Maine Seaweed Benchmarking Report

August, 2023

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MAINE AQUACULTURE ASSOCIATION

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Executive summary

Maine's farmed seaweed harvest has grown exponentially over the last 5 years. In an effort to characterize how the recent expansion of the sector has impacted the financial and production efficiency of individual seaweed aquaculture businesses, we calculated a comprehensive set of sector-wide benchmarks. This work builds upon the prior Maine aquaculture sector benchmarking study (Engle et al., 2020) and attempts to capture improvements between the 2017 and 2022 harvest seasons.

We interviewed 16 farmers operating seaweed aquaculture businesses in Maine state waters. Lease, harvest, production, sales, risk, and financial information was recorded over the course of our conversations. First, we present the median, average, and standard deviation (SD) for each benchmark calculated across all 16 participants. The full suite of metrics, including maximums, minimums, and coefficients of variation (CV) can be found in the Appendix. Second, farms were categorized based on wet lbs. of seaweed harvested in 2022, which included three groupings: Group A farms ≤10,000 lbs., Group B farms 10,001 – 75,000 lbs., and Group C farms >75,000 lbs. The 5 farms in Group C harvested 72% of the seaweed included in this study, while the 5 farms in Group B harvested 25% and the 6 farms in Group A harvested 3%. We then recalculated benchmarks according to size groupings.

Between 2017 and 2022, yield, efficiency, and profitability increased on kelp farms in Maine. These gains can likely be attributed to increased farmer knowledge, "learning by doing", extension support, and improved seed production and handling practices. The 16 farmers we interviewed harvested, in total, over 1 million lbs. (wet weight) of seaweed in the Spring of 2022, ~22 times the harvest volume from the 2017 season.

Metric	'17 Median	'22 Median	'17 Avg ± SD	'22 Avg ± SD
Yield (lbs./ft. of grow-line)	3.7	4.24	2.7 ± 1.8	4.25 ± 2.13
Labor cost contribution ($/lb.)	$3.35	$0.11	$2.90 ± $2.95	$0.18 ± $0.21
Labor efficiency (lbs. harvested per hr of labor + management)	7.55	103.76	22.14 ± 32.89	107.45 ± 58.77
Breakeven price above variable cost ($/lb.)	$4.97	$0.29	$3.86 ± $3.14	$0.71 ± $0.97
Breakeven price above total cost ($/lb.)	$6.89	$0.66	$4.86 ± $3.74	$1.22 ± $1.45
Breakeven yield above total cost (lbs./ft.)	12.64	2.69	16 ± 16.67	3.26 ± 2.41
Net margin ($/lb.)	-$6.41	$0.16	-$4.38 ± $3.78	-$0.04 ± $1.16
Operating expense/revenue ratio	13.8	0.41	9.8 ± 8.2	0.51 ± 0.44
Depreciation expense ratio	0.6	0.18	0.7 ± 0.4	0.18 ± 0.09
Net farm income from operations ratio	-13.4	0.20	-9.8 ± 8.7	0.06 ± 0.66

Increases in scale and farmer experience drove increases in yield, labor efficiency, and net farm income. Break even farm gate prices ($/lb. of harvested kelp) were negatively correlated with scale as farms in groups A, B, and C reported break even prices of $2.52, $0.70, and $0.36/lb., respectively. As a result, 9 of the 16 farms were profitable, and positive net margins were largely dependent on farm size. Seven of the ten Group B and C farms were profitable, while no farms in Group A had positive net margins.

Farm owner/operators spent a median of 174 hours working on their farms throughout the season, or roughly 4 work weeks (Monday to Friday) consisting of 8-hour days. Farms incurred a median hired labor expense of $2,812 over the course of the year. Given that only 50% of farm owners took a salary or cash draw at the end of the season, the opportunity cost of kelp farming should be considered. We recommend that farmers assess the projected income from kelp farming and compare it to the time and effort that could be invested in other activities that require a similar time commitment and could be held during the fishing offseason.

Benchmarks can be accessed by farmers, processors, wholesalers, researchers, regulators, and lenders. This report should be used as a guide, as notable variation existed between farms. Overall, we observed significant sector-wide progress between the 2017 and 2022 harvest seasons. Yield, labor efficiency, production costs, financial efficiency, and profitability all improved. Fishermen, shellfish farmers, and other members of the working waterfront continue to leverage seaweed farming as a worthwhile source of supplementary income.

KEY FINDINGS SINCE 2017

- Median seaweed yields increased by 28%, from 3.3 to 4.24 lbs./ft., while average yields increased by 57%, from 2.7 to 4.25 lbs./ft.

