Oyster Aquaculture: Cost Differentials of Gear Types and Profitability

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1. Introduction

This report uses existing literature, an online-survey, and interviews to analyze the costs of labor and equipment of alternative oyster grow out gear types. In 2018, studies demonstrated that oyster aquaculture was the most valuable form of marine aquaculture in the United States, with production of oysters valued at over $200 million[1] annually [1]. Ideally, if the industry continues to grow in value, producers will look at growing oysters in a way that is not only profitable but also factors in the influence of various gear types on nearby environments [2].

This report reviews the various gear types, addresses the profitability of growing oysters using different gear types, illustrates the various expenses associated with growing oysters, and provides cost estimates for on bottom and off bottom growing methods.

2. Review of various gear types

There are two main categories of oyster aquaculture that are discussed throughout this section, off bottom and on bottom oyster aquaculture. Off bottom, or intensive culture, is often more expensive because it requires more labor to maintain the gear [3]. However, off bottom aquaculture results in a more uniform product that can sell at a higher price in the "boxed" and "half-shell markets" [3]. The second aquaculture production method is known as on bottom, or extensive culture. This method includes spat on shell and clutched production. This is a more traditional way of growing oysters from larvae, and is usually less expensive once planted because it does not require the same amount of labor given there is no gear and equipment to maintain once planted [3]. Despite the lower labor costs, there is usually a higher mortality rate for these oysters given the lack of protection from cages and bags, and are usually destined solely for the shucked market which receives a lower price and includes the cost of shucking and packaging [3].

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[1] This $200 million estimate was taken in 2018 from the USDA. This does not reflect the accrued inflation from 2018 to 2023. If there is no footnote for a price, the reader can assume the estimate is from 2023. If there is a footnote, the year that estimate was calculated is noted.

Table 1. Summary of common oyster aquaculture methods.

On Bottom Growing Methods	
Spat on Shell	Oysters are cultured as larvae in a hatchery. The larvae attach to an oyster shell in setting tanks, then these shells can be placed in bays and estuaries where they grow to the adult state in this natural setting. [4]
Cultched Production	Cultch is a mixture of limestone rock, concrete, oyster shell and other materials that are placed in oyster spawning grounds. This provides a substrate in which free swimming oyster larvae can attach and then grow into the adult stage prior to being harvested. [5]
Off Bottom (Suspended) Growing Methods	
Adjustable Longline System (ALS) Includes: BST Crosshatch (mid-water ALS with baskets), BST Longline, Seapa	This method utilizes an adjustable line with baskets attached that can be raised or lowered into the water column depending on the season and the environmental conditions. This provides growers greater control over their stock as they can adjust the height of the longline where it is attached to posts in the water column. [6]
Floating Cages Includes: OysterGro	This system utilizes multiple cages that hold bags of oysters, and are suspended by twin floats. These floats are anchored to the ground, and have removable caps, allowing farmers to fill and flip the cages to control biofouling. [7]
Rack and Bag	Oysters are grown in bags suspended in the water column on steel racks which allows water to flow around the oysters, allowing them to feed while also being protected from predators. [8]

3. On Bottom Culture

3.1 Overview

This section covers the costs of on bottom oyster farming. This information was collected primarily from a literature review as the main goal of this report is to address off bottom gear types.

Previous studies examined the cost structures across on bottom farms, determining the categories where expenses were the highest. Many studies noted that fuel was the greatest expense for bottom culture farms, accounting for upwards of 15-25% of total costs depending on the production scale [9]. The second largest expense was the value of the equipment for small scale farms, and labor for large scale production [10]. Other studies found that labor and insurance were some of the greatest expenses for on bottom farms [9]. The largest problems faced by on bottom, cultured oysters were primarily regulations, such as acquiring leases and permits, followed by a lack of funding/loans, accessibility to seeds, and bottom type [10]. Many loans needed for bottom culture farms go towards operating loans or equipment loans [10].

3.2 Startup Costs

One paper examined costs for farms over a ten year period. These costs ranged from $900,000 for a five-acre lease to $8.6 million[2] for a 100 acre lease [11]. Using an online cost analysis spreadsheet created by Matt Parker, the average cost per acre ranged from $12,767 to $26,553 per acre, while other estimates provided in the literature generally calculate costs per acre between $1,017 and $19,750[3] [11].

Other studies looked at the cost of on bottom cages and found the start up costs vary between $58,000 and $96,000[4] for the material and equipment across the initial years [12]. However, this study does not include the cost for a boat in their initial estimates. This varied range accounts for different qualities of equipment as well as sourcing triploid vs. diploid seed [12].

With regards to the profitability of the farm after it is established, there was not a clear relationship between profitability and grow out time like there is for other farm types [13]. Established on bottom farms have high labor costs, meaning that the faster turnover of a crop, which usually means increased profits on other farms, means more labor for on bottom

[2] These financial estimates were calculated in 2020 and do not reflect the accrued inflation from 2020 to 2023.
[3] These financial estimates were calculated in 2020 and do not reflect the accrued inflation from 2020 to 2023.
[4] These financial estimates were calculated in 2007 and do not reflect the accrued inflation from 2007 to 2023.

cultured oysters [13]. Other studies demonstrated that the three most unprofitable farms they examined were those with the longest grow out time, however, the less profitable the farm, the greater the labor costs [14]. The profitability of gear types is expanded upon in a later section of the report.

Table 2. On bottom oyster aquaculture startup costs

Category	Low End Estimate	High End Estimate
Average Cost per Acre	$1,017	$26,553
Startup Costs[5]	$58,000	$96,000

4. Off Bottom Culture

4.1 Overview

There are various methods of off bottom culture that result in different start-up costs, expenses and profitability. There are also other variables that impact the cost and profitability within the different methods of off bottom aquaculture such as the size of the farm, and whether it is a new farm or an established farm. This section will cover the costs and profitability of various methods of off bottom oyster farming. This information has been collected from a literature review, interviews with gear suppliers, as well as surveys from growers across the Pacific Northwest.

