This increase is important because the number of TFL holders obtaining bottom-culture leases is a reasonable indicator that commercial watermen see the economic potential of farming oysters as a means to supplement their income (Maryland Aquaculture Coordinating Council, 2018).

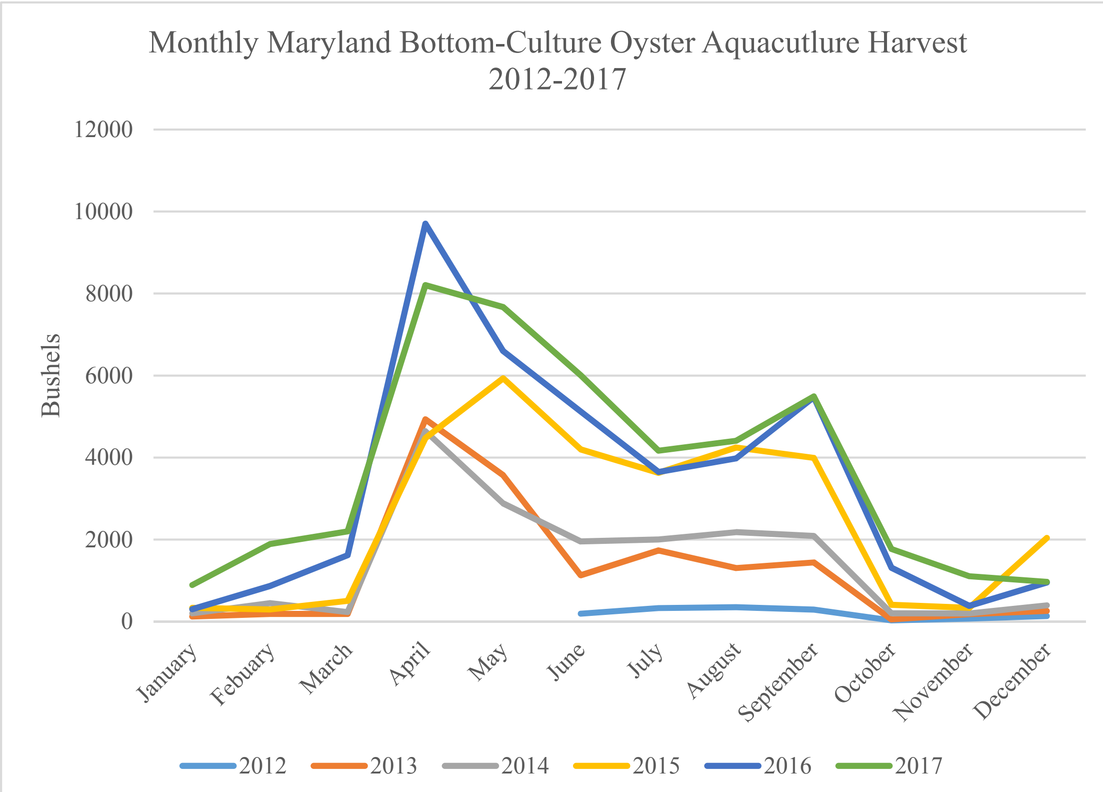


Figure 4. Reported monthly harvest of oysters from bottom-culture operations in Maryland, Chesapeake Bay from 2012-2017 (MDNR, 2018).

The majority of bottom-culture oysters are harvested and sold to restaurants and shucking houses for the oyster-meat market (Maryland Aquaculture Coordinating Council, 2018). However, there may be a harvest portion that is suitable for the half-shell market. Although this latter harvest portion is not known, it could be as high as 25% of production based on information from growers and industry experts. The half-shell market would require the producer to sort, clean, and market single oysters to distributors, restaurants, or the public, but yields a higher return.

Water Column Production of oysters in Maryland

While water-column oyster aquaculture is not as prevalent in Maryland as bottom-culture (Maryland Deptartment of Natural Resources, 2017), it has grown in acres and production since leasing laws were revised in 2009. From 2012 to 2017, aquaculture production from water-column aquaculture increased from 1,922 bushels in 2012 to 29,261 bushels in 2017 (Figure 3) due to the increase in water-column leases from 20 to 75 during the same time period (Maryland Aquaculture Coordinating Council, 2013, 2018). In 2017 there were 92 leases in operation totaling 191 acres (Maryland Aquaculture Coordinating Council, 2018).

While oyster harvest from bottom-culture operations tends to be when the wild oyster season is closed, data from MDNR indicates harvest of aquaculture oysters from water-column operations occurs year round (Figure 5) without any noticeable trends. Industry participants have speculated that drops in reported production from month-to-month may be due to a lack of inventory from some farms, as sales rebound when market-size product becomes available.

Most of the oysters produced in water-column operations are single oysters for the half-shell market (Maryland Aquaculture Coordinating Council, 2018). The oysters produced for this market command a higher market price than those produced utilizing bottom-culture methods, which has drawn many growers to produce oysters using water-column methods, despite the higher capital requirements when compared to bottom-culture. Higher capital costs are attributed to the equipment needed to produce market size oysters on a water-column lease. In Maryland, the "Virginia style" bottom cages (Figure 6) are the most prevalent water-column gear type, however, there are operations utilizing various configurations of floating gear or small Australian long-line style cages (Figure 7; Webster and Meritt, 2013). Cages vary in price based on the style, manufacturer and where they are purchased. As production increases, more cages are needed for the operation. Additionally a boat outfitted with a hoist is often required to remove cages from the water to process and harvest oysters. Some growers also purchase additional equipment such as tumblers, graders, and shell washers resulting in higher capital costs.

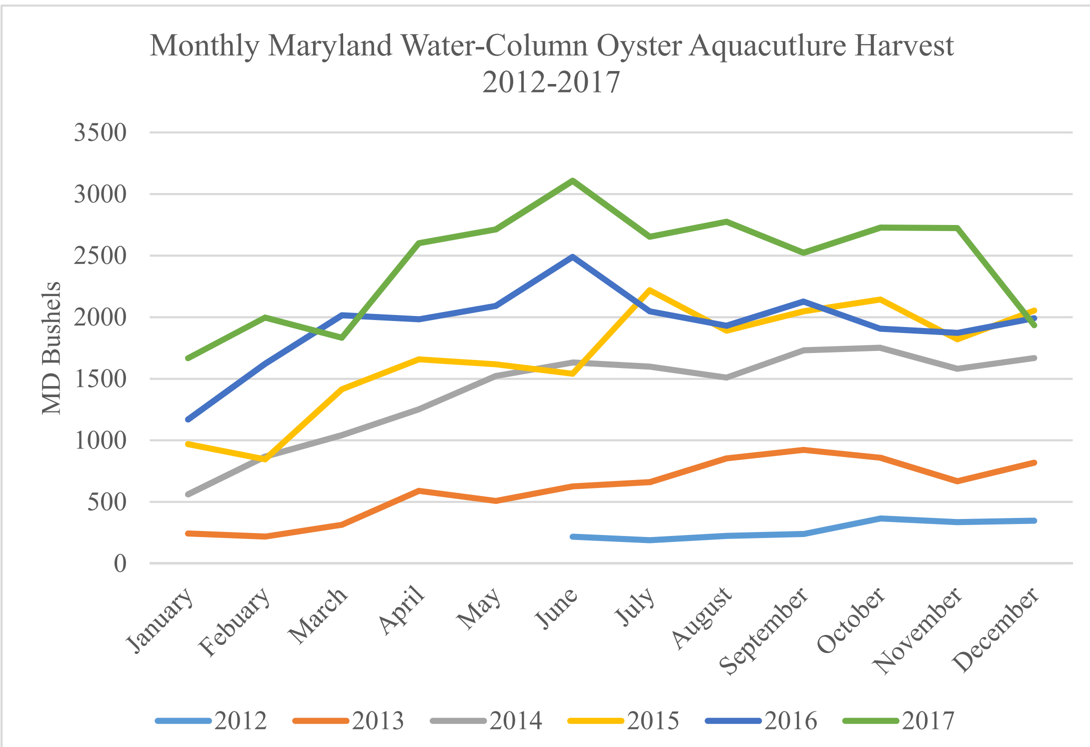


Figure 5. Reported montly harvest of oysters from water-column operations in the Maryland Chesapeake Bay from 2012-2017(MDNR, 2018).

Figure 6. Typical double-stack oyster bottom cages used in water-column oyster production in Maryland (Photo Credit-Matt Parker).

Figure 7. Example of Australian Longline Oyster Aquaculture System. (Photo Credit- Hoopers Island Oyster Company)

Ecosystem Services Provided by Oysters

Coupled to the economic benefits derived from increased oyster production in Maryland as a food source is the fact oysters are widely recognized for their filtering capacity and associated environmental benefits (Cornwell et al., 2016; Testa et al., 2015; Rose et al., 2014b, 2014a; Kellogg et al., 2014; 2013; Fulford et al., 2010; North et al., 2010; Kemp et al., 2005; Newell et al., 2005; Newell, 1988). The environmental benefit, or ecosystem service, is effected by oysters removing nutrients from the water in the form of nitrogen and phosphorus through normal filter-feeding activity (Cornwell et al., 2016). Oysters feed on phytoplankton and detritus and through digestion, nutrients are used for growth of tissue and shell development (Newell, 1988). Excess nitrogen and phosphorus in the water-column are known to contribute to eutrophication problems in the Bay and any mitigation of their impact on water quality is a significant ecological advantage (Newell et al., 2005b).

Seeing the need for more tools to help improve the health of the Chesapeake Bay, the Oyster Recovery Partnership (ORP), under the direction of the EPA Chesapeake Bay Program, formed an expert panel to develop a set of oyster-related BMP's and estimate nutrient-credit reduction effectiveness attributed to oysters in the Bay. Panel membership was approved by the Water Quality Goal Implementation Team (WQGIT) in 2015 (Chesapeake Bay Program Water Quality Goal Implementation Team, 2015). The panel evaluated oyster data from various studies to determine the amounts of nitrogen and phosphorus in oysters to calculate a nutrient reduction effectiveness (Wiedenhoft, 2017; Cornwell et al., 2016). The reported amount of nitrogen and phosphorus in oyster tissue and shell is variable and site dependent (Cornwell et al., 2016). The amount of nitrogen and phosphorus removed in the meat of aquacultured oysters was quantified by a USEPA Expert Panel[1] (Table 1; Cornwell et al., 2016). The average percentage amount of nitrogen by dry weight of oyster tissue was reported to be 8.22 ± 0.89% SD and reported amounts of nitrogen in shell ranges from 0.19% to 0.21% (Kellogg et al., 2013). The Panel's initial recommendations were approved by the Chesapeake Bay WQGIT in December 2016 resulting in an approved BMP for nutrient removal attributed to oyster aquaculture (Davis-Martin et al., 2016). Logically, increasing the numbers of oysters in the Bay through aquaculture will increase the overall filtering capacity of the total oyster population and increase the amount of nitrogen and phosphorus assimilated into oyster tissue and shell. Overall, when compared to other BMP's, oysters are equally if not more efficient than those practices approved for use in the Chesapeake Bay (Rose et al., 2014a).

In addition to the nitrogen and phosphorus directly assimilated into oyster tissue and shell, it is possible for there to be an increase in denitrification associated with restored oyster reefs (Sisson et al., 2011). Increased denitrification was not associated with intensive water-column aquaculture operations as described by Kellogg et al. (2014), however, a study in Rhode Island showed oyster aquaculture in bottom cages had comparable denitrification rates to restored oyster reefs in the area (Humphries et al., 2016). Other research suggests if one considers more than just the footprint of the aquaculture farm (leased bottom), there could be a net benefit of denitrification due to

[1] The USA EPA Expert Panel plans to research and make recommendations for nutrients removed via the wild oyster fishery at a later date (Cornwell et al., 2016).

aquaculture on a site-specific basis (Testa et al., 2015). While some studies have shown there could be some localized negative effects due to shellfish aquaculture (Burkholder and Shumway, 2011), this research warrants further consideration of the value of site-specific denitrification associated with aquaculture.

Table 1. Default estimates of nutrient reduction effectiveness from aquaculture oyster tissue approved by the Chesapeake Bay WQGIT as a BMP in the Chesapeake Bay. (Cornwell et al., 2016)

Default Estimates						
Oyster Size Class Range (inches)	Size Class Midpoint (inches)	Size Class Midpoint (mm)	Content in Oyster Tissue (g/oyster)			
			Diploid		Triploid	
			Nitrogen	Phosphorus	Nitrogen	Phosphorus
2.0 - 2.49	2.25	57	0.05	0.01	0.06	0.01
2.5 - 3.49	3	76	0.09	0.01	0.13	0.01
3.5 - 4.49	4	102	0.15	0.02	0.26	0.03
4.5 - 5.49	5	127	0.22	0.02	0.44	0.05
≥ 5.5	6	152	0.31	0.03	0.67	0.07

Eutrophication in Chesapeake Bay

As mentioned previously, TMDL requirements were imposed by the EPA in the Clean Water Act in 2010 to address water quality concerns (33 U.S.C. §§1251-1387). The TMDL is the amount of pollution a water body can receive and still meet water quality standards. The TMDL for Chesapeake Bay was enacted in December 2010 with the intention of creating a “pollution diet” and restore clean water to the watershed (United State Environmental Protection Agency, n.d.). The TMDL was designed to achieve a nutrient and sediment levels by 2025 that would result in fully restored water quality needed for aquatic habitat in the Chesapeake Bay, with 60% of pollution reductions to be completed by 2017 (United State Environmental Protection Agency, 2017). The TMDL limits for the watershed are set at 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus, and 6.45 billion pounds of sediment per year (United

States Environmental Protection Agency, 2017a). The 2017 TMDL midpoint assessment report was published in June 2018 and stated that Maryland has reached its overall goal for phosphorus and sediment reductions, but had not met the goal for nitrogen reductions (Chesapeake Bay Foundation, 2018).

The Chesapeake Bay Foundation and University of Maryland Center for Environmental Sciences (UMCES) have been issuing reports grading the health of the Chesapeake Bay since 1998. Both reports indicate the health of the Bay has been improving; however, grades have ranged from “C” to “E” depending on which water quality parameter was measured and the locality (Chesapeake Bay Foundation, 2016; University of Maryland Center for Environmental Science, 2016). Even though dissolved oxygen and phosphorus levels have improved, overall the Bay water quality has held steady with no significant change over time from 1986 to 2016 (Chesapeake Bay Foundation, 2016). Some experts feel the grades from these reports may worsen in the future due to an increase in sedimentation in the Bay as the Conowingo Reservoir’s trapping efficiency diminishes (Zhang and Blomquist, 2018; Zhang et al., 2016). With BMP approval, nitrogen and phosphorus removed via oyster tissue harvested from aquaculture operations in the Bay can be credited toward the TMDL. This action is an important first step toward any potential financial compensation to Chesapeake Bay oyster farmers for the nutrient removal, also known as ecosystem services, by the oysters on their farms. Financial compensation could come from selling nutrient credits in an established market place or by policy changes designed to help expand the Maryland aquaculture industry. This study assumed payments were based on transaction in a nutrient credit marketplace established by the state of Maryland.

Impact Investment Financing

Impact investing can be described as an investment that intends to generate a social or environmental good along with financial returns (Clarkin and Cangioni, 2016; Bocken, 2015; Bugg-Levine and Emerson, 2011; Bugg-Levine and Goldstein, 2009). Early adopters of impact financing have been philanthropists, charitable foundations, and other organizations or individuals. Lately, investors have begun to raise concerns as to the practicality of impact investments. Broadly stated, the challenges associated with impact financing have revolved around complying with statutory and general laws, including impact financing in modern portfolios, developing the appropriate infrastructure, the sustainability of investments, and finding individuals or firms with the expertise to manage the investments (Ormiston et al., 2015). These concerns echo sentiments expressed by Bugg-Levine and Goldstein (2009) when they described challenges that must be addressed such as creating standards, developing markets, and supportive policy reform. Bolstering these concerns is the scarcity of published studies on impact investment (Clarkin and Cangioni, 2016; Ormiston et al., 2015). However, there still appears to be a sizable amount of activity in impact investing in the form of microfinance loans around the world (Saeed, 2014). Impact investing has been mostly limited to developing countries until the financial crisis of 2008. The establishment of the Grameen America Bank in 2008, along with provision of microcredit to small famers through the Farm Service Agency (FSA), and the development of organizations like MARBIDCO, impact investing has been expanding in recent years (Saeed, 2014; Srnec et al., 2009).

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 debt financing through a lending source such as FSA, the Farm Credit System, Bank of America, or Wells Fargo. FSA loans are often aimed at small and beginning farmers who do not qualify for credential lending and are used for land, livestock, seed, and other farming inputs (Srnec et al., 2009). 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. 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 Based Industry Development Corporation, 2017). The MARBIDCO has approved over 50 shellfish aquaculture loans in its program since 2011 totaling over $3 million (Maryland Agricultural Based Industry Development, n.d.); however, there have been no attempts to assess the impact of the loan fund on farm-level profitability. Anecdotally, and motivations for this study, the author has seen first-hand instances where it appears that certain size farms with low levels of predicted production may be financially better off using personal funds for starting an aquaculture business, rather than participate in the MARBIDCO program. This assessment is due to the MARBIDCO loan structure where the remaining principle is amortized over a two-year period, which results in exceedingly large loan payments compared to incoming revenue.

An alternate form of impact investing is the development of environmental or green bonds. While most impact investment has been in the form of Social Impact Bonds, there has been less investment in the environmental side of the sector (Nicola, 2013). Green bonds began to emerge in 2007 and have grown tremendously with issuers such as the World Bank (Carolyn et al., 2015). In 2016, the District of Columbia Water and Sewer Authority, in partnership with Goldman Sachs Urban Investment Group and Calvert Foundation, issued an environmental impact bond at a 30-year, tax exempt, $25 million face value to finance storm-water management improvements (United States Environmental Protection Agency, 2017b).

Nicola (2013) noted water quality trading programs can be considered as an impact investment tool and could be bolstered by the establishment of an environmental impact bond (EIB). He further describes an EIB as a “pay-for-performance” contract to address an environmental issue, which represents a “monetization of future costs savings. The EIB establishes a fund where investors are paid a return-for-cost savings generated by a project. However, if such a system were functioning properly, an EIB is not needed (Nicola, 2013). In 2010, Maryland developed a water-quality trading tool as a way to help meet its TMDL goals (Maryland Department of Agriculture, 2010b). As of 2017, there have not been any successful trades from this marketplace due to the lack of market demand (Jones et al., 2017). With this lack of a successful trading system, it seems the Maryland portion of the Chesapeake Bay would be a likely candidate for the implementation of an EIB to help facilitate a marketplace where oyster aquaculture operations could participate.

Summary

As wild-oyster harvests in Maryland are predicted to decline and oyster aquaculture continues to grow, a clear need has emerged to evaluate the impact MARBIDCO funding will have on the profitability of future oyster farms in Maryland. In addition, with the interest in ecosystem services provided by oysters and inclusion of oyster aquaculture in Chesapeake Bay TMDL BMP's, industry has expressed a need to evaluate the potential for other forms of impact financing to increase oyster aquaculture and to evaluate their impacts on farm profitability.

Chapter 2: Evaluating the Effects of Different Funding Sources on Maryland Oyster Aquaculture Profitability

While aquaculture has been growing in the state of Maryland since the revision of leasing laws, there remains an absence of information on the industry in peer-reviewed publications, particularly in respect to how different sources of capital relate to farm profitability. The following study examined the potential profitability of bottom-culture, spat-on-shell oyster operations and water-column oyster operations in Maryland over a 10-year period, and evaluates the differences when the operation is 1) self-financed 2) financed by MARBIDCO, and 3) funded by conventional lending sources. In addition, each financing scenario was evaluated with and without compensation for ecosystems services rendered in the form of nutrient-removal payments. 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 due to allow multiple crops to be produced during the study simulation.

When possible, public agency 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 author’s experiences working in the industry, and attendees from University of Maryland Extension Aquaculture Workshops. Where possible, model assumptions were developed using published, peer-reviewed data. Due to the young oyster aquaculture industry, however, many model assumptions were developed though informal interviews, discussion with industry experts, active industry producers, participants in University of Maryland Extension Aquaculture Workshops, and the author's personal experience.[2]

Materials and Methods

In order to compare the effects of different financing options and payments for nutrient removal on oyster-operation profitability, capital-budgeting analyses published by University of Maryland Extension (Parker et al., 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 rather than production values due to how aquaculture operations are described by industry members. Modifications to water-column production analysis included the ability to estimate harvests during operation start up and estimates of labor were based on production levels for water-column oyster culture. The water-column production analysis was also modified to base production on the number of individual oysters to be harvested once a farm reached full production due to 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 were added to each budget. The financing modifications allowed up to three loans from MARBIDCO with

[2] Personal communications: Karl Roscher, Maryland Department of Natural Resources; Don Webster, University of Maryland Extension; Don Meritt, University of Maryland Center for Environmental Sciences; Eric Wisner, Eric Wisner Oysters; JD Blackwell, 38 Degrees North Oyster Company; Scott Budden, Orchard Point Oyster Company; Ted Cooney, Madhouse Oyster Company; Bill Cox, Honga Oyster Company; Steve Vilnit, Capital Seaboard; Jason Ruth, W.H. Harris Company; Mike McWilliams, Captain Walter Oyster Company; Myron Horzesky, Ketchum Traps; Steve McHenry, MARBIDCO.

financing terms of an interest-only period and partial principle forgiveness corresponding to the MARBIDCO loan fund options. For comparison, three loans from conventional financing agencies without the interest-only period or partial principle-forgiveness terms were included.

Due to the interest in nutrient removals provided by oysters aquaculture, a calculation of nitrogen and phosphorus reduction efficiencies was included in the modified capital budgeting analysis based on the BMP recommendations adopted by the Chesapeake Bay Program in 2016 for oyster-tissue harvested from aquaculture operations (Cornwell et al., 2016). A variable for different payment rates for nitrogen and phosphorus removal was also included.

Annual cash-flow statements and ten-year enterprise budgets were incorporated into the capital budgeting analysis for each source of financing with and without nutrient payments for each production system budget. The cash-flow statements and enterprise budgets were constructed so that all inputs would be the same for each source of capital with and without nutrient payments. Each simulation yielded six unique data sets to afford comparisons between funding sources with and without nutrient payments.

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 and with 5,000 iterations. Statistical analysis was performed using the StatTools version 7.6 add-in that is part of the @Risk software package.

Model Description

The model is a spreadsheet workbook, containing annual cash flow calculations and enterprise budgets, which estimate average profits per firm using estimated 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). Information and data to create the model were gathered from peer-reviewed literature and industry representatives. Monte Carlo simulation was used to input a range of cost and production estimates on business performance over a ten-year period based on constructed risk distributions. Yearly accounting profit, ten-year net present value (NPV), ten-year internal rate of return (IRR), and the payback period were calculated for each annual 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 with and without nutrient credit payments. A ten-year period was chosen to evaluate profitability due to the length of time it takes to grow oysters to market size for each production method, allowing multiple crops to be produced to better estimate farm profitability metrics in the Maryland portion of the Chesapeake Bay that is conducive to oyster aquaculture.

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, and are presented in Table 2. Assumptions specific to a given production method are discussed later in individual sections. 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, 3-inch market size, oysters per bushel (Meritt and Webster, 2014a) was used to convert single oyster production to bushel equivalents and vice versa.

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

Table 2. Common model assumptions values used in analysis of profitability calculations for bottom-culture and water-column oyster production in the Maryland Chesapeake Bay.

Operating Cost Assumptions	**Value in Model**
Market-Size Oysters Per Bushel	275 (Meritt and Webster, 2014a)
Retail Containers for Half-Shell Market	100 count box(Parker et al., 2013)
Cost Of Retail Containers for Half-Shell Market	$1.00 per box
General Labor Rate	$12.50 per hour
Supervisory/Owner Labor Rate	$20.00 per hour
Supervisory/Owner Operator Labor Hours Per Week	40
Unemployment Insurance Tax	2.6% of payroll
Federal Insurance Contributions Act (FICA)	6.2% of payroll
Workman's Comp	5% of payroll
General Liability Insurance	$1,000 per $150,000 in revenue per year (Bankers Insurance, 2016)
Boat Insurance	$600 per boat per year (Bankers Insurance, 2016)
Auto Insurance	$683 per auto per year (Bankers Insurance, 2016)
Repairs and Maintenance	1% of variable costs – employment expenses
Overhead	3% of variable costs

Wage rates were established through a combination of 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 University of Maryland Extension business planning workshops in 2016. A wage of $20.00 per hour is estimated for a supervisor. If a farm supervisor is not employed, this payment rate is assumed to represent owner salary. If a supervisor is employed, the owner's compensation is assumed the operation profit. Costs associated with employees beyond wages are included in Table 2.

Business insurance costs for are calculated based on insurance shellfish aquaculture industry estimates (Bankers Insurance, 2016). These rates are $1,000 per $150K 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.

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 operations in Maryland and regional industry experts (Table 3). 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. According to MDNR in May 2017, the mean size for bottom leases was 18.51 acres, the median was 9.15 acres, and the mode was 5 acres. Therefore, to estimate profitability and returns for common lease sizes in Maryland, four production levels were simulated (5 acres, 10 acres, 20 acres, 100 acres). Each production level was simulated with and without compensation for the ecosystem service provision of nitrogen and phosphorus removal from harvested oyster tissue.

Table 3. Specific static model assumptions values used in analysis of profitability calculations unique for bottom-culture oyster production in the Maryland Chesapeake Bay.

Bottom-Culture Operating Cost Assumptions	**Value in Model**
Percent of lease suitable for planting before bottom stabilization	80%
% of Lease Harvested Each Year	33%
Annual Seeding Density	2,000,000 spat per acre (Meritt and Webster, 2014a)
Predicted Survival From Planting To Harvest	15% (Abbe et al., 2010; Kingsley-Smith et al., 2009; Congrove, 2008)
Purchase Price Of Bulk Spat	$3.50 per 1000 spat (Horn Point Oyster Hatchery, 2018a)
Percent of oysters reaching market size in year 1	0% (Congrove, 2008)
Percent of oysters reaching market size in year 2	37% (Congrove, 2008)
Percent of oysters reaching market size in year 3	100% (Congrove, 2008)
Lease Rent	$3.50 per acre
Supervisory/Owner Operator Labor Weeks Per Year	40
General Labor Weeks Per Year	35

Bottom condition is an important factor in the siting of shellfish bottom-culture leases (Webster and Meritt, 1988). It is rare to have a lease with 100% of the bottom suitable for oyster culture. Consequentially, spatial patchiness is problematic, difficult to determine, and hard to monitor with regard to anticipated total production capability (Meritt and Webster, 2014b). Furthermore, to minimize the amount of oysters that may end up outside of the leased areas, a buffer space is often left along the outside edges of the lease. Oysters outside of the leased area may be harvested by others, and reduce overall production from the lease. Therefore, 80% of total bottom space available was the modeled threshold used to consider this variability. It is also assumed operators know the approximate locations of the unsuitable areas in their lease and avoid planting seed in those areas as best as possible, which is included in this 80% assumption.

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 three inches. After the annual harvest, the area that was harvested was reseeded with spat-on-shell oysters the following year. For example, a 5-acre lease with 80% suitable bottom will harvest and seed approximately 1.32 acres annually.

Bottom-culture operations are planted with diploid, spat-on-shell, oyster seed annually at an equivalent rate of 2 million spat-on-shell, seed oysters per acre 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 on small oysters from crabs, cownose rays, and other predators.

Survival from planting to harvest was estimated at 15%. This value was determined by reviewing information published for the survival of bottom-cultured oysters in the Chesapeake Bay (Abbe et al., 2010; Kingsley-Smith et al., 2009; Congrove, 2008). Greater weight was given to the values presented by Congrove (2008) because he specifically focused on aquaculture objectives more closely related to current practices in Maryland. 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.

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 in the third and subsequent years.

Conversations with industry producers suggested an operation with a vessel previously used for wild harvest of oysters could harvest 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 150 acres. Typically, there are two deck hands operating per boat during the harvest. Thus, a good estimate of labor assumes two employees working 40 hours per week for 30 weeks per year. Harvest records submitted to MDNR indicate bottom-culture spat–on-shell oyster harvest occurs only from March until October. Additional harvests occur between Thanksgiving and Christmas because of historical seasonal market demand (Figure 4). Supervisory labor was assumed to be 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.

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 4). 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). Each production level was modeled with and without compensation for nitrogen and phosphorus removed from harvested oyster tissue. Specific static model assumptions values used in analysis of profitability calculations unique water-column oyster production in the Maryland Chesapeake Bay.

It was assumed that, double-stack “Virginia tray style” cages, measuring 3 feet by 4 feet, (Figure 6) are deployed containing 1,200 three-inch 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.

Table 4. Specific static model assumptions values used in analysis of profitability calculations unique water-column oyster production in the Maryland Chesapeake Bay.

Water-Column Culture Operating Cost Assumption	**Value in Model**
Lease Size	5
Percent of lease harvested each year	50%
Acres of lease harvested each year	2.5
Predicted Survival From Planting To Harvest	50% (Proestou et al., 2016; Callam, 2013; Hudson et al., 2012; Paynter et al., 1992, 2008; Wieland, 2007; Calvo et al., 1999)
Market Size Oysters Per Grow out Container	1200 (Myron Horzesky, Ketchum Traps, personal communication)
Percent of oysters harvested in first year	25%
Percent of oysters harvested in second year	75%
Percent of oysters harvested in years 3+	100%
Percentage of oysters sold to half-shell market	100%
Sq. ft. per container	12
Number of mesh bags per container	6
Mesh Bag Cost	$6.00 (Ketcham Supply Company, 2018)
Purchase Price Of Seed	$17.00 per 1000(Horn Point Oyster Hatchery, 2018b)
Lease Rent/acre annual	$25.00
General Labor Hours per year	Based on calculation
Supervisory Labor Hours Per year	2,080

The lease size for all farming operations is assumed five acres. Based on data from MDNR in May of 2017, the mean water-column lease size was 4.69 acres, the median lease size as 4.1 acres. The modal water-column lease size was 5 acres. The number of cages per acre varies in the Maryland industry based on owner preference, lease configuration, and production goals. The theoretical maximum number of cages that could be put on a five-acre lease is 18,150 cages based on cages taking up 12 square feet per cage. The 2.5 million oyster per year simulation requires only 4,168 cages.

Thus, the five-acre lease size assumption gives ample room for all cages, for all production levels analyzed.

Fifty percent of each lease is harvested per year based on two-year average growth to a market size of three inches. 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 (Proestou et al., 2016; Callam, 2013; Hudson et al., 2012; Paynter et al., 1992, 2008; Wieland, 2007; Calvo et al., 1999). Fifty percent mortality was selected as a medium level of mortality based on the published data and discussions with commercial operations.

Additionally, 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 25% of oysters stocked at farm startup were harvested in the first year. Seventy-five percent of oysters stocked at farm startup were harvested in the second year. The farm will reach steady state of oyster harvests in the third and subsequent years.

Based on consultation with industry and industry experts, currently all oysters harvested from water-column operations in the state of Maryland are sold into 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, 2018b) 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, all energy is devoted to growth resulting in better meat quality year round. Many producers also feel triploid oysters grow faster than diploid oysters based on published data (Maryland Aquaculture Coordinating Council, 2018; Dégremont et al., 2012).

A formula (Equation 1) for general labor was calculated based on regression analysis (Figure 8) of data available from Virginia operations (Hudson et al., 2012), which also included some supervisory labor in their estimates. General labor in the current analysis included office labor, which is unclear if it is also included in Hudson et al. (2012). Supervisory labor in this analysis is assumed owner labor and is accounted for separately.

Equation 1. Equation for calculating general labor hours for water-column oyster aquaculture operations in the Maryland Chesapeake Bay.

$$\boldsymbol{General\ hours\ per\ year = \left(4631.4 \times LN(Number\ of\ seed\ deployed)\right) - 55{,}129}$$

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. The annual MDNR lease rate for water-column leases is $25.00 per acre.

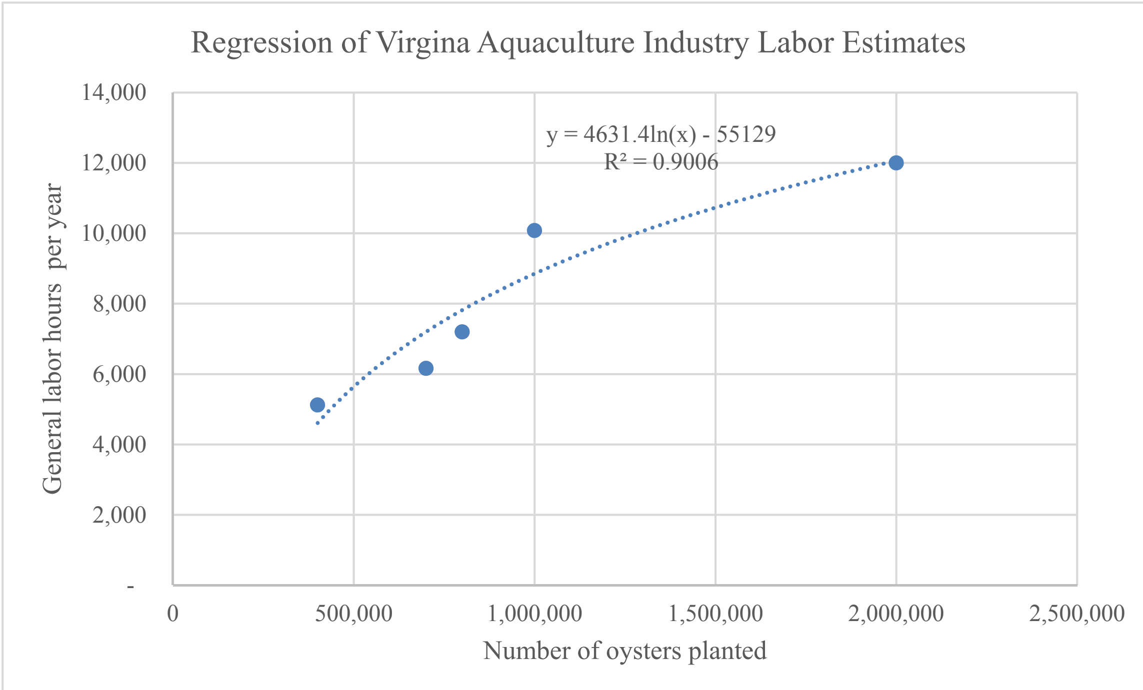


Figure 8. Regression of labor estimates in Virginia Aquaculture Industry based on data from Hudson et al.(2012).