- Labor efficiency improved by 1,275%, from 7.55 to 103.8 lbs. harvested per hour of labor and management input

- Median breakeven prices above total costs dropped by 90%, from $6.89/lb. to $0.66/lb. for all farms, and were $2.52, $0.70, and $0.36/lb. for farms in Groups A, B, and C, respectively

- Almost all farms that harvested 75,000 lbs. or more were profitable (5 of 6 farms), while only 4 of the 10 farms that produced <75,000 lbs. were profitable

- Net margins ($/lb.) increased with farm size (total lbs. harvested), while breakeven price decreased with farm size, indicating economies of scale

- Despite overall reductions in product loss between the 2017 and 2022 harvests, line tangling and gear failure continue to pose risks to financial success

- Over 80% of the respondents made their primary income on the water, and the majority were fishermen, underscoring the fact that seaweed farming can provide a seasonal source of income for members of the working waterfront that already own equipment such as boats

- Based on the magnitude of improvement between the 2017 and 2022 harvest season, we anticipate that continued experience, learning, and increases in scale will lead to further improvements to the production and economic health of the farmed seaweed sector in Maine

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Introduction

In the last decade, the farmed seaweed sector in Maine has undergone exponential growth, bringing forth new opportunities. In 2015, producers landed ~14,500 lbs. of farmed kelp (DMR, 2022). In 2022, that number increased by a factor of 70, with over 1,000,000 lbs. harvested, the largest recorded season in both Maine and any region in North America to date. Growers in Maine primarily farm sugar kelp (*Sacharina latissima*), and a local varietal known as skinny kelp (*Sacharina angustissima*). Farmed seaweeds require minimal land and freshwater inputs over the full farm-gate production chain, and can be used as raw materials for a variety of applications (Grebe et al., 2019). The current market for U.S. farmed kelp is dominated by value-added food products destined for human consumption, but growers and processors are exploring animal feed, fertilizer, pharmaceutical, biofuel, and bioplastics applications (Piconi et al., 2020). The value chain encompasses land-based nursery production, marine cultivation, first stage processing (or "stabilization"), and second stage or "final" processing (McKinley Research Group, 2021). The emerging seaweed aquaculture sector has created an environmentally and economically sustainable opportunity to diversify Maine's working waterfronts and bolster the blue economy.

The domestic kelp aquaculture sector, encompassing both coasts, is set against the backdrop of a ~$95 million U.S. seaweed imports market (FAO, 2022), as well as a U.S. wild harvest sector that landed ~18.3 million lbs. of seaweed in 2020 (McKinley Research Group, 2021). Farmed Maine kelp has avoided competition with lower priced imported or wild harvested seaweed products through market differentiation and a scale up in domestic processing capabilities for value-added food products. However, the seaweed aquaculture sector in Maine alone is projected to expand by an additional 2.5 million lbs., potentially reaching 4.1 million lbs. perhaps even by 2025 (Piconi et al., 2020; personal communications, Maine seaweed expert). A potential outcome of this growth may be increased efficiencies, economies of scale, and a reduction in farm-gate production costs, thereby opening new markets for domestic producers and processors.

Kelp farming, like most aquaculture ventures, can be capital intensive. Growers and business owners must undertake careful planning and financial management to avoid under or overcapitalization, navigate the challenging pre-profit growth stage, and maximize returns in a sector often characterized by narrow margins. As the Maine kelp sector expands, growers, processors, and distributors of farmed seaweed products will require accurate financial and production information to enable informed decision making.

Benchmarks are commonly used by business owners within the agricultural industry to access a snapshot of a specific sector. These metrics are calculated by aggregating sector-wide data across a suite of business and on-farm production categories, and then quantifying the maximum, minimum, range, median, and average for each value. Benchmarks can then be accessed by farmers to compare the performance of their individual business against the sector as a whole. A farm's inputs and outputs, such as labor costs and per acre yield, can be measured against sector averages/medians, and production strategies subsequently altered if needed. Additionally, lenders commonly lean on sector benchmarks to evaluate prospective business plans during the loan underwriting process. In this manner, benchmarks provide a third-party perspective on the expected economic performance of farms, allowing lenders to confidently approve financing and farmers to access critical startup or growth capital. Lastly, benchmarks can be useful risk management tools for farmers, particularly with respect to identifying areas of potential financial exposure or loss leaders. The success of aquaculture businesses is often determined by a farmer's ability to effectively manage inputs (such as labor and operating expenses) and maximize yields. Therefore, quality financial benchmarks can facilitate data-driven decision making.

The primary goal of this study was to calculate a comprehensive set of benchmarks for the Maine farmed seaweed sector. This work builds upon a 2020 Maine aquaculture sector benchmarking report and provides updated information on the seaweed aquaculture sector, specifically. The 2020 report was constructed using data from a limited number of kelp farmers (n=6) operating during the 2016 – 2017 harvest season, during which growers produced a collective 53,564 lbs. (DMR, 2022; Engle et al., 2020). Given the recent growth in both the number of operational farms and the total harvest in the state, economies of scale and production efficiencies may have been realized. In addition to capturing the long-term improvement and learning that has occurred within the sector, this study provides updated benchmarks which can be leveraged by growers, processors, lenders, and researchers. We focused on four main objectives:

1. Calculate sector-wide benchmarks to support both established and startup seaweed farms
2. Provide an accessible summary of the data to inform farmers, processors, and researchers
3. Compare the results of the present study to the 2020 benchmarking analysis to help the seaweed community understand changes in the sector and project future growth
4. Provide quality and transparent economic data that can be accessed by researchers studying the dynamics of kelp farming in the Gulf of Maine

Methods

Interviews and participants

We adhered to the methodology described in Engle et al (2020) to quantify financial and productivity benchmarks for the Maine farmed seaweed sector (Engle et al., 2020) and amended the interview questionnaire to include production metrics specific to seaweed farming. To identify potential participants, we first compiled a Maine seaweed lease catalog using the publicly available Maine Department of Marine Resources (DMR) aquaculture lease database. Leases and limited purpose aquaculture licenses (LPAs) were filtered based on whether or not the lease/license listed seaweed as an approved species. Contact information for lease and license holders was gleaned from publicly available lease application and decisions records. A combination of email and phone outreach was then conducted to schedule interviews with growers. Respondents were provided with a brief overview of the project, the goals of the study, and the structure of the interview.