Despite large traditional on bottom culture being the least risky avenue for oyster growers, studies have demonstrated that the most profitable category for oyster farmers is large-scale container, or off bottom culture [10]. However, this study noted that risk is greater for both large and small container culture compared to traditional bottom culture [10]. This study also ranked the greatest concerns of container culture, showcasing that acquiring leases and permits was among the larger problems faced by container culture, followed by oyster deaths, regulations, substrate, and lack of loans [10]. As for labor costs, there were some differences between traditional cultures and container cultures. Compared to on bottom culture respondents, one study demonstrated that a greater percentage of off bottom farms paid salaries and wages for laborers, while few on or off bottom farms paid management salaries [10].

[5] For material and equipment over the initial years (these estimates do not include the cost of a boat).

Initial investment costs for container culture, or off bottom farms, are significantly greater than on bottom farms. One study found the overall investment requirements to be four times greater for container farms than on bottom, traditional culture farms [10]. Much of that greater initial investment in off bottom farms is connected to the purchasing of cages, bags, and longlines, equipment that is often not found in on bottom farming [10]. Despite the greater initial investment per unit, off bottom culture has demonstrated higher per unit revenues [11].

4.2 Startup Costs

This report examines the startup costs and initial investments of various grow out gear types, especially for off bottom cultures. The following tables showcase some of the startup costs, the source and location of those costs, and which gear type is associated with those costs.

4.2.1 Startup Costs - Literature Review

Study One:
Table 3 illustrates the costs of different off bottom gear types utilized at the University of Maryland's Center for Environmental Science's Horn Point Laboratory (HPL) Oyster Hatchery. The five equipment types that were chosen include Seapa, Rack and Bag, OysterGro, BST Longline and BST Crosshatch [15].

This 2016-2018 study was hosted on the one acre plot at HPL [15]. The goal of this project was to address start up costs for oyster growers as well as the advantages and disadvantages of each gear type from production, growth, worm infestations and shell morphology [15]. The following costs are in 2016 US dollars, and do not account for the cost of pilings needed to set up some of this equipment [15].

Other notes from this experiment that relate to profitability are the number of oysters able to be deployed per gear type, as well as the number of oysters harvested. BST™ Crosshatch allowed for the greatest oyster deployment with 40,000 oysters deployed, and 18,828 harvested [15]. This was followed by the OysterGro® system which allowed for 36,000 oysters deployed and 14,476 oysters harvested [15]. These two systems allowed for significantly more oysters than the other gear types, with rack and bag allowing the fewest number of oysters deployed at 6,000 oysters, and Seapa equipment had the fewest oysters harvested with 1,863 oysters [15]. The highest survival rate was rack and bag, despite not having as many initial oysters deployed, over 64% made it to harvest while Seapa gear had the lowest survival rate at this site with only 29% making it to harvest [15].

Table 3. Summary of Horn Point Laboratory Study: Oyster Gear Costs[6].

Gear Type	Capital & Installation Costs	Production Cost per Oyster	Percent Survival
Seapa™	$3,175.46	$0.59	29%
Rack and Bag	$1,800.05	$0.15	64%
OysterGro®	$6,068.80	$0.33	40%
BST™ Longline	$2,308.34	$0.34	36%
BST™ Crosshatch	$20,465.08	$0.37	47%

Study Two:
Another study looked at the Chesapeake Bay where wild oyster stocks are becoming quite depleted [12]. Therefore, cultured oysters are becoming widely used in that area, and different methods of growing are being examined. This study addressed the startup costs for on bottom cages, floating cages, and spat on shell oysters (on bottom method). The startup costs for on bottom floats and spat on shell were discussed in the section above, while the costs for floating cages will be discussed below.

In Maryland, many aquaculture farms are beginning to use floating cages for large scale oyster production [12]. This study examined the initial costs for aquaculture floats in this area, accounting for equipment and material costs, as well as labor and energy costs. Equipment and material costs include oyster seed, a floating upweller, floating cages, bags/liners, a shaker table and a sorter [12]. These equipment costs did not include a boat as these oysters were grown in water that ranged from 3 to 6 feet deep, and were mostly worked by hand without a boat [12]. The labor and energy costs were more difficult to estimate for this grow out type. It was estimated that this grow out type would require 2,080 hours of labor for 1 million oysters grown [12]. These labor costs include the planting of oysters, working the floats, harvesting and cleaning. The energy costs for this gear are low and were not considered significant for this study [12].

The estimated start up costs for this gear are between $52,407 and $95,864[7] [12]. The initial investment varies given differing factors per the unit product. Oyster seeds can be purchased either as triploid (low-end to high-end) or diploid (low-end to high-end), with diploid oysters

[6] These financial estimates were calculated in 2016 and do not reflect the accrued inflation from 2016 to 2023.
[7] These financial estimates were calculated in 2007 and do not reflect the accrued inflation from 2007 to 2023.

being more expensive. This study was conducted in 2007, and therefore the costs would be a bit higher today to account for inflation.

4.2.2 Startup Costs - Interviews

In addition to a literature review, commercial gear suppliers were contacted via email to understand the start up costs for various and off bottom oyster grow out gear types. The standardized set of questions emailed is provided below:

- *What are the costs of your shellfish aquaculture gear for one acre?*
    - *What is the cost of the gear and accessories (i.e. clips) needed for that size plot?*
- *What are the labor costs for installation (if this is a service that is provided or estimated hours of labor for installing said gear)?*
- *In this cost estimate, what is the spacing of the gear? We know spacing can vary depending on the gear type, so we can go with what is most commonly purchased for that size plot.*
- *How many workers would this farm likely require given the size and amount of gear?*
- *Approximately, how many oysters could this farm produce given the spacing, acreage, and size of equipment?*
- *What are the upsides and or downsides of using your particular gear type?*

There are not a large number of gear suppliers in the United States so overseas gear suppliers were also contacted. Some gear suppliers sell equipment for various methods of growing oysters, while others specialize in more specific technology. Initial emails were sent to gauge interest from the gear distributors, then follow up emails were sent with the questionnaire. The response rate to the questionnaire was approximately 50%. Some respondents answered each of the questions provided, while others offered catalogs and less detailed information in response to the questions.