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, which 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. 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. The risks common to bottom-culture and water-column culture, along with their expected values, are presented in Table 5. 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 et al., 2016; Johnson, 1997). Triangular distributions are used when there is a lack of information regarding the mean or the variable may not be symmetric. All risk analysis distributions in this study are assumed to be triangular distributions. Given these assumptions, the expected price for a bushel of oysters ranges from \$50-\$65 based on the time of year. For the risk analysis a 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).

Given the paucity of nutrient credit transactions, there is great uncertainty surrounding the price of nutrient credits. Here it is assumed that the price for nitrogen-credit sales range from \$3.00 to \$100 with \$5.00 being the most likely value. Weber et al. (2018) conducted an analysis with prices ranging from \$10 to \$190 per pound of nitrogen. The prices for nitrogen removal in this analysis were reduced from those proposed by Weber et al (2018) to provide a more conservative approach to estimating additional income from nutrient payments. Generally, phosphorus removal costs are twice that of nitrogen among non-point source management practices (Lisa Wainger, Chesapeake Bay Biological Laboratory, personal communication). Therefore, the price assumed for phosphorus-credit sales range from $6.00 to $200 with $10.00 being the most likely value.

Nutrient reduction efficiencies for a three-inch diploid oysters are calculated from the approved Best Management Practice (BMP) (Cornwell et al., 2016) at a rate of 198 pounds nitrogen and 22 pounds phosphorus per million oysters harvested, respectively. The nutrient removal values for one million harvested three-inch triploid oysters are 287 pounds of nitrogen and 22 pounds of phosphorus (Cornwell et al., 2016). It is assumed nutrient payments received are net payments and any transaction costs associated with receiving nutrient payments have been subtracted from the payment rate.

Table 5. Risk distribution input values utilized for bottom-culture and water-column oyster production analysis in the Maryland Chesapeake Bay. All distributions are triangular

Input Variable	**Minimum Value**	**Most Likely Value**	**Maximum Value**	**Mean**
Bushel Oyster Price	$35	$55	$65	$51.67
Price of Nitrogen Payments	$3	$5	$100	$36
Price of Phosphorus Payment	$6	$10	$200	$72
Average yearly fuel cost	$1,000	$3,000	$6,000	$3,333.33
Cost of vehicle	$0	$15,000	$30,000	$15,000

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 to $6,000 per year with $3,000 per year being selected as the most likely value.

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 to $30,000 per vehicle with the most likely value estimated at $15,000.

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 pricing for half-shell oysters, yearly survival, and the amount of equipment needed. Inputs that represent uncertainties in bottom-culture are presented in Table 6.

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 to $0.55 per oyster is based on input from producers.

Every oyster operation model will 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 cost of the boat ranges from $0 to $55,000 per boat 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 to $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.

Table 6. Risk distribution input values utilized for bottom-culture oyster production analysis in the Maryland Chesapeake Bay. All distributions are triangular.

Input Variable	**Minimum Value**	**Most Likely Value**	**Maximum Value**	**Mean**
Half-shell Oyster Price	$0.35	$0.50	$0.55	$0.47
Percentage of Oysters sold to half-shell market	0%	10%	25%	12%
Percentage of oysters sold to bushel market	100%	90%	75%	88%
Marketing expenses	$0.00	$200	$1,000	$400
Monitoring costs	$0.00	$300	$1,000	$433.33
Year 1 survival factor	25%	100%	120%	82%
Year 2 survival factor	25%	100%	120%	82%
Year 3 survival factor	25%	100%	120%	82%
Year 4 survival factor	25%	100%	120%	82%
Year 5 survival factor	25%	100%	120%	82%
Year 6 survival factor	25%	100%	120%	82%
Year 7 survival factor	25%	100%	120%	82%
Year 8 survival factor	25%	100%	120%	82%
Year 9 survival factor	25%	100%	120%	82%
Year 10 survival factor	25%	100%	120%	82%
Cost of harvest vessel	$0	$20,000	$55,000	$25,000
Cost of other equipment	$1,500	$5,000	$30,000	$15,500

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 to $1,000 per year was estimated for monitoring with most likely value being $300 per year.

To account for 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, or other factors such as 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 basket 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 to $30,000 with $5,000 being the most likely value.

Water-Column Aquaculture Risks

Like bottom-culture, there are uncertainties in production that are unique to water-column production of oysters (Table 7). For example, there may be environmental factors such as drought or excess rain that 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 to $0.60 per oyster was based on input from producers.

Double-stack tray cages (Figure 6) vary in price depending on which supplier the cages are purchased. Ketcham Traps 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 to $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 (Figure 9), while others use small skiffs (Figure 10). 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 to $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.

Table 7. Risk distribution input values utilized for water-column oyster production analysis in the Maryland Chesapeake Bay. All distributions are triangular.

Input variable	Minimum Value	Most Likely Value	Maximum Value	Mean
Half-shell oyster price	$0.35	$0.50	$0.60	$0.48
Cage cost	$87	$101.40	$137	$108.47
Marketing expenses	$0	$4,000	$5,500	$3,166.67
Monitoring costs	$0	$1,000	$2,000	$1000
Year 1 survival factor	35%	100%	125%	87%
Year 2 survival factor	35%	100%	125%	87%
Year 3 survival factor	35%	100%	125%	87%
Year 4 survival factor	35%	100%	125%	87%
Year 5 survival factor	35%	100%	125%	87%
Year 6 survival factor	35%	100%	125%	87%
Year 7 survival factor	35%	100%	125%	87%
Year 8 survival factor	35%	100%	125%	87%
Year 9 survival factor	35%	100%	125%	87%
Year 10 survival factor	35%	100%	125%	87%
Cost of harvest vessel	$0	$25,000	$55,000	$26,667
Cost of other equipment	$15,000	$30,000	$40,000	$28,333

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 $0.00 to $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 $0.00 to $2,000 per year is estimated with most likely value being $1,000 per year.

As with bottom-culture, there is variability in survival from year to year in water-column culture of oysters. 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, year 6 survival 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

Figure 9. Commercial fishing boat used by Honga Oyster Company to harvest bottom cages from their water-column oyster operation in Maryland. (Photo Credit- Suzanne Bricker).

Figure 10. Skiff used by Orchard Point Oyster Company to harvest bottom cages from their water-column oyster operations in Maryland. (Photo Credit- Suzanne Bricker).

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 to $40,000 with $30,000 being the most likely value.

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 affords 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 zero 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 zero, year one, and year two and feature a three-year, interest only period at an interest 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 year zero, year one, and year two, and feature an interest rate of 7.0% amortized over six years. Loan amounts for bottom-culture operations are presented in Table 8.

Loans terms obtained for water-column operations from MARBIDCO vary based on purposes of the loan. For this analysis, the first loan, taken in year zero, and second loan, taken in year one, from MARBIDCO, which include production equipment, for water-column operations have a three-year interest only period with an interest rate of 3.0%. Forty percent of the principle for the first loan, and 25% of the principle of the second loan are forgiven, with the remaining principle amortized over a three-year period at an interest rate of 5.0%. The third MARBIDCO water-column operating loan, taken in year two, which can include the purchase of seed oysters, features a three-year interest only period with an interest rate of 3.0%. Twenty-five percent of the principle is forgiven, with the remaining principle amortized over two years at an interest 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 9 for water-column operations.

Table 8. MARBIDCO and Conventional loan amounts for each production level used in bottom-culture production analysis for oyster aquaculture in the Maryland Chesapeake Bay.

	Loan #1	**Loan #2**	**Loan #3**
5 Acres	$30,000	$12,000	$12,000
10 Acres	$40,000	$20,000	$20,000
20 Acres	$70,000	$40,000	$40,000
100 Acres	$100,000	$100,000	$100,000

Table 9. MARBIDCO and Conventional loan amounts for each production level used in water-column culture production analysis for oyster aquaculture in the Maryland Chesapeake Bay.

	Loan #1	**Loan #2**	**Loan #3**
500,000 oysters per year	$100,000	$60,000	$20,000
1,000,000 oysters per year	$100,000	$100,000	$35,000
2,000,000 oysters per year	$100,000	$100,000	$70,000
2,500,000 oysters per year	$100,000	$100,000	$87,000

Metrics to measure success of oyster aquaculture operations in simulations

To assess if an operations 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 decisions making to start oyster aquaculture operations. 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 economics profit (Carole Engle, Engle-Stone Aquatic$, 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 were calculated before taxes.

Average Annual Accounting Profit

Accounting profit (Equation 2) is a measure of the operation's cash-based profitability. It is often relied on by new operations to determine if they will be able to make debt payments as the operation starts (Engle, 2010). 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, annual accounting profit was averaged over the modeled 10-year period.

Equation 2. Formula for accounting profit in oyster aquaculture in Maryland.

$$\textbf{Accounting Profit} = (\boldsymbol{Total\ Revenue - Total\ Cash\ Operating\ Expenses - Debt\ Payments})$$

Net Present Value (NPV)

The NPV is a method used to calculate the current value of a stream of future cash flows (Ruiz Campo and Zuniga-Jara, 2018). NPV (Equation 3) is calculated for each iteration and used as an indicator of operation value and profitability. NPV in the simulation is calculated on the predicted cash flows over the first 10 years of operation. 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 (Campi and Zuniga-Jara, 2018), 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.

Equation 3. Net Present Value

$$\boldsymbol{NPV = \sum_{i=0}^{n} \frac{Annual\ Profit_i - Principle\ Forgiveness}{(1 + Discount\ Rate)^i} - (Investment\ Costs - Principle\ Forgiveness)}$$

Internal Rate of Return (IRR)

A 10-year IRR was calculated based on the first 10 years of the operation. The IRR is the discount rate (See Equation 3) where the NPV will be equal to zero. If cash flows are all negative in any given simulation iteration, it is not possible to determine the IRR and is counted as a failed operation.

Percent of operations with negative IRR and negative NPV

The percentage of operations having a negative or un-calculable IRR and a negative NPV was determined. Operations meeting both of these criteria are considered failed operations.

Payback period

The payback period was calculated to determine the number of years it takes to recoup initial investment costs during the business startup period (Engle, 2010). The model operates for 10 years. If an operation cannot recoup its initial investment and costs in the 10-year simulation, it is considered a failed operation.

Statistical Analysis

The model was constructed in such a way where each simulation resulted in an individual data set, or population, for each source of financing with nutrient and without nutrient payments. As a result, a single-population mean for the yearly accounting profit, NPV, IRR, and payback period was calculated for each scenario. To determine if there was a significant difference ($p<0.05$) between financing scenarios with and without nutrient credit payments, mean yearly accounting profit, mean NPV, mean IRR, and mean payback periods 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 (Palisade Corporation, 2018; Keller and Warrack, 2003). For policy relevance, results will only be compared and discussed when either source of financing is held constant, thereby, comparing the difference between receiving and not receiving nutrient payments, or when the receiving or not receiving nutrient payments is held constant to compare differences between financing sources. For example, MARBIDCO financing with nutrient credit payments was compared with MARBIDCO financing without nutrient credit payments, and MARBIDCO financing without nutrient credit payments was compared with self-financing without nutrient credit payments.

Sensitivity Analysis

A "what if" sensitivity analysis was performed for all production levels comparing each source of capital with and without nutrient payments to determine which risk distribution had the greatest effect on the output means of the accounting indicators analyzed and are available upon request from the author. The sensitivity analysis for the self-financed operations without nutrient payments (Appendix A) was analyzed, as this would show the impacts of risk distributions without the influence of financing or nutrient payments.

Results

In this analysis, profitability was evaluated based on the average accounting income, NPV and IRR over a 10-year period and its payback period. In addition, the percentage of firms with both a negative NPV and negative IRR were determined. Operations with a negative NPV and IRR were deemed a failed investment. Each source of capital was evaluated with and without additional income in the form of payments for nutrients removed via aquaculture-produced oyster tissue.

Bottom-culture Results

Current operations utilizing bottom-culture production methods have expressed difficulty in determining the average number of bushels harvested per acre. All bottom-culture simulations resulted in a mean 745 bushels per harvested acre per year over the ten-year model simulation. The following results are based on the modeled 745 bushels per harvested acre per year regardless of the size of the operation.

Five Acre Bottom-Culture Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit would be negative for all five-acre bottom-culture operations for all financing scenarios (Table 10).

Table 10. Yearly accounting profit for five-acre bottom-culture operation for oyster aquaculture in the Chesapeake Bay with base model assumptions for each source of capital with and without nutrient payments.[3]

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	-$29,561	-$57,700	$639	$8,027
Self-financing without nutrient payments	-$31,713	-$58,639	-$4,906	$7,829
MARBIDCO Financing with nutrient payments	-$28,437	-$56,577	$1,763	$8,027
MARBIDCO Financing without nutrient payments	-$30,589	-$57,515	-$3,782	$7,829
Conventional Financing with nutrient payments	-$35,587	-$63,726	-$5,387	$8,027
Conventional Financing without nutrient payments	-$37,739	-$64,665	-$10,932	$7,829

Net Present Value and Internal Rate of Return

The model results suggested that the mean NPV and mean IRR would be negative for all five-acre bottom-culture operations for all financing scenarios (Table 11 and Table 12).

[3] Discussion for bottom-culture operations will be in terms of lease size rather than total yearly production for ease of comparison.

Table 11. NPV for 5 acre bottom-culture operation for oyster aquaculture in the Chesapeake Bay with base model assumptions for each source of capital with and without nutrient payments.

Net Present Value	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	-$230,458	-$423,296	-$27,648	$52,223
Self-financing without nutrient payments	-$244,133	-$429,199	-$63,196	$50,970
MARBIDCO Financing with nutrient payments	-$218,426	-$411,263	-$15,616	$52,223
MARBIDCO Financing without nutrient payments	-$232,101	-$417,167	-$51,163	$50,970
Conventional Financing with nutrient payments	-$275,328	-$468,165	-$72,517	$52,223
Conventional Financing without nutrient payments	-$289,003	-$474,069	-$108,065	$50,970

Table 12. IRR for five-acre bottom-culture operation for oyster aquaculture in the Chesapeake Bay with base model assumptions for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	-23.94%	-78.46%	1.16%	11.77%
Self-financing without nutrient payments	-27.04%	-73.01%	-9.02%	12.83%
MARBIDCO Financing with nutrient payments	-22.70%	-58.42%	3.62%	10.69%
MARBIDCO Financing without nutrient payments	-23.76%	-53.29%	-8.18%	10.14%
Conventional Financing with nutrient payments	-28.83%	-53.23%	-9.25%	12.30%
Conventional Financing without nutrient payments	-29.44%	-54.89%	-15.85%	10.92%

Payback Period

The model results suggest no operations were able to recover the initial investment or operating expenses in the 10-year model simulation, regardless of the source of capital or receiving nutrient payments.

Sensitivity Analysis

The input risk distributions with the greatest impact on the mean yearly profit and NPV were the price per bushel and percentage of oysters sold to the half-shell market (Appendix A, Figures A-1 & A-2). When examining the effects of risk distributions on the IRR of operations with self-financing without nutrient payments (Appendix A, Figure A-3) survival in year three and five were the two top influences on the IRR of modeled firms.

Five-Acre Model Discussion

Based on the analysis of the accounting profit, NPV, IRR, and payback period, a five-acre bottom-culture operation would not be profitable and would not represent an ideal investment opportunity for any of the financing scenarios in the simulation. An enterprise budget (Appendix B, Table B-1) was prepared for the total cost over the 10-year simulation for each source of capital with and without nutrient payments to determine input costs that may affect the profitability of a five-acre bottom-culture oyster operation.

With all sources of capital with and without nutrient payments, mean labor costs represented over 70% of the total fixed and variable cost of the operation over a ten-year period. The cost of spat-on-shell oysters was the next highest percentage of total fixed and variable costs. Mean accounting break-even costs for each source of capital without nutrient payments are presented in Table 13. The resulting accounting break-even prices per bushel from the model are much higher than what could realistically be expected based on current industry averages due to the costs associated with paid labor. Receiving nutrient payments has no effect on the cost of production since all payments received are assumed net payments.

Table 13. Break-even cost of production for five-acre bottom-culture aquaculture operations in the Maryland Chesapeake Bay per bushel marketed from all sources of capital funding given the original base model assumptions.

Mean Accounting Break Even Price over 10 years	$ per bushel
Self-financing	$91.17
MARBIDCO Financing	$92.06
Conventional Financing	$92.43

Ten-acre Bottom-Culture Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit for all ten-acre bottom-culture operations would be positive for all financing scenarios (Table 14).

Table 14. Yearly accounting profit for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$17,685	-$32,382	$76,415	$15,978
Self-financing without nutrient payments	$13,397	-$36,508	$70,592	$15,619
MARBIDCO Financing with nutrient payments	$19,391	-$30,676	$78,120	$15,978
MARBIDCO Financing without nutrient payments	$15,103	-$34,803	$72,297	$15,619
Conventional Financing with nutrient payments	$8,758	-$41,309	$67,487	$15,978
Conventional Financing without nutrient payments	$4,470	-$45,436	$61,664	$15,619

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 15.

*Table 15. Results of Tukey's parwise comparison of yearly accounting profit confidence interevals for each source of capital with and without nutrient payments for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay operations. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1-Scenario 2		**Difference of Mean Yearly Accounting Profit**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$4,288*	**-$5,188**	**-$3,387**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$10,633*	**-$11,534**	**-$9,733**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$8,927*	**-$9,828**	**-$8,027**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$10,633*	**-$11,534**	**-$9,733**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$8,927*	**-$9,828**	**-$8,027**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$4,288*	**$3,387**	**$5,188**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$1,706*	**$805**	**$2,606**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$1,706*	**$805**	**$2,606**
Self-financing with nutrient payments	Self-financing without nutrient payments	$4,288*	**$3,387**	**$5,188**

Net Present Value

The model results suggested that the mean NPV for all ten-acre bottom-culture operations would be positive for all financing scenarios, except ones where conventional financing was used (Table 16).

Table 16. NPV for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Net Present Value (Income, expenses, debt)	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	$65,799	-$249,762	$441,259	$102,534
Self-financing without nutrient payments	$38,552	-$281,046	$394,807	$100,263
MARBIDCO Financing with nutrient payments	$83,766	-$231,794	$459,226	$102,534
MARBIDCO Financing without nutrient payments	$56,520	-$263,078	$412,775	$100,263
Conventional Financing with nutrient payments	-$250	-$315,811	$375,210	$102,534
Conventional Financing without nutrient payments	-$27,497	-$347,095	$328,758	$100,263

An ANOVA indicated there was a significant difference (p<0.05) between the mean NPV when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 17.

*Table 17. Results of Tukey's parwise comparison of NPV confidence interevals for each source of capital with and without nutrient payments for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean NPV**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$27,246*	**-$33,026**	**-$21,467**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$84,017*	**-$89,796**	**-$78,237**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$66,049*	**-$71,829**	**-$60,269**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$84,017*	**-$89,796**	**-$78,237**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$66,049*	**-$71,829**	**-$60,269**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$27,246*	**$21,467**	**$33,026**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$17,968*	**$12,188**	**$23,747**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$17,968*	**$12,188**	**$23,747**
Self-financing with nutrient payments	Self-financing without nutrient payments	$27,246*	**$21,467**	**$33,026**

Internal Rate of Return

The model results suggested that the mean IRR for all ten-acre bottom-culture operations would be positive for all financing scenarios (Table 18).

An ANOVA indicated there was a significant difference (p<0.05) between the mean IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 19.

Table 18. IRR for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	16.80%	-45.57%	59.04%	13.40%
Self-financing without nutrient payments	13.64%	-60.13%	57.65%	13.57%
MARBIDCO Financing with nutrient payments	21.18%	-57.28%	75.71%	15.25%
MARBIDCO Financing without nutrient payments	17.73%	-55.50%	73.90%	15.20%
Conventional Financing with nutrient payments	8.26%	-42.71%	47.05%	12.87%
Conventional Financing without nutrient payments	5.30%	-44.90%	45.66%	12.78%

*Table 19. Results of Tukey's parwise comparison of IRR confidence interevals for each source of capital with and without nutrient payments for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience intervals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-2.96%*	**-3.78%**	**-2.13%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-12.43%*	**-13.25%**	**-11.60%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-8.34%*	**-9.16%**	**-7.51%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-12.92%*	**-13.73%**	**-12.11%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-8.54%*	**-9.35%**	**-7.73%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	3.45%*	**2.63%**	**4.26%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	4.38%*	**3.57%**	**5.18%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	4.09%*	**3.27%**	**4.91%**
Self-financing with nutrient payments	Self-financing without nutrient payments	3.16%*	**2.35%**	**3.97%**

Percentage of firms with negative NPV and negative IRR

The model results suggested that MARBIDCO financed firms had the lowest percentage of negative NPV and negative IRR (Table 20). Firms with conventional financing had the highest percentage of operations with a negative NPV and negative IRR.

Table 20. Percentage of firms with negative NPV and IRR for ten-acre bottom-culture operation in the Maryland Chesapeake Bay for all sources of capital with and without nutrient layments.

Operations with negative NPV & negative IRR	**%**
Self-financing with nutrient payments	23.76%
Self-financing without nutrient payments	31.64%
MARBIDCO Financing with nutrient payments	18.14%
MARBIDCO Financing without nutrient payments	24.54%
Conventional Financing with nutrient payments	47.44%
Conventional Financing without nutrient payments	57.40%

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean percentage of operations with a negative NPV and negative IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 21.

*Table 21. Results of Tukey's parwise comparison of operations with negative NPV and IRR confidence interevals for each source of capital with and without nutrient payments for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences ($p<0.05$) in means are marked with an * and confience interevals are in bold..*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean Percentage of operations with negative NPV and negative IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-9.96%*	**-12.64%**	**-7.28%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-32.87%*	**-35.55%**	**-30.19%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-25.77%*	**-28.45%**	**-23.10%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-29.31%*	**-31.94%**	**-26.67%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-23.69%*	**-26.33%**	**-21.05%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	6.40%*	**3.77%**	**9.03%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	5.62%*	**3.00%**	**8.23%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	7.10%*	**4.45%**	**9.74%**
Self-financing with nutrient payments	Self-financing without nutrient payments	7.88%*	**5.24%**	**10.51%**

Payback Period

The model results suggested the mean payback period (7-8 years) was similar for all financing scenarios (Table 22).

Table 22. Payback period for ten-acre bottom-culture operations for oyster aquaculture in the Maryland Chesapeake Bay for all sources of capital with and without nutrient payments.

Payback Period	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	7	3	11	2.28
Self-financing without nutrient payments	7	3	11	2.40
MARBIDCO Financing with nutrient payments	7	3	11	2.57
MARBIDCO Financing without nutrient payments	7	3	11	2.63
Conventional Financing with nutrient payments	7	3	11	2.46
Conventional Financing without nutrient payments	8	3	11	2.46

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 23.

*Table 23. Results of Tukey's parwise comparison of payback period (years) confidence interevals for each source of capital with and without nutrientnutrinet payments for ten-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean Payback Period**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	0.58*	**0.44**	**0.72**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	0.66*	**0.52**	**0.80**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	0.89*	**0.75**	**1.03**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	0.67*	**0.53**	**0.81**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	0.84*	**0.70**	**0.98**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	-0.60*	**-0.74**	**-0.46**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	0.17*	**0.03**	**0.31**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	0.23*	**0.09**	**0.37**
Self-financing with nutrient payments	Self-financing without nutrient payments	-0.54*	**-0.68**	**-0.40**

Sensitivity Analysis

The input risk distributions with the greatest impact on the mean yearly profit, NPV, and IRR were the price per bushel, percentage of oysters sold to the half-shell market, and survival in various years (Appendix A, Figures A-4, A-5, & A-6).

Ten-acre Model Discussion

A ten-acre bottom-culture operation can be a viable business, but there is still a high chance of failure when using a negative NPV and IRR as metrics for success (Table 20). Operations that were MARBIDCO financed resulted in a higher yearly accounting profit, NPV, and IRR than operations with other forms of financing. The significant differences between MARBIDCO and other financing options are attributed to the interest-only period and principle forgiveness features of the MARBIDCO loan program that reduce the overall costs associated with principle and interest payments over the ten-year model.

In addition, simulations showed operations with MARBIDCO financing had a lower percentage of firms with a negative NPV and negative IRR. The differences seen between self-financed and conventionally financed operations in mean accounting profit, NPV, and IRR are caused by the increased costs associated with debt financing when compared to self-financing. While the amount of personal investment to start the operation is reduced using debt, monthly principle and interest payments affect yearly cash flow in a negative manner.

An enterprise budget (Appendix B, Table B-2) was prepared for the total cost over the 10-year simulation for each source of capital with and without nutrient payments to determine which input costs that affect the profitability of a ten-acre bottom-culture oyster operation. As with the five-acre bottom-culture operation, labor was the primary expense in the ten-acre bottom-culture operation representing over 65% of the total costs for all financing scenarios.

The price of spat-on-shell oysters was the second highest input cost as a percentage of total fixed and variable costs. Mean accounting break-even costs for each source of capital payments are presented in Table 24. Break-even cost of production prices are in the middle of the reported current industry pricing structure and within the model-pricing assumptions. As with five-acre bottom-culture operations, break-even prices are higher for operations utilizing debt financing, reflecting the effects of principle and interest payments on the cost of production.

Table 24. Break-even cost of production for ten-acre bottom-culture operations for oyster aquaculture in the Maryland Chesapeake Bay from all sources of capital.

Mean Accounting Break Even Price over 10 years	$ per bushel
Self-financing	$50.62
MARBIDCO Financing	$51.25
Conventional Financing	$51.55

Twenty-Acre Bottom-Culture Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit for all twenty-acre bottom-culture operations would be positive for all financing scenarios (Table 25).

Table 25. Yearly accounting profit for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$121,312	-$5,902	$239,631	$34,770
Self-financing without nutrient payments	$111,772	-$9,422	$224,515	$33,759
MARBIDCO Financing with nutrient payments	$124,379	-$2,835	$242,698	$34,770
MARBIDCO Financing without nutrient payments	$114,838	-$6,355	$227,582	$33,759
Conventional Financing with nutrient payments	$105,197	-$22,016	$223,517	$34,770
Conventional Financing without nutrient payments	$95,657	-$25,537	$208,400	$33,759

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 26.

*Table 26. Results of Tukey's parwise comparison of yearly accounting profit confidence interevals for each source of capital with and without nutrient payments for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean Yearly Accounting Profit**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$8,673*	**-$10,448**	**-$6,898**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$19,983*	**-$21,758**	**-$18,209**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$16,739*	**-$18,514**	**-$14,965**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$19,983*	**-$21,758**	**-$18,209**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$16,739*	**-$18,514**	**-$14,965**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$8,673*	**$6,898**	**$10,448**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$3,244*	**$1,469**	**$5,019**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$3,244*	**$1,469**	**$5,019**
Self-financing with nutrient payments	Self-financing without nutrient payments	$8,673*	**$6,898**	**$10,448**

Net Present Value

The model results suggested that the mean NPV for all twenty-acre bottom-culture operations would be positive for all financing scenarios (Table 27).

Table 27. NPV for twenty-acre bottom-culture oyster aquaculture in Maryland Chesapeake for each source of capital with and without nutrient payments.

Net Present Value	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	$656,786	-$99,497	$1,342,252	$201,070
Self-financing without nutrient payments	$601,672	-$119,228	$1,228,591	$195,202
MARBIDCO Financing with nutrient payments	$690,634	-$65,648	$1,376,100	$201,070
MARBIDCO Financing without nutrient payments	$635,521	-$85,379	$1,262,440	$195,202
Conventional Financing with nutrient payments	$533,421	-$222,862	$1,218,887	$201,070
Conventional Financing without nutrient payments	$478,307	-$242,593	$1,105,226	$195,202

An ANOVA indicated there was a significant difference (p<0.05) between the mean NPV when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey’s pairwise comparison method and are presented in Table 28.

*Table 28. Results of Tukey’s parwise comparison of NPV confidence interevals for each source of capital with and without nutrientpayments for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold..*

Confidence Interval Tests Scenario 1-Scenario 2		**Difference of Mean NPV**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$55,113*	**-$66,407**	**-$43,819**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$157,214*	**-$168,508**	**-$145,919**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$123,365*	**-$134,659**	**-$112,071**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$157,214*	**-$168,508**	**-$145,919**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$123,365*	**-$134,659**	**-$112,071**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$55,113*	**$43,819**	**$66,407**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$33,849*	**$22,554**	**$45,143**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$33,849*	**$22,554**	**$45,143**
Self-financing with nutrient payments	Self-financing without nutrient payments	$55,113*	**$43,819**	**$66,407**

Internal Rate of Return

The model results suggested that the mean IRR for all twenty-acre bottom-culture operations would be positive for all financing scenarios (Table 29).

An ANOVA indicated there was a significant difference (p<0.05) between the mean IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey’s pairwise comparison method and are presented in Table 30.

Table 29. IRR for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	61.56%	-2.55%	122.40%	14.95%
Self-financing without nutrient payments	58.12%	-5.01%	113.73%	14.77%
MARBIDCO Financing with nutrient payments	81.80%	-0.23%	227.01%	22.96%
MARBIDCO Financing without nutrient payments	77.22%	-3.00%	206.80%	22.29%
Conventional Financing with nutrient payments	48.55%	-12.64%	102.10%	14.21%
Conventional Financing without nutrient payments	45.05%	-15.04%	96.43%	14.09%

*Table 30. Results of Tukey's parwise comparison of IRR confidence interevals for each source of capital with and without nutrinet payments for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold..*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-3.49%*	**-4.50%**	**-2.49%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-32.17%*	**-33.17%**	**-31.16%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-13.06%*	**-14.07%**	**-12.06%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-33.25%*	**-34.26%**	**-32.24%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-13.02%*	**-14.02%**	**-12.01%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	4.57%*	**3.57%**	**5.58%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	20.23%*	**19.23%**	**21.24%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	19.10%*	**18.10%**	**20.11%**
Self-financing with nutrient payments	Self-financing without nutrient payments	3.44%*	**2.44%**	**4.45%**

Percentage of firms with negative NPV and negative IRR

The model results suggested over 99.5% of all operations had a positive NPV and positive IRR for all financing scenarios (Table 31).

Table 31. Percentage of firms with negative NPV and IRR for twenty-acre bottom-culture operationl for oyster aquaculture in the Chesapeake for all sources of capital with and without nutrient payments.

Operations with negative NPV & negative IRR	**%**
Self-financing with nutrient payments	0.04%
Self-financing without nutrient payments	0.04%
MARBIDCO Financing with nutrient payments	0.02%
MARBIDCO Financing without nutrient payments	0.04%
Conventional Financing with nutrient payments	0.22%
Conventional Financing without nutrient payments	0.32%

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean percentage of operations with a negative NPV and negative IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 32.

*Table 32. Results of Tukey's parwise comparison of operations with negative NPV and IRR confidence interevals for each source of capital with and without nutrinet payments for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Percentage of Operations with Negative NPV and Negative IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-0.10%	-0.29%	0.09%
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-0.28%*	**-0.47%**	**-0.09%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-0.28%*	**-0.47%**	**-0.09%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-0.20%*	**-0.39%**	**-0.01%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-0.18%	-0.37%	0.01%
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	0.02%	-0.17%	0.21%
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	0.02%	-0.17%	0.21%
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	0.00%	-0.19%	0.19%
Self-financing with nutrient payments	Self-financing without nutrient payments	0.00%	-0.19%	0.19%

Payback Period

The model results suggested the mean payback period (3-4 years) was similar for all financing scenarios (Table 33).

Table 33. Payback period for twenty-acre bottom-culture operations for oyster aquaculture in the Chesapeake for all sources of capital with and without nutrient payments.

Payback Period	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	3	3	11	0.65
Self-financing without nutrient payments	3	3	11	0.72
MARBIDCO Financing with nutrient payments	3	2	11	0.55
MARBIDCO Financing without nutrient payments	3	2	11	0.62
Conventional Financing with nutrient payments	3	2	11	0.76
Conventional Financing without nutrient payments	4	3	11	0.84

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean payback period when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 34.

*Table 34. Results of Tukey's parwise comparison of payback period (years) confidence intervals for each source of capital with and without nutrinet payments for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience intervals are in bold..*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Payback Period**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	0.09*	**0.05**	**0.13**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	0.30*	**0.26**	**0.33**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	0.01	-0.03	0.05
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	0.27*	**0.23**	**0.31**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	0.00	-0.04	0.04
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	-0.07*	**-0.11**	**-0.03**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	-0.28*	**-0.32**	**-0.24**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	-0.29*	**-0.33**	**-0.25**
Self-financing with nutrient payments	Self-financing without nutrient payments	-0.08*	**-0.12**	**-0.04**

Sensitivity Analysis

The input risk distributions with the greatest impact on the mean yearly profit and NPV were the price per bushel and percentage of oysters sold to the half-shell market (Appendix A, Figures A-7 & A-8). The risk distributions that had the greatest impacts on the IRR were price per bushel and the survival of oysters in year three of the operation (Appendix A, Figure A-9).