Table 1. Participants

Initial contact list	46
Not in business	11
Final list	35
Refusals	0
No response	19
Completed interviews	16
Participation rate	45.71%

The interview tool was tested in mock interviews with other researchers and extension agents prior to delivery to sector participants. The full interview script can be found in the **Appendix**. Interviews lasted approximately 1 – 2 hours and were conducted over the phone or zoom. All interviews were recorded. Only the audio was saved and individual businesses were linked to responses with a key (i.e., Q1, Q2, etc.) to preserve anonymity.

We completed interviews with 16 seaweed farmers in Maine operating at various scales (**Table 1**). After providing a brief overview of their business, growers were asked a series of questions related to the financial performance and productivity of their businesses. 46 businesses were initially contacted. 11 respondents reported that they were no longer in business. Of the 35 requests for an interview 19 did not respond. There were no refusals.

Data analysis

We then entered the data into a spreadsheet and matched individual businesses to responses using the anonymous respondent key. Initially, we calculated benchmarks using data for all participants combined (n=16). However, the scale at which an aquaculture business operates can have a strong influence on the cost structure and performance of the farm. Therefore, we also partitioned farms into groups "A", "B", and "C" based on annual harvest quantities (lbs. wet weight). Group A farms landed ≤ 10,000 lbs., Group B farms landed between 10,000 and 75,000 lbs., and Group C growers landed > 75,000 lbs. In total, there were 6 Group A, 5 Group B, and 5 Group C farms. It should be noted that by international standards, even Maine's largest seaweed farms (harvesting >75,000 lbs.) are considered small-scale operations.

Benchmarks

Benchmarks were broken down into qualitative and quantitative metrics. Qualitative metrics included perceived risks, sources of crop loss, and concerns of potential seaweed market saturation. Quantitative metrics included financial and productivity indicators.

Each benchmark was calculated separately for each participant, and then medians, minimums, maximums, averages, standard deviations (SD), and coefficients of variation (CV; SD divided by the mean) were calculated across all individual observations. The resulting benchmark statistics are presented as follows: production (harvest, lease, and license data); sales; expense (direct operating/variable costs and ownership/fixed/overhead costs); total annual costs, breakeven prices, and breakeven yields; profitability; risks; repayment analysis; labor (costs, efficiency, and wages), market saturation, startup costs, financial, and financial efficiency. The full list of benchmarks can be found in the **Appendix**.

Cost structures of seaweed farms were examined by calculating the relative proportions of line-item costs such as fuel, labor, maintenance, etc. To examine whether economies of scale influenced the dynamics of seaweed production in 2022, we assessed the relationship between the average cost of production (break-even price above total costs, in $/lb.) and production scale (total quantity of seaweed sold) for all 16 farms.

To further explore the impact of farm scale on performance, we quantified the relationship between total wet lbs. sold and yield (lbs./ft.), breakeven yield above total cost (lbs./ft.), net margins ($/lb.), and labor efficiency (lbs. harvested per hour of labor and management), respectively.

Farm size analysis

Key benchmarks were then tabulated for farms in Groups A, B, and C. We calculated production (acres planted, yield, ft. of line), sales, labor costs, labor efficiency, costs (variable/fixed) breakeven prices, breakeven yields, profitability, and financial efficiency benchmarks for each size grouping. We also quantified the relationship between farm size (A, B, or C) and yield (both lbs./acre and lbs./ft.), variable costs as a % of total costs, ownership (or fixed) costs as a % of total costs, breakeven price above total costs ($/lb.), and labor efficiency (lbs. harvested per hour of labor and management), respectively.

Results: aggregated farm size analysis

Production: harvest, lease, license, and sales data

The 16 farmers we interviewed in Maine operated on a combined 22 leases and 35 Limited Purpose Aquaculture (LPA) licenses, which collectively spanned over 86 acres (**Table 2**). Growers leased a median of 5 acres per farm, ranging from 0.01 to 12.04 acres. Only 6 of the farms held LPAs. An LPA is 400 sq. ft., or 0.01 acres. Those who held LPAs had a median of 5.5 individual LPAs per farm. 11 farms held leases with a median of 8 acres per farm (**Table 2**). Fewer than 3 farms held both a lease and LPA. Of the 16 farmers included in the study, 9 participated in commercial fishing, and an additional 4 also ran other marine-based businesses, totaling 13 farmers (>80%) who participated in Maine's working waterfront in addition to farming seaweed.