The distributors that responded to the questionnaire were Flip Farm, Seapa, and Hexcyl. Flip Farm is a system of floating cages intended to maximize economic output and includes a mechanism to flip the cages. Originally developed in New Zealand, this gear is now available in the United States through distributors in Maine. Seapa is a company that designs multiple products specifically for oyster growers including longline, floating, subtidal and fixed systems. Their baskets are designed to facilitate tumbling and provide consistently developed and well shaped oysters with high meat content. The information provided from Seapa addresses their floating systems as well as their adjustable longline system. The third company, Hexcyl, creates baskets and adjustable longline farming systems out of Australia. Hexcyl provided catalogs with their standard gear set up as well as prices for a hectare, so these configurations were amended to fit the one acre standard set for this section.[8] The estimates might be slightly off given these amendments, and they have not been thoroughly vetted by the company.

Table 4 below illustrates the responses shared from the respondents of the questionnaire as it corresponds to their respective gear type.

Table 4. Flip Farm survey responses (2023).

Questions	**Flip Farm Responses**
What are the costs of your shellfish aquaculture gear for one acre? What is the cost of the gear and accessories (i.e. clips) needed for that size plot?	One acre plot: 350’ x 92’ (6’ - 8’ depth) Fits: maximum of 8 lines, 300 baskets per line 300 baskets x 8 string lines = 2,400 Baskets About 150 market oysters (2 1/2" - 3") per basket 45k oysters per line and a total of 360k oysters on the site Complete (unassembled) FlipFarm Baskets cost about $46 each. $46 x 2,400 = $110,400 Complete set of machinery/mechanization equipment which can be used for growing millions of oysters costs about $55k Machinery/mechanization equipment is ideal for sharing among multiple small farms Multiple farms could own "About 15 to 20 baskets can be assembled per hour. Deployment of the gear is similar to the deployment of other floating bag/cage string lines."
What are the labor costs for installation (if this is a service that is provided or estimated hours of labor for installing said gear)?	About 15 to 20 baskets can be assembled per hour. Deployment of the gear is similar to the deployment of other floating bag/cage string lines.

[8] Steps for determining costs for Hexcyl Systems:

1. Their response was provided in hectares, with pallet configurations, equipment needed for the growing of 1 million oysters (4 million oysters at the 4 various life stages), as well as a costs sheet.
2. Converted the growing of 1 million oysters (actually 4 million oysters) from the 10 hectares it required to acres, our desired metric. Additionally, this information provided how many oysters one acre could provide.
3. From there, the information sheet also provided the infrastructure needed for one hectare of oyster production, so that was also converted to acres. The infrastructure and gear required was adjusted to fit the desired one acre study area.
4. The price sheet was consulted after determining the amount of gear needed for the one acre. The price sheet did not include the costs for all equipment required (nails, posts, and strainers) as well as costs for a boat, lease, and other aquaculture-related expenses.
5. The price configuration includes the costs under a 21 carton pallet with 315 baskets per pallet. The 20’ container comes with 10 pallets, bringing in a total of 3,150 baskets.
6. The basket pricing configuration was determined from the information sheet provided where the configuration of baskets per grow out size were determined, and then applied to the 1 acre number of baskets. Prices and inventory of baskets were determined using this model.

In this cost estimate, what is the spacing of the gear? We know spacing can vary depending on the gear type, so we can go with what is most commonly purchased for that size plot.	Pilings or anchors may be used similar to other oyster growing gear. A minimum of 20' should be maintained between string lines. Tandem lines can be used to maximize water space. Tandem lines spaced at 5' to 7' then a minimum of 20' between each set of tandem lines. Each string line must maintain about 25' of open space before the baskets at each end. This is for getting the Heli-Cat Flipper on and off the line.
How many workers would this farm likely require given the size and amount of gear?	One farmer can easily grow over 1 million oysters with the semi-automated FlipFarm Growing System. The work tasks are substantially easier to perform.
Approximately, how many oysters could this farm produce given the spacing, acreage, and size of equipment?	The maximum would be 360k oysters in 2,400 baskets with a tandem line layout.
What are the upsides and or downsides of using your particular gear type?	**Upsides:** ● FlipFarm replaces the heavy lifting and hard manual labor tasks with much easier and enjoyable tasks. ● The pool of applicants with a FlipFarm Growing System is much larger, including young people who don't want a dead-end manual labor job, graduate students, older experienced fisheries workers, people with physical limitations. ● FlipFarm drastically reduces labor hours per oyster - one farmer can easily grow 1 million oysters. ● Average production for a small floating bag/cage oyster farm is about 150k to 300k oysters per worker per year - FlipFarm is easily over 1 million and closer to 2 million oysters per worker per year. This is important considering that labor accounts for nearly 3/4 of operating cost on a small oyster farm - oyster farming is all about labor. ● One person farm with 250k oysters in floating bags/cages has an operating cost of about $.36 per oyster. Operating cost drops to about $.15 per oyster with FlipFarm **Downsides:** ● The downside of the FlipFarm System is the upfront cost. It's similar to the moment when land based farmers were faced with the choice of an expensive tractor versus cheap horse drawn plows. ● In Maine we used to get time away from school during the potato harvest but that would be foolish now that we use tractor combines. Farmers who don't make the investment will not survive with substantially lower production and higher operating costs. Smaller farms will be cost competitive with large farms even when both are using the FlipFarm System but we must help the small farmer with up front costs.
Total Startup Costs:	**$110, 400**

Table 5. Seapa survey response for Floating Longline [9] (2023).

Questions	Seapa - Floating Longline Responses
What are the costs of your shellfish aquaculture gear for one acre? What is the cost of the gear and accessories (i.e. clips) needed for that size plot?	One acre plot: 63m x 63m Setup: It is possible to set 12 floating lines of 60m. Each line can hold 75 baskets. Then, it is 900 baskets/acre (12 lines x 75 baskets). Tools and equipment Float x No. of baskets +1 (cost US$3 up: US$3/float x 76 floats = US$228/line) Rope x 1/line (cost US$75/line) Anker x 2/line (cost site specific) Buoy x 2/line (at the end of each line) (cost sight specific) Roller on a boat
What are the labor costs for installation (if this is a service that is provided or estimated hours of labor for installing said gear)?	NA
In this cost estimate, what is the spacing of the gear? We know spacing can vary depending on the gear type, so we can go with what is most commonly purchased for that size plot.	One acre plot: 63m x 63m Setup: It is possible to set 12 floating lines of 60m. Each line can hold 75 baskets. Then, it is 900 baskets/acre (12 lines x 75 baskets).
How many workers would this farm likely require given the size and amount of gear?	Three workers are usually required to attach and reattach baskets to/from lines.
Approximately, how many oysters could this farm produce given the spacing, acreage, and size of equipment?	NA
What are the upsides and or downsides of using your particular gear type?	**Upsides:** ● Easy to install ● Low cost ● Any areas subtidal **Downsides:** ● Biofouling management ● Production per water column
Total Startup Costs:	**Not Provided**

[9] The responses for the Seapa floating longline are limited in comparison to the other interview responses. For that reason, this gear type cannot be compared to the same degree as the other methods.