Twenty-Acre Model Discussion

Based on the model assumptions, a twenty-acre bottom-culture operation can be a viable business, but the chances of failure increase if conventional debt financing is used. As with the ten-acre production model, mean yearly accounting profit, NPV, and IRR was highest for MARBIDCO financed firms and lowest with firms utilizing conventional financing sources. Firms with MARBIDCO financing also had the lowest percentage of negative NPV and negative IRR. Firms with conventional financing had the highest percentage of operations with a negative NPV and negative IRR. Mean payback period was similar for all operations.

An enterprise budget (Appendix B, Table B-3) was prepared for the total cost over the 10-year simulation for each source of capital with and without nutrient payments to determine which input costs may affect the profitability of a twenty-acre bottom-culture oyster operation. As with the five-acre and ten-acre bottom-culture operations, labor was the primary expense in the twenty-acre bottom-culture operation representing over 55% of the total costs. The price of spat-on-shell oysters was the second highest input cost as a percentage of total costs. Mean accounting break-even costs for each source of capital payments are presented in Table 35. These estimates are below the pricing assumptions and below the prices previously reported by growers who sell product during the summer.

Table 35. Break-even cost of production for twenty-acre bottom-culture operations for oyster aquaculture in the Maryland Chesapeake Bay from all sources of capital.

Mean Accounting Break Even Price over 10 years	**$ per bushel**
Self-financing	$30.59
MARBIDCO Financing	$31.16
Conventional Financing	$31.47

One Hundred-Acre Bottom-Culture Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit for all one-hundred acre bottom-culture operations would be positive for all financing scenarios (Table 36).

Table 36. Yearly accounting profit for one hundred-acre bottom-culturecutlure operation for oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$864,205	$338,730	$1,467,693	$157,008
Self-financing without nutrient payments	$821,243	$316,288	$1,401,941	$153,433
MARBIDCO Financing with nutrient payments	$871,060	$345,586	$1,474,549	$157,008
MARBIDCO Financing without nutrient payments	$828,099	$323,144	$1,408,796	$153,433
Conventional Financing with nutrient payments	$830,727	$305,252	$1,434,215	$157,008
Conventional Financing without nutrient payments	$787,765	$282,810	$1,368,463	$153,433

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 37.

*Table 37. Results of Tukey's parwise comparison of yearly accounting profit confidence interevals for each source of capital with and without nutrient payments for one hundred-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Yearly Accounting Profit**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$42,962*	**-$51,809**	**-$34,114**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$40,333*	**-$49,181**	**-$31,486**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$33,478*	**-$42,325**	**-$24,631**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$40,333*	**-$49,181**	**-$31,486**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$33,478*	**-$42,325**	**-$24,631**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$42,962*	**$34,114**	**$51,809**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$6,855	-$1,992	$15,703
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$6,855	-$1,992	$15,703
Self-financing with nutrient payments	Self-financing without nutrient payments	$42,962*	**$34,114**	**$51,809**

Net Present Value

The model results suggested that the mean NPV for all one-hundred acre bottom-culture operations would be positive for all financing scenarios (Table 38).

An ANOVA indicated there was a significant difference (p<0.05) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 39.

Table 38. NPV for one hundred-acre bottom-culture oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Net Present Value	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$5,372,205	$2,053,194	$9,251,278	$999,496
Self-financing without nutrient payments	$5,099,297	$1,909,801	$8,831,706	$976,883
MARBIDCO Financing with nutrient payments	$5,441,176	$2,122,164	$9,320,248	$999,496
MARBIDCO Financing without nutrient payments	$5,168,268	$1,978,772	$8,900,677	$976,883
Conventional Financing with nutrient payments	$5,129,291	$1,810,279	$9,008,363	$999,496
Conventional Financing without nutrient payments	$4,856,383	$1,666,886	$8,588,791	$976,883

*Table 39. Results of Tukey's parwise comparison of NPV confidence interevals for each source of capital with and without nutrient payments for one hundred-acre bottom-culture operation for oyster aquaculture Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean NPV**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$272,908*	**-$329,234**	**-$216,582**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$311,885*	**-$368,211**	**-$255,559**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$242,915*	**-$299,241**	**-$186,589**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$311,885*	**-$368,211**	**-$255,559**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$242,915*	**-$299,241**	**-$186,589**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$272,908*	**$216,582**	**$329,234**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$68,971*	**$12,645**	**$125,297**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$68,971*	**$12,645**	**$125,297**
Self-financing with nutrient payments	Self-financing without nutrient payments	$272,908*	**$216,582**	**$329,234**

Internal Rate of Return

The model results suggested that the mean IRR for all one-hundred acre bottom-culture operations would be positive for all financing scenarios (Table 40).

Table 40. IRR for one hundred-acre bottom-culture oyster aquaculture in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	163.97%	83.63%	289.59%	28.68%
Self-financing without nutrient payments	158.17%	78.47%	280.85%	28.10%
MARBIDCO Financing with nutrient payments	225.70%	101.82%	625.64%	53.89%
MARBIDCO Financing without nutrient payments	216.79%	98.02%	588.97%	51.53%
Conventional Financing with nutrient payments	150.65%	71.80%	270.04%	27.61%
Conventional Financing without nutrient payments	144.90%	67.23%	261.45%	27.07%

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 41.

*Table 41. Results of Tukey's parwise comparison of IRR confidence interevals for each source of capital with and without nutrient payments for one hundred-acre bottom-culture operation for oyster aquaculture Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-5.75%*	**-7.92%**	**-3.59%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-71.89%*	**-74.06%**	**-69.72%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-13.27%*	**-15.44%**	**-11.11%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-75.05%*	**-77.22%**	**-72.88%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-13.32%*	**-15.49%**	**-11.16%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	8.91%*	**6.74%**	**11.08%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	61.73%*	**59.56%**	**63.89%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	58.62%*	**56.45%**	**60.79%**
Self-financing with nutrient payments	Self-financing without nutrient payments	5.80%*	**3.64%**	**7.97%**

Percentage of firms with negative NPV and negative IRR

The model resulted suggest all operations had a positive NPV and positive IRR for all financing scenarios.

Payback Period

The model resulted the mean payback period was two years for all sources of capital except self-financed operations (Table 42).

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean payback period when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 43.

Table 42. Payback period for one hundred-acre bottom-culture operations for oyster aquaculture in the Chesapeake for all sources of capital with and without nutrient payments.

Payback Period	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	3	2	4	0.50
Self-financing without nutrient payments	3	2	4	0.50
MARBIDCO Financing with nutrient payments	2	2	3	0.33
MARBIDCO Financing without nutrient payments	2	2	3	0.35
Conventional Financing with nutrient payments	2	2	4	0.41
Conventional Financing without nutrient payments	2	2	4	0.43

*Table 43. Results of Tukey's parwise comparison of payback period (years) confidence intervevals for each source of capital with and without nutrinet payments for twenty-acre bottom-culture operation for oyster aquaculture in the Maryland Chesapeake Bay. Statistical differcences ($p<0.05$) in means are marked with an * and confience intervevals are in bold..*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean Payback Period**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	0.03*	**0.01**	**0.06**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	0.09*	**0.07**	**0.12**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-0.31*	**-0.34**	**-0.29**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	0.08*	**0.06**	**0.10**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-0.29*	**-0.32**	**-0.27**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	-0.02	-0.04	0.01
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	-0.37*	**-0.40**	**-0.35**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	-0.41*	**-0.43**	**-0.38**
Self-financing with nutrient payments	Self-financing without nutrient payments	-0.05*	**-0.08**	**-0.03**

Sensitivity Analysis

The input risk distributions with the greatest impact on the mean yearly profit, and NPV were the price per bushel and percentage of oysters sold to the half-shell (Appendix A, Figures A-10 & A-11). The risk distributions that had the greatest impacts on the IRR were price per bushel and the survival of oysters in year 3 of the operation (Appendix A, Figure A-12).

One Hundred-Acre Model Discussion

Results show a one hundred-acre bottom-culture operation is successful with the model assumptions for all sources of capital with and without nutrient payments. MARBIDCO financed operations significantly outperformed those with other sources of capital due to the interest only period and partial principle forgiveness features of the program. However, there was not a significant difference in mean yearly accounting profit between self-financed and MARBIDCO financed operations. The similarity of the mean yearly accounting profit for these two funding sources is attributed to the reduced amount of MARBIDCO funds as a percentage of the overall initial investment and yearly operating expenses.

An enterprise budget (Appendix B, Table B-4) was prepared for the total cost over the 10-year simulation for each source of capital with and without nutrient payments. Unlike the five-acre, ten-acre, and twenty-acre bottom-culture operations, the cost of spat-on-shell oysters was the highest input cost representing over 60% of total fixed and variable costs. The second highest production cost was associated with paid labor representing over 24% of total costs. Mean accounting break-even costs for each source of capital payments are presented in Table 44. These estimates are below the pricing assumptions and below prices previously reported by growers who sell product during the summer. Self-financed operations had lower break-even prices than those with debt financing. Operations with MARBIDCO financing had a lower break-even price than those with conventional financing due to the principle forgiveness feature of the MARBIDCO loan program. All break-even prices were below the range estimated in the simulation.

Table 44. Break-even cost of production for one hundred-acre bottom-culture operations for oyster aquaculture in the Maryland Chesapeake Bay from all sources of capital.

Mean Accounting Break Even Price over 10 years	**$ per bushel**
Self-financing	$14.59
MARBIDCO Financing	$14.79
Conventional Financing	$14.94

Water-column Results

When describing their operations, water-column oyster operations 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. The predicted harvest was based on assumptions before the environmental factor has been incorporated.

Five hundred thousand oysters harvested per year water-column operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit would be negative for all water-column operations producing 500,000 oysters per year for all financing scenarios (Table 45).

Table 45. Yearly accounting profit for a 500,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	-$35,379	-$107,477	$37,151	$21,839
Self-financing without nutrient payments	-$39,595	-$110,225	$29,164	$21,564
MARBIDCO Financing with nutrient payments	-$32,312	-$104,411	$40,217	$21,839
MARBIDCO Financing without nutrient payments	-$36,529	-$107,159	$32,230	$21,564
Conventional Financing with nutrient payments	-$39,102	-$111,200	$33,427	$21,839
Conventional Financing without nutrient payments	-$43,318	-$113,948	$25,440	$21,564

Net Present Value and Internal Rate of Return

The model results suggested that the mean NPV and mean IRR would be negative for all water-column operations producing 500,000 oysters per year for all financing scenarios (Table 46 and Table 47).

Table 46. NPV for 500,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Net Present Value	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	-$329,085	-$806,877	$129,470	$143,431
Self-financing without nutrient payments	-$356,650	-$824,640	$95,696	$141,632
MARBIDCO Financing with nutrient payments	-$293,870	-$771,662	$164,684	$143,431
MARBIDCO Financing without nutrient payments	-$321,435	-$789,425	$130,911	$141,632
Conventional Financing with nutrient payments	-$358,953	-$836,745	$99,601	$143,431
Conventional Financing without nutrient payments	-$386,518	-$854,508	$65,828	$141,632

Table 47. IRR for a 500,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	-11.51%	-56.45%	17.54%	10.93%
Self-financing without nutrient payments	-12.61%	-54.31%	15.68%	10.36%
MARBIDCO Financing with nutrient payments	-9.62%	-56.41%	22.74%	11.26%
MARBIDCO Financing without nutrient payments	-11.05%	-54.98%	20.35%	10.76%
Conventional Financing with nutrient payments	-12.71%	-55.13%	14.93%	10.28%
Conventional Financing without nutrient payments	-14.02%	-57.88%	13.18%	10.13%

Percentage of firms with negative NPV and negative IRR

The model results suggested over 90% of water-column operations producing 500,000 oyster per year would have a negative mean NPV and negative mean IRR for all financing scenarios (Table 48).

Table 48. Percentage of firms with negative NPV and IRR for a 500,000 oyster per year water-column operation in the Maryland Chesapeake Bay for all sources of capital with and without nutrient payments.

Operations with negative NPV & negative IRR	**%**
Self-financing with nutrient payments	97.52%
Self-financing without nutrient payments	98.78%
MARBIDCO Financing with nutrient payments	94.42%
MARBIDCO Financing without nutrient payments	96.78%
Conventional Financing with nutrient payments	98.82%
Conventional Financing without nutrient payments	99.26%

Payback Period

The model results suggest the mean payback period was longer than the simulation (>10 years) for all financing scenarios.

Sensitivity Analysis

The input risk distribution with the greatest impact on the mean yearly profit, NPV, and IRR was the price per oyster followed by survival in various years of the operation (Appendix A, Figures A-13, A-14, & A-15).

Five hundred thousand oysters per year Model Discussion

Based on the analysis of the accounting profit, NPV, IRR, and payback period an operation utilizing the original model assumption, a 500,000 oyster per year water-column operation would not be profitable and would not represent an ideal investment opportunity for any of the sources of capital in the simulation. An enterprise budget (Appendix B, Table B-5) was prepared for the total cost over the 10-year model simulation for each source of capital with and without nutrient payments to determine input costs that may affect the profitability of a 500,000 oysters per year water-column operation. With all sources of capital with and without nutrient payments, labor costs represented over 75% of the total fixed and variable cost of the operation over a ten-year period. The cost of seed was the second highest percentage of total fixed and variable costs. Mean accounting break-even costs for each source of capital payments are presented in Table 49. Break-even prices are within the range of prices analyzed in the model, but above the most likely price of $0.55 per oyster.

Table 49. Break-even cost of production for 500,000 oyster per year water-column operations in the Maryland Chesapeake Bay from all sources of capital.

Mean Accounting Break Even Price over 10 years	$ per oyster
Self-financing	$0.56
MARBIDCO Financing	$0.57
Conventional Financing	$0.57

One Million Oysters per year Water-Column Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit would be positive for all water-column operations producing 1,000,000 oysters per year for all financing scenarios (Table 50).

Table 50. Yearly accounting profit for a 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$65,724	-$77,284	$214,686	$45,045
Self-financing without nutrient payments	$57,279	-$80,838	$198,942	$44,431
MARBIDCO Financing with nutrient payments	$69,291	-$73,718	$218,253	$45,045
MARBIDCO Financing without nutrient payments	$60,846	-$77,271	$202,509	$44,431
Conventional Financing with nutrient payments	$60,863	-$82,145	$209,825	$45,045
Conventional Financing without nutrient payments	$52,418	-$85,699	$194,081	$44,431

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 51

*Table 51. Results of Tukey's pairwise comparison of yearly accounting profit confidence intervals for each source of capital with and without nutrient payments for a 1,000,000, oyster per year water-column operation in the Maryland Chesapeake Bay. Statistical differences (p<0.05) in means are marked with an * and confidence intervals are in bold.*

Confidence Interval Tests Scenario 1-Scenario 2		**Difference of Mean Yearly Accounting Profit**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$8,445*	**-$10,995**	**-$5,895**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$8,428*	**-$10,977**	**-$5,878**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$4,861*	**-$7,411**	**-$2,311**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$8,428*	**-$10,977**	**-$5,878**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$4,861*	**-$7,411**	**-$2,311**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$8,445*	**$5,895**	**$10,995**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$3,567*	**$1,017**	**$6,117**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$3,567*	**$1,017**	**$6,117**
Self-financing with nutrient payments	Self-financing without nutrient payments	$8,445*	**$5,895**	**$10,995**

Net Present Value

The model results suggested that the mean NPV would be positive for all water-column operations producing 1,000,000 oysters per year for all financing scenarios (Table 52). An ANOVA indicated there was a significant difference (p<0.05) between the mean NPV when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 53.

Table 52. NPV for 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Net Present Value	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$282,092	-$671,707	$1,258,370	$294,381
Self-financing without nutrient payments	$226,880	-$694,650	$1,142,848	$290,383
MARBIDCO Financing with nutrient payments	$323,322	-$630,477	$1,299,600	$294,381
MARBIDCO Financing without nutrient payments	$268,110	-$653,420	$1,184,078	$290,383
Conventional Financing with nutrient payments	$243,598	-$710,201	$1,219,876	$294,381
Conventional Financing without nutrient payments	$188,386	-$733,144	$1,104,355	$290,383

*Table 53. Results of Tukey's pairwise comparison of NPV confidence intervals for each source of capital with and without nutrient payments for 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1-Scenario 2		**Difference of Mean NPV**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$55,212*	**-$71,877**	**-$38,547**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$79,724*	**-$96,388**	**-$63,059**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$38,494*	**-$55,158**	**-$21,829**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$79,724*	**-$96,388**	**-$63,059**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$38,494*	**-$55,158**	**-$21,829**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$55,212*	**$38,547**	**$71,877**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$41,230*	**$24,565**	**$57,895**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$41,230*	**$24,565**	**$57,895**
Self-financing with nutrient payments	Self-financing without nutrient payments	$55,212*	**$38,547**	**$71,877**

Internal Rate of Return

The model results suggested that the mean IRR would be positive for all water-column operations producing 1,000,000 oysters per year for all financing scenarios (Table 54).

An ANOVA indicated there was a significant difference (p<0.05) between the mean IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 55.

Table 54. IRR for a 1,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	19.78%	-40.12%	57.22%	12.64%
Self-financing without nutrient payments	17.57%	-43.29%	55.51%	12.75%
MARBIDCO Financing with nutrient payments	23.38%	-47.80%	67.23%	14.12%
MARBIDCO Financing without nutrient payments	20.95%	-42.56%	65.23%	14.16%
Conventional Financing with nutrient payments	17.84%	-54.12%	54.79%	12.64%
Conventional Financing without nutrient payments	15.69%	-41.91%	53.09%	12.70%

*Table 55. Results of Tukey's pairwise comparison of IRR confidence intervals for each source of capital with and without nutrient payments for a 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences(p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-2.16%*	**-2.91%**	**-1.40%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-5.26%*	**-6.02%**	**-4.51%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-1.89%*	**-2.64%**	**-1.13%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-5.54%*	**-6.29%**	**-4.78%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-1.93%*	**-2.69%**	**-1.18%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	2.43%*	**1.68%**	**3.19%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	3.61%*	**2.85%**	**4.36%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	3.38%*	**2.62%**	**4.14%**
Self-financing with nutrient payments	Self-financing without nutrient payments	2.20%*	**1.45%**	**2.96%**

Percentage of firms with negative NPV and negative IRR

The model results suggested MARBIDCO financed firms had a lower percentage of operations with a negative NPV and negative IRR, while conventionally financed operations had the highest percentage of operations with a negative NPV and negative IRR (Table 56).

Table 56. Percentage of firms with negative NPV and IRR for a 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Operations with negative NPV & negative IRR	**%**
Self-financing with nutrient payments	17.24%
Self-financing without nutrient payments	21.54%
MARBIDCO Financing with nutrient payments	14.10%
MARBIDCO Financing without nutrient payments	17.46%
Conventional Financing with nutrient payments	20.66%
Conventional Financing without nutrient payments	25.20%

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 57.

*Table 57. Results of Tukey's parwise comparison of operations with negative NPV and IRR confidence interevals for each source of capital with and without nutrinet payments for a 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean Percentage of Operations with a negative NPV and negative IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-4.54%*	**-6.80%**	**-2.29%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-7.75%*	**-10.01%**	**-5.49%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-3.66%*	**-5.92%**	**-1.40%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-6.57%*	**-8.82%**	**-4.32%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-3.42%*	**-5.67%**	**-1.17%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	3.37%*	**1.11%**	**5.62%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	3.15%*	**0.90%**	**5.40%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	4.09%*	**1.83%**	**6.35%**
Self-financing with nutrient payments	Self-financing without nutrient payments	4.30%*	**2.05%**	**6.56%**

Payback Period

The model results suggested that the mean payback period would be 5-7 years for all water-column operations producing 1,000,000 oysters per year for all financing scenarios (Table 58).

Table 58. Payback period for a 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Year farm gets back to positive cash balance	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	6	3	11	2.15
Self-financing without nutrient payments	6	3	11	2.27
MARBIDCO Financing with nutrient payments	5	2	11	2.39
MARBIDCO Financing without nutrient payments	5	2	11	2.58
Conventional Financing with nutrient payments	6	2	11	2.52
Conventional Financing without nutrient payments	7	3	11	2.54

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 59.

*Table 59. Results of Tukey's pairwise comparison of payback period confidence intervals for each source of capital with and without nutrient payments for a 1,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Payback Period**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	1.24*	**1.11**	**1.38**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	1.80*	**1.66**	**1.93**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	0.68*	**0.54**	**0.82**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	0.92*	**0.78**	**1.06**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-0.21*	**-0.35**	**-0.07**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	-0.37*	**-0.51**	**-0.23**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	-1.13*	**-1.27**	**-0.99**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	-1.11*	**-1.25**	**-0.98**
Self-financing with nutrient payments	Self-financing without nutrient payments	-0.35*	**-0.49**	**-0.22**

Sensitivity Analysis

The input risk distribution with the greatest impact on the mean yearly profit, NPV, and IRR was the price per oyster, followed by survival (Appendix A, Figures A-16, A-17, A-18).

One million oysters per year Model Discussion

Based on the original model assumptions, a 1,000,000 oysters per year operation appears to be a viable, albeit potentially risky business investment. Operations with

MARBIDCO financing performed better financially than those with other forms of financing due to the interest only period and principle forgiveness features of the program.

An enterprise budget (Appendix B, Table B-6) was prepared for the total cost over the 10-year model simulation for each source of capital with and without nutrient payments. With all sources of capital with and without nutrient payments, costs associated with paid employees was the highest percentage of total cost, representing over 65% of the total cost of the operation over a ten-year period. As seen with the 500,000 oyster per year model, the cost of seed was the second highest percentage of total fixed and variable costs.

Mean accounting break-even costs for each source of capital payments are presented in Table 60. Break-even prices are within the range of prices analyzed in the model, and below the most likely price of $0.55 per oyster.

Table 60. Break-even cost of production for a 1,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital.

Mean Accounting Break Even Price over 10 years	**$ per oyster**
Self-financing	$0.38
MARBIDCO Financing	$0.38
Conventional Financing	$0.39

Two Million Oysters per year Water-Column Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit would be positive for all water-column operations producing 2,000,000 oysters per year for all financing scenarios (Table 61).

Table 61. Yearly accounting profit for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	$307,915	$55,775	$611,210	$87,506
Self-financing without nutrient payments	$290,885	$50,021	$579,892	$86,260
MARBIDCO Financing with nutrient payments	$311,847	$59,707	$615,143	$87,506
MARBIDCO Financing without nutrient payments	$294,817	$53,954	$583,825	$86,260
Conventional Financing with nutrient payments	$302,330	$50,190	$605,625	$87,506
Conventional Financing without nutrient payments	$285,300	$44,437	$574,307	$86,260

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 62.

*Table 62. Results of Tukey's pairwise comparison of yearly accounting profit confidence intervals for each source of capital with and without nutrient payments for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences ($p<0.05$) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Yearly Accounting Profit**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$17,030*	**-$21,982**	**-$12,078**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$9,517*	**-$14,470**	**-$4,565**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$5,585*	**-$10,537**	**-$633**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$9,517*	**-$14,470**	**-$4,565**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$5,585*	**-$10,537**	**-$633**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$17,030*	**$12,078**	**$21,982**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$3,933	-$1,019	$8,885
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$3,933	-$1,019	$8,885
Self-financing with nutrient payments	Self-financing without nutrient payments	$17,030*	**$12,078**	**$21,982**

Net Present Value

The model results suggested that the mean NPV would be positive for all water-column operations producing 2,000,000 oysters per year for all financing scenarios (Table 63).

Table 63. NPV for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Net Present Value	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	$1,771,471	$160,691	$3,746,446	$571,453
Self-financing without nutrient payments	$1,660,138	$86,099	$3,586,563	$563,366
MARBIDCO Financing with nutrient payments	$1,816,597	$205,817	$3,791,572	$571,453
MARBIDCO Financing without nutrient payments	$1,705,264	$131,226	$3,631,690	$563,366
Conventional Financing with nutrient payments	$1,727,793	$117,013	$3,702,768	$571,453
Conventional Financing without nutrient payments	$1,616,459	$42,421	$3,542,885	$563,366

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean NPV when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 64.

*Table 64. Results of Tukey's pairwise comparison of NPV confidence intervals for each source of capital with and without nutrient payments for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean NPV**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$111,333*	**-$143,674**	**-$78,993**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$88,805*	**-$121,145**	**-$56,464**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$43,678*	**-$76,019**	**-$11,338**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$88,805*	**-$121,145**	**-$56,464**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$43,678*	**-$76,019**	**-$11,338**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$111,333*	**$78,993**	**$143,674**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$45,126*	**$12,786**	**$77,467**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$45,126*	**$12,786**	**$77,467**
Self-financing with nutrient payments	Self-financing without nutrient payments	$111,333*	**$78,993**	**$143,674**

Internal Rate of Return

The model results suggested that the mean IRR would be positive for all water-column operations producing 2,000,000 oysters per year for all financing scenarios (Table 65).

Table 65. IRR for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	47.96%	12.77%	90.15%	11.96%
Self-financing without nutrient payments	45.79%	10.09%	85.35%	11.87%
MARBIDCO Financing with nutrient payments	52.28%	14.04%	98.91%	13.09%
MARBIDCO Financing without nutrient payments	49.94%	11.33%	93.75%	12.97%
Conventional Financing with nutrient payments	46.62%	11.68%	88.61%	11.90%
Conventional Financing without nutrient payments	44.46%	9.05%	83.81%	11.81%

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 66.

*Table 66. Results of Tukey's pairwise comparison of IRR confidence intervals for each source of capital with and without nutrient payments for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-2.16%*	**-2.86%**	**-1.46%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-5.48%*	**-6.18%**	**-4.78%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-1.34%*	**-2.04%**	**-0.64%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-5.66%*	**-6.36%**	**-4.96%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-1.34%*	**-2.04%**	**-0.64%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	2.34%*	**1.64%**	**3.04%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	4.32%*	**3.62%**	**5.02%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	4.15%*	**3.45%**	**4.84%**
Self-financing with nutrient payments	Self-financing without nutrient payments	2.16%*	**1.47%**	**2.86%**

Percentage of firms with negative NPV and negative IRR

Based on model results, all firms at the two million oyster per year production level had a positive NPV and IRR for all financing scenarios.

Payback Period

The model results suggested that the mean payback period was 3-4 years for all water-column operations producing 2,000,000 oysters per year for all financing scenarios (Table 67).

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 68.

Table 67. Payback period for a 2,000.000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Year farm gets back to positive cash balance	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	3	2	8	0.71
Self-financing without nutrient payments	4	2	8	0.76
MARBIDCO Financing with nutrient payments	3	2	7	0.68
MARBIDCO Financing without nutrient payments	3	2	8	0.71
Conventional Financing with nutrient payments	3	2	8	0.77
Conventional Financing without nutrient payments	3	2	9	0.85

*Table 68. Results of Tukey's pairwise comparison of payback period confidence intervals for each source of capital with and without nutrient payments for a 2,000,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical diffcerences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Payback Period**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	0.37*	**0.33**	**0.42**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	0.50*	**0.45**	**0.54**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-0.08*	**-0.12**	**-0.04**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	0.22*	**0.17**	**0.26**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-0.37*	**-0.41**	**-0.33**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	-0.09*	**-0.13**	**-0.05**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	-0.59*	**-0.63**	**-0.54**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	-0.58*	**-0.62**	**-0.54**
Self-financing with nutrient payments	Self-financing without nutrient payments	-0.08*	**-0.13**	**-0.04**

Sensitivity Analysis

As with the one million-oyster production level, the input risk distribution with the greatest impact on the mean yearly profit, NPV, and IRR was the price per oyster (Appendix A, Figures A-19, A-20, & A-21), followed by survival.

Two million oysters per year Model Discussion

Based on the original model assumptions, a 2,000,000 oysters per year operation is a viable business investment. Operations with MARBIDCO financing performed better financially than those with other sources of financing due to the interest only period and partial principle forgiveness features of the program. However, there was not a significant difference in mean yearly accounting profit between self-finance operations and those with funding from MARBIDCO.

An enterprise budget (Appendix B, Table B-7) was prepared for the total cost over the 10-year model simulation for each source of capital with and without nutrient payments. With all sources of capital with and without nutrient payments, costs associated with paid employees represented over 60% of the total cost of the operation over a ten-year period followed by the cost of seed. Mean accounting break-even costs for each source of capital payments are presented in Table 69. Break-even prices are below the most likely price of $0.55 per oyster and below the range of priced used in the model.

Table 69. Break-even cost of production for 2,000,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital.

Mean Accounting Break Even Price over 10 years	**$ per oyster**
Self-financing	$0.26
MARBIDCO Financing	$0.26
Conventional Financing	$0.26

Two million five hundred thousand Oysters per year Water-Column Operation

Average Yearly Accounting Profit

The model results suggested that the mean yearly accounting profit would be positive for all water-column operations producing 2,500,000 oysters per year for all financing scenarios (Table 70).

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 71.

Table 70. Yearly accounting profit for a 2,500,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Average Yearly Accounting Profit	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	$437,607	$110,307	$838,513	$109,262
Self-financing without nutrient payments	$416,203	$91,108	$819,657	$107,793
MARBIDCO Financing with nutrient payments	$441,717	$114,418	$842,623	$109,262
MARBIDCO Financing without nutrient payments	$420,314	$95,218	$823,767	$107,793
Conventional Financing with nutrient payments	$431,670	$104,371	$832,576	$109,262
Conventional Financing without nutrient payments	$410,267	$85,171	$813,721	$107,793

*Table 71. Results of Tukey's pairwise comparison of yearly accounting profit confidence intervals for each source of capital with and without nutrient payments for a 2,500,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience intervals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean Yearly Accounting Profit**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$21,403*	**-$27,589**	**-$15,217**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$10,047*	**-$16,233**	**-$3,861**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$5,936	-$12,122	$249
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$10,047*	**-$16,233**	**-$3,861**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$5,936	-$12,122	$249
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$21,403*	**$15,217**	**$27,589**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$4,110	-$2,075	$10,296
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$4,110	-$2,075	$10,296
Self-financing with nutrient payments	Self-financing without nutrient payments	$21,403*	**$15,217**	**$27,589**

Net Present Value

The model results suggested that the mean NPV would be positive for all water-column operations producing 2,500,000 oysters per year for all financing scenarios (Table 72).

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean NPV when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 73.

Table 72. NPV for a 2,500,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Net Present Value	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	$2,574,578	$382,781	$5,260,498	$714,141
Self-financing without nutrient payments	$2,434,648	$257,907	$5,136,055	$704,711
MARBIDCO Financing with nutrient payments	$2,621,597	$429,800	$5,307,517	$714,141
MARBIDCO Financing without nutrient payments	$2,481,667	$304,925	$5,183,074	$704,711
Conventional Financing with nutrient payments	$2,528,382	$336,585	$5,214,302	$714,141
Conventional Financing without nutrient payments	$2,388,451	$211,710	$5,089,858	$704,711

*Table 73. Results of Tukey's pairwise comparison of NPV confidence intervals for each source of capital with and without nutrient payments for a 2,500,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences ($p<0.05$) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1 – Scenario 2		**Difference of Mean NPV**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-$139,930*	**-$180,365**	**-$99,495**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-$93,215*	**-$133,650**	**-$52,780**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-$46,196*	**-$86,631**	**-$5,761**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-$93,215*	**-$133,650**	**-$52,780**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-$46,196*	**-$86,631**	**-$5,761**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	$139,930*	**$99,495**	**$180,365**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	$47,019*	**$6,584**	**$87,454**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	$47,019*	**$6,584**	**$87,454**
Self-financing with nutrient payments	Self-financing without nutrient payments	$139,930*	**$99,495**	**$180,365**

Internal Rate of Return

The model results suggested that the mean IRR would be positive for all water-column operations producing 2,500,000 oysters per year for all financing scenarios (Table 74).

An ANOVA indicated there was a significant difference ($p<0.05$) between the mean IRR when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 75.

Table 74. IRR for 2,500,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

10 Year Internal Rate of Return	**Mean**	**Min**	**Max**	**Standard Deviation**
Self-financing with nutrient payments	55.30%	15.57%	102.81%	12.35%
Self-financing without nutrient payments	53.11%	13.26%	96.22%	12.24%
MARBIDCO Financing with nutrient payments	59.47%	16.92%	111.29%	13.37%
MARBIDCO Financing without nutrient payments	57.12%	14.52%	104.18%	13.23%
Conventional Financing with nutrient payments	54.12%	14.62%	101.45%	12.29%
Conventional Financing without nutrient payments	51.93%	12.30%	94.87%	12.18%

*Table 75. Results of Tukey's pairwise comparison of IRR confidence intervals for each source of capital with and without nutrnent payments for a 2,500,000 oysters per year water-column operation in the Maryland Chesapeake Bay. Statistical differcences (p<0.05) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests Scenario 1- Scenario 2		**Difference of Mean IRR**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	-2.19%*	**-2.91%**	**-1.47%**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	-5.19%*	**-5.91%**	**-4.47%**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-1.17%*	**-1.89%**	**-0.45%**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	-5.35%*	**-6.07%**	**-4.63%**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-1.18%*	**-1.90%**	**-0.46%**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	2.35%*	**1.63%**	**3.06%**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	4.17%*	**3.45%**	**4.89%**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	4.02%*	**3.30%**	**4.74%**
Self-financing with nutrient payments	Self-financing without nutrient payments	2.19%*	**1.47%**	**2.91%**

Percentage of firms with negative NPV and negative IRR

The model results suggested that all water-column operations producing 2,500,000 oysters per year for all financing scenarios would have a positive mean NPV and positive mean IRR.

Payback Period

The model results suggested that the mean payback period would be three-years for all water-column operations producing 2,500,000 oysters per year for all financing scenarios (Table 76).