Table 2. Number and acreage of leases held by respondents

	Unit	Total	Average per farm	Std. Dev (SD)	Median per farm
Number of leases					
Standard and experimental	number	22	2	0.89	5
LPAs	number	35	5.83	4.17	0.06
Total acreage of leases					
Standard and experimental	acres	86.04	7.82	3	8
LPAs	acres	0.35	0.06	0.04	0.06

In total, the farmers in this study deployed 222,260 ft. of grow line and harvested just over 1 million wet lbs. of kelp. All references to lbs. refer to wet lbs. of kelp harvested and sold. The following per acre production calculations are based on the reported area of standard and experimental leases and area adjusted LPA acreages. A typical LPA is 400 sq. ft., or roughly 0.01 acres. However, LPAs are usually spaced next to each other as one would align longlines within a multi-acre lease (10 - 20 ft. between LPAs). To compare the true "leased area" between, for example, 4 longlines within LPAs and 4 longlines within a standard lease requires a standardization. To control for this difference, we standardized the acreage of LPAs based on the average square footage per individual longline on each LPA. We multiplied the median line spacing of 11.5 feet by the area of an LPA, 400ft^2, to gauge the true footprint of a typical longline within an LPA: 4,600 sq. ft., or 0.1056 acres. Thus, each LPA was multiplied by 10.56 to obtain an adjusted acreage. The small footprint of LPAs has skewed the results of other studies analyzing Maine aquaculture, including those exploring regulatory costs (van Senten et al., *in prep*). LPAs were not adjusted in the previous seaweed benchmarking study (Engle et al., 2020), meaning that per acre production and financial benchmarks should not be directly compared across the two studies.

Farmers seeded a median of 3,250 ft. of grow line per acre, with a median linear yield of 4.24 lbs. per foot of grow line (**Table 3**). We observed a positive correlation between farm size (total lbs. harvested) and linear yield (lbs. harvested per foot of grow line) across our entire study sample

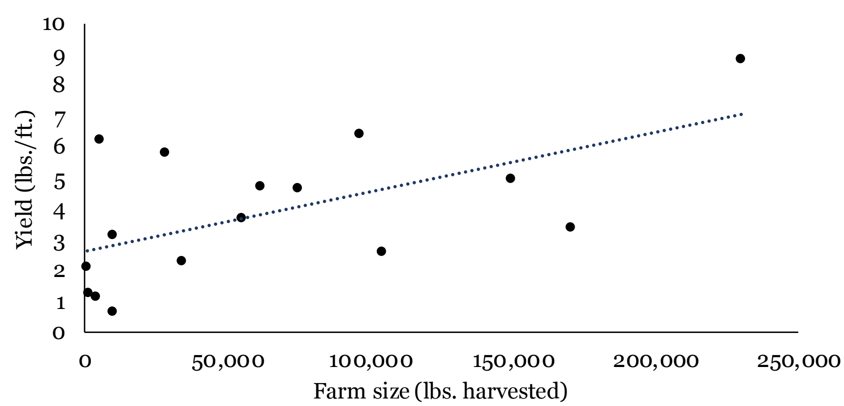
(**Figure 1**). It is worth noting that the previous benchmarking study (Engle et al., 2020) recorded a *maximum* yield of 4.5 lbs. per foot of line – about half the maximum recorded in 2022, 8.85 lbs./ft, and marginally higher than the average. In the previous study, 2 of the 6 respondents reported near total crop losses. In this study, none of the 16 respondents reported a total crop loss.

Table 3. Production and yield per farm

Metric	Unit	Median	Average	SD
Longline	ft/acre	3,250	2,693	1,152
Longline spacing	ft	11.50	20.92	17.27
Longline depth	ft	6.50	6.79	1.12
Yield	wet lbs./ft	4.24	4.25	2.13
Yield	wet lbs./acre	9,128	11,207	7,747

Grow lines were spaced a median of 11.50 feet apart and were held at a median depth of 6.50 feet (**Table 3**). Although we observed no clear relationship between grow line spacing and lbs. harvested per linear foot, several growers mentioned that they will be adding space between lines in the upcoming season to mitigate tangling, a substantial source of loss. Growers also noted that when line to line interactions occur, only 0-33% of kelp from tangled lines is typically recovered for harvest. Growers harvested a median of 9,128 lbs. per acre (**Table 3**).

Figure 1. Effects of farm size on linear yield (lbs./ft.)



Over 95% of harvested seaweed was sold to a value-added processor (**Table 4**). While some farms did process and sell dried seaweed, there were not enough of such farms or sales to be able to report these figures without compromising confidentiality.