Table 6. Seapa survey response for Adjustable Longline System (2023).

Questions	Seapa - Adjustable Longline System Responses
What are the costs of your shellfish aquaculture gear for one acre? What is the cost of the gear and accessories (i.e. clips) needed for that size plot?	An ideal farm layout for an acre of Seapa baskets on an adjustable longline system (ALS) would comprise of 32 lines for baskets. Each line would have 300' of lineal usable space for baskets. A group of 4 lines would be called a row. A row would be 7' wide adjacent to the row would be a channel 12' wide that allows boat access. Each line would have space for 120 baskets, each row 480 baskets, and space for 3,840 baskets total. SEAPA offers three different volume baskets the 15 liter, 25-liter, and the GTX which is a 20-liter. This is the first variable for cost. There are 3 other variables for cost. The mesh size, the style of clip used, and the type of end cap. I generally always recommend our Storm breaker Clip system and streamline end caps. Depending on the farmer's needs the mesh size varies. 15-liter baskets are available with 3,6,12 and 20-mm mesh. There are also spat socks. Inserts for the 20mm baskets that have 1 or 1.6 mm mesh. The GTX is currently only available with 12mm mesh The 25-liter is available with 12mm or 20mm mesh. Seapa's general guidance on the mesh size for baskets is that the oysters should be double the size of the mesh. We also generally recommend that a basket is filled to ¼ of the total basket's volume and then split when the volume of oysters approaches ½. With more oysters at a smaller size going into nursery baskets, we sell less of those size mesh. Also, many farmers either have flupsys or upwellers or are purchasing larger seed from the hatcheries or contract growers. The highest quantity of baskets that we sell on the west coast and in the world is a 12mm mesh basket because these baskets generally have a lower density of oysters. The 15-liter baskets are the most widely purchased worldwide, because of the different size mesh options allowing farmers to plant smaller seed but also because they are not as big and hold fewer oysters they do not get as heavy. This allows many farmers to expand their labor pool and avoid potential injuries due to heavy repetitive lifting. I consider the 1mm, 1.6mm, 3mm, and 6mm to be nursery baskets. 12mm baskets can be nursery but are also the transition to "grow out". In the United States and on the West Coast many farmers use the 25-liter baskets with 12mm mesh. It is seldom that US Farmers use 20mm mesh baskets. Recently though more US farmers are gravitating towards the GTX baskets. The design is more sturdy, the price point is less than the 25-liter baskets and they are far more efficient for shipping. When ordering large quantities the GTX is by far the most efficient for stock holding relative to shipping costs. FYI, Seapa maintains a warehouse of stock in the US to support customers in North America and offers volume pricing. For purchases of 300 to 1000 units there is a 5% discount, 1000 plus units is a 10% discount. A 15% discount can be negotiated for orders larger then that. But at a 40' container volume of purchase, the pricing is discounted by 20% or slightly more. Additional containers after the first often have slightly better discounting again.

	For the 1-acre farm if we assume that a farmer starts with approximately 250,000 6mm seed in 3mm baskets the distribution of baskets could look similar to this: 270 X 15L-3mm mesh 500 X 15L- 6mm mesh 3500 X 25L-12mm mesh *These numbers are highly variable depending on growth rates, mortality, and the stocking density related to how often a farmer wants to split densities. Splitting densities has a direct correlation to labor costs. Lower densities can mean fewer labor costs, and faster and more consistent growth and shape but that also equals more gear and space for the gear. Most West Coast and US farmers in general overstock the baskets or whatever container they are using at densities much too high. I am a big advocate for “less is more” The labor costs associated with overstocking baskets are hard to pull apart and calculate but I believe are quite significant.
What are the labor costs for installation (if this is a service that is provided or estimated hours of labor for installing said gear)?	After the initial learning curve, and with good jigs and tools to assist with installation, an estimate of a crew of 4 could install a row consisting of 4 lines with all the riser posts, anchors posts, and clamp bearings in 2 x 3-hour tide runs with some time left over to start the next row. An experienced crew can install 8 to 12 lines in a tide run. Usually, this work is broken up into stages. First anchor posts are installed, next the lines are strung and tightened, then riser posts (with riser clips already on) are installed, then the line is tightened again and clamp bearings are put onto the lines. Some farmers contract out the piling/anchor post installation. Basket Assembly, figure about 1 minute per basket.
In this cost estimate, what is the spacing of the gear? We know spacing can vary depending on the gear type, so we can go with what is most commonly purchased for that size plot.	The 1-acre farm described would need 64 anchor posts and 992 riser posts. Actually, gear spacing doesn’t necessarily vary by the type of basket used. I like to space lines #1 and #2, 2’ apart. Line #2 and#3, 2.5’ to 3’ apart Line #3 and #4, 2’ apart. For a total row width of 6.5’ to 7’. This spacing allows a farm worker to walk down the middle of the row between lines #2 and #3 and reach all four lines to either remove or place baskets. The boat channels between rows only need to be wide enough to navigate the farm's boat between the rows, generally, that means 10’ at a minimum but could potentially be up to 20’ Starting from one end of a line you would have an anchor post, then a minimum of 6’ to the first riser post. Subsequent riser posts would be placed every 10’ after 31 riser posts (300’) are placed there would be a 6’ space to the other anchor post. Depending on the substrate anchor posts are placed ⅔ of their total length deep. Riser posts should be a minimum of ⅓ their length into the substrate. Line height can be variable (by design) but ideally, the predominant line height used is at waist level to minimize bending and lifting by the crew. The minimum line height could be 1.5’ above the substrate. The maximum should be no more than about 6’. Again to minimize physical strain on the crew.