However, due to the differences in the maximum payback periods, an ANOVA indicated there was a significant difference (p<0.05) between the mean yearly accounting profit when comparing all possible combinations of financing scenarios. Confidence intervals of policy relevant financing scenarios pairs were compared using Tukey's pairwise comparison method and are presented in Table 77.

Table 76. Payback period for a 2,500,000 oysters per year water-column operation in the Maryland Chesapeake Bay for each source of capital with and without nutrient payments.

Year farm gets back to positive cash balance	Mean	Min	Max	Standard Deviation
Self-financing with nutrient payments	3	2	7	0.56
Self-financing without nutrient payments	3	2	7	0.59
MARBIDCO Financing with nutrient payments	3	2	6	0.60
MARBIDCO Financing without nutrient payments	3	2	7	0.62
Conventional Financing with nutrient payments	3	2	7	0.65
Conventional Financing without nutrient payments	3	2	8	0.66

*Table 77. Results of Tukey's pairwise comparison of payback period confidence intervals for each source of capital with and without nutrient payments for a 2,500,000 oyster per year water-column in the Maryland Chesapeake Bay. Statistical differcences ($p<0.05$) in means are marked with an * and confience interevals are in bold.*

Confidence Interval Tests		**Difference of Mean Payback Period**	**Tukey**	
			Lower	**Upper**
Conventional Financing without nutrient payments	Conventional Financing with nutrient payments	0.28*	**0.24**	**0.31**
Conventional Financing without nutrient payments	MARBIDCO Financing without nutrient payments	0.36*	**0.32**	**0.39**
Conventional Financing without nutrient payments	Self-financing without nutrient payments	-0.14*	**-0.17**	**-0.10**
Conventional Financing with nutrient payments	MARBIDCO Financing with nutrient payments	0.15*	**0.12**	**0.19**
Conventional Financing with nutrient payments	Self-financing with nutrient payments	-0.35*	**-0.38**	**-0.31**
MARBIDCO Financing with nutrient payments	MARBIDCO Financing without nutrient payments	-0.07*	**-0.10**	**-0.03**
MARBIDCO Financing with nutrient payments	Self-financing with nutrient payments	-0.50*	**-0.53**	**-0.46**
MARBIDCO Financing without nutrient payments	Self-financing without nutrient payments	-0.50*	**-0.53**	**-0.46**
Self-financing with nutrient payments	Self-financing without nutrient payments	-0.07*	**-0.10**	**-0.03**

Sensitivity Analysis

The input risk distribution with the greatest impact on the mean yearly profit, NPV, and IRR was the price per oyster (Appendix A, Figures A-22, A-23, & A-24), followed by survival.

Two million five hundred thousand oysters per year Model Discussion

Based on the original model assumptions, a 2,500,000 oysters per year operation is a viable business investment. Operations with MARBIDCO financing performed significantly better financially than those with other sources of financing due to the interest-only period and partial principle forgiveness features of the program for NPV, IRR, and payback period. However, there was only a significant difference in mean yearly accounting profit between conventionally financed operations and those with funding from MARBIDCO. This difference is due to the reduced overall interest expense of the MARBIDCO loan program and the partial principle forgiveness. At this production level, the total amount of money financed through debt represents a smaller proportion to the overall capital needed to start and operate the operation, resulting in debt payments having a smaller impact on accounting profit.

An enterprise budget (Appendix B, Table B-8) was prepared for the total cost over the 10-year model simulation for each source of capital with and without nutrient payments. With all sources of capital with and without nutrient payments, costs associated with paid employees represented over 55% of the total cost of the operation over a ten-year period followed by the cost of seed.

Mean accounting break-even costs for each source of capital payments are presented in Table 78. Break-even prices are below the most likely price of $0.55 per oyster.

Table 78. Break-even cost of production for a 2,500,000 oyster per year water-column operation in the Maryland Chesapeake Bay for each source of capital.

Mean Accounting Break Even Price over 10 years	**$ per oyster**
Self-financing	$0.23
MARBIDCO Financing	$0.23
Conventional Financing	$0.23

Chapter 3: Summary, Conclusions, and Future Work

Discussion on the use of debt financing in bottom-culture and water-column aquaculture oyster production

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 risks 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 use of self-financing to start and fund an operation, along with debt financing options were analyzed. The debt-financing analysis focused on the MARBIDCO Maryland Shellfish Loan Program and conventional debt financing from institutions such as the Farm Credit System, Wells Fargo, or Bank of America.

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 finance a business. In all simulations at all production scales, 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 were better off financially, when viewed over a 10-year period, than those 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 costs but are not 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. 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, 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 payments have the potential to place a financial burden on the operation's cash flow but can be anticipated and managed given input assumptions for the model tend to be slightly conservative. 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. 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). In this study, however, operations with MARBIDCO financing had shorter payback periods than operations that used conventional or self-financing.

While not a focus of the study, to determine if there was a difference between accounting and economic profit, opportunity costs were calculated based on the foregone interest that could have been earned on personal funds used to initially finance the modeled operation. In scenarios where a mix of loans and personal funds were used to finance the operation, opportunity costs were calculated on the personal funds that were used to start the operation. Interest was compounded annually based on the ten-year Treasury bond rate (2.88% on 8/14/2018). Operations that utilized self-financing had higher opportunity costs than those that used MARBIDCO or conventional lenders for all bottom-culture and water-column production levels (Table 79). Opportunity costs were the same for operations utilizing MARBIDCO or conventional lenders since loan amounts to start the operations were equal. At the twenty and one hundred-acre bottom-culture operation sizes, the opportunity costs were negative, indicating the loan amount may have been more than the initial investment.

Table 79. Mean opportunity costs for oyster aquaculture operations in the Maryland Chesapeake Bay based on model assumptions for initial investment and loan amounts.

	Self-financing	MARBIDCO financing	Conventional financing
Five-acre bottom-culture operation	$18,239	$8,389	$8,389
Ten-acre bottom-culture operation	$18,260	$5,127	$5,127
Twenty-acre bottom-culture operation	$18,236	-$4,748	-$4,748
One hundred-acre bottom-culture operation	$18,350	-$14,484	-$14,484
Five hundred thousand oysters per year water-column operation	$46,197	$13,363	$13,363
One million oyster per year water-column operation	$69,478	$36,644	$36,644
Two million oyster per year water-column operation	$115,757	$82,923	$82,923
Two million five hundred thousand oyster per year water-column operation	$138,849	$106,015	$106,015

Discussion on nutrient payments

When operations received nutrient payments, financial indicators were greater than when the same operations did not receive nutrient payments. In the study it was assumed there was no additional cost associated with participating in a nutrient-payment program or the cost of participating in the program was deducted from any payment received, resulting in net positive payment. This assumptions was made following the rational in Weber et al. (2018). While nutrient credits represent a small percentage of income (2-4%) compared to aquaculture oyster sales, based on enterprise budgets found in Appendix B, the addition of nutrient payments could have the potential to provide substantial amounts of income, as nutrient credit payments are based on production. For example, the model results suggest over a ten-year period a one-hundred acre bottom-culture operation and a 2,500,000 oyster per year water-column operation could receive $472,577 and $235,453 respectively (Appendix B, Tables B-4 and B-8). As mentioned previously receiving nutrient credit payments had a positive effect on operation success, and could potentially be used as a way to improve profitability should an unexpected loss occur to a portion of the oysters grown on the lease.

Bottom-culture Aquaculture Conclusions

In this study, the model results suggest there are economies of scale for the bottom-culture of aquaculture oysters in Maryland. Using the production estimates from the operations sizes analyzed in this study and examining self-financed operations, to remove the influence of debt financing, without nutrient payments, as the number of bushels harvested from the representative lease sizes increased the break-even price per bushel decreased (Figure 11).

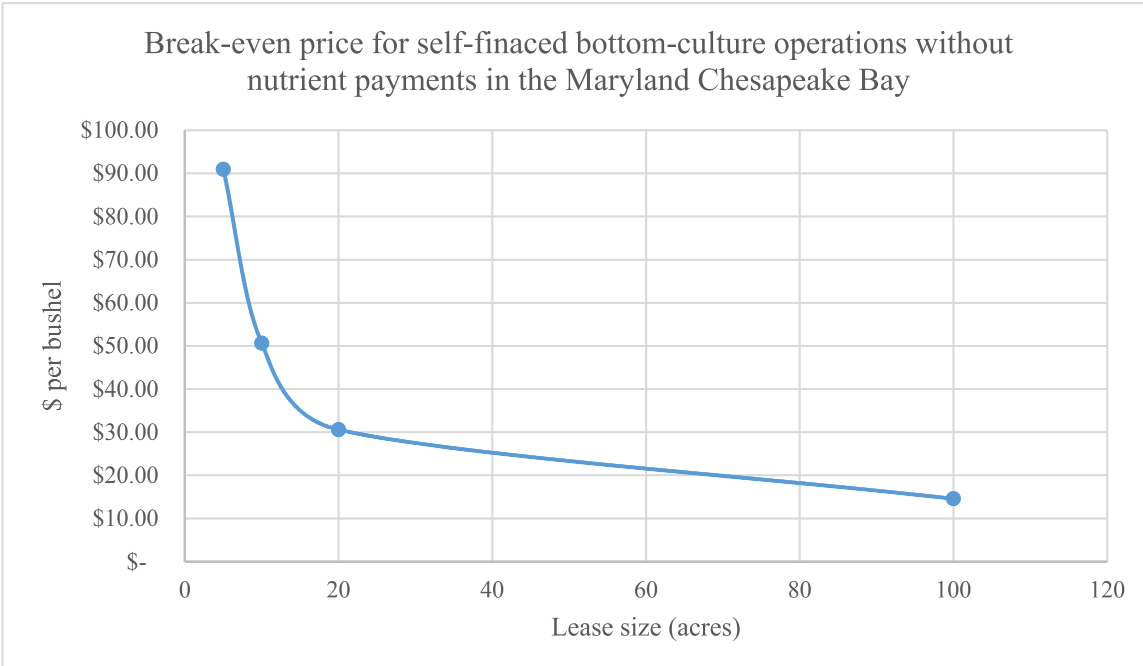


Figure 11. Break-even price per bushel for self-financed bottom-culture operations for oyster aquaculture in the Chesapeake without nutrient payments with model assumptions for labor.

Operators should carefully consider the costs of inputs, which affect the break-even price of the operation, especially regarding the amount and type of labor used. For example, the mean yearly accounting profit for a five-acre, self-financed, bottom-culture operation without nutrient payments was -$31,718, while a self-financed, one-hundred-acre, bottom-culture operation without nutrient payments was $901,533 (Figure 12) using the model assumptions for overall production.

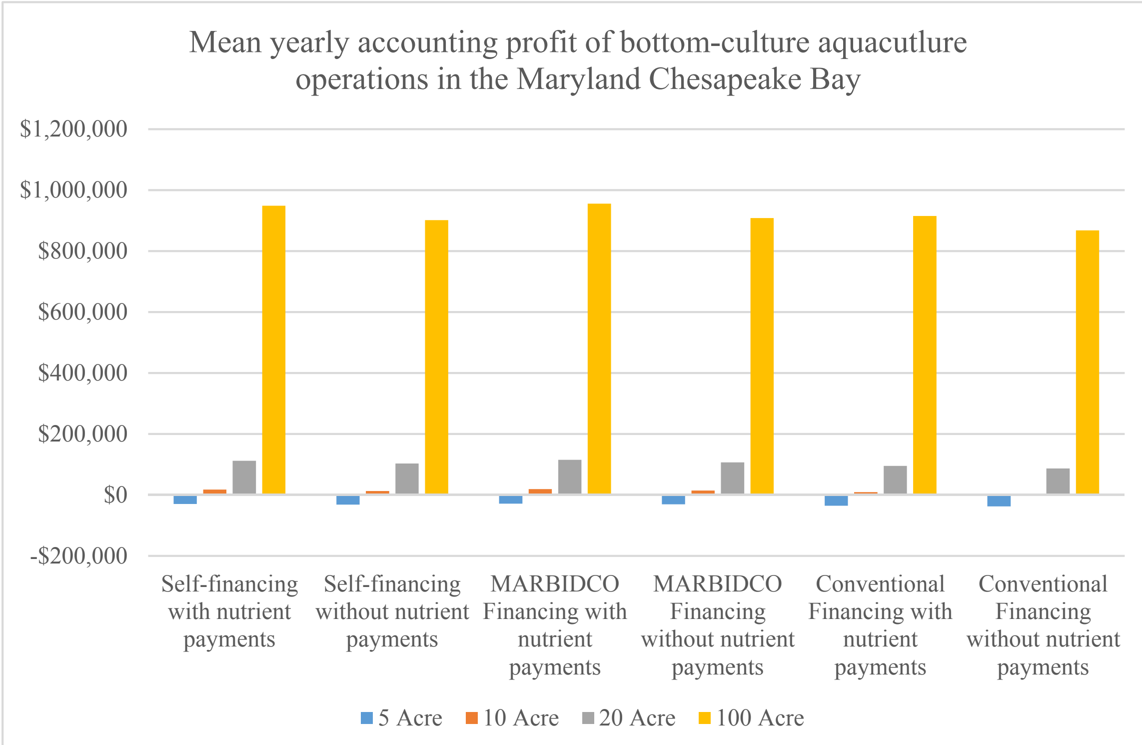


Figure 12. Mean yearly accounting profit for all bottom-culture production levels, different sources of capital, for oyster aquaculture in the Maryland Chesapeake Bay with and without nutrient payments.

When examining NPV for operations of different production scales, the same trend was seen as production scale increased (Figure 13). As expected, larger operations were more profitable with a greater NPV than smaller operations. The model suggests smaller operations may not be a profitable investment, however, if operation are able to lower costs, especially in respect to labor, it may be possible for them to achieve a positive NPV

There was also a reduction in the percentage of operations with a negative NPV and negative IRR as production scales increased (Figure 14).

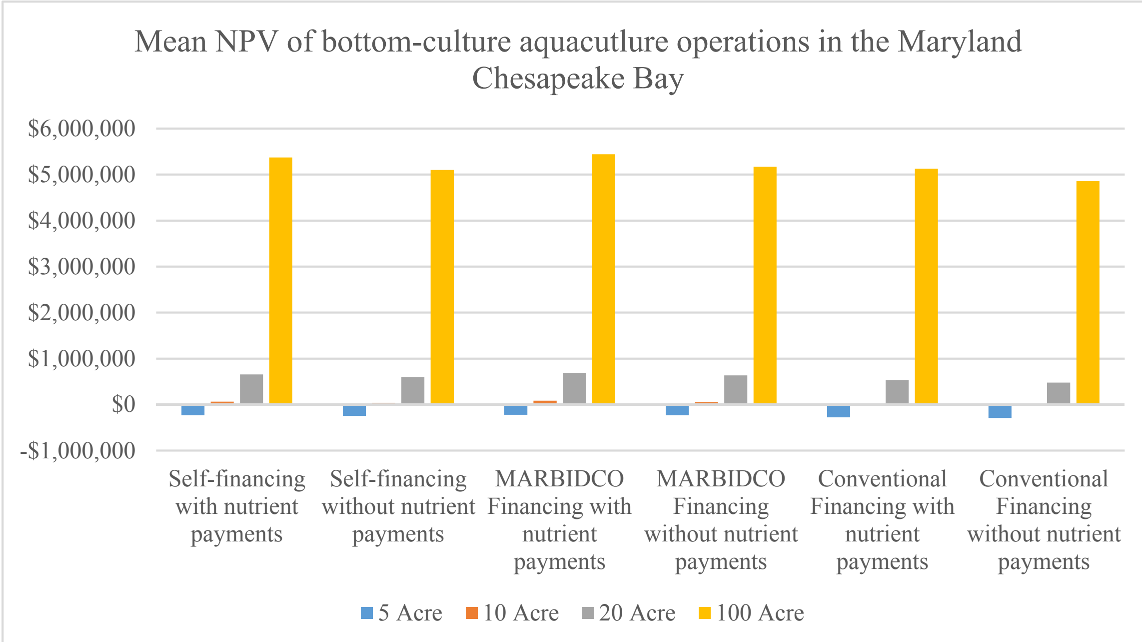


Figure 13. Mean NPV for oyster aquaculture operations in the Maryland Chesapeake Bay for all bottom-culture production levels, sources of capital, with and without nutrient payments.

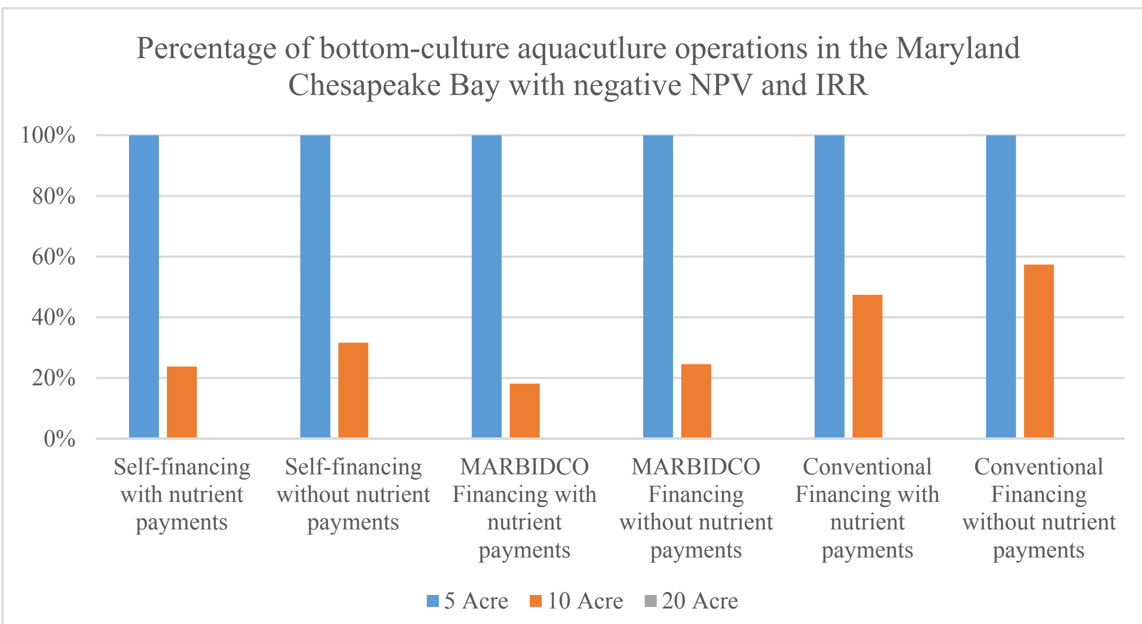


Figure 14. Percentage oyster aquaculture operations with negative NPV and IRR in the Maryland Chesapeake Bay for all bottom-culture production levels, sources of capital, with and without nutrient payments. One hundred-acre bottom-culture operations all had a positive NPV and IRR. Note the percentage of operations with a negative NPV and negative IRR for the 20-acre operations were less than 1% and do not show up due to scale.

Some operations with smaller leases may view their operation as supplemental family income, similar to a part-time job, which enables them to operate the lease with unpaid family labor due to the small area harvested each year. A simulation was performed to determine the difference between the mean yearly accounting profit, NPV, IRR, and percentage of operations with negative NPV & IRR from the original model and one where unpaid family labor was used (Table 80). There was a significant difference in the average yearly accounting profit, NPV, IRR for five, ten, and twenty-acre operations. The difference in percentage of operations with a negative NPV and IRR was only significant at the five and ten-acre sized operations. If an operation is small enough to operate as supplemental income with unpaid family labor, this strategy represents a way for small leases to be profitable operations.

*Table 80. Comparison of the effects of unpaid family labor on self-financed bottom-culture aquaculture operations not receiving nutrient payments in the Maryland Chesapeake Bay. Significant differences are marked with an *.*

Average Yearly Accounting Profit	Original Model Assumptions Mean	No Labor Costs Mean
Five Acre	-$31,713*	$34,316*
Ten-Acre	$12,911*	$79,270*
Twenty-Acre	$103,268*	$168,884*
Mean NPV		
Five Acre	-$244,133*	$192,064*
Ten-Acre	$38,552*	$473,551*
Twenty-Acre	$601,672*	$1,035,093*
Mean IRR		
Five Acre	-27.04%*	42.42%*
Ten-Acre	13.64%*	67.76%*
Twenty-Acre	58.12%*	98.26%*
Percentage of operations with negative NPV & IRR		
Five Acre	100.00%*	0.00%*
Ten-Acre	31.64%*	0.00%*
Twenty-Acre	0.04%	0.00%

Sensitivity analysis consistently indicated that the price per bushel had a large impact on the mean yearly accounting profit, NPV, and IRR of operations across all production levels despite the funding source. There is little an operation can do to influence the market price for oysters. However, some smaller-sized operators may try increasing the number of single oysters they produce for the half-shell market by "working" areas of their lease more often (i.e., pulling a bag-less dredge across areas of the lease to breakup oyster clumps). Alternatively, other options include actively sizing, washing, and boxing the harvest to present a more attractive product or selling their crop at venues such as local farmers markets where higher prices can be obtained for fresh shellfish are possible.

A simulation was performed to determine if doubling the amount of oysters sold to the half-shell market would have a significant effect on the mean yearly accounting profit, NPV, IRR and number of operations with a negative NPV and IRR on operations with smaller leases (Table 81). While there was a significant increase in the financial metrics for five, ten, and twenty-acre operations, the mean yearly accounting profit, NPV, and IRR was still negative for the five-acre operation. This finding indicates simply doubling the percentage of single oysters sold to the half-shell market, without reducing production costs per oyster, will not ensure the financial success of the smallest of operations. Assuming the same bushel per acre production level, operations at the ten and twenty-acre size had a positive mean yearly accounting profit with the original model assumptions, and may not feel that the potential additional is worth the additional return.

*Table 81. Comparison of the effects of doubling sales to the half-shell market on self-financed bottom-culture aquaculture operations not receiving nutrient payments in the Maryland Chesapeake Bay. Significant differences are marked with an *.*

Average Yearly Accounting Profit	Original Model Assumptions	Doubled Half-shell Sales
Five Acre	-$31,713*	-$23,936*
Ten-Acre	$12,911*	$28,545*
Twenty-Acre	$103,268*	$134,259*
Mean NPV		
Five Acre	-$244,133*	-194,630*
Ten-Acre	$38,552*	$134,526*
Twenty-Acre	$601,672*	$797,837*
Mean IRR		
Five Acre	-27.04%	-14.49%
Ten-Acre	13.64%*	24.37%*
Twenty-Acre	58.12%*	69.43%*
Percentage of operations with negative NPV & IRR		
Five Acre	100.00%	98.38%
Ten-Acre	31.64%	12.86%*
Twenty-Acre	0.04%	0.00%

Water-column Aquaculture Conclusions

As with the bottom-culture analysis, it was determined that there were economies of scale for water-column production of aquaculture oysters in the Maryland Chesapeake Bay. By examining self-financed operations without nutrient payments, as production increased, the break-even price per oyster decreased (Figure 15).

Special attention should be paid to the costs of inputs that affect the break-even price of the operation, especially regarding the amount and type of labor used. Labor hour estimates in this analysis 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 estimated in this analysis, or to forgo an owner's salary if they have other sources of income. Ted Cooney of Madhouse Oysters stated once, "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."

A simulation was performed for a self-financed, 500,000 oysters per year water-column operation that did not receiving nutrient payments to compare different labor management options. In the first simulation, general labor was reduced by 50% of the labor used in the original simulation. A second simulation was completed in which the effects of paying employees the original estimated labor amount, but without supervisory-owner salary (Table 82). Results indicate there was a significant difference in the mean yearly accounting profit, NPV, IRR, percentage of operations with negative NPV and IRR, and the payback period when labor costs were reduced by half. This infers reducing the general labor needed, possibly combined with the owner not drawing a salary, and could be one management strategy to help smaller water-column oyster operations to be profitable so they may build capital to expand production in the future. With both of these alternate strategies examined, there were still a high percentage of operations with a negative NPV and IRR. This result indicates, even with reduced labor costs, a 500,000 oyster per year water-column operation is a risky business investment, however if an operation receives payments for nutrient credits, they can help increase the chances of a positive NPV and positive IRR.

As seen in the analysis of bottom-culture operations, when the production scale increased, so did the value of the financial indicators. The mean yearly accounting profit for a 500,000 oysters harvested per year water-column operation was -$39,595 for a self-financed operation without nutrient payments, while in comparison, a 2.5 million oysters harvested per year farm with the same source of capital was $416,203 (Figure 16). This trend was true for all sources of capital, with and without nutrient payments. When examining NPV for operations of different production scales, as production scale increased (Figure 17) so did the NPV.

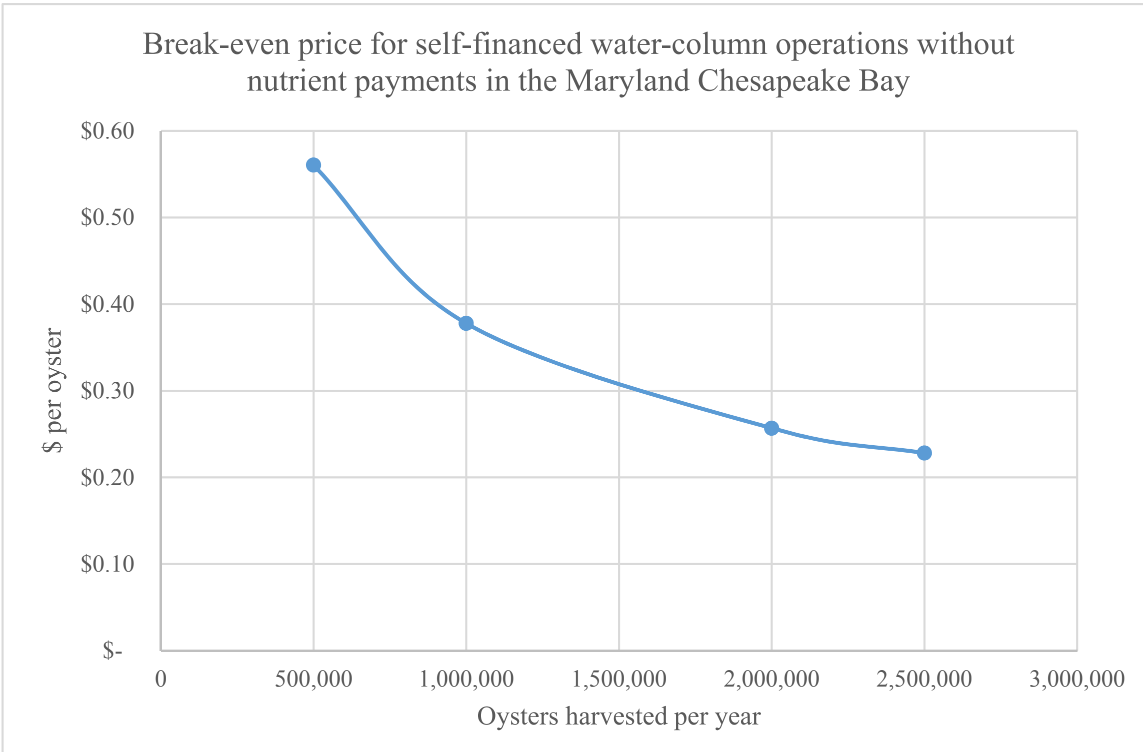


Figure 15. Break-even price per oyster harvested for self-financed water-column culture operations without nutrient payments with original model assumptions for labor and survival in Maryland, Chesapeake Bay.

*Table 82. Comparison of the effects of reduced labor estimates on a self-financed, 500,000 oysters harvested per year water-column aquaculture operation not receiving nutrient payments in the Maryland Chesapeake Bay. Significant differences are marked with an *.*

	Original Model	50% of estimated general labor	No Owner Salary
Mean Yearly Accounting Profit	-$39,595*	$18,608*	$6,966*
Mean NPV	-$356,650*	$31,990*	-$39,703*
Mean IRR	-12.61%*	10.09%*	5.08%*
Percent of operations with negative NPV and IRR	98.78%*	39.88%*	55.88%*
Mean Payback Period	>10 years*	7*	8*

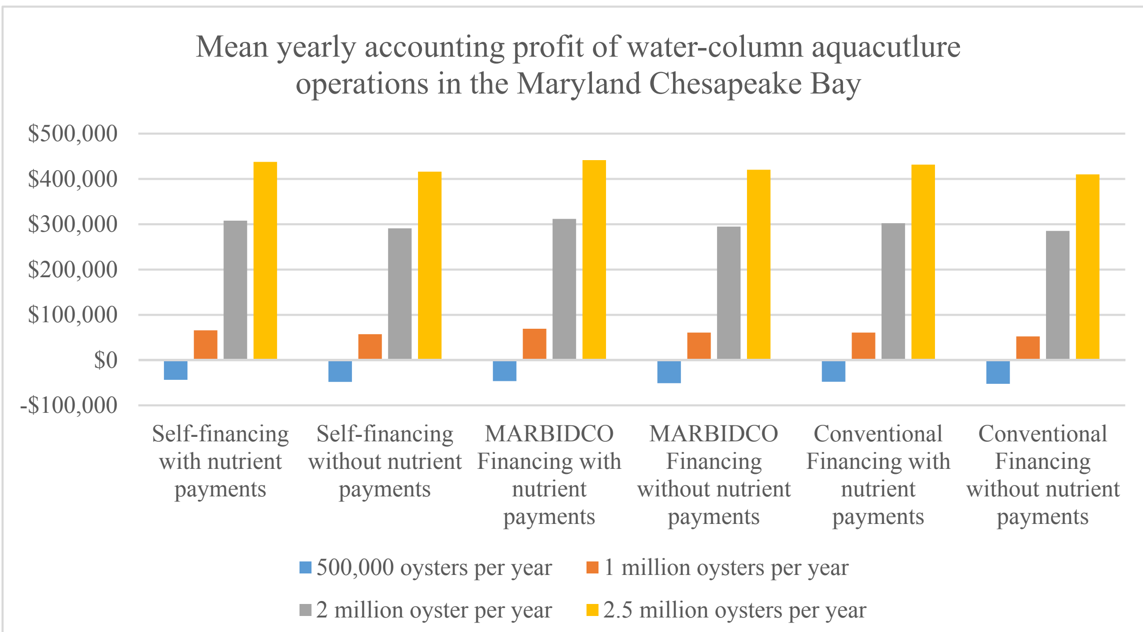


Figure 16. Mean yearly accounting profit for all water-column production levels, sources of capital, with and without nutrient payments in Maryland, Chesapeake Bay.

Sensitivity analysis consistently indicated that the price per oyster had a large impact on the mean yearly accounting profit, mean NPV, and mean IRR of operations across all production levels. As mentioned previously an aquaculture operation has limited influenced on the price of oysters they sell.

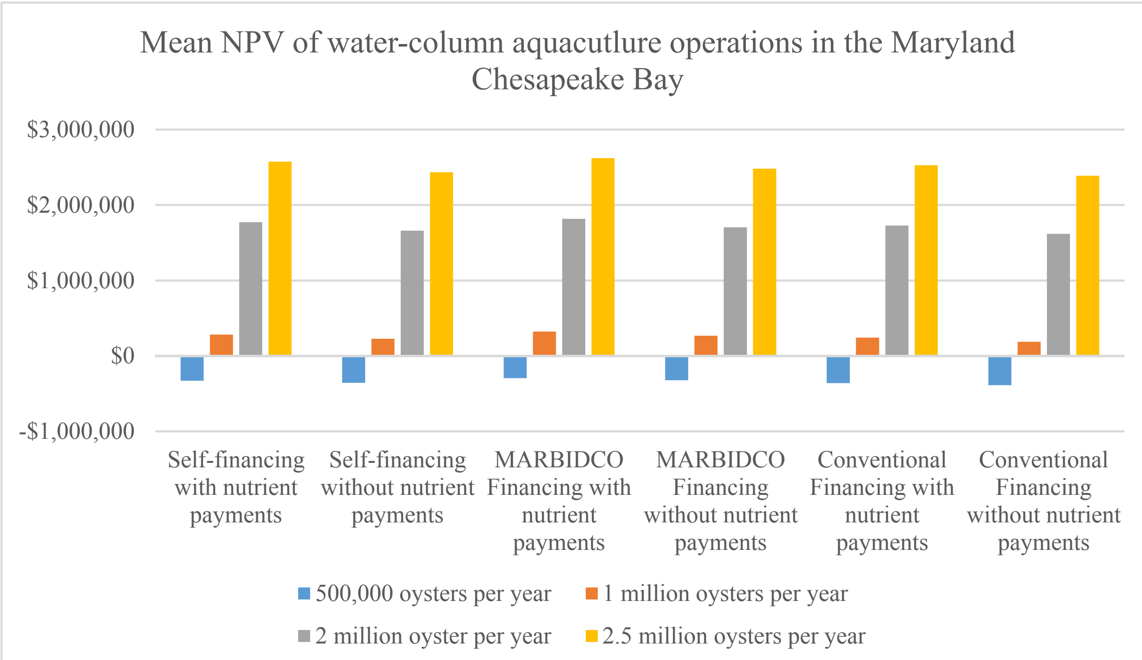


Figure 17. Mean NPV for all water-column culture production levels, sources of capital, with and without nutrient payments in theMaryland, Chesapeake Bay.

Overall 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 size before break-even profits were realized (Figure 11 &, Figure 15). 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 this industry may not have the needed capital to start their operation and have no other choice than to utilize some form of debt financing. 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.

Future Work

As seen in the ten-year enterprise budgets (Appendix B) one of the major factors influencing the financial success of any oyster aquaculture operation in the state of Maryland are costs associated with labor. As production levels increase, so does the amount of labor needed. As a result, many farms are looking for ways to mechanize parts of the production process or reduce overall labor costs in both bottom-culture and water-column oyster culture. Future studies should examine the costs of labor as different types of equipment are designed and implemented. For bottom-culture and water-column culture operations, a detailed analysis of labor usage in the Maryland aquaculture industry is needed to make better recommendations on farm profitability.