Table 4. Sales

Metric	Unit	Median	Average	SD
Seaweed sold unprocessed wet	% of total	100%	95.25%	18.73%
Seaweed sold to value added processor	% sold	100%	95.19%	18.72%
Seaweed sold direct to consumer	% sold	0%	4.81%	18.72%

Expense benchmarks

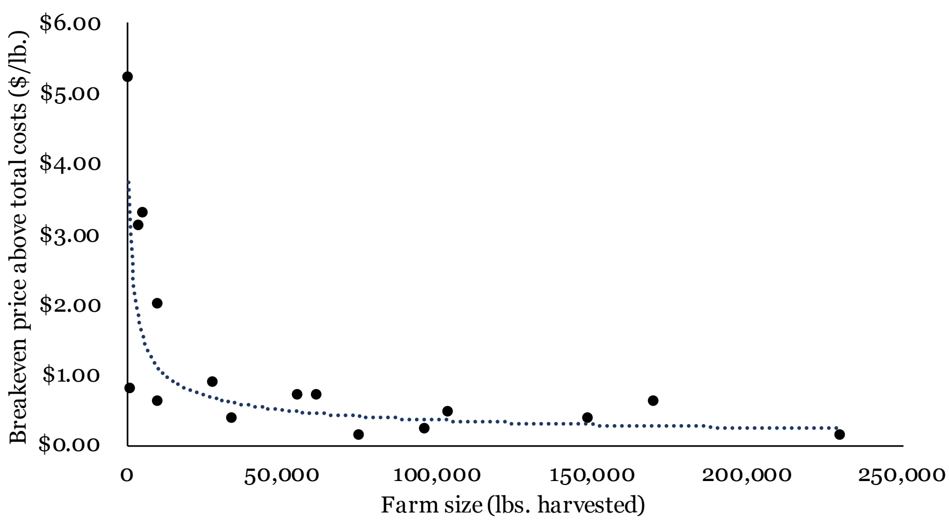
The median breakeven price above variable costs was $0.29/lb. harvested (**Table 5**). Variable costs accounted for a median of 63.71% of total costs, while fixed (ownership) costs accounted for a median of 36.29% of total costs (**Table 5**). Median breakeven price above total costs ($/lb.) was $0.66/lb., while the average was $1.22/lb. (**Table 5**). Part of the discrepancy between the average and median is that 4 farmers reported breakeven prices above total costs that ranged from $2 - $5/lb. It is worth noting that all four of these farms harvested 10,000 or fewer pounds of kelp.

Table 5. Cost, breakeven price, and breakeven yield

Benchmark	Unit	Median	Average	SD
Total variable (operating) cost	% of total cost	63.71%	57.35%	19.93%
Total ownership (fixed) cost	% of total cost	36.29%	42.65%	19.93%
Cost of Goods Sold (COGS)	$/planted acre	$1,141	$1,760	$1,487
Total cost (variable and ownership)	$/planted acre	$4,408	$9,479	$10,826
Breakeven price above variable cost	$/lb. harvested	$0.29	$0.71	$0.97
Breakeven price above total cost	$/lb. harvested	$0.66	$1.22	$1.45
Breakeven yield above variable cost	lbs./acre	3,544	4,932	4,546
Breakeven yield above total cost	lbs./acre	7,347	9,182	7,080
Breakeven yield above variable cost	lbs./foot of grow-line	1.21	1.71	1.36
Breakeven yield above total cost	lbs./foot of grow-line	2.69	3.26	2.41

The farms that generated the lowest breakeven prices above total costs harvested 75,000 or more pounds of kelp (**Figure 2**), highlighting the economies of scale found in the 2022 Maine farmed seaweed sector. Breakeven yield above total costs indicated that farmers must harvest a median of 2.69 lbs. of seaweed per ft. of grow line to be profitable (**Table 5**), and that larger farms were required to harvest fewer lbs. per foot to be successful (**Figure 3, Appendix**).

Figure 2. Effects of farm size on breakeven price above total costs ($/lb.)



The largest contributor to variable costs, on a median dollars per harvested lb. basis, was labor, followed by maintenance and fuel. (**Table 6; Figure 4, Appendix**). It is worth noting that when we removed one of the smaller farms from the analysis, which was a marketing cost outlier, the average contribution of marketing costs to total costs fell from $0.26 to $0.04/lb. While 7 of the 16 farms incurred marketing costs, these farms only represented ~15% of the total harvest from our sample. Therefore, in line with the data on sales and distribution channels, only a small fraction of farmed seaweed produced in Maine is marketed by the farmers themselves.

Table 6. Breakdown of variable costs ($/lb.)

Benchmark	Median	Min	Max	Average	SD	CV
Labor	$0.11	$0.00	$0.83	$0.18	$0.21	116.6%
Fuel	$0.03	$0.00	$0.58	$0.08	$0.16	196.0%
Marketing	$0.00	$0.00	$3.41	$0.26	$0.87	330.9%
Maintenance	$0.05	$0.01	$0.09	$0.04	$0.03	72.8%
Consumables (Misc supplies)	$0.02	$0.00	$0.94	$0.14	$0.29	213.6%
Other variable costs (diver, etc.)	$0.00	$0.00	$0.40	$0.09	$0.15	162.6%
Total breakeven price above variable costs	$0.29	$0.08	$3.56	$0.69	$0.93	134.2%

Median fixed costs per lb. harvested were $0.33/lb., with depreciation and insurance as the two largest cost contributors (**Figure 5, Appendix; Table 7**). The fact that depreciation was the largest driver of fixed costs was unsurprising, given that many operators already own and use large pieces of infrastructure on their farms, such as lobster boats. When assigning depreciation costs for capital equipment, such as a lobster boat, only the portion of the piece of equipment dedicated to the seaweed business was incorporated into the calculation. It is also worth noting that cost of depreciation was heavily dependent on farm scale. Out of the 16 farms we analyzed, 4 of the 5 smallest farms had the highest levels of depreciation on a $/lb. basis, indicating increases in return on assets at with larger production volumes.