How many workers would this farm likely require given the size and amount of gear?	A crew of 3 with the proper infrastructure support in place could manage a farm this size quite well. This would include maintenance, harvest and sort, planting, and grading.
Approximately, how many oysters could this farm produce given the spacing, acreage, and size of equipment?	250,000 - 300,000 oysters
What are the upsides and or downsides of using your particular gear type?	**Upsides:** ● Given normal wear and tear at a farm that has been sited and installed correctly. Operational costs such as repair and maintenance are significantly reduced. Keeping farmers farming and not fixing gear failures. ● Baskets (the mesh) have been known to last for over 20 years. Parts that move like doors should last at least 10 years and clips should last well over 5 years. Lines should last 5 to 10 years. ● Operational costs associated with rumbling or tipping oysters are greatly reduced due to the off bottom design that captures wind and wave energy and that can be easily managed and adjusted in height to change how much feeding time and wind and wave energy the farmer wants the oysters to have relative to their size and condition ● Off bottom culture has been shown to improve the growth rates of oysters while minimizing impacts and in some cases improving areas for SAVs ● Designs minimize or eliminate the need for single-use materials like zip ties. For example, because the baskets have doors that latch shut cable ties are not needed. ● Seapa has a community of farmers that they work with around the world including Japan, France, Europe, Australia, Mexico, and across the North American continent. This provides a resource of knowledge and experience that Seapa actively encourages customers to utilize. This resource is also used by Seapa in their design process to continually adapt and improve their product lines. ● For North America, the sales rep has close to 15 years of experience directing oyster farm operations. ● Maintains an inventory of almost all Seapa equipment at a warehouse in the United States. This allows farmers to order their gear and have it delivered to their farm usually within 7 days **Downsides:** ● A high initial investment of capital, relatively technical installation and assembly process, with a steep learning curve. ● Variable site conditions including (but not limited to) substrate, tides, prevailing wind, and wave energy, and regulations can have significant effects on how and what infrastructure is installed. There is no 1 right method that works for every site. (Though I would say this is true of any farm and the gear being used)
Total Startup Costs:	**$150,708**

Table 7. Hexcyl survey response (2023).

Questions	Hexcyl Responses
What are the costs of your shellfish aquaculture gear for one acre? What is the cost of the gear and accessories (i.e. clips) needed for that size plot?	The infrastructure required for one acre of growing oysters with triple lines includes: ● 410 plastic posts ● 9 end strainer posts ● 2,050 post riser clips ● 4,100 stainless steel twist shank nails ● 1,394 meters of Hexcyl line ● 1,230 meters of oyster tube ● 410 wear reduction sleeves ● 1,230 Hexcyl Pro Series Shellfish Baskets Hexcyl provided the costs for some of the above items, but did not include prices for the plastic posts, strainer posts, or nails. The above pricing also does not include the prices for other needs such as a boat or sorting tools. The Hexcyl Pro Baskets would likely accommodate the various growth stages of the oysters. For example, if a grower wanted to grow 1,000,000 oysters, they would purchase enough oysters and baskets for a continuous rotation of stock. Therefore, 1,000,000 oysters would actually be a total of 4,000,000 oysters, with 1,000,000 at each of the four key grow out stages, with 4 different categories of mesh baskets for those stages.
What are the labor costs for installation (if this is a service that is provided or estimated hours of labor for installing said gear)?	Once you have the 100+ posts nailed up with clips and anchor posts in place it should take 2 x people 3 - 3.5 hours for one row of triple lines to be completed.
In this cost estimate, what is the spacing of the gear? We know spacing can vary depending on the gear type, so we can go with what is most commonly purchased for that size plot.	10 meter spacing between rows allows sufficient wave energy and uninterrupted water flow through the area being farmed. 10 meter spacing also allows enough room to safely navigate and turn a vessel around in between the rows.
How many workers would this farm likely require given the size and amount of gear?	One person (part time) could easily manage 5 x rows of triple line containing 1,500 baskets.
Approximately, how many oysters could this farm produce given the spacing, acreage, and size of equipment?	To account for the 4 key grow out stages of oysters on a one acre lease, the farm could grow approximately 40,485 oysters for each continuous key grow out stage, or 161,943 oysters in total.

What are the upsides and or downsides of using your particular gear type?	The main upside is the adjustability of the line. This feature allows the farmer the ability to adjust the growing height of the oysters to manage shell growth, shell hygiene as well as conditioning of the oyster meat. Adjusting 100 yards of triple line can be done by one person in under 10 minutes.
Total Startup Costs:	**$25,780.64 AUD**[10]

Table 8. Summary of startup cost by gear.

Gear Type	Costs (2023)	Oysters Grown
Flip Farm	$110, 400 USD	360k oysters
Seapa - Adjustable Long Line	$150,708 USD	250,000 - 300,000 oysters
Hexcyl	$25,780.64 AUD	161,943 oysters

4.2.3 Startup Costs - Surveys

To gather more information about gear and labor costs, Pacific Shellfish Institute implemented an on-line survey to growers in Washington, Oregon and California in 2022-23. The survey focused on the size of the farm, the gear used, the costs of gear, the costs of labor, as well as how spacing of gear impacts costs of growing and labor as well. The survey was sent to the Pacific Coast Shellfish Growers Association members as well as individuals outside the organization. Unfortunately, there was a minimal response rate to the survey. No significant statistical analysis was feasible as a result.

All respondents grow oysters in Washington, and their farms range in size from 2 acres to 100 acres, with most of the farms ranging from 2-5 acres. Each of the respondents either use flip bags, on bottom methods, or a combination of the two. The initial investments varied depending on the size of the farm, the gear needed, and the spacing of the gear. Table 9 illustrates these responses, as well as the annual costs to repair the gear and as costs of labor.

[10] This calculation was emailed to the Hexcyl sales representative, and they said the estimate sounded accurate. This estimate is missing the costs of posts and nails which varies in price depending on the types used, as well as missing costs for other equipment needed to run this gear type.