As mechanisms for a nutrient trading marketplace are completed, and more oyster BMPs are approved for nutrient removal, further analysis should be undertaken to complement the analysis performed by Weber et al. (2018) to determine the effects of nutrient trading on farm profitability.

Concerning financing oyster aquaculture operations, more research is needed on the effects of combining financing sources. For example, an operation may borrow money from MARBIDCO to get started and then refinance the remaining principle after the interest-only period has expired with a conventional lender. This approach could stretch principle payments out over a longer period. While possibly increasing the overall cost of debt financing, the effects of refinancing the remaining principle on farm cash flow should be explored and compared with self-financed operations. Additionally, it should be determined how long an owner could realistically go without a paid salary as the operation grows before the operation fails.

Many growers expect a catastrophic mortality event to affect their farms at least once every ten years as a result of severe weather or increased prevalence of diseases. By all accounts 2018, was an unusually wet year for the Chesapeake Bay watershed and the effects on oysters growing in the Chesapeake Bay are still to be determined (Smedinghoff, 2018). As the model is refined, catastrophic mortality events should be incorporated to better estimate associated impacts on farm level profitability.

Appendices

Appendix A- Sensitivity Analysis Results

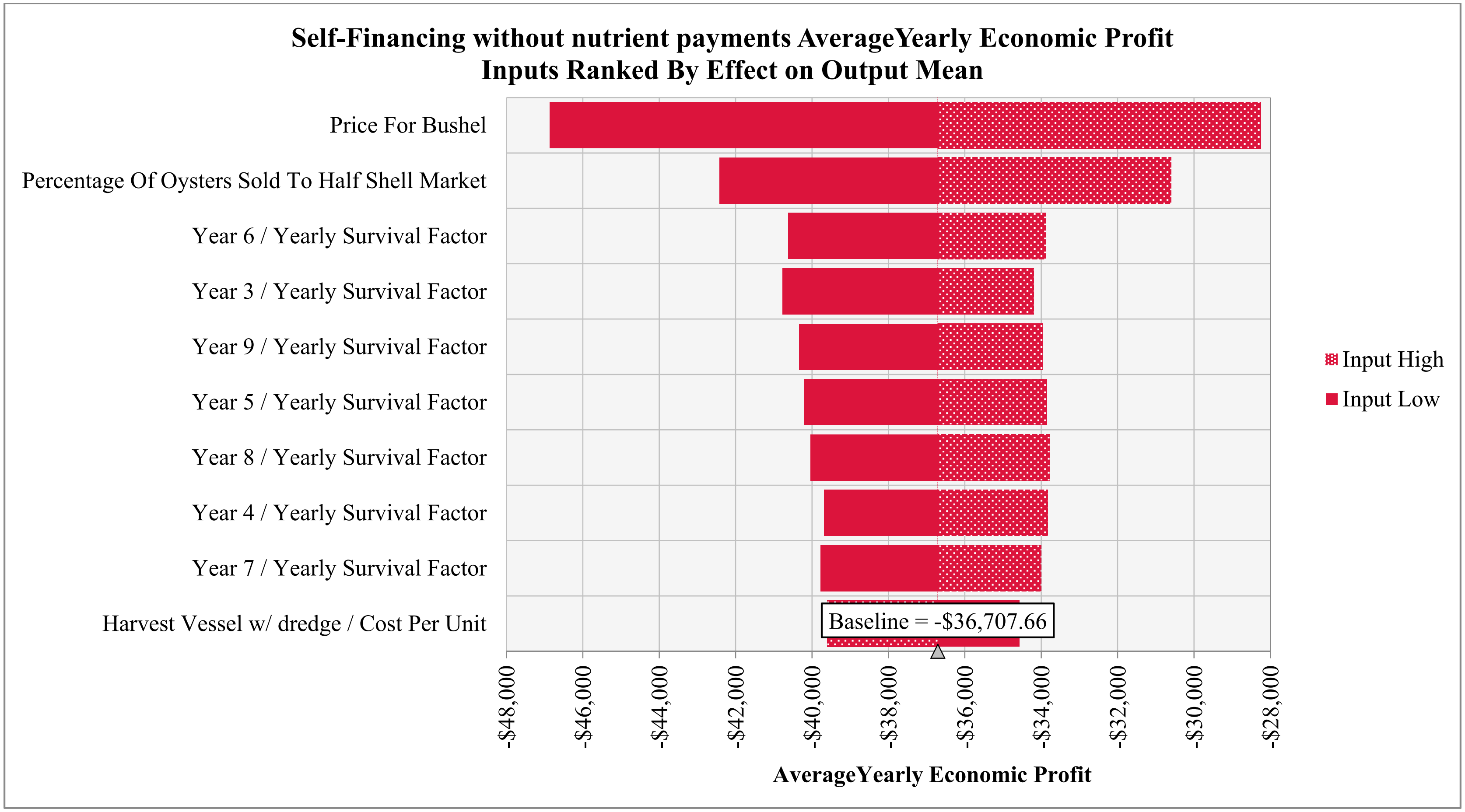


Figure A-1. Sensitivity Analysis for average yearly accounting profit for five-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

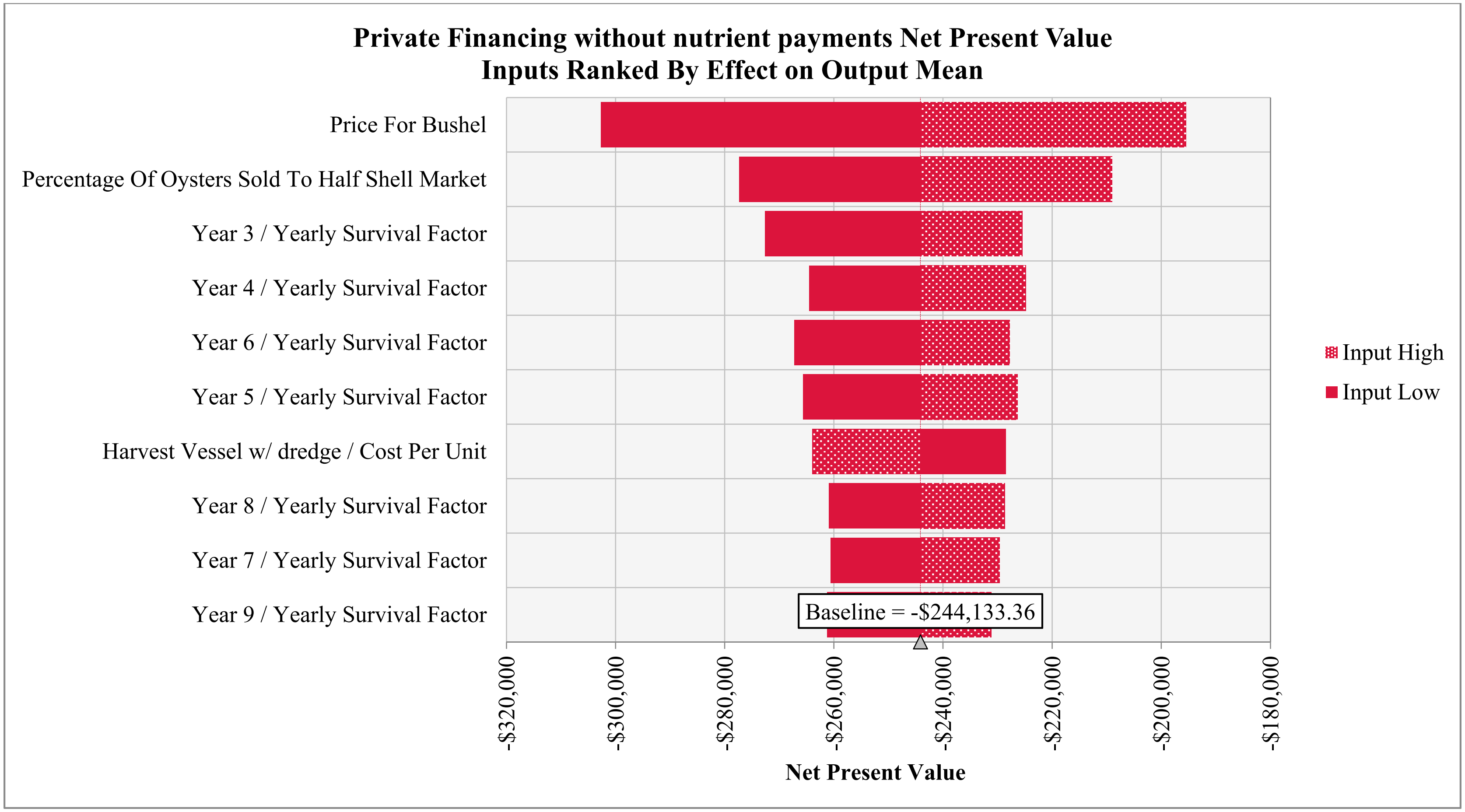


Figure A-2. Sensitivity Analysis for NPV for five-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

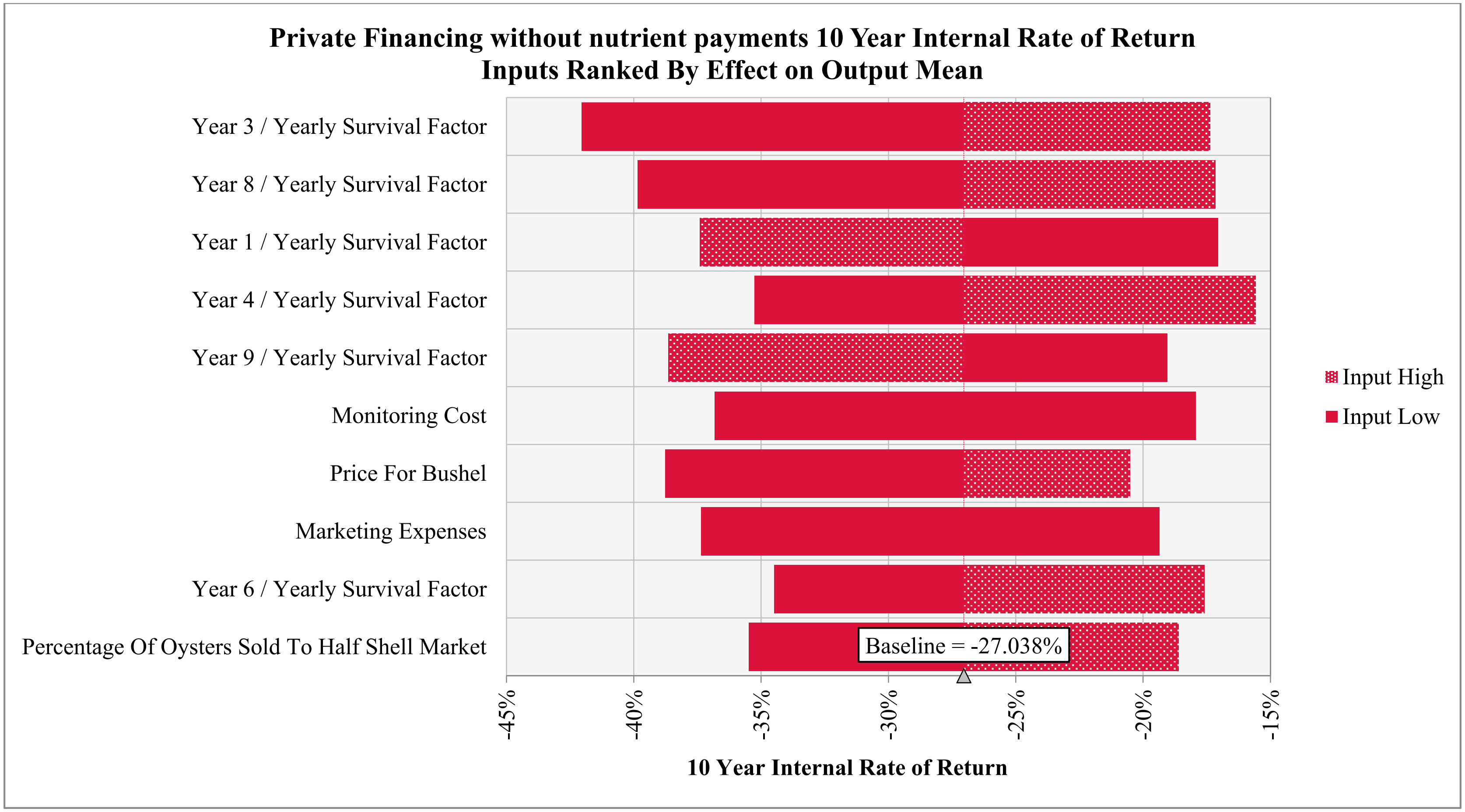


Figure A-3. Sensitivity Analysis for IRR for five-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

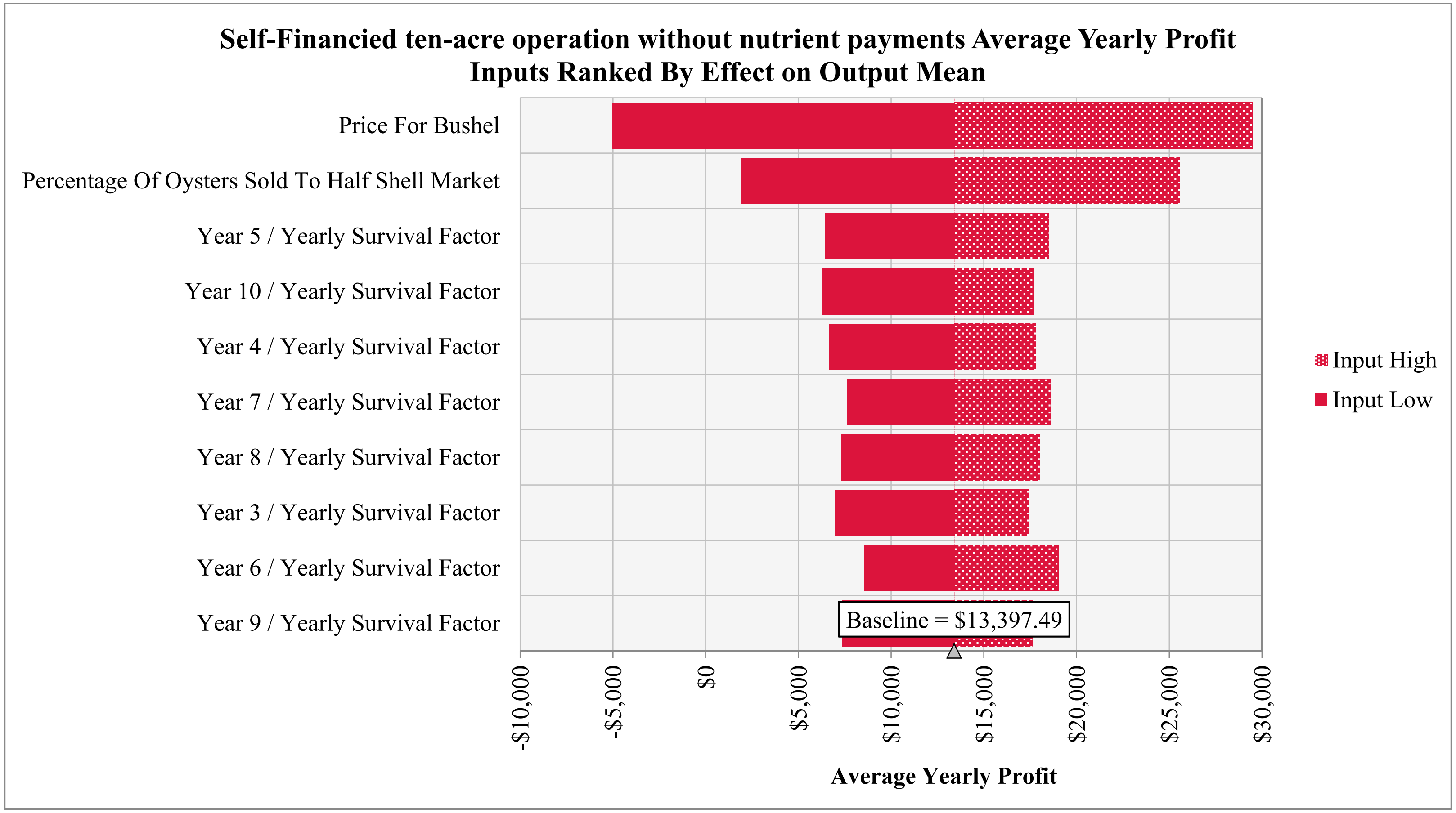


Figure A-4. Sensitivity Analysis for average yearly accounting profit for ten-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

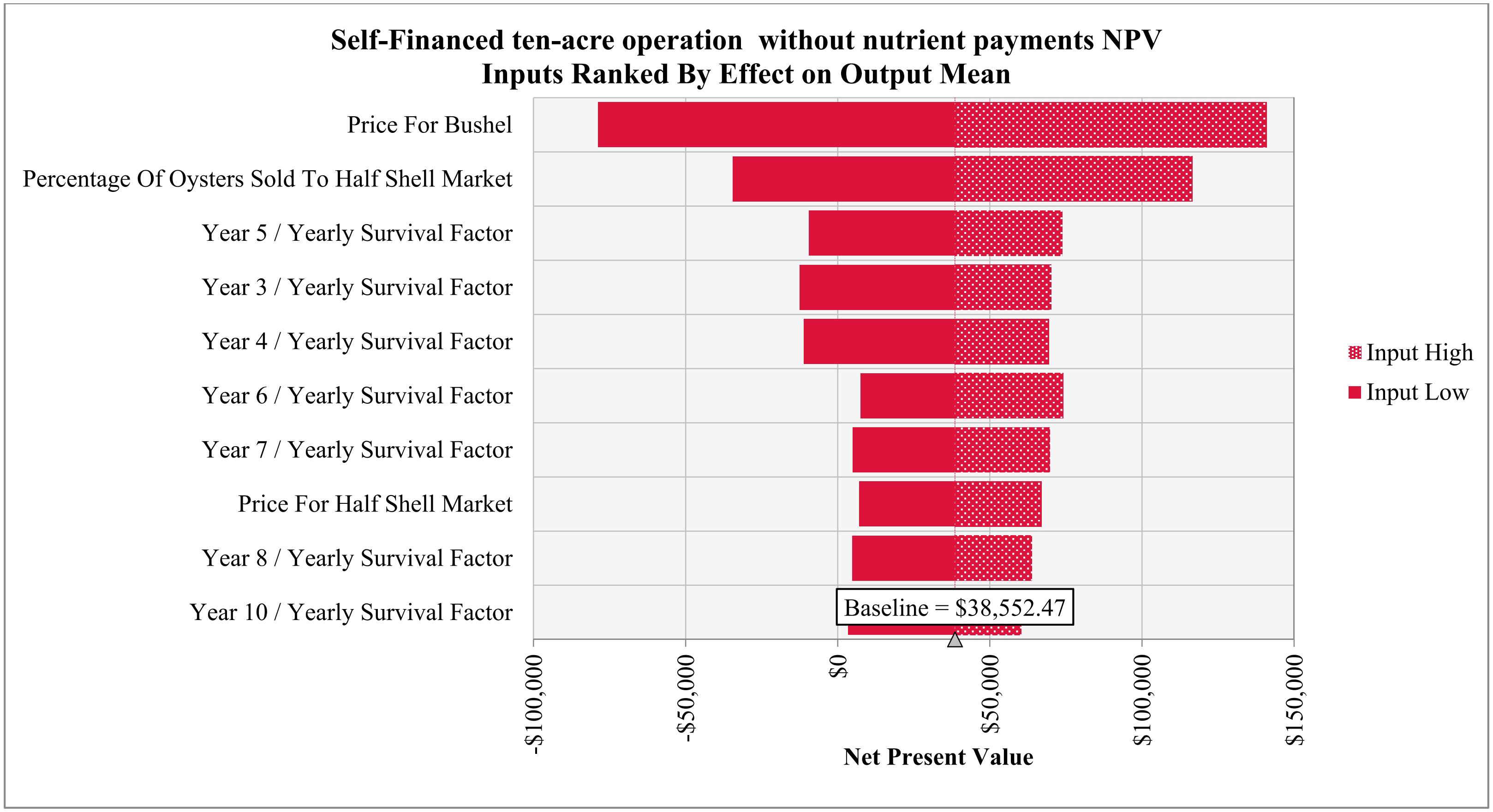


Figure A-5. Sensitivity Analysis for mean NPV for ten-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

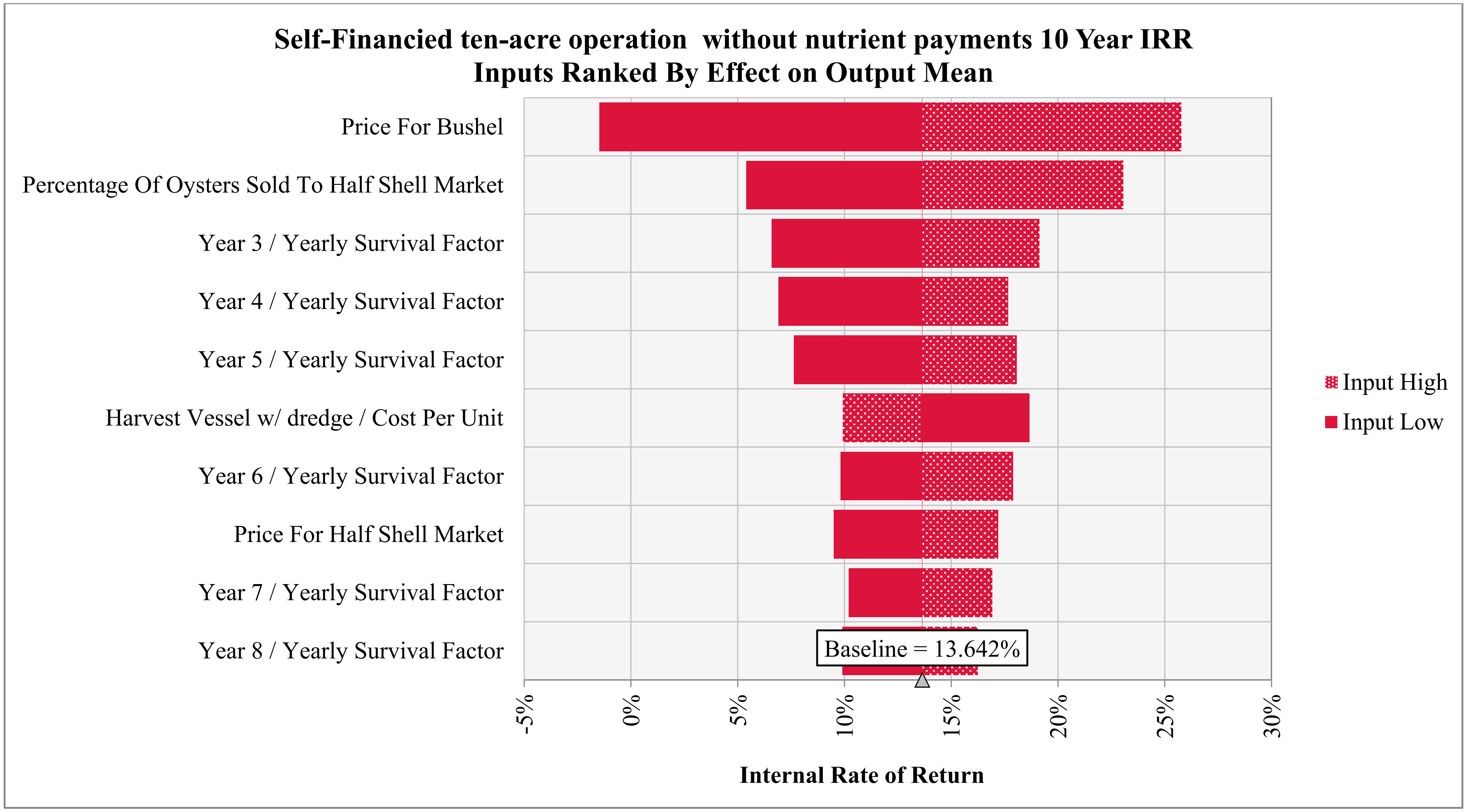


Figure A-6. Sensitivity Analysis for mean IRR for ten-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

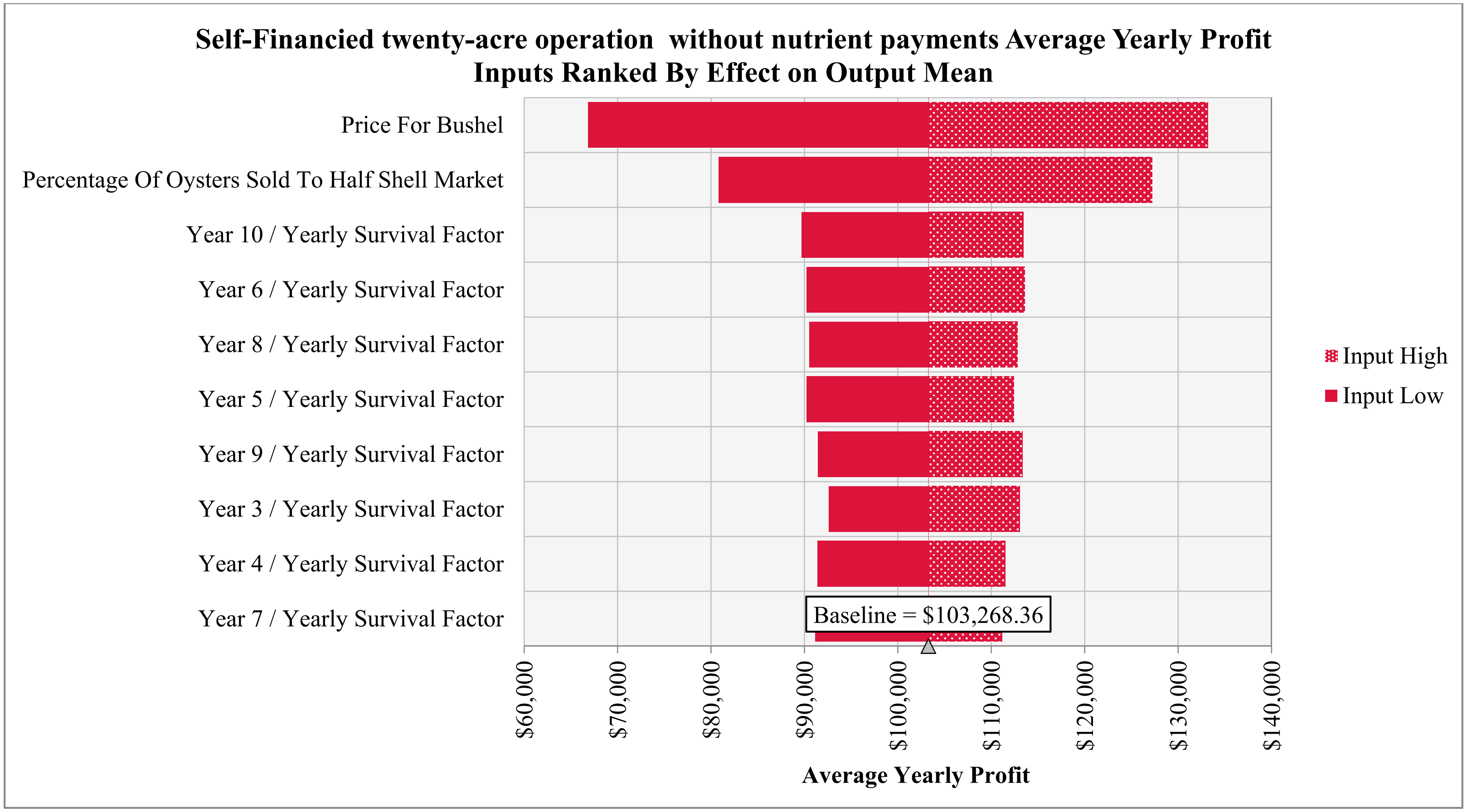


Figure A-7. Sensitivity Analysis for average yearly accounting profit for twenty-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

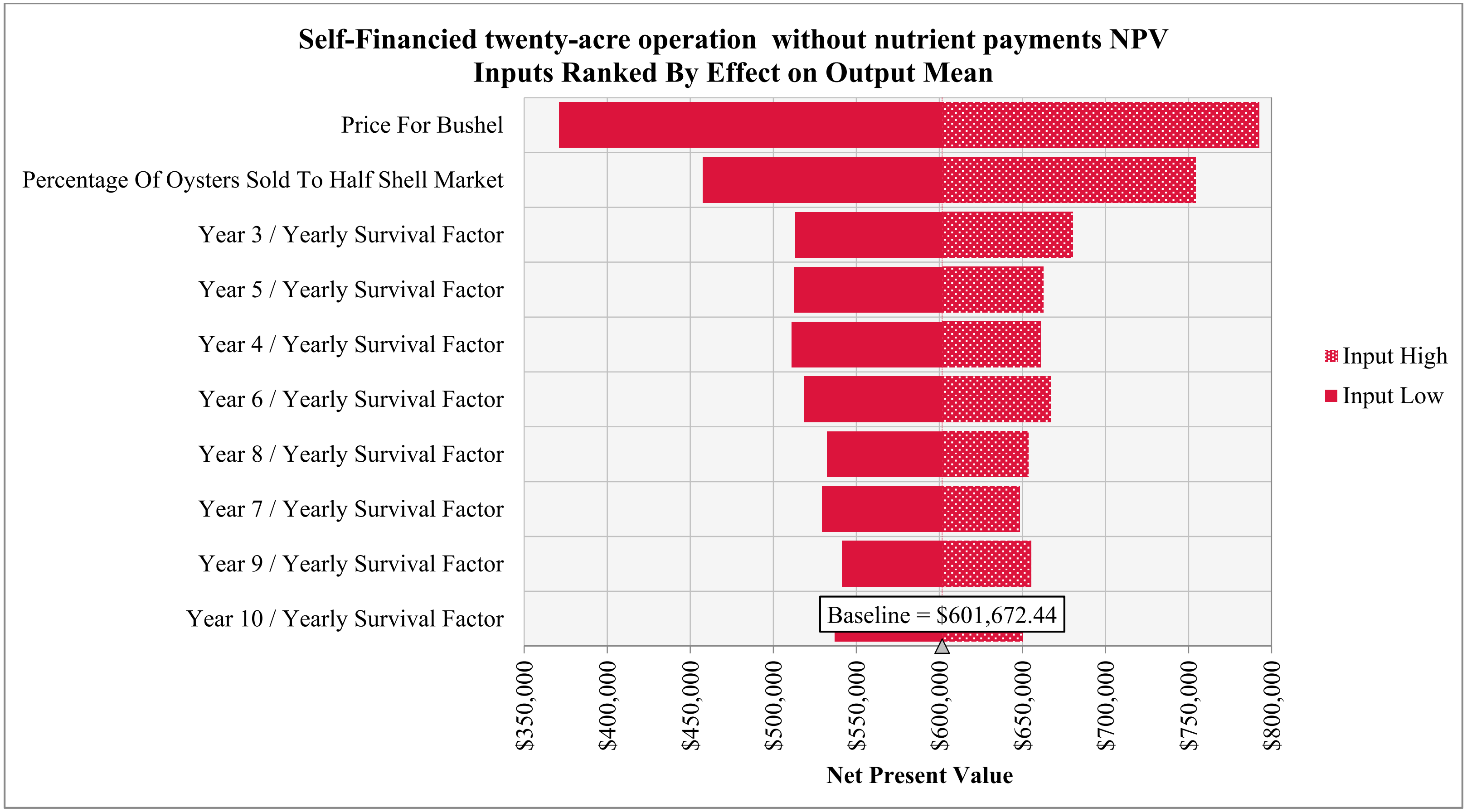


Figure A-8. Sensitivity Analysis for mean NPV for twenty-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

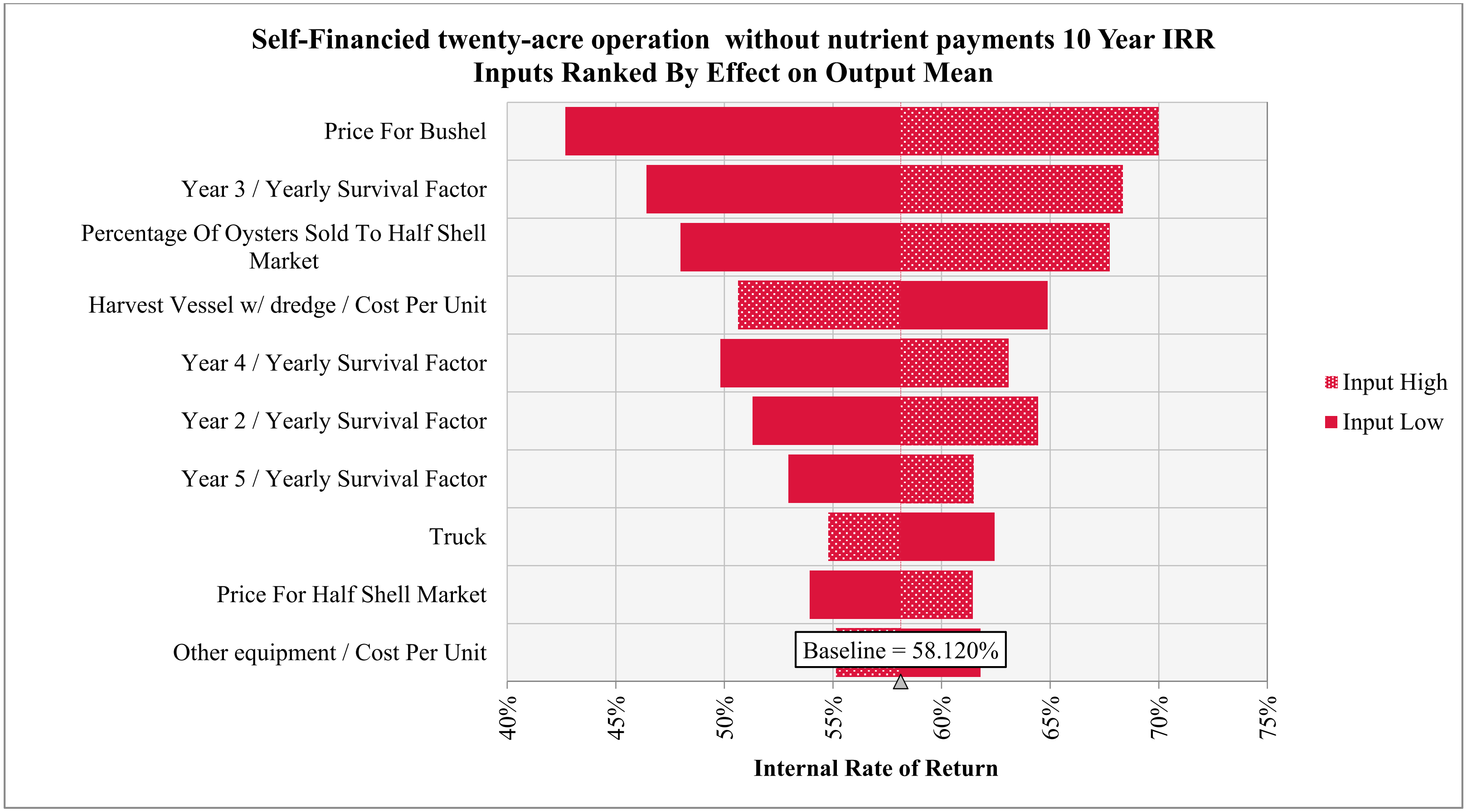


Figure A-9. Sensitivity Analysis for mean IRR for twenty-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