Table 7. Breakdown of ownership (fixed) costs ($/lb.)

Benchmark	Median	Min	Max	Average	SD	CV
Telephone + internet	$0.00	$0.00	$0.01	$0.00	$0.00	273.6%
Insurance	$0.01	$0.00	$0.26	$0.05	$0.09	179.9%
Office expenses	$0.00	$0.00	$0.00	$0.00	$0.00	370.4%
Legal	$0.00	$0.00	$0.21	$0.03	$0.07	213.6%
Depreciation	$0.08	$0.01	$1.12	$0.27	$0.41	150.8%
Mooring fee	$0.00	$0.00	$0.03	$0.00	$0.01	376.8%
Lease fees	$0.01	$0.00	$0.24	$0.06	$0.07	134.8%
Vehicle/boat registration	$0.00	$0.00	$0.09	$0.02	$0.03	190.1%
Accounting	$0.00	$0.00	$0.21	$0.03	$0.07	221.3%
Management	$0.00	$0.00	$0.71	$0.11	$0.21	194.0%
Total ownership costs	$0.33	$0.03	$1.90	$0.53	$0.60	113.0%

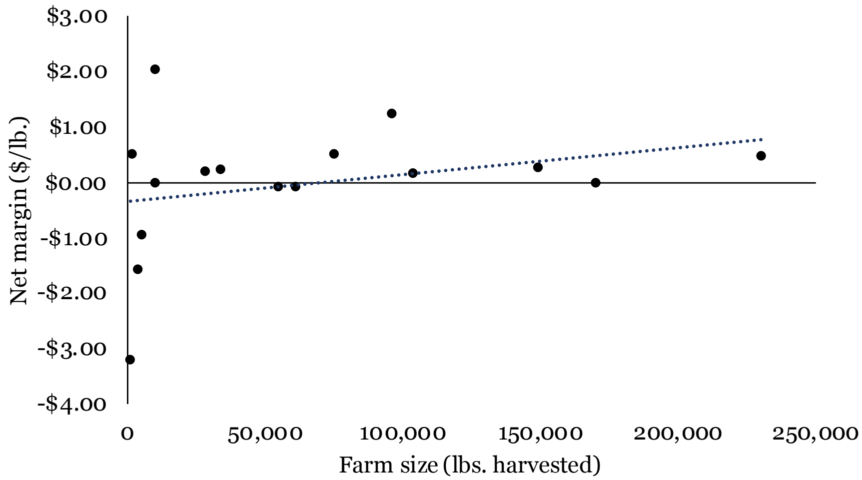
Profitability benchmarks

The median net margin, or net farm income, per pound harvested was $0.16/lb. (**Table 8**). Based on the CV, range, and discrepancy between the average and median values for net margins, it is clear that we observed wide variability in this metric across all farms. Similar to breakeven yield, net margin per pound harvested also tended to increase with total harvest volume (**Figure 6**). In the previous benchmarking study (Engle et al., 2020), only one farm had positive net margins, or was profitable. In this study, 9 of 16 farms (56%) were profitable, indicating incredible improvement across the sector.

Table 8. Profitability metrics

Benchmark	Unit	Median	Avg	SD
Market price	$/lb.	$0.60	$1.01	$0.53
Gross cash revenue (lease)	$/planted acre	$8,863	$11,613	$11,252
Grass cash revenue (harvest)	$ /lb. harvested	$0.60	$1.19	$0.94
Gross cash revenue (linear)	$/ft. longline	$2.81	$4.47	$4.20
Gross margin (lease)	$/planted acre	$3,971	$6,232	$9,709
Gross margin (harvest)	$/lb. harvested	$0.40	$0.48	$0.83
Gross margin (linear)	$/ft. longline	$1.40	$2.35	$3.07
Net margin, Net farm income (lease)	$/planted acre	$1,342	$2,133	$10,479
Net margin, Net farm income (harvest)	$/lb. harvested	$0.16	-$0.04	$1.16
Net margin, Net farm income (linear)	$/ft. longline	$0.43	$0.54	$3.73
EBITDA (lease)	$/planted acre	$1,981	$3,675	$9,398
EBITDA (harvest)	$/lb. harvested	$0.21	$0.23	$0.90
EBITDA (linear)	$/ft. longline	$0.73	$1.39	$3.03
Net margins per hour of labor	$/hr. of labor	$40.89	$62	$117
Net margins per hour of labor and management	$/hr. of labor and mgmt.	$23.75	$39	$67
Net margins per $ of investment capital	$/dollar of invested capital	$0.13	$0.49	$0.98
Rate of return on farm assets (ROA)	%	4.65%	8.56%	143.3%
Rate of return on farm equity (ROE)	$	$0.05	$0.09	$1.43
Operating profit margin	$	$0.20	$0.06	$0.66
Net income ratio	$	$0.62	-$2.08	$10.01