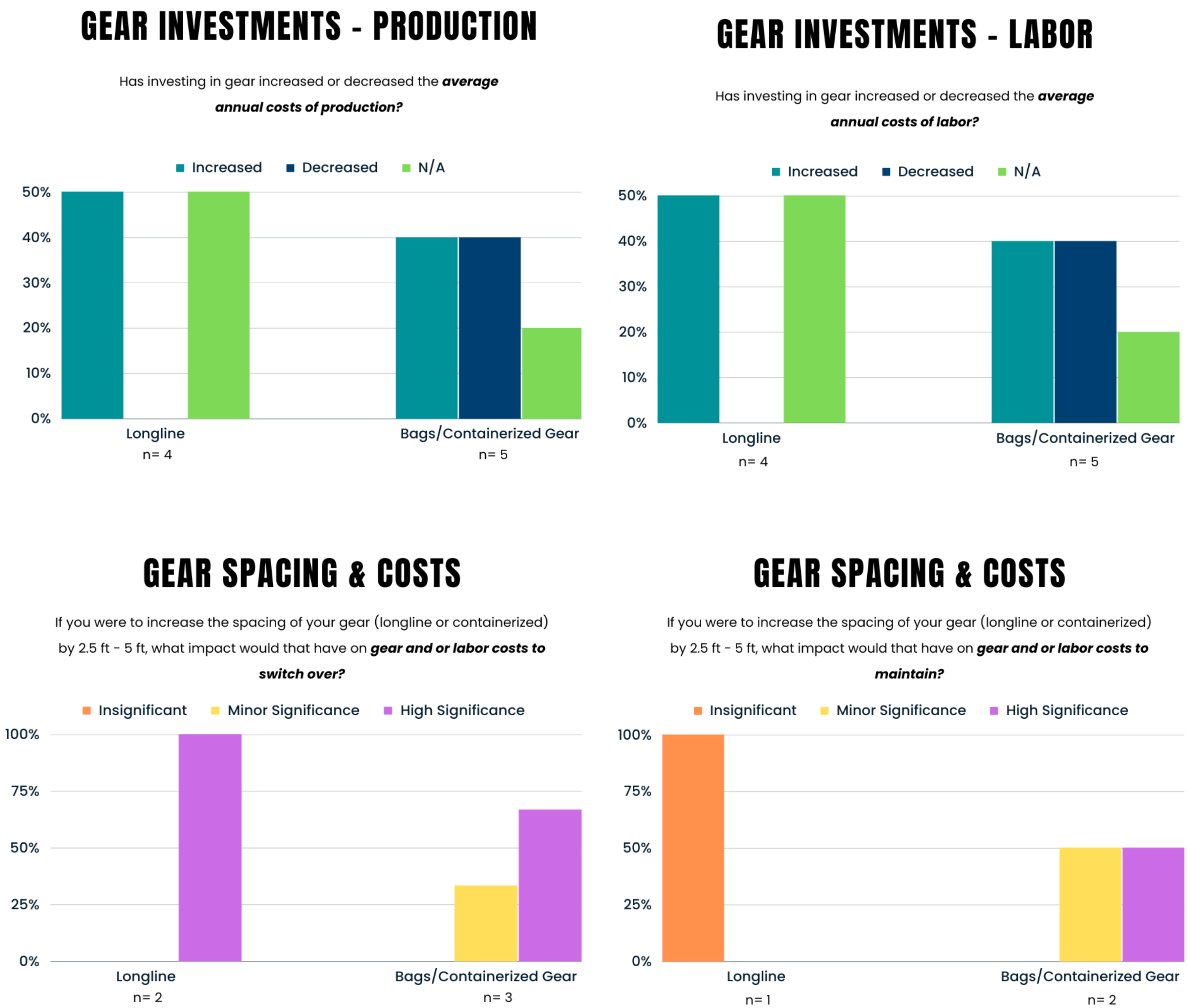
Table 9. Summary of gear investment specification and costs.

Farm	Size	Gear	Spacing	Initial Investment (Gear[11])	Annual Repair Costs (Gear[9])	Labor Costs
Farm One	2 acres	Flip Bags & On Bottom	4 feet - 8 feet	$22,000	$1,200 - $1,500	$1,800 - $3,500
Farm Two	2 acres	Flip Bags	7 feet - 8 feet	$160,000	$30,000 - $40,000	$200,000 - $255,000
Farm Three	5 acres	Flip Bags & On Bottom	1 foot	$15,000	$1,000	$1,250
Farm Four	100 acres	On Bottom	N/A	N/A	N/A	$40,000 - $45,000
Farm Five	5 acres	Flip Bags	Varies	Parts of system are 20 years old - estimated $250,000 to rebuild	$10,000 - $20,000	$100,000 - $200,000

The second half of the survey asked a series of questions to better understand how investing in gear has impacted annual costs of production and labor. There were also questions regarding how the spacing of gear impacts costs. The responses to each question varied between 1 and 5 responses, with an average of 2.83 responses per question. Figure 10 illustrates the responses provided for the latter part of the survey.

[11] Gear refers to bags and containerized gear, this cost estimate does not include boats, personal equipment etc.

Figure 10. Survey response summary.



The final questions of the survey asked about where growers sourced their gear. The growers who utilize longline gear sourced their equipment from Norplex, while growers who utilize containerized gear and bags sourced their equipment from Norplex, Zapco, Seapa, and Taylor Shellfish.

5. Profitability Between On and Off Bottom Cultures

The profitability of oyster farms is dependent on multiple factors including the age of the farm, size of the farm, growing method, as well as farm expenditures. This section provides key findings from previous studies on the profitability of farms as well as recommendations for startup oyster farms.

One of the primary factors that influences profitability on farms is their ability to produce. A recent study illustrated that across the various gear types, large-scale[12] oyster farms were more productive, producing up to more than two times the amount of oysters per hectare when compared to small and medium-scale oyster operations [13]. Another factor that largely influences profitability is the grow out time from seed to market size [13]. For established off bottom farms, profitability was greater with shorter grow out times, while the relationship between productivity and profitability was less clear on startup farms [13]. Regardless, there seems to be a relationship between these two factors as the three most unprofitable farms had the longest growing periods [13].