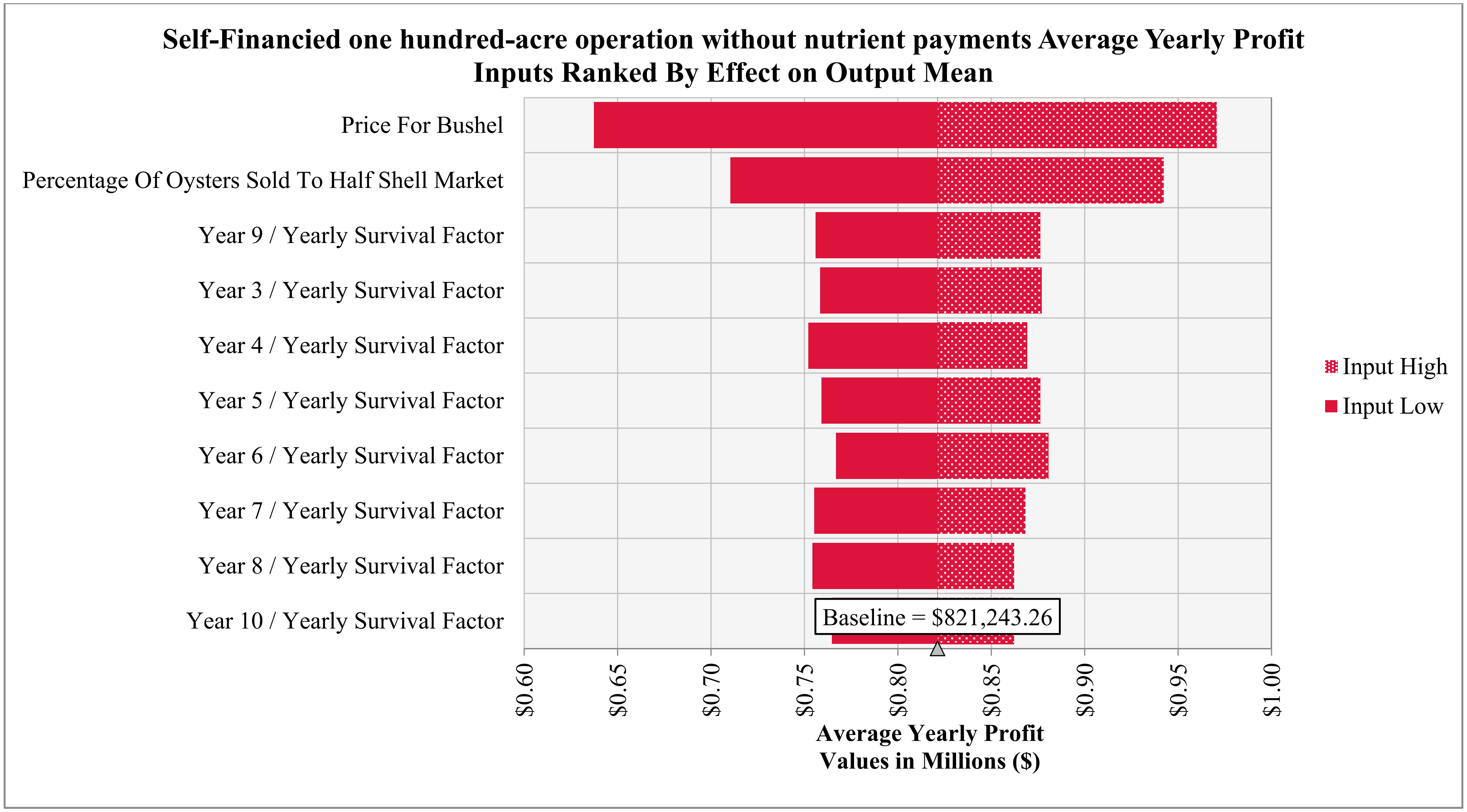


Figure A-10. Sensitivity Analysis for average yearly accounting profit for one hundred-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

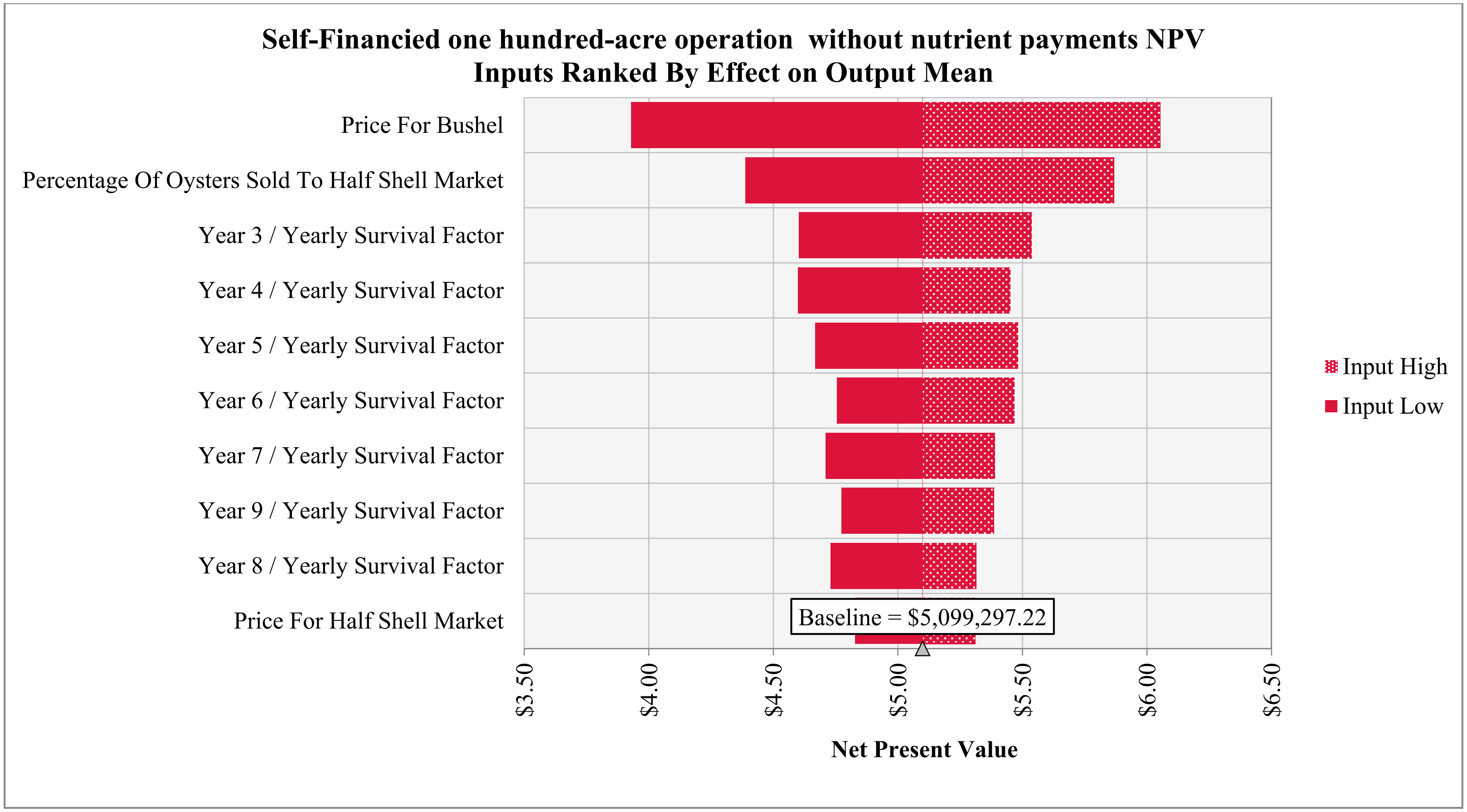


Figure A-11. Sensitivity Analysis for mean NPV for one hundred-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

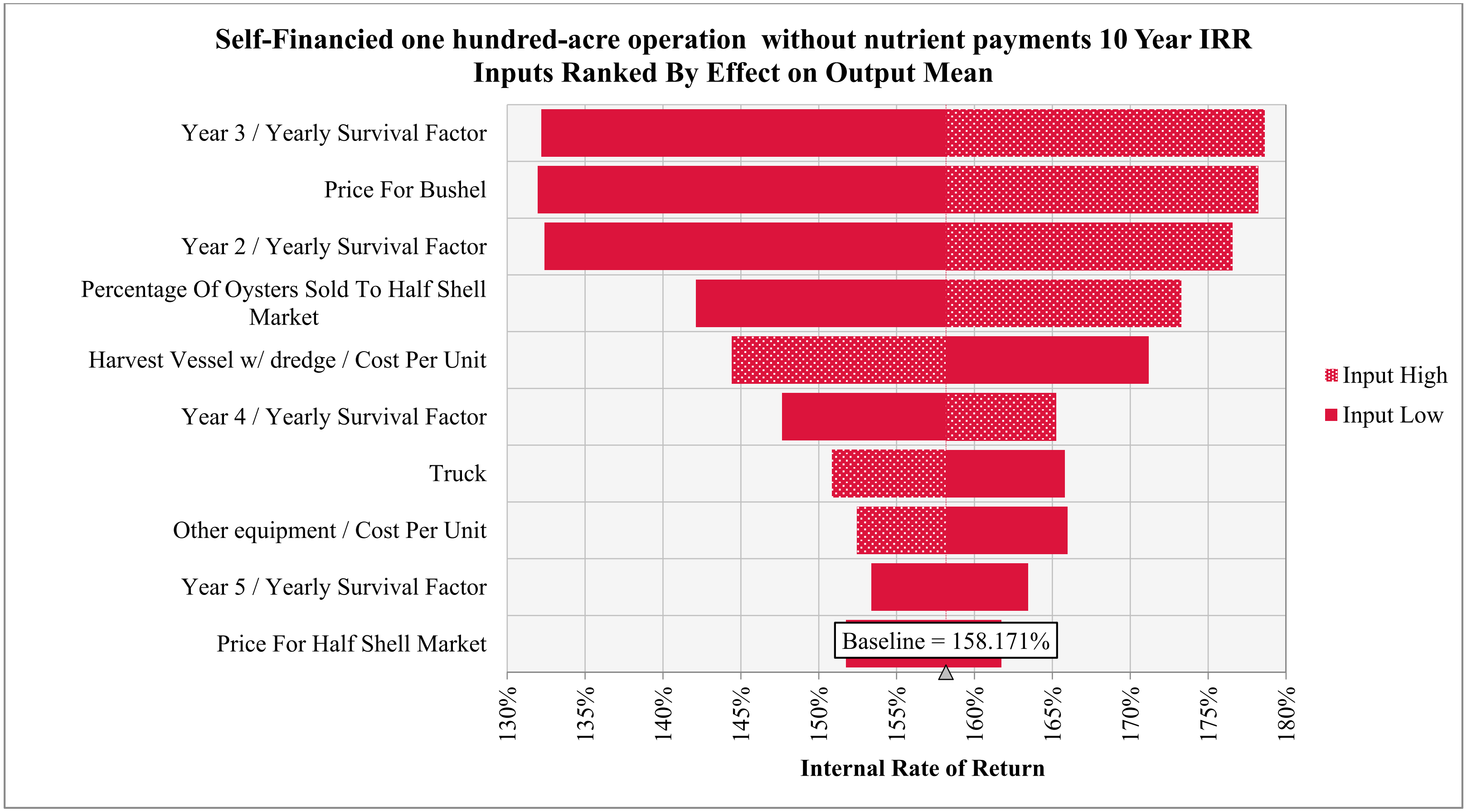


Figure A-12. Sensitivity Analysis for mean IRR for one hundred-acre bottom-culture oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

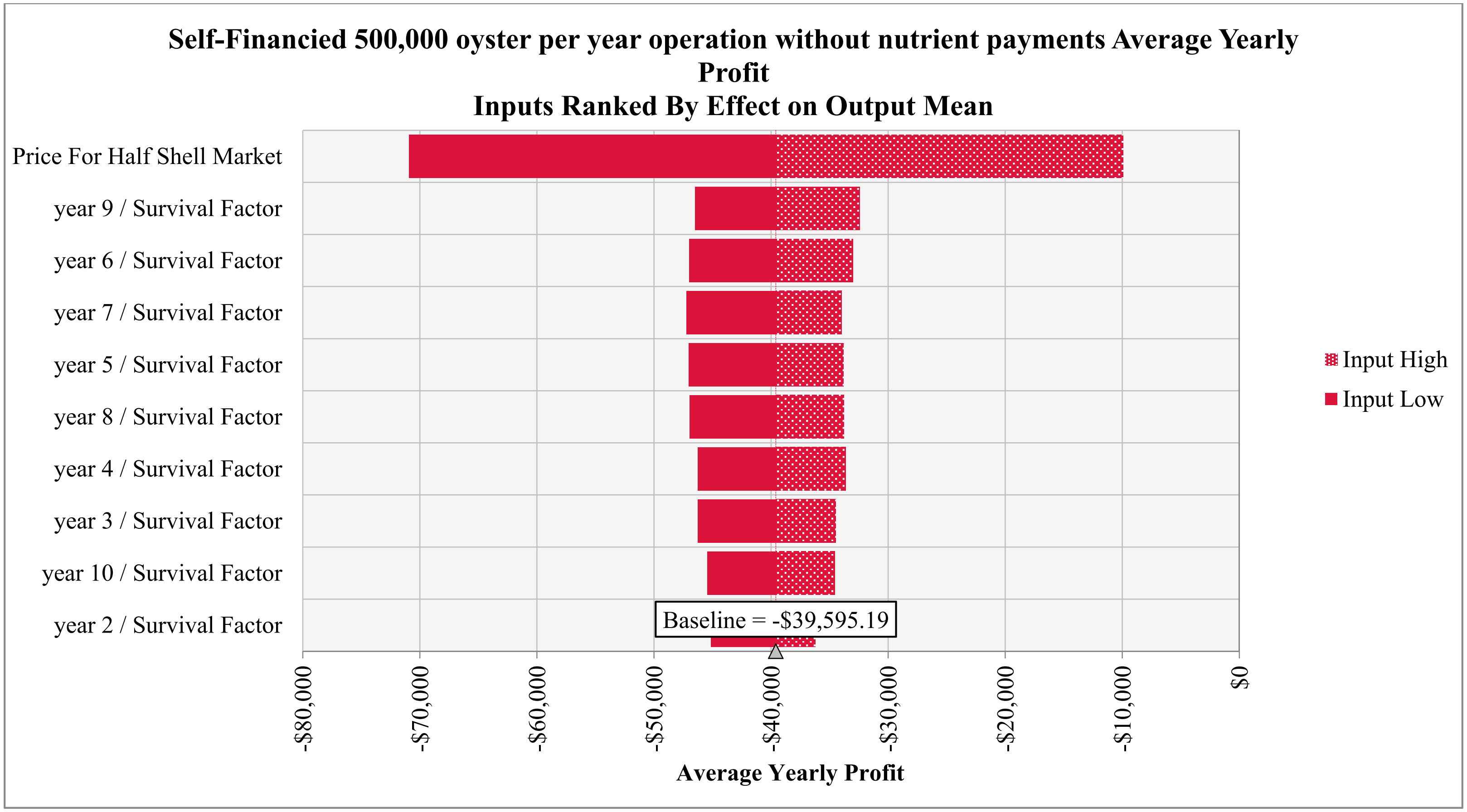


Figure A-13. Sensitivity Analysis for average yearly accounting profit for 500,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

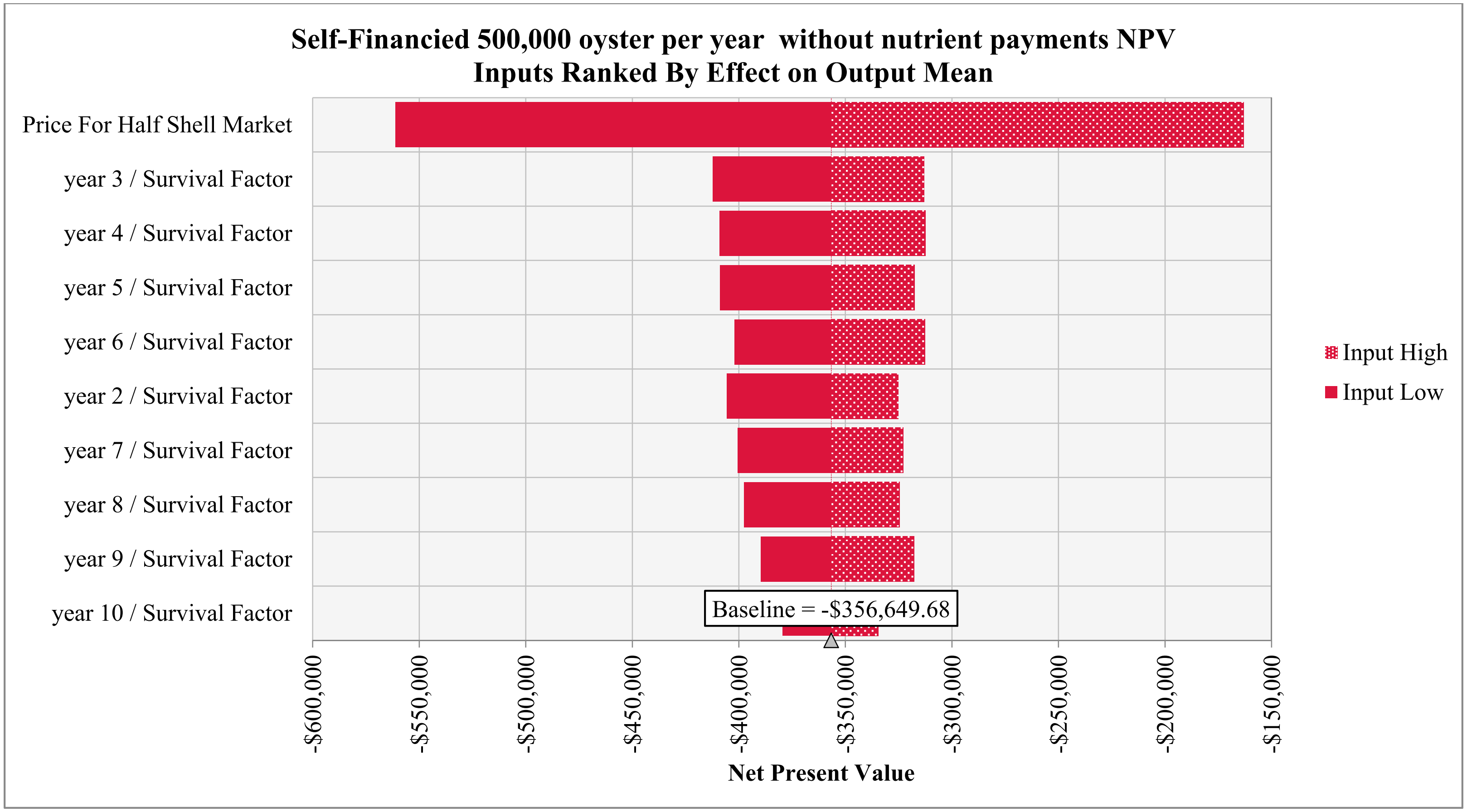


Figure A-14. Sensitivity Analysis mean NPV for 500,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

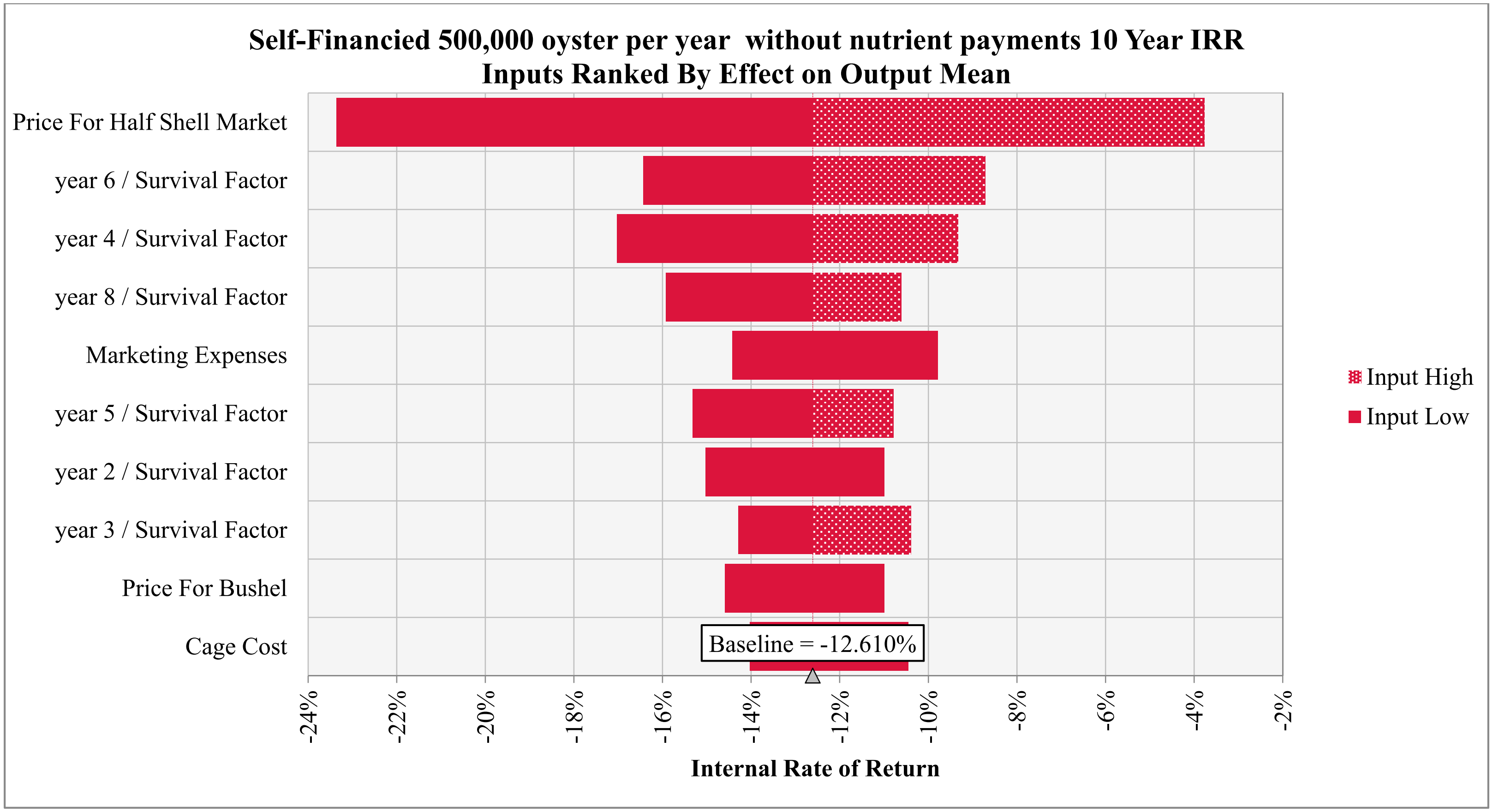


Figure A-15. Sensitivity Analysis mean IRR for 500,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

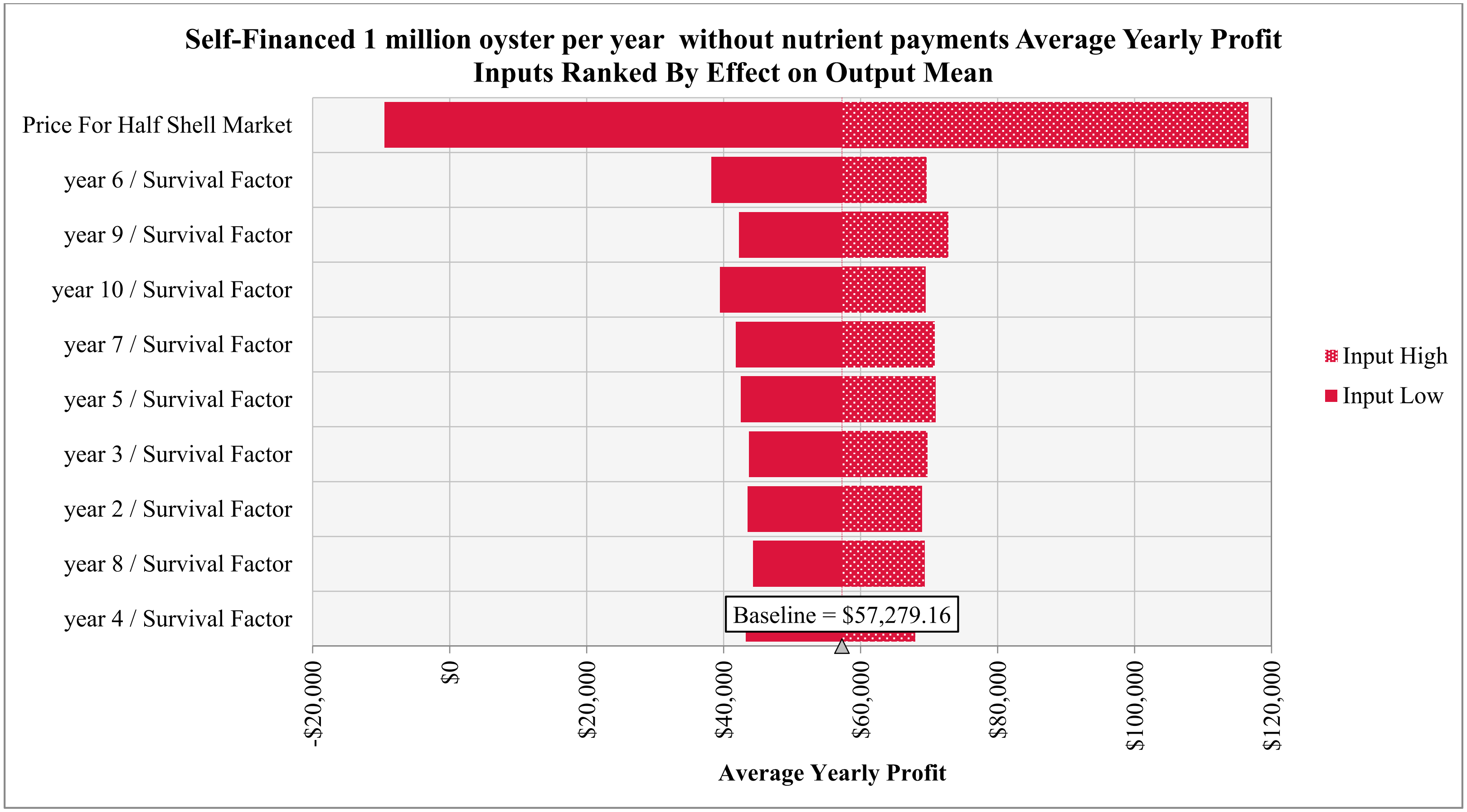


Figure A-16. Sensitivity Analysis for average yearly accounting profit for 1,000,000 oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

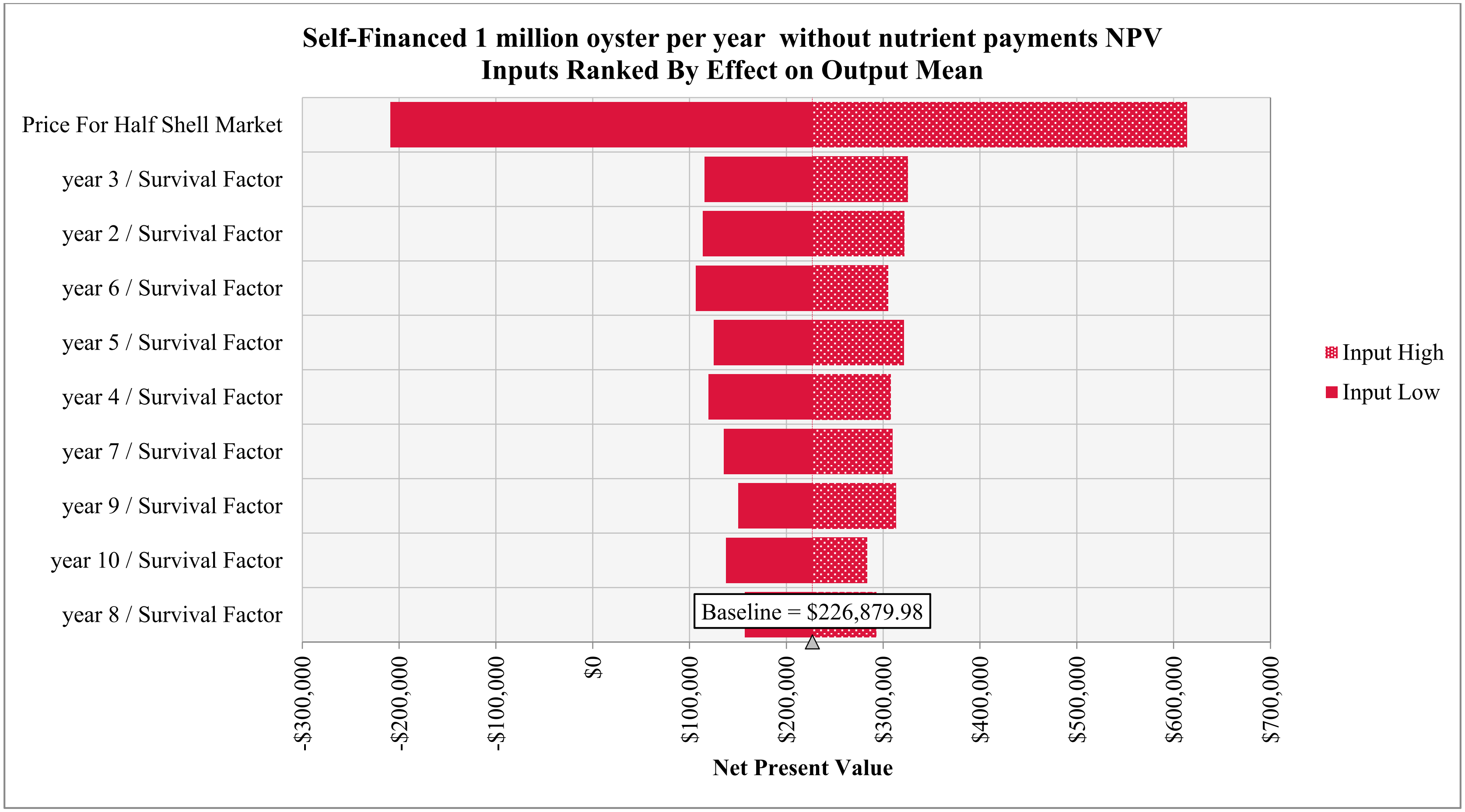


Figure A-17. Sensitivity Analysis for mean NPV for 1,000,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