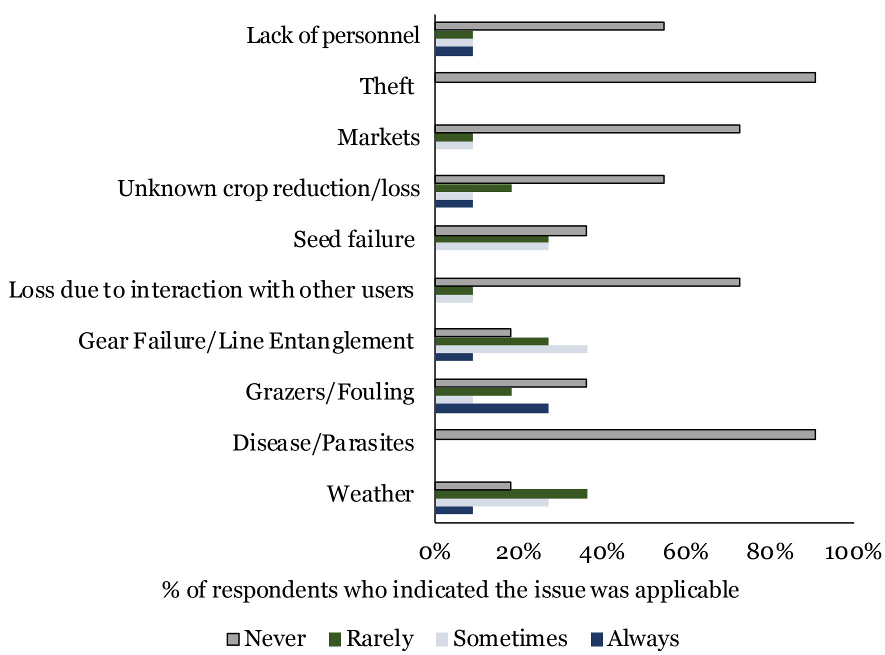
Figure 6. Impacts of farm size on net margins ($/lb. harvested)



Risks

Growers identified gear failure and line tangling as the greatest issues facing their farms; 9% of producers reported it as "always" a problem, 36% reported it as "often" a problem, 27% reported it as "sometimes" a problem, and only 18% reported it as "never" a problem (**Figure 7**). Many of the farmers who observed low yields (harvested lbs./ft.) also had more tangled lines and/or gear failure, while those with the highest yields experienced little to no tangled lines/gear failure. Weather was rated by farmers as the second largest problem and grazers/fouling and seed failure were the closest third and fourth most referenced problems (**Figure 7**).

Figure 7. Sources of risk



Repayment analysis

25% of farmers reported an active loan associated with their seaweed farm. Of active loans held, 50% were operating loans and the other 50% were equipment loans (**Table 9**). Collateral ranged from "none" and "good will" to "business assets" and "the asset itself plus one other skiff." Due to the fact that many farmers' seaweed businesses are linked to other marine enterprises, such as fishing or shellfish farming, it was difficult to disentangle seaweed loans from fishing loans. However, even if we failed to record some of the loans held by seaweed farmers in this study, it is clear that the vast majority of debt in the seaweed sector was used to primarily finance other business ventures, such as fishing.

Table 9. Loan reporting

Share of respondents who held loans (any type)	25%
Share of respondents who held operating loan	18.75%
Share of respondents who held equipment/real estate loan	18.75%

Labor costs and labor efficiency

The median labor input across all farms was 279 total hours for the 2021-2022 season, 200 hours of which was hired labor and 174 were owner hours (**Table 10**). We excluded processing labor, as the sample size was not large enough to ensure confidentiality. The median owner-operator logged 22, 8-hour work days over the course of the 2021 - 2022 growing season (**Table 11**). Only 50% of owner-operators reported taking any pay or draw, all of whom produced >10,000 lbs. of seaweed. Several other farmers reported that they had either not yet taken a draw because they had not yet turned a profit, or because everything was reinvested in the business. The fact that some of the larger kelp farms in our sample were generating positive net margins with minimal (3 – 4 weeks) time input is one of the more notable results of the study.

Table 10. Labor inputs

Task	Median	Min	Max	Average	SD	CV
Total person hours worked (hired labor + owner/operator time)						
Gear installation	48	0	160	58.27	57.8	99.19%
Seeding	54	6	180	64.08	50.21	78.36%
Maintenance	31.50	0	480	87.69	133.7	152.4%
Harvest	144	16	1,024	302	349.5	115.7%
Total Person Hours Worked	279	0	1,784	435.47	494.8	113.6%
Total hired labor hours (not including owner/operator time)						
Gear installation	10	0	120	33.42	42.06	125.8%
Seeding	20	0	120	28.30	33.37	117.9%
Maintenance	0	0	192	26.50	56.49	213.1%
Harvest	98	0	550	170.8	185.7	108.7%
Total Hired Labor Hours	200	0	752	262.5	232.9	88.71%
Owner/operator hours worked						
Gear installation	36	10	84	43.00	28.08	65.31%
Seeding	40	4	84	38.82	21.98	56.61%
Maintenance	72	6	288	90.17	98.45	109.2%
Harvest	96	14	576	149.9	183.7	122.6%
Total Owner Hours Worked	174	0	1032	233.5	286.5	122.7%