A separate study in Maine reported the results of benchmarks that served as guidance for prospective shellfish growers based on growing methods (on bottom vs. off bottom) and the number of years a business has been operating (>5 years in business vs. <5 years in business) [14]. Some of the key findings from this report illustrated [14]:

1. Larger farms were more productive than smaller farms, producing more oysters per acre than smaller farms
2. Larger oyster farms were more efficient with their labor use than smaller farms
3. Larger oyster farms were able to better maximize and efficiently invest startup funds than smaller farms
4. Once suspended culture farms that are established, profitability decreased with longer growing times
5. For startup farms, profitability decreased with lower working capital
6. The cost structures, expenses and startup costs differed between suspended oyster farms, established bottom culture farms, and startup suspended oyster farms
    a. Greatest costs for suspended, off bottom oyster farms: labor (62%), marketing (10%), depreciation (8%), management (5%), and insurance (4%)
    b. Greatest costs for established bottom culture oyster farms: labor (48%), insurance (13%), depreciation (11%), seed (8%), repairs (6%), and marketing (3%)
    c. Greatest costs for startup oyster farms: depreciation (28%), seed costs (20%), labor (16%), repairs (8%), and insurance (5%)

[12] Large-scale oyster farms in this study were determined by the production scale (250,000 or more oysters sold).

Given these key findings, the Maine Aquaculture Financial Benchmarking Report outlined recommendations for startup oyster farms [14]. These recommendations assist in the profitability of newly established aquaculture operations. The recommendations include [14]:

1. Have adequate startup capital, but ensure you keep the farm within a comfortable level of financial risk (debt/asset ratio less than 50%).
2. Develop a 3-year cash flow budget to account for periods of lessened income before the full oyster production is underway.
3. Start slowly - purchase less oyster seed in the beginning to account for the learning curve.
4. When producing oysters, monitor the farm's success through tracking mortalities, harvest quantities per acre, and the amount of labor needed to produce oysters to set benchmarks that will guide the future of the farm.

5.1 Age of Farm

The age of an aquaculture farm affects the profitability which was demonstrated by a few different studies. One study found that the expenses were different on established suspended farms compared to established bottom culture farms, where established off bottom farms spent 68% more on labor than established on bottom farms [13].

Other studies illustrated the finances for startup oyster farms [14]. One study found that four of the starting farms they surveyed had negative gross and net margins, with working capital less than an average startup farm [14]. Three of the four farms shared common characteristics that may have contributed to the farm’s inability to increase their profit margin. Those shared traits are in comparison to the average startup farm and include [14]:

- Longer grow out period of oysters from spat to market size
- Fewer oysters harvested per acre
- Had more breakeven prices above total costs
- Had a larger amount of variable costs per acre

Two of the four startup farms with negative net income had even more shared characteristics when compared to the average startup farm that impacted their ability to increase profit margins [14]:

- More oysters were planted per acre
- Higher startup costs per acre
- Greater seed costs per acre
- Negative working capital

5.2 Regulations

One of the key considerations for the profitability of an oyster farm are the regional and state regulations set in place for oyster aquaculture operations. In addition to the learning curve of growing oysters for start up farms, a recent survey indicated that 51% of respondents in Washington, Oregon and California found that regulations were the primary challenge of running their oyster farms [16]. Across the three state study areas, the total regulatory costs were over $11.5 million[13] [16]. When divided between the farms across the three states, the average costs per farm were estimated to be around $240,621 with a median cost per farm of $58,769[10] [16]. California had the highest costs among the three states, with Washington following closely behind [16]. Oregon had a lower total regulatory cost as well as a lower average farm regulatory cost, however their median regulatory cost was similar to Washington State [16].

This survey also addressed the various types of permits and their associated costs in Washington, Oregon and California. Of the permitting categories, the most expensive regulatory permits were the environmental management permits and the regulatory filings for the Pacific coast [16]. These regulations averaged $84,615 per farm[10] [16]. Aquaculture permits were the second most expensive regulatory category, averaging $65,974 per farm[10] [16]. This was followed by food safety permits ($28,149/farm), the legal and labor standards ($1,563/farm) with interstate transport regulations costing the least of the six categories ($393/farm)[10] [16]. From this survey, it was determined that the size of the farm has an impact on the regulatory costs per hectare. Larger farms had the lowest regulatory costs per hectare with a mean of $514/ha and a median costs of $363/ha[10]. Smaller farms, classified as extra small in this survey, had the largest regulatory costs with the average cost per hectare being 382 times greater than the largest farm size surveyed [16].

5.3 Labor

One study examined the financial benchmarks for marine aquaculture in Maine given farm data. This study found labor accounted for the highest percentage of production costs for both on and off bottom cultures for established aquaculture operations [13]. On suspended farms, labor costs constituted 68% of the total costs, while they accounted for 48% on bottom culture farms [13]. This cost structure varied slightly in other studies when looking specifically at gear type, however, many of the studies consistently found that labor was the greatest cost on off bottom container farms [13].

[13] These financial estimates were calculated in 2020 and do not reflect the accrued inflation from 2020 to 2023.

An additional survey looked at the labor needed for oyster farms as well as the job opportunities provided by aquaculture in the state of Washington. Survey respondents provided information on the number of individuals employed as well as the number of acres for the farm. From that information, the study concluded that the average Washington grower employs one person per acre farmed [17]. The minimum employment on aquaculture farms in Washington resulted in .01 persons per acre farmed, or 1 person per 100 acres farmed [17]. The maximum employment was as great as 5 people per acre farmed [17]. The original research team from the survey believe that many of the non-responses to the questions stem from growers who are self-employed and do not hire additional staff, but do not include themselves as employees when reporting [17]. Given the lower employment ratio, this study estimated that Washington's shellfish aquaculture operations provide 1,840 jobs throughout the state [17].

5.4 Financial Modeling

A recent study addressed modeling and financial viability of mollusk and bivalve aquaculture in the Gulf of Mexico. This study looked at various risks such as the market price of oysters, biofouling, changes in water temperature and salinity, mortality, labor, and equipment longevity [1]. This study examined the financial feasibility of floating bags, floating cages, and adjustable longlines under various levels of environmental uncertainty [1]. This model has several assumptions that were in place in order to compare the systems equally. These assumptions include all oysters being sold into the half shell market and capital expenditures are self-financed (except for a boat) [1].

According to this model, floating bags, floating cages, and adjustable longlines were all profitable each year of the ten year study period when there were no additional environmental risks added [1]. Additionally, each of the gear types had reached maximum production capacity by year six [1]. Of the three gear types, floating bags were the most profitable and were able to reach positive net gain faster than the two other types of grow out gear [1]. Floating cages demonstrated the highest survival rate for oysters in the model, however, it did not appear to be the most economically sustainable method of production when the assumptions of the model were used [1]. The floating cages did not have any net gain by year ten in the scenarios provided. Lastly, floating bags also achieved net profits by year ten under the highest risk scenario of the model, despite being the most negatively impacted by environmental risk [1].