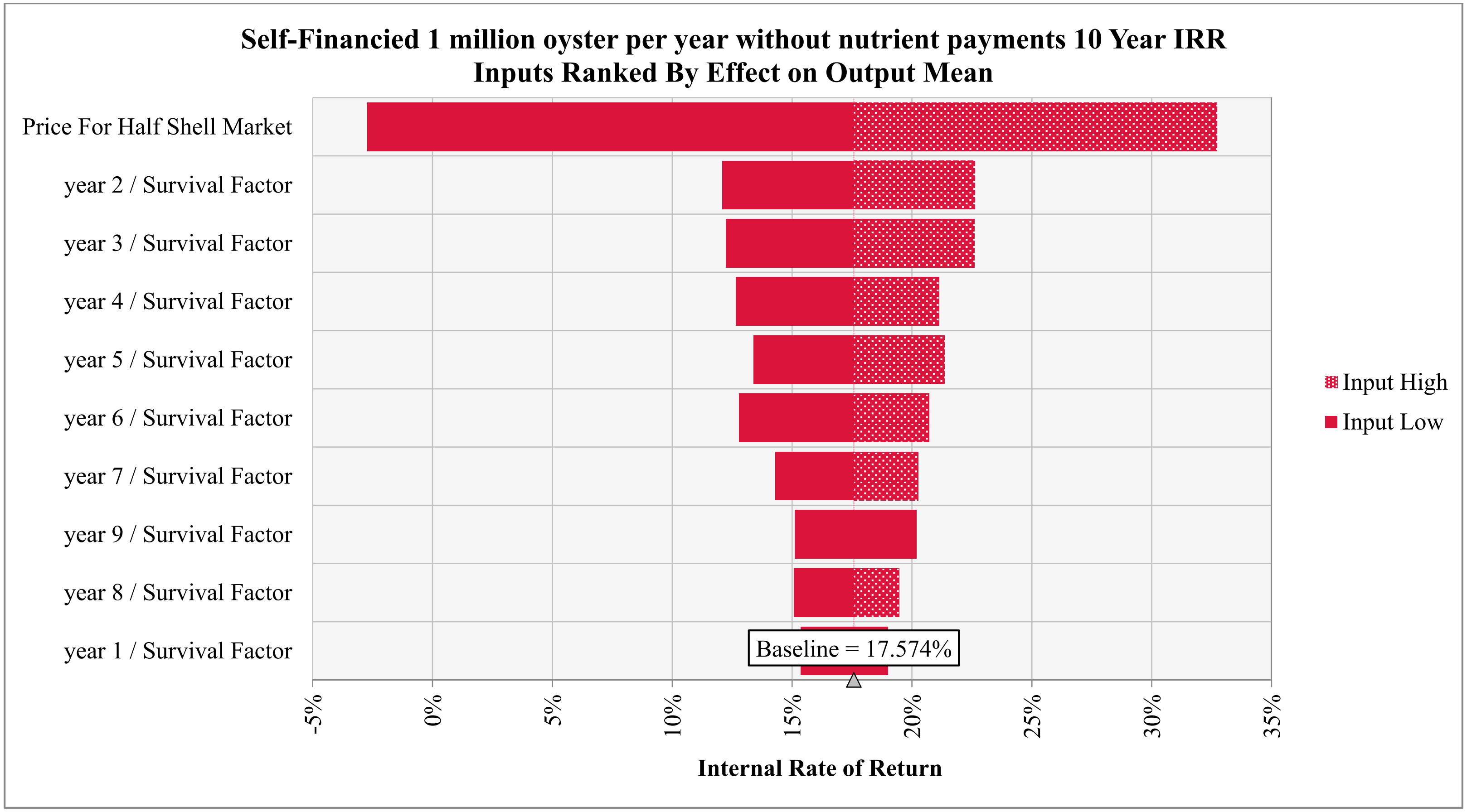


Figure A-18. Sensitivity Analysis for mean IRR for 1,000,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

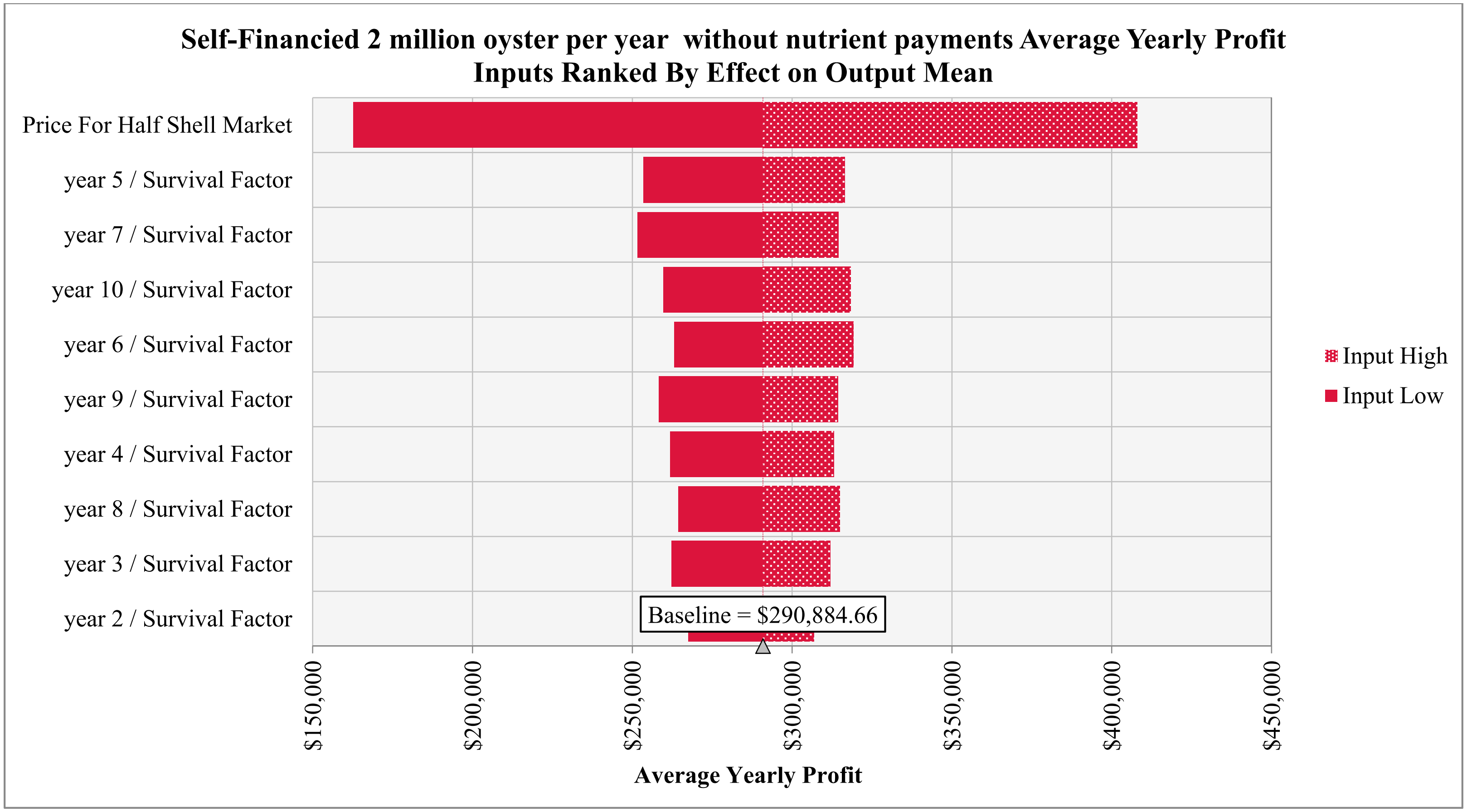


Figure A-19. Sensitivity Analysis for average yearly accounting profit for 2,000,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

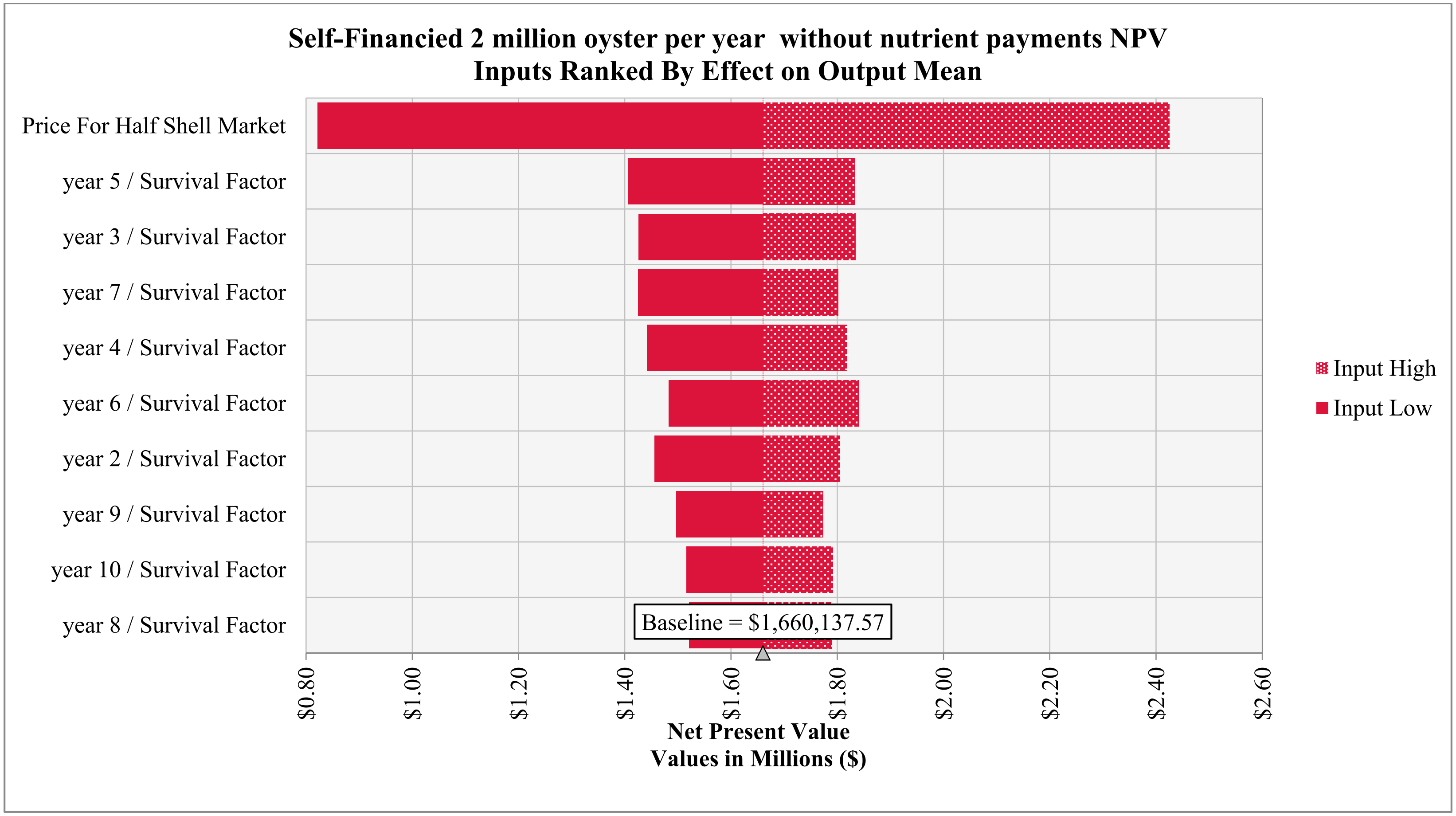


Figure A-20. Sensitivity Analysis for mean NPV for 2,000,000 oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

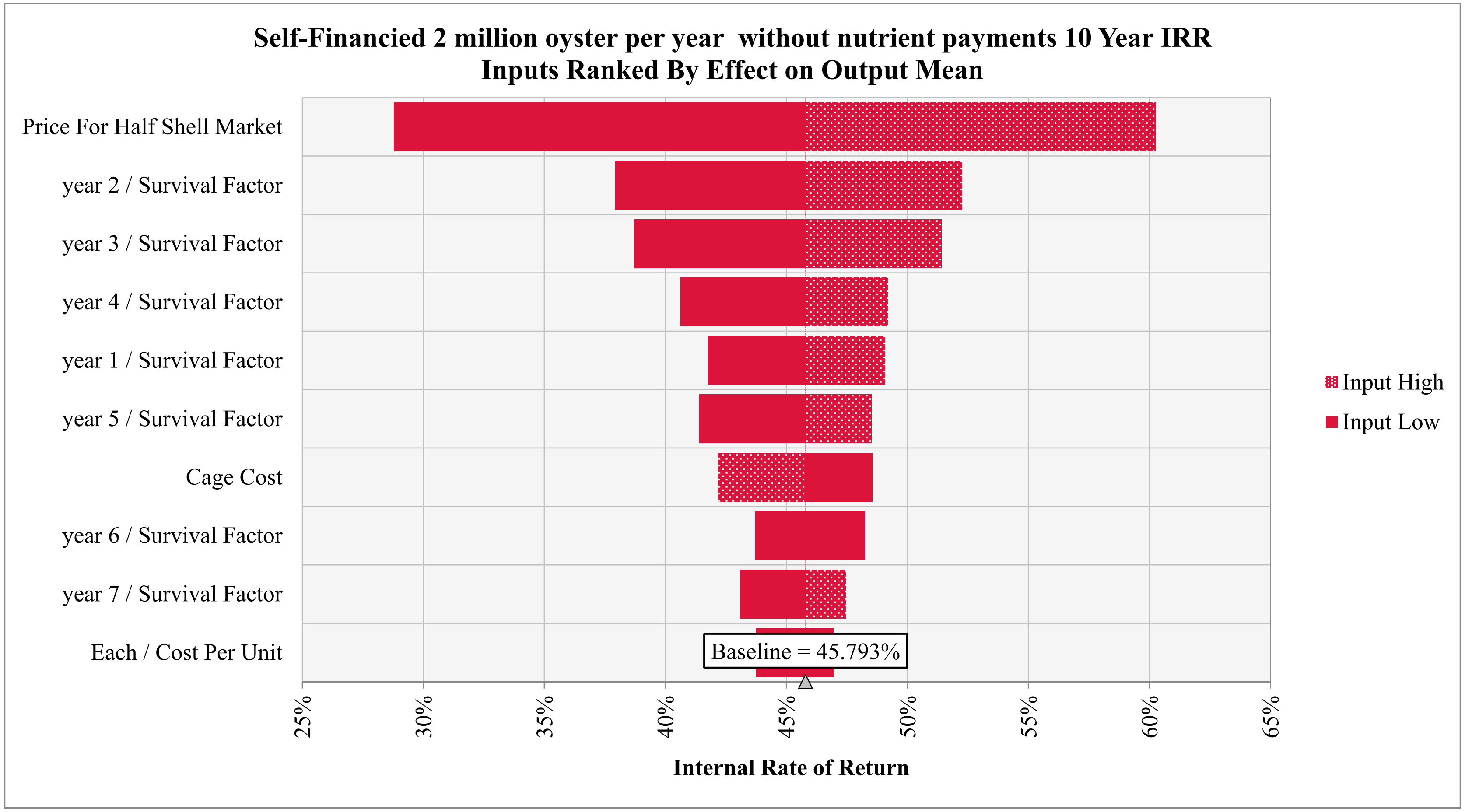


Figure A-21. Sensitivity Analysis for mean IRR for 2,000,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

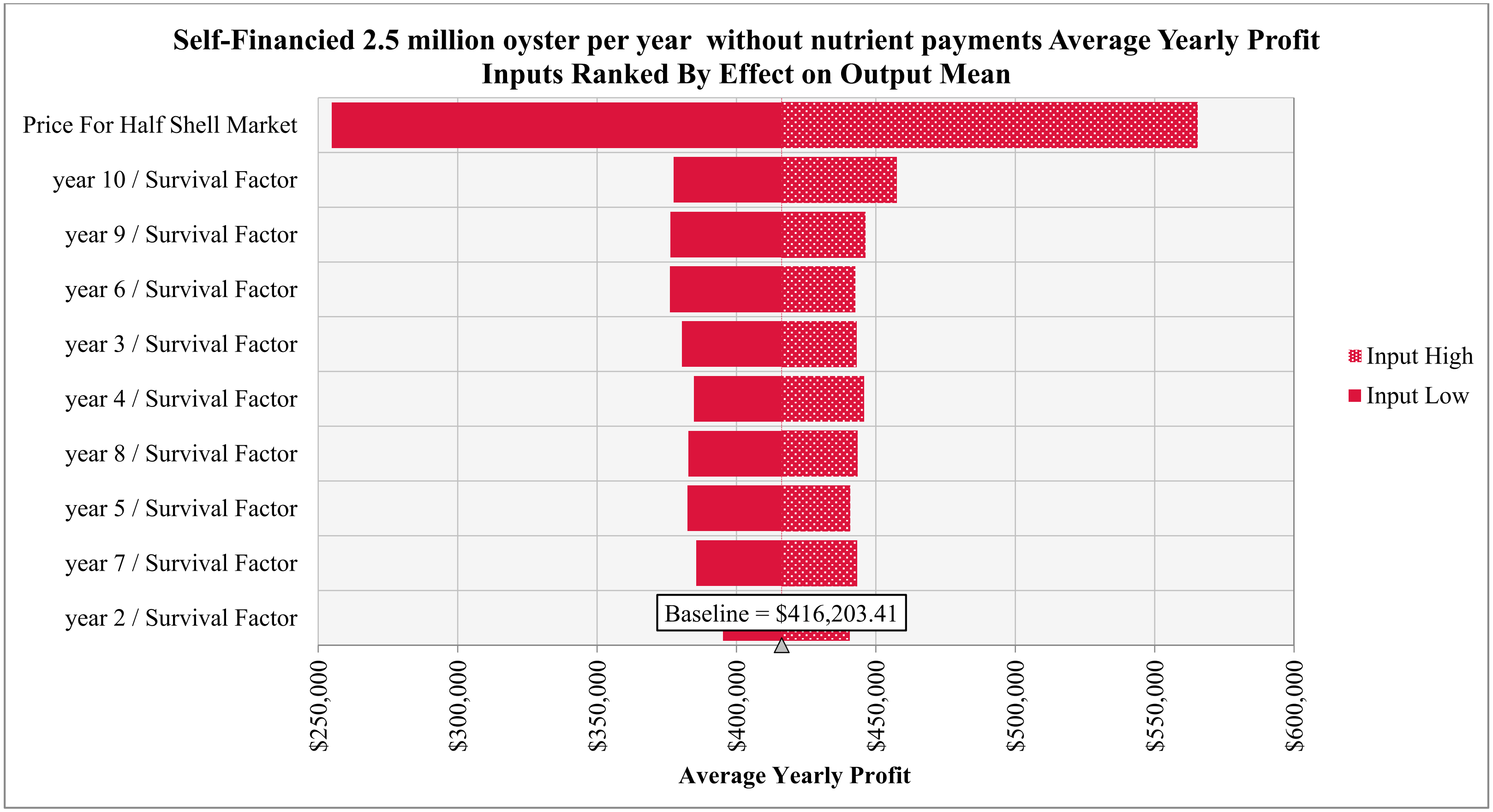


Figure A-22. Sensitivity Analysis for average yearly accounting profit for 2,500,000 oysters per year water-column operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

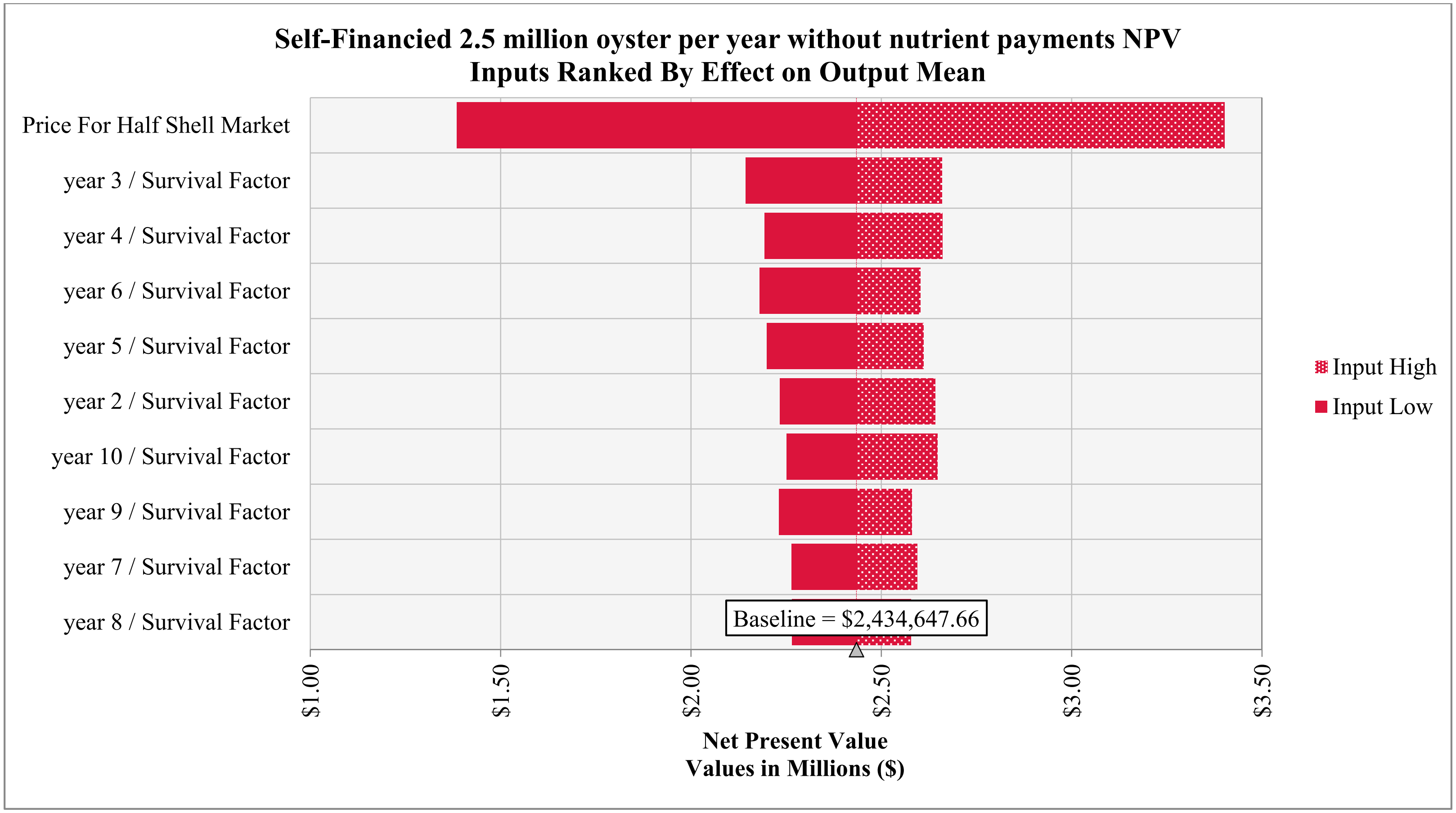


Figure A-23. Sensitivity Analysis for mean NPV for 2,500,000 oysters per year water-column oyster aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay.

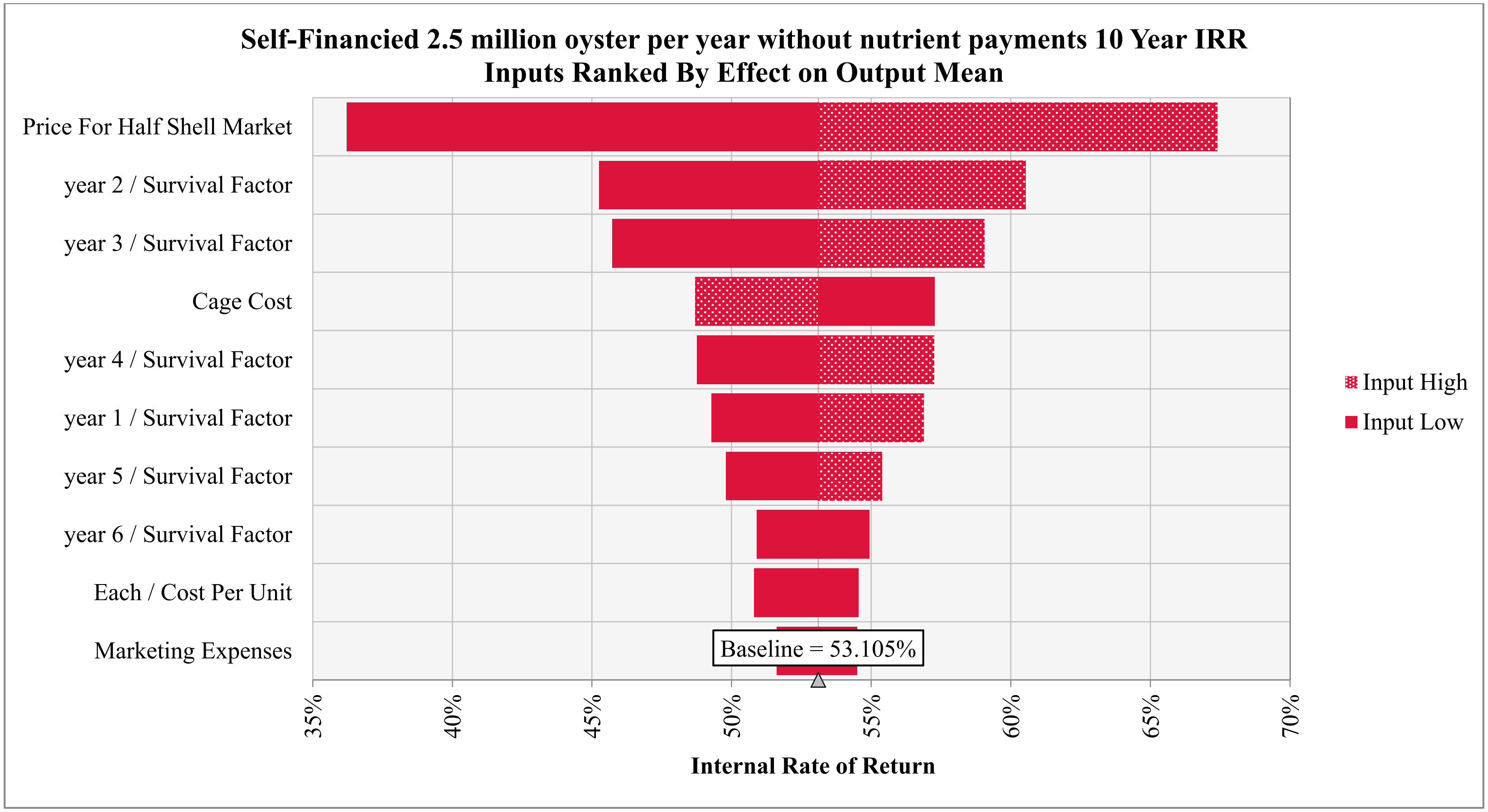


Figure A-24. Sensitivity Analysis for mean IRR for 2,500,000 oysters per year water-column aquaculture operation with private financing not receiving nutrient payments in the Maryland Chesapeake Bay

Appendix B- 10 Year Enterprise Budgets

	Private Funds with Nutrient Payments		Private Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	***Total $***	% of Income	***Total $***	% of Income	***Total $***	% of Income	***Total $***	% of Income	***Total $***	% of Income	***Total $***	% of Income
Half Shell Market Oysters	$ 145,961	23.53%	$ 145,961	24.47%	$ 145,961	23.53%	$ 145,961	24.47%	$ 145,961	23.53%	$ 145,961	24.47%
Bushel Oyster Markets	$ 450,585	72.65%	$ 450,585	75.53%	$ 450,585	72.65%	$ 450,585	75.53%	$ 450,585	72.65%	$ 450,585	75.53%
Total Nutrient Payments	$ 23,668	3.82%			$ 23,668	3.82%			$ 23,668	3.82%		
Total Gross Income	$ 620,214		$ 596,546		$ 620,214		$ 596,546		$ 620,214		$ 596,546	
Variable Cost												
Item	***Total $***	***Percentage Of Total Cost***	***Total $***	***Percentage Of Total Cost***	***Total $***	***Percentage Of Total Cost***	***Total $***	***Percentage Of Total Cost***	***Total $***	***Percentage Of Total Cost***	***Total $***	***Percentage Of Total Cost***
Spat on Shell	$ 92,400	9.78%	$ 92,400	9.78%	$ 92,400	9.69%	$ 92,400	9.69%	$ 92,400	9.65%	$ 92,400	9.65%
Labor												
General Labor	$ 297,500	31.48%	$ 297,500	31.48%	$ 297,500	31.20%	$ 297,500	31.20%	$ 297,500	31.08%	$ 297,500	31.08%
Supervisory Labor	$ 320,000	33.86%	$ 320,000	33.86%	$ 320,000	33.55%	$ 320,000	33.55%	$ 320,000	33.43%	$ 320,000	33.43%
Unemployment Insurance Ta	$ 16,055	1.70%	$ 16,055	1.70%	$ 16,055	1.68%	$ 16,055	1.68%	$ 16,055	1.68%	$ 16,055	1.68%
FICA	$ 38,285	4.05%	$ 38,285	4.05%	$ 38,285	4.01%	$ 38,285	4.01%	$ 38,285	4.00%	$ 38,285	4.00%
Workman's Comp	$ 30,875	3.27%	$ 30,875	3.27%	$ 30,875	3.24%	$ 30,875	3.24%	$ 30,875	3.23%	$ 30,875	3.23%
Fuel	$ 33,420	3.52%	$ 33,420	3.52%	$ 33,420	3.49%	$ 33,420	3.49%	$ 33,420	3.48%	$ 33,420	3.48%
Monitoring	$ 4,326	0.46%	$ 4,326	0.46%	$ 4,326	0.45%	$ 4,326	0.45%	$ 4,326	0.45%	$ 4,326	0.45%
Retail Containers	$ 3,138	0.33%	$ 3,138	0.33%	$ 3,138	0.33%	$ 3,138	0.33%	$ 3,138	0.33%	$ 3,138	0.33%
Marketing Expenses	$ 4,005	0.42%	$ 4,005	0.42%	$ 4,005	0.42%	$ 4,005	0.42%	$ 4,005	0.42%	$ 4,005	0.42%
Overhead	$ 25,200	2.67%	$ 25,200	2.67%	$ 25,200	2.64%	$ 25,200	2.64%	$ 25,200	2.63%	$ 25,200	2.63%
Total Variable Costs	$ 865,205	91.54%	$ 865,205	91.54%	$ 865,205	90.71%	$ 865,205	90.71%	$ 865,205	90.36%	$ 865,205	90.36%
Fixed Costs												
Item	***Total $***		***Total $***		***Total $***		***Total $***		***Total $***		***Total $***	
Insurance	$ 22,830	2.42%	$ 22,830	2.42%	$ 22,830	2.39%	$ 22,830	2.39%	$ 22,830	2.38%	$ 22,830	2.38%
Lease Fees	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%
Permit Fees	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
Repairs	$ 1,625	0.17%	$ 1,625	0.17%	$ 1,625	0.17%	$ 1,625	0.17%	$ 1,625	0.17%	$ 1,625	0.17%
Conventional Loan Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 12,287	1.28%	$ 12,287	1.28%
MARBIDCO Loan Payments	$ -	0.00%	$ -	0.00%	$ 8,639	0.91%	$ 8,639	0.91%	$ -	0.00%	$ -	0.00%
Depreciation	$ 55,549	5.86%	$ 55,549	5.86%	$ 55,549	5.80%	$ 55,549	5.80%	$ 55,549	5.78%	$ 55,549	5.78%
Total Fixed Cost	$ 80,179	8.46%	$ 80,179	8.46%	$ 88,818	9.29%	$ 88,818	9.29%	$ 92,465	9.64%	$ 92,465	9.64%
			$ -									
Total Costs	$ 945,384	100.00%	$ 945,384	100.00%	$ 954,022	100.00%	$ 954,022	100.00%	$ 957,670	100.00%	$ 957,670	100.00%
Income Before Taxes	$ (325,169)		$ (348,838)		$ (333,808)		$ (357,476)		$ (337,456)		$ (361,124)	

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 146,178	23.61%	$ 146,178	24.54%	$ 146,178	23.61%	$ 146,178	24.54%	$ 146,178	23.61%	$ 146,178	24.54%
Bushel Oyster Markets	$ 449,414	72.60%	$ 449,414	75.46%	$ 449,414	72.60%	$ 449,414	75.46%	$ 449,414	72.60%	$ 449,414	75.46%
Total Nutrient Payments	$ 23,472	3.79%		0.00%	$ 23,472	3.79%		0.00%	$ 23,472	3.79%		0.00%
Total Gross Income	$ 619,065	100%	$ 595,593	100%	$ 619,065	$ 1.0	$ 595,593	$ 1.0	$ 619,065	100%	$ 595,593	100%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Spat on Shell	$ 92,400	10.38%	$ 92,400	10.28%	$ 92,400	9.34%	$ 92,400	10.28%	$ 92,400	10.24%	$ 92,400	10.24%
Labor												
General Labor	$ 297,500	33.43%	$ 297,500	33.11%	$ 297,500	30.06%	$ 297,500	33.11%	$ 297,500	32.98%	$ 297,500	32.98%
Supervisory Labor	$ 320,000	35.96%	$ 320,000	35.61%	$ 320,000	32.33%	$ 320,000	35.61%	$ 320,000	35.47%	$ 320,000	35.47%
Unemployment Insurance Tax	$ 16,055	1.80%	$ 16,055	1.79%	$ 16,055	1.62%	$ 16,055	1.79%	$ 16,055	1.78%	$ 16,055	1.78%
FICA	$ 38,285	4.30%	$ 38,285	4.26%	$ 38,285	3.87%	$ 38,285	4.26%	$ 38,285	4.24%	$ 38,285	4.24%
Workman's Comp	$ 30,875	3.47%	$ 30,875	3.44%	$ 30,875	3.12%	$ 30,875	3.44%	$ 30,875	3.42%	$ 30,875	3.42%
Fuel	$ 33,459	3.76%	$ 33,459	3.72%	$ 33,459	3.37%	$ 33,459	3.72%	$ 33,459	3.71%	$ 33,459	3.71%
Monitoring	$ 4,302	0.48%	$ 4,302	0.48%	$ 4,302	0.44%	$ 4,302	0.48%	$ 4,302	0.48%	$ 4,302	0.48%
Retail Containers	$ 3,138	0.35%	$ 3,138	0.35%	$ 3,138	0.32%	$ 3,138	0.35%	$ 3,138	0.35%	$ 3,138	0.35%
Marketing Expenses	$ 4,016	0.45%	$ 4,016	0.45%	$ 4,016	0.40%	$ 4,016	0.45%	$ 4,016	0.45%	$ 4,016	0.45%
Overhead	$ 25,201	2.83%	$ 25,201	2.80%	$ 25,201	2.55%	$ 25,201	2.80%	$ 25,201	2.79%	$ 25,201	2.79%
Total Variable Costs	$ 865,230	97.23%	$ 865,230	96.30%	$ 865,230	87.42%	$ 865,230	96.30%	$ 865,230	95.91%	$ 865,230	95.91%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 22,830	2.57%	$ 22,830	2.54%	$ 22,830	2.31%	$ 22,830	2.54%	$ 22,830	2.53%	$ 22,830	2.53%
Lease Fees	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%	$ 175	0.02%
Repairs	$ 1,625	0.18%	$ 1,625	0.18%	$ 1,625	0.16%	$ 1,625	0.18%	$ 1,625	0.18%	$ 1,625	0.18%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 12,287	1.36%	$ 12,287	1.36%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.96%	$ 8,639	4.51%	$ 8,639	0.96%	$ -	0.00%	$ -	0.00%
Total Fixed Cost	$ 24,630	2.77%	$ 33,269	3.70%	$ 8,639	12.58%	$ 33,269	3.70%	$ 36,917	4.09%	$ 36,917	4.09%
Total Costs	$ 889,861	100.00%	$ 898,499	100.00%	$ 873,869	100.00%	$ 898,499	100.00%	$ 902,147	100.00%	$ 902,147	100.00%
Income Before Taxes	$ (270,795)		$ (302,907)		$ (254,804)		$ (302,907)		$ (283,082)		$ (306,554)	