This study illustrated that the least costly and most profitable system of the three was the floating bag system [1]. Another system with great potential for growing as well as profit is the adjustable longline system. Compared to the other systems, adjustable longlines require low labor and have lower long term costs for production, despite the greater initial costs [1]. The main downside to adjustable longlines, however, is the lower production per acre when compared to floating systems [1]. There are ways to increase production through quad-run setups, but systems that allow for more dense production, such as the floating bags or cages, allow for higher concentrations of oysters during production.

6. Indigenous Methods of Aquaculture

Indigenous aquaculture (IA) varies from the gear types mentioned in the above sections. From the creation of clam gardens to fish ponds, IA explores the biocultural systems of management through cultivated ecosystems and place-based knowledge of the land and water [18]. Through IA, communities have access to traditional coastal foods while also increasing seafood production. These practices strengthen not only relations with the environment and one another, but also build towards “solutions for climate adaptation and coastal restoration” [IA website].

Given these goals of IA, there is not a wide amount of literature on the costs and economics of these practices. However, one study examined the economic feasibility of producing oysters using cages through a small-scale, Hawaiian fishpond model [19]. This project acknowledged how traditional fishpond aquaculture has declined in Hawai’i with the increase of global trade, however the cultivation of oysters can help with maintaining the culturally important practice and use of fishpond aquaculture [19].

The goal of this study was to gather more information on the profitability of a hybrid approach to fishpond aquaculture for oyster production as well as utilize stochastic modeling to determine the variety of economic outcomes [19]. This project revealed that the budget returned an insignificant negative profit, with the majority of operating costs being designated towards labor [19]. However, further analysis illustrated that this farm model could be profitable with an increase in oyster market price from US $1.25 to $1.35[14], or if oyster mortality were to decrease from 50% to 45.9%. [19]. From this model, researchers identified labor and oyster seed as the highest costs, with the budget comprising 64.1% of labor and 10.9% seed [19].

The startup costs for this method of growing were also determined. Oysters were grown using the fish pond model in 7.6L/2 gallon cylindrical floating cages. Oyster seeds were started in 5

[14] These financial estimates were calculated in 2016 and do not reflect the accrued inflation from 2016 to 2023.

mm mesh, then were transferred to cages lined with 12.7mm mesh after 14 days [19]. After 56 days, the oysters are then placed in unlined cages [19]. It takes 6-12 months for these oysters to reach market size, and the pond used for this model could support the growing of the initial stocking of seed which were 312,000 seeds [19]. This model utilizes depuration tanks as well, where market size oysters are depurated in batches of 1,000 every 48 hours [19]. Given the gear used, the total startup costs for year 0 are $156,447 [19]. The majority of this cost is due to the equipment, vehicles and other gear needed to start the farm, which accounts for 46.2% of the startup budget [19]. Some of the other components of this budget are the cages, which account for 20.1% of the budget (or $31,500)[11] [19]. The depuration facility accounts for 9.6% of the startup budget, while permitting and initial fees are around 53.7% of the budget [19].

7. Report Overview

This report focuses on the costs and profitability associated with various grow out types for oyster aquaculture. This report begins by outlining the various gear types in both on and off bottom aquaculture as it pertains to oyster cultivation. It then dives more deeply into each discipline respectively.

On bottom cultures refer to the cultivation of oysters grown on substrate. Some of the largest expenses for this method of growing are fuel, labor, and equipment. The startup costs for on bottom cultivation varied greatly, however the majority of the literature found costs per acre to range between $1,017 and $19,750 [11]. The majority of the information from this section was sourced during the literature review, whereas the off bottom section gathered information from a literature review, surveys, and interviews.

While some studies have demonstrated that on bottom culture is less risky, large-scale off bottom culture tends to be more profitable. Initial investments for container, or off bottom operations, are significantly higher than that of on bottom operations. However, off bottom culture has demonstrated higher per unit revenues than on bottom culture. The specific start up costs for off bottom farms vary not only in the literature, but also in the surveys and interviews. The costs for starting an off bottom farm vary depending on the size of the farm and the gear used. This section is divided up into three parts: literature review, interviews and the survey questions to address the origins for the start up cost estimates. The literature review portion highlights a couple case studies that examined the various costs of alternative gear types on the Atlantic coast. The interview portion provided the questions sent out to gear suppliers and distributors of alternative gear types, as well as the answers provided for their gear as it pertains to the start up costs, equipment needed, and the benefits and drawbacks of their specific gear. The last subsection analyzes the survey responses sent to oyster growers in

Washington, Oregon and California. The survey addresses startup costs, maintenance costs, labor costs, as well as how spacing of the gear can impact those financial markers.

The following section of this report shifts away from the startup costs and examines profitability between on and off bottom cultures. There are several factors beyond gear type that influence a farm's profitability such as the age of the farm, regulations, and labor. This section also discusses financial modeling as these are themes central to how a farm operates, and provides helpful classifications within each of those themes to help support farms increase their profit.

The final section of this report addresses Indigenous aquaculture as it pertains to Western methods of growing, especially focusing on the costs of this practice. There are not many studies that address the economic feasibility of Indigenous aquaculture, however, one paper examined Hawaiian fishponds as a model for growing oysters utilizing a hybrid approach. There are many benefits to Indigenous aquaculture and hybrid approaches, so this section aims to highlight the integration of Indigenous aquaculture methods not only for cultural revitalization, but also environmental and economic sustainability.

Table 11. Startup costs between on and off bottom oyster culture.

Aquaculture Method	**Cost Estimate per Acre**
On Bottom Costs	General Costs: $1,017 - $26,553 per acre[15] Startup Costs (initial years): $58,000 - $96,000
Off Bottom Costs	Flip Farm Start Up Costs (1 acre): $110,400 Seapa Adjustable Longline System Costs (1 acre): $150,708 Hexcyl Costs (1 acre): $25,780 AUD

[15] These financial estimates were calculated in 2020 and do not reflect the accrued inflation from 2020 to 2023.

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