Table B-1. Enterprise budgets for five-acre bottom-culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 294,405	23.74%	$ 294,405	24.68%	$ 294,405	23.74%	$ 294,405	23.74%	$ 294,405	23.74%	$ 294,405	24.68%
Bushel Oyster Markets	$ 898,640	72.46%	$ 898,640	75.32%	$ 898,640	72.46%	$ 898,640	72.46%	$ 898,640	72.46%	$ 898,640	75.32%
Total Nutrient Payments	$ 47,165	3.80%		0.00%	$ 47,165	3.80%	$ 47,165	3.80%	$ 47,165	3.80%		0.00%
Total Gross Income	$ 1,240,210	100.00%	$ 1,193,045	100.00%	$ 1,240,210	100.00%	$ 1,240,210	100.00%	$ 1,240,210	100.00%	$ 1,193,045	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Spat on Shell	$ 184,800	18.67%	$ 184,800	18.67%	$ 184,800	18.44%	$ 184,800	18.44%	$ 184,800	18.33%	$ 184,800	18.33%
Labor												
General Labor	$ 297,500	30.05%	$ 297,500	30.05%	$ 297,500	29.68%	$ 297,500	29.68%	$ 297,500	29.51%	$ 297,500	29.51%
Supervisory Labor	$ 320,000	32.32%	$ 320,000	32.32%	$ 320,000	31.93%	$ 320,000	31.93%	$ 320,000	31.74%	$ 320,000	31.74%
Unemployment Insurance Tax	$ 16,055	1.62%	$ 16,055	1.62%	$ 16,055	1.60%	$ 16,055	1.60%	$ 16,055	1.59%	$ 16,055	1.59%
FICA	$ 38,285	3.87%	$ 38,285	3.87%	$ 38,285	3.82%	$ 38,285	3.82%	$ 38,285	3.80%	$ 38,285	3.80%
Workman's Comp	$ 30,875	3.12%	$ 30,875	3.12%	$ 30,875	3.08%	$ 30,875	3.08%	$ 30,875	3.06%	$ 30,875	3.06%
Fuel	$ 33,371	3.37%	$ 33,371	3.37%	$ 33,371	3.33%	$ 33,371	3.33%	$ 33,371	3.31%	$ 33,371	3.31%
Monitoring	$ 4,322	0.44%	$ 4,322	0.44%	$ 4,322	0.43%	$ 4,322	0.43%	$ 4,322	0.43%	$ 4,322	0.43%
Retail Containers	$ 6,336	0.64%	$ 6,336	0.64%	$ 6,336	0.63%	$ 6,336	0.63%	$ 6,336	0.63%	$ 6,336	0.63%
Marketing Expenses	$ 3,991	0.40%	$ 3,991	0.40%	$ 3,991	0.40%	$ 3,991	0.40%	$ 3,991	0.40%	$ 3,991	0.40%
Overhead	$ 28,066	2.83%	$ 28,066	2.83%	$ 28,066	2.80%	$ 28,066	2.80%	$ 28,066	2.78%	$ 28,066	2.78%
Total Variable Costs	$ 963,600	97.33%	$ 963,600	97.33%	$ 963,600	96.14%	$ 963,600	96.14%	$ 963,600	95.57%	$ 963,600	95.57%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 23,499	2.37%	$ 23,499	2.37%	$ 23,499	2.34%	$ 23,499	2.34%	$ 23,499	2.33%	$ 23,499	2.33%
Lease Fees	$ 350	0.04%	$ 350	0.04%	$ 350	0.03%	$ 350	0.03%	$ 350	0.03%	$ 350	0.03%
Repairs	$ 2,609	0.26%	$ 2,609	0.26%	$ 2,609	0.26%	$ 2,609	0.26%	$ 2,609	0.26%	$ 2,609	0.26%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 18,202	1.81%	$ 18,202	1.81%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 12,238	1.22%	$ 12,238	1.22%	$ -	0.00%	$ -	0.00%
Total Fixed Cost	$ 26,458	2.67%	$ 26,458	2.67%	$ 38,696	3.86%	$ 38,696	3.86%	$ 44,660	4.43%	$ 44,660	4.43%
Total Costs	$ 990,059	100.00%	$ 990,059	100.00%	$ 1,002,296	100.00%	$ 1,002,296	100.00%	$ 1,008,261	100.00%	$ 1,008,261	100.00%
Income Before Taxes	$ 250,152		$ 202,987		$ 237,914		$ 237,914		$ 231,949		$ 184,784	

Table B-2. Enterprise budget for ten-acre bottom-culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 583,933	23.52%	$ 583,933	24.46%	$ 583,933	23.52%	$ 583,933	24.46%	$ 583,933	23.52%	$ 583,933	24.46%
Bushel Oyster Markets	$ 1,803,492	72.64%	$ 1,803,492	75.54%	$ 1,803,492	72.64%	$ 1,803,492	75.54%	$ 1,803,492	72.64%	$ 1,803,492	75.54%
Total Nutrient Payments	$ 95,403	3.84%	$ -	0.00%	$ 95,403	3.84%		0.00%	$ 95,403	3.84%		0.00%
Total Gross Income	$ 2,482,828	100.00%	$ 2,387,426	100.00%	$ 2,482,828	100.00%	$ 2,387,426	100.00%	$ 2,482,828	100.00%	$ 2,387,426	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Spat on Shell	$ 369,600	30.90%	$ 369,600	30.90%	$ 369,600	30.34%	$ 369,600	30.34%	$ 369,600	30.05%	$ 369,600	30.05%
Labor												
General Labor	$ 297,500	24.88%	$ 297,500	24.88%	$ 297,500	24.42%	$ 297,500	24.42%	$ 297,500	24.19%	$ 297,500	24.19%
Supervisory Labor	$ 320,000	26.76%	$ 320,000	26.76%	$ 320,000	26.27%	$ 320,000	26.27%	$ 320,000	26.01%	$ 320,000	26.01%
Unemployment Insurance Tax	$ 16,055	1.34%	$ 16,055	1.34%	$ 16,055	1.32%	$ 16,055	1.32%	$ 16,055	1.31%	$ 16,055	1.31%
FICA	$ 38,285	3.20%	$ 38,285	3.20%	$ 38,285	3.14%	$ 38,285	3.14%	$ 38,285	3.11%	$ 38,285	3.11%
Workman's Comp	$ 30,875	2.58%	$ 30,875	2.58%	$ 30,875	2.53%	$ 30,875	2.53%	$ 30,875	2.51%	$ 30,875	2.51%
Fuel	$ 33,491	2.80%	$ 33,491	2.80%	$ 33,491	2.75%	$ 33,491	2.75%	$ 33,491	2.72%	$ 33,491	2.72%
Monitoring	$ 4,373	0.37%	$ 4,373	0.37%	$ 4,373	0.36%	$ 4,373	0.36%	$ 4,373	0.36%	$ 4,373	0.36%
Retail Containers	$ 12,528	1.05%	$ 12,528	1.05%	$ 12,528	1.03%	$ 12,528	1.03%	$ 12,528	1.02%	$ 12,528	1.02%
Marketing Expenses	$ 4,041	0.34%	$ 4,041	0.34%	$ 4,041	0.33%	$ 4,041	0.33%	$ 4,041	0.33%	$ 4,041	0.33%
Overhead	$ 33,802	2.83%	$ 33,802	2.83%	$ 33,802	2.77%	$ 33,802	2.77%	$ 33,802	2.75%	$ 33,802	2.75%
Total Variable Costs	$ 1,160,550	97.04%	$ 1,160,550	97.04%	$ 1,160,550	95.26%	$ 1,160,550	95.26%	$ 1,160,550	94.35%	$ 1,160,550	94.35%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 30,106	2.52%	$ 30,106	2.52%	$ 30,106	2.47%	$ 30,106	2.47%	$ 30,106	2.45%	$ 30,106	2.45%
Lease Fees	$ 700	0.06%	$ 700	0.06%	$ 700	0.06%	$ 700	0.06%	$ 700	0.06%	$ 700	0.06%
Repairs	$ 4,578	0.38%	$ 4,578	0.38%	$ 4,578	0.38%	$ 4,578	0.38%	$ 4,578	0.37%	$ 4,578	0.37%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 34,129	2.77%	$ 34,129	2.77%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 22,316	1.83%	$ 22,316	1.83%	$ -	0.00%	$ -	0.00%
Total Fixed Cost	$ 35,384	2.96%	$ 35,384	2.96%	$ 57,700	4.74%	$ 57,700	4.74%	$ 69,513	5.65%	$ 69,513	5.65%
Total Costs	$ 1,195,934	100.00%	$ 1,195,934	100.00%	$ 1,218,250	100.00%	$ 1,218,250	100.00%	$ 1,230,063	100.00%	$ 1,230,063	100.00%
Income Before Taxes	$ 1,286,895		$ 1,191,492		$ 1,264,579		$ 1,169,176		$ 1,252,765		$ 1,157,362	

Table B-3. Enterprise budget for twenty-acre bottom-culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 2,971,777	23.94%	$ 2,971,777	24.88%	$ 2,971,777	23.94%	$ 2,971,777	24.88%	$ 2,971,777	23.94%	$ 2,971,777	24.88%
Bushel Oyster Markets	$ 8,970,351	72.26%	$ 8,970,351	75.12%	$ 8,970,351	72.26%	$ 8,970,351	75.12%	$ 8,970,351	72.26%	$ 8,970,351	75.12%
Total Nutrient Payments	$ 472,577	3.81%	$ -	0.00%	$ 472,577	3.81%		0.00%	$ 472,577	3.81%		0.00%
Total Gross Income	$ 12,414,705	100.00%	$ 11,942,128	100.00%	$ 12,414,705	100.00%	$ 11,942,128	100.00%	$ 12,414,705	100.00%	$ 11,942,128	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Spat on Shell	$ 1,848,000	64.78%	$ 1,848,000	64.78%	$ 1,848,000	63.90%	$ 1,848,000	63.90%	$ 1,848,000	63.27%	$ 1,848,000	63.27%
Labor												
General Labor	$ 297,500	10.43%	$ 297,500	10.43%	$ 297,500	10.29%	$ 297,500	10.29%	$ 297,500	10.19%	$ 297,500	10.19%
Supervisory Labor	$ 320,000	11.22%	$ 320,000	11.22%	$ 320,000	11.06%	$ 320,000	11.06%	$ 320,000	10.96%	$ 320,000	10.96%
Unemployment Insurance Tax	$ 16,055	0.56%	$ 16,055	0.56%	$ 16,055	0.56%	$ 16,055	0.56%	$ 16,055	0.55%	$ 16,055	0.55%
FICA	$ 38,285	1.34%	$ 38,285	1.34%	$ 38,285	1.32%	$ 38,285	1.32%	$ 38,285	1.31%	$ 38,285	1.31%
Workman's Comp	$ 30,875	1.08%	$ 30,875	1.08%	$ 30,875	1.07%	$ 30,875	1.07%	$ 30,875	1.06%	$ 30,875	1.06%
Fuel	$ 32,971	1.16%	$ 32,971	1.16%	$ 32,971	1.14%	$ 32,971	1.14%	$ 32,971	1.13%	$ 32,971	1.13%
Monitoring	$ 4,319	0.15%	$ 4,319	0.15%	$ 4,319	0.15%	$ 4,319	0.15%	$ 4,319	0.15%	$ 4,319	0.15%
Retail Containers	$ 63,613	2.23%	$ 63,613	2.23%	$ 63,613	2.20%	$ 63,613	2.20%	$ 63,613	2.18%	$ 63,613	2.18%
Marketing Expenses	$ 4,009	0.14%	$ 4,009	0.14%	$ 4,009	0.14%	$ 4,009	0.14%	$ 4,009	0.14%	$ 4,009	0.14%
Overhead	$ 79,669	2.79%	$ 79,669	2.79%	$ 79,669	2.75%	$ 79,669	2.75%	$ 79,669	2.73%	$ 79,669	2.73%
Total Variable Costs	$ 2,735,296	95.89%	$ 2,735,296	95.89%	$ 2,735,296	94.58%	$ 2,735,296	94.58%	$ 2,735,296	93.65%	$ 2,735,296	93.65%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 93,444	3.28%	$ 93,444	3.28%	$ 93,444	3.23%	$ 93,444	3.23%	$ 93,444	3.20%	$ 93,444	3.20%
Lease Fees	$ 3,500	0.12%	$ 3,500	0.12%	$ 3,500	0.12%	$ 3,500	0.12%	$ 3,500	0.12%	$ 3,500	0.12%
Repairs	$ 20,326	0.71%	$ 20,326	0.71%	$ 20,326	0.70%	$ 20,326	0.70%	$ 20,326	0.70%	$ 20,326	0.70%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 68,259	2.34%	$ 68,259	2.34%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 39,592	1.37%	$ 39,592	1.37%	$ -	0.00%	$ -	0.00%
Total Fixed Cost	$ 117,270	4.11%	$ 117,270	4.11%	$ 156,862	5.42%	$ 156,862	5.42%	$ 185,529	6.35%	$ 185,529	6.35%
Total Costs	$ 2,852,566	100.00%	$ 2,852,566	100.00%	$ 2,892,158	100.00%	$ 2,892,158	100.00%	$ 2,920,825	100.00%	$ 2,920,825	100.00%
Income Before Taxes	$ 9,562,139		$ 9,089,562		$ 9,522,547		$ 9,049,970		$ 9,493,880		$ 9,021,303	

Table B-4. Enterprise budget for one-hundred-acre bottom-culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 1,883,867	97.60%	$ 1,883,867	100.00%	$ 1,883,867	97.60%	$ 1,883,867	100.00%	$ 1,883,867	97.60%	$ 1,883,867	100.00%
Bushel Oyster Markets	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
Total Nutrient Payments	$ 46,383	2.40%	$ -	0.00%	$ 46,383	2.40%	$ -	0.00%	$ 46,383	2.40%	$ -	0.00%
Total Gross Income	$ 1,930,250	100.00%	$ 1,883,867	100.00%	$ 1,930,250	100.00%	$ 1,883,867	100.00%	$ 1,930,250	100.00%	$ 1,883,867	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Seed	$ 170,000	7.67%	$ 170,000	7.80%	$ 170,000	7.71%	$ 170,000	7.71%	$ 170,000	7.66%	$ 170,000	7.66%
Labor												
General Labor	$ 1,051,668	47.47%	$ 1,051,668	48.27%	$ 1,051,668	47.69%	$ 1,051,668	47.69%	$ 1,051,668	47.38%	$ 1,051,668	47.38%
Supervisory Labor	$ 416,000	18.78%	$ 416,000	19.09%	$ 416,000	18.87%	$ 416,000	18.87%	$ 416,000	18.74%	$ 416,000	18.74%
Worker's Comp	$ 73,383	3.31%	$ 73,383	3.37%	$ 73,383	3.33%	$ 73,383	3.33%	$ 73,383	3.31%	$ 73,383	3.31%
FICA	$ 90,995	4.11%	$ 90,995	4.18%	$ 90,995	4.13%	$ 90,995	4.13%	$ 90,995	4.10%	$ 90,995	4.10%
Unemployment Insurance	$ 38,159	1.72%	$ 38,159	1.75%	$ 38,159	1.73%	$ 38,159	1.73%	$ 38,159	1.72%	$ 38,159	1.72%
Fuel	$ 33,262	1.50%	$ 33,262	1.53%	$ 33,262	1.51%	$ 33,262	1.51%	$ 33,262	1.50%	$ 33,262	1.50%
Monitoring	$ 9,901	0.45%	$ 9,901	0.45%	$ 9,901	0.45%	$ 9,901	0.45%	$ 9,901	0.45%	$ 9,901	0.45%
Retail Containers	$ 38,995	1.76%	$ 38,995	1.79%	$ 38,995	1.77%	$ 38,995	1.77%	$ 38,995	1.76%	$ 38,995	1.76%
Marketing Expenses	$ 31,658	1.43%	$ 31,658	1.45%	$ 31,658	1.44%	$ 31,658	1.44%	$ 31,658	1.43%	$ 31,658	1.43%
Cages Purchased	$ 45,190	2.04%	$ 45,190	2.07%	$ 45,190	2.05%	$ 45,190	2.05%	$ 45,190	2.04%	$ 45,190	2.04%
Mesh Bags Purchased	$ 15,012	0.68%	$ 15,012	0.69%	$ 15,012	0.68%	$ 15,012	0.68%	$ 15,012	0.68%	$ 15,012	0.68%
Overhead	$ 60,427	2.73%	$ 60,427	2.77%	$ 60,427	2.74%	$ 60,427	2.74%	$ 60,427	2.72%	$ 60,427	2.72%
Total Variable Costs	$ 2,074,650	93.65%	$ 2,074,650	95.22%	$ 2,074,650	94.09%	$ 2,074,650	94.09%	$ 2,074,650	93.47%	$ 2,074,650	93.47%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 98,773	4.46%	$ 98,773	4.53%	$ 98,773	4.48%	$ 98,773	4.48%	$ 98,773	4.45%	$ 98,773	4.45%
Lease Fees	$ 1,250	0.06%	$ 1,250	0.06%	$ 1,250	0.06%	$ 1,250	0.06%	$ 1,250	0.06%	$ 1,250	0.06%
Repairs and maintenance	$ 4,044	0.18%	$ 4,044	0.19%	$ 4,044	0.18%	$ 4,044	0.18%	$ 4,044	0.18%	$ 4,044	0.18%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 26,271	1.19%	$ 26,271	1.19%	$ -	0.00%	$ -	0.00%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 40,955	1.85%	$ 40,955	1.85%
Total Fixed Cost	$ 140,697	6.35%	$ 104,067	4.78%	$ 130,338	5.91%	$ 130,338	5.91%	$ 145,022	6.53%	$ 145,022	6.53%
Total Costs	$ 2,215,347	100.00%	$ 2,178,717	100.00%	$ 2,204,988	100.00%	$ 2,204,988	100.00%	$ 2,219,672	100.00%	$ 2,219,672	100.00%
Income Before Taxes	$ (285,098)		$ (294,850)		$ (274,739)		$ (321,121)		$ (289,422)		$ (335,805)	

Table B-5. Enterprise budget for 500,000 oyster per year water-column culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 3,779,378	97.60%	$ 3,779,378	100.00%	$ 3,779,378	97.60%	$ 3,779,378	100.00%	$ 3,779,378	97.60%	$ 3,779,378	100.00%
Bushel Oyster Markets	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
Total Nutrient Payments	$ 92,895	2.40%	$ -	0.00%	$ 92,895	2.40%	$ -	0.00%	$ 92,895	2.40%	$ -	0.00%
Total Gross Income	$ 3,872,273	100.00%	$ 3,779,378	100.00%	$ 3,872,273	100.00%	$ 3,779,378	100.00%	$ 3,872,273	100.00%	$ 3,779,378	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Seed	$ 340,000	11.57%	$ 340,000	11.57%	$ 340,000	11.44%	$ 340,000	11.44%	$ 340,000	11.29%	$ 340,000	11.37%
Labor			$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
General Labor	$ 1,432,885	48.78%	$ 1,432,885	48.78%	$ 1,432,885	48.21%	$ 1,432,885	48.21%	$ 1,432,885	47.59%	$ 1,432,885	47.90%
Supervisory Labor	$ 416,000	14.16%	$ 416,000	14.16%	$ 416,000	14.00%	$ 416,000	14.00%	$ 416,000	13.82%	$ 416,000	13.91%
Worker's Comp	$ 92,444	3.15%	$ 92,444	3.15%	$ 92,444	3.11%	$ 92,444	3.11%	$ 92,444	3.07%	$ 92,444	3.09%
FICA	$ 114,631	3.90%	$ 114,631	3.90%	$ 114,631	3.86%	$ 114,631	3.86%	$ 114,631	3.81%	$ 114,631	3.83%
Unemployment Insurance	$ 48,071	1.64%	$ 48,071	1.64%	$ 48,071	1.62%	$ 48,071	1.62%	$ 48,071	1.60%	$ 48,071	1.61%
Fuel	$ 33,029	1.12%	$ 33,029	1.12%	$ 33,029	1.11%	$ 33,029	1.11%	$ 33,029	1.10%	$ 33,029	1.10%
Monitoring	$ 10,079	0.34%	$ 10,079	0.34%	$ 10,079	0.34%	$ 10,079	0.34%	$ 10,079	0.33%	$ 10,079	0.34%
Retail Containers	$ 78,074	2.66%	$ 78,074	2.66%	$ 78,074	2.63%	$ 78,074	2.63%	$ 78,074	2.59%	$ 78,074	2.61%
Marketing Expenses	$ 31,808	1.08%	$ 31,808	1.08%	$ 31,808	1.07%	$ 31,808	1.07%	$ 31,808	1.06%	$ 31,808	1.06%
Cages Purchased	$ 90,463	3.08%	$ 90,463	3.08%	$ 90,463	3.04%	$ 90,463	3.04%	$ 90,463	3.00%	$ 90,463	3.02%
Mesh Bags Purchased	$ 30,024	1.02%	$ 30,024	1.02%	$ 30,024	1.01%	$ 30,024	1.01%	$ 30,024	1.00%	$ 30,024	1.00%
Overhead	$ 81,525	2.78%	$ 81,525	2.78%	$ 81,525	2.74%	$ 81,525	2.74%	$ 81,525	2.71%	$ 81,525	2.73%
Total Variable Costs	$ 2,799,034	95.28%	$ 2,799,034	95.28%	$ 2,799,034	94.17%	$ 2,799,034	94.17%	$ 2,799,034	92.97%	$ 2,799,034	93.58%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 130,470	4.44%	$ 130,470	4.44%	$ 130,470	4.39%	$ 130,470	4.39%	$ 130,470	4.33%	$ 130,470	4.36%
Lease Fees	$ 1,250	0.04%	$ 1,250	0.04%	$ 1,250	0.04%	$ 1,250	0.04%	$ 1,250	0.04%	$ 1,250	0.04%
Repairs and maintenance	$ 6,950	0.24%	$ 6,950	0.24%	$ 6,950	0.23%	$ 6,950	0.23%	$ 6,950	0.23%	$ 6,950	0.23%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 34,516	1.16%	$ 34,516	1.16%	$ -	0.00%	$ -	0.00%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 53,469	1.78%	$ 53,469	1.79%
Total Fixed Cost	$ 138,670	4.72%	$ 138,670	4.72%	$ 173,186	5.83%	$ 173,186	5.83%	$ 211,604	7.03%	$ 192,139	6.42%
Total Costs	$ 2,937,704	100.00%	$ 2,937,704	100.00%	$ 2,972,220	100.00%	$ 2,972,220	100.00%	$ 3,010,637	100.00%	$ 2,991,173	100.00%
Income Before Taxes	$ 934,569		$ 841,674		$ 900,053		$ 807,158		$ 861,636		$ 788,205	

Table B-6. Enterprise budget for 1,000,000 oyster per year water-column culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 7,540,957	97.58%	$ 7,540,957	100.00%	$ 7,540,957	97.58%	$ 7,540,957	100.00%	$ 7,540,957	97.58%	$ 7,540,957	100.00%
Bushel Oyster Markets	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
Total Nutrient Payments	$ 187,332	2.42%	$ -	0.00%	$ 187,332	2.42%		0.00%	$ 187,332	2.42%		0.00%
Total Gross Income	$ 7,728,289	100.00%	$ 7,540,957	100.00%	$ 7,728,289	100.00%	$ 7,540,957	100.00%	$ 7,728,289	100.00%	$ 7,540,957	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Seed	$ 680,000	17.05%	$ 680,000	17.05%	$ 680,000	16.88%	$ 680,000	16.88%	$ 680,000	16.79%	$ 680,000	16.79%
Labor			$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
General Labor	$ 1,814,101	45.48%	$ 1,814,101	45.48%	$ 1,814,101	45.04%	$ 1,814,101	45.04%	$ 1,814,101	44.79%	$ 1,814,101	44.79%
Supervisory Labor	$ 416,000	10.43%	$ 416,000	10.43%	$ 416,000	10.33%	$ 416,000	10.33%	$ 416,000	10.27%	$ 416,000	10.27%
Worker's Comp	$ 111,505	2.80%	$ 111,505	2.80%	$ 111,505	2.77%	$ 111,505	2.77%	$ 111,505	2.75%	$ 111,505	2.75%
FICA	$ 138,266	3.47%	$ 138,266	3.47%	$ 138,266	3.43%	$ 138,266	3.43%	$ 138,266	3.41%	$ 138,266	3.41%
Unemployment Insurance	$ 57,983	1.45%	$ 57,983	1.45%	$ 57,983	1.44%	$ 57,983	1.44%	$ 57,983	1.43%	$ 57,983	1.43%
Fuel	$ 33,237	0.83%	$ 33,237	0.83%	$ 33,237	0.83%	$ 33,237	0.83%	$ 33,237	0.82%	$ 33,237	0.82%
Monitoring	$ 9,983	0.25%	$ 9,983	0.25%	$ 9,983	0.25%	$ 9,983	0.25%	$ 9,983	0.25%	$ 9,983	0.25%
Retail Containers	$ 156,164	3.92%	$ 156,164	3.92%	$ 156,164	3.88%	$ 156,164	3.88%	$ 156,164	3.86%	$ 156,164	3.86%
Marketing Expenses	$ 31,634	0.79%	$ 31,634	0.79%	$ 31,634	0.79%	$ 31,634	0.79%	$ 31,634	0.78%	$ 31,634	0.78%
Cages Purchased	$ 180,625	4.53%	$ 180,625	4.53%	$ 180,625	4.48%	$ 180,625	4.48%	$ 180,625	4.46%	$ 180,625	4.46%
Mesh Bags Purchased	$ 60,012	1.50%	$ 60,012	1.50%	$ 60,012	1.49%	$ 60,012	1.49%	$ 60,012	1.48%	$ 60,012	1.48%
Overhead	$ 110,685	2.77%	$ 110,685	2.77%	$ 110,685	2.75%	$ 110,685	2.75%	$ 110,685	2.73%	$ 110,685	2.73%
Total Variable Costs	$ 3,800,194	95.27%	$ 3,800,194	95.27%	$ 3,800,194	94.35%	$ 3,800,194	94.35%	$ 3,800,194	93.83%	$ 3,800,194	93.83%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 174,608	4.38%	$ 174,608	4.38%	$ 174,608	4.33%	$ 174,608	4.33%	$ 174,608	4.31%	$ 174,608	4.31%
Lease Fees	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%
Repairs and maintenance	$ 12,623	0.32%	$ 12,623	0.32%	$ 12,623	0.31%	$ 12,623	0.31%	$ 12,623	0.31%	$ 12,623	0.31%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 39,240	0.97%	$ 39,240	0.97%	$ -	0.00%	$ -	0.00%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 61,433	1.52%	$ 61,433	1.52%
Total Fixed Cost	$ 188,481	4.73%	$ 188,481	4.73%	$ 227,722	5.65%	$ 227,722	5.65%	$ 249,914	6.17%	$ 249,914	6.17%
Total Costs	$ 3,988,676	100.00%	$ 3,988,676	100.00%	$ 4,027,916	100.00%	$ 4,027,916	100.00%	$ 4,050,108	100.00%	$ 4,050,108	100.00%
Income Before Taxes	$ 3,739,613		$ 3,552,282		$ 3,700,373		$ 3,513,041		$ 3,678,181		$ 3,490,849	

Table B-7. Enterprise budget for 2,000,000 oyster per year water-column culture oyster aquaculture operations in the Maryland Chesapeake Bay.

	Personal Funds with Nutrient Payments		Personal Funds without Nutrient Payments		MARBIDCO Funds with Nutrient Payments		MARBIDCO Funds without Nutrient Payments		Conventional Funds with Nutrient Payments		Conventional Funds without Nutrient Payments	
Gross Income												
Item	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income	Total $	% of Income
Half Shell Market Oysters	$ 9,432,650	97.56%	$ 9,432,650	100.00%	$ 9,432,650	97.56%	$ 9,432,650	100.00%	$ 9,432,650	97.56%	$ 9,432,650	100.00%
Bushel Oyster Markets	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%
Total Nutrient Payments	$ 235,435	2.44%	$ -	0.00%	$ 235,435	2.44%	$ -	0.00%	$ 235,435	2.44%	$ -	0.00%
Total Gross Income	$ 9,668,085	100.00%	$ 9,432,650	100.00%	$ 9,668,085	100.00%	$ 9,432,650	100.00%	$ 9,668,085	100.00%	$ 9,432,650	100.00%
Variable Cost												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Seed	$ 850,000	19.18%	$ 850,000	19.18%	$ 850,000	19.00%	$ 850,000	19.00%	$ 850,000	18.90%	$ 850,000	18.90%
Labor												
General Labor	$ 1,936,825	43.71%	$ 1,936,825	43.71%	$ 1,936,825	43.30%	$ 1,936,825	43.30%	$ 1,936,825	43.07%	$ 1,936,825	43.07%
Supervisory Labor	$ 416,000	9.39%	$ 416,000	9.39%	$ 416,000	9.30%	$ 416,000	9.30%	$ 416,000	9.25%	$ 416,000	9.25%
Worker's Comp	$ 117,641	2.65%	$ 117,641	2.65%	$ 117,641	2.63%	$ 117,641	2.63%	$ 117,641	2.62%	$ 117,641	2.62%
FICA	$ 145,875	3.29%	$ 145,875	3.29%	$ 145,875	3.26%	$ 145,875	3.26%	$ 145,875	3.24%	$ 145,875	3.24%
Unemployment Insurance	$ 61,173	1.38%	$ 61,173	1.38%	$ 61,173	1.37%	$ 61,173	1.37%	$ 61,173	1.36%	$ 61,173	1.36%
Fuel	$ 33,458	0.76%	$ 33,458	0.76%	$ 33,458	0.75%	$ 33,458	0.75%	$ 33,458	0.74%	$ 33,458	0.74%
Monitoring	$ 10,035	0.23%	$ 10,035	0.23%	$ 10,035	0.22%	$ 10,035	0.22%	$ 10,035	0.22%	$ 10,035	0.22%
Retail Containers	$ 195,044	4.40%	$ 195,044	4.40%	$ 195,044	4.36%	$ 195,044	4.36%	$ 195,044	4.34%	$ 195,044	4.34%
Marketing Expenses	$ 31,781	0.72%	$ 31,781	0.72%	$ 31,781	0.71%	$ 31,781	0.71%	$ 31,781	0.71%	$ 31,781	0.71%
Cages Purchased	$ 225,673	5.09%	$ 225,673	5.09%	$ 225,673	5.05%	$ 225,673	5.05%	$ 225,673	5.02%	$ 225,673	5.02%
Mesh Bags Purchased	$ 75,024	1.69%	$ 75,024	1.69%	$ 75,024	1.68%	$ 75,024	1.68%	$ 75,024	1.67%	$ 75,024	1.67%
Overhead	$ 122,956	2.77%	$ 122,956	2.77%	$ 122,956	2.75%	$ 122,956	2.75%	$ 122,956	2.73%	$ 122,956	2.73%
Total Variable Costs	$ 4,221,486	95.26%	$ 4,221,486	95.26%	$ 4,221,486	94.38%	$ 4,221,486	94.38%	$ 4,221,486	93.88%	$ 4,221,486	93.88%
Fixed Costs												
Item	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost	Total $	% of Total Cost
Insurance	$ 193,356	4.36%	$ 193,356	4.36%	$ 193,356	4.32%	$ 193,356	4.32%	$ 193,356	4.30%	$ 193,356	4.30%
Lease Fees	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%	$ 1,250	0.03%
Repairs and maintenance	$ 15,440	0.35%	$ 15,440	0.35%	$ 15,440	0.35%	$ 15,440	0.35%	$ 15,440	0.34%	$ 15,440	0.34%
MARBIDCO Interest Payments	$ -	0.00%	$ -	0.00%	$ 41,535	0.93%	$ 41,535	0.93%	$ -	0.00%	$ -	0.00%
Conventional Interest Payments	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ -	0.00%	$ 65,301	1.45%	$ 65,301	1.45%
Total Fixed Cost	$ 210,045	4.74%	$ 210,045	4.74%	$ 251,580	5.62%	$ 251,580	5.62%	$ 275,346	6.12%	$ 275,346	6.12%
Total Costs	$ 4,431,531	100.00%	$ 4,431,531	100.00%	$ 4,473,066	100.00%	$ 4,473,066	100.00%	$ 4,496,832	100.00%	$ 4,496,832	100.00%
Income Before Taxes	$ 5,236,554		$ 5,001,119		$ 5,195,019		$ 4,959,584		$ 5,171,253		$ 4,935,819	

Table B-8. Enterprise budget for 2,500,000 oyster per year water-column culture oyster aquaculture operations in the Maryland Chesapeake Bay

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