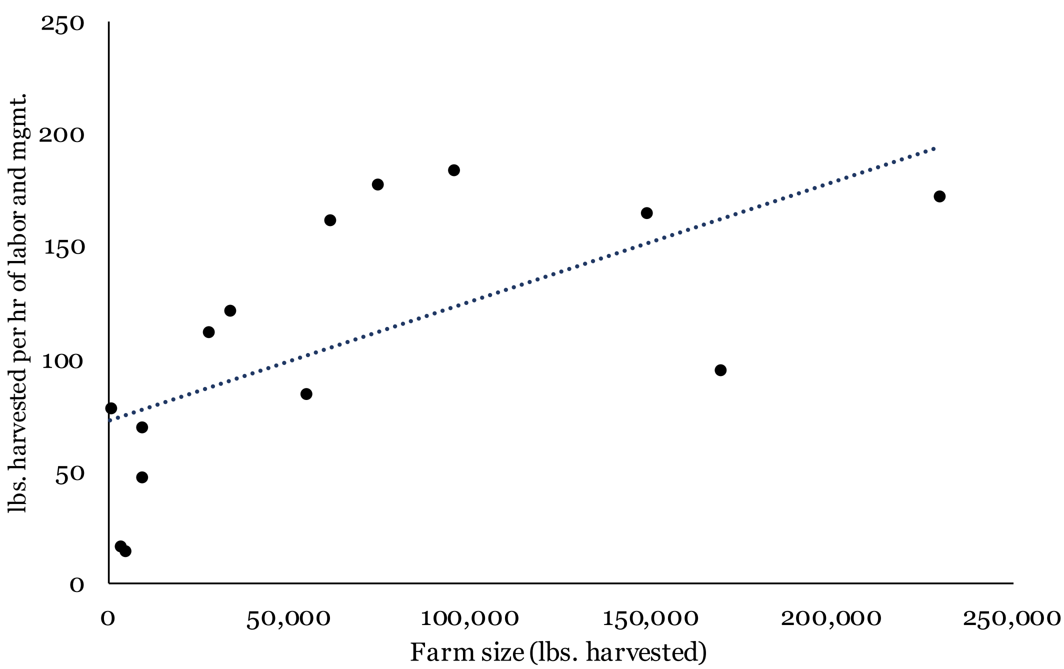
The median total wages paid per farm, not including owner/operator wages (if any were taken), were $2,812. However, this value varied considerably across the largest and smallest farms, ranging from $0 to ~$24,000 (**Appendix**). On average, the majority of labor hours (58%) were dedicated to harvest, followed by overwinter maintenance, seeding, and farm setup (18%, 13%, and 12%, respectively) (**Table 10; Table 11**). However, the average overwinter maintenance input was greater than that of seeding. This was likely skewed by a farmer who logged over double the next most overwinter maintenance hours, and recorded above average yield (lbs./ft.) and net margin ($/lb. harvested). The median hourly wage was $20.64/hr. and the median employee age was 40 (**Table 11**).

Table 11. Wages and employees per farm

Benchmark	Unit	Median	Min	Max	Average	SD	CV
Non-owner wages	$/year	$2,812	$0.00	$24,300	$7,188	$9,023	125.5%
Hourly wage	$/hr.	$20.64	$0.00	$64.91	$22.64	$17.14	75.71%
Employee age	Years	40	30	65	42.35	8.95	21.13%

Many of the farms included in our analysis benefitted from a substantial number of non-paid labor hours, either from family or volunteer help. Therefore, we often observed discrepancies between the total labor time input and the total labor costs assumed by a business. This trend was even more pronounced when considering that owner-operators spent a median of 174 hours working on the water over the course of the season and only 50% took any pay. Each owner should therefore assess existing assets, staff support, and the seasonality of other fisheries or marine-based work opportunities to determine if seaweed is a good fit as a supplemental income source.

Figure 8. Impacts of farm size on labor efficiency



We observed a strong positive correlation between farm size (in terms of total lbs. harvested) and labor efficiency (lbs. harvested per hour of labor and management) (**Figure 8**). Across all participants, median labor efficiency was 103.8 lbs. harvested per hr. of labor and management (**Table 12**). However, we also observed a wide range (15 - 184 lbs. per hr) for this benchmark, further underscoring the impacts of scale on efficiency (**Table 12**).

Table 12. Labor efficiency

Benchmark	Unit	Median	Min	Max	Avg	SD	CV
Pounds of seaweed harvest per hour of labor	lbs./hr.	206.7	24.04	411.8	202.7	129.4	63.86%
Pounds of seaweed harvest per $ of labor	lbs./$	6.13	1.2	28	7.87	7.34	93.20%
Pounds harvested per hour of labor and management	lbs./hr.	103.8	15.06	184.2	107.5	58.77	54.69%
Labor cost per lb. harvested	$/lb.	$0.11	$0.00	$0.83	$0.17	$0.21	123.1%
Labor and management cost per lb. harvested	$/lb.	$0.18	$0.00	$0.83	$0.28	$0.28	99.70%
Sales revenue per hour of labor	$/hr.	$132.6	$56.43	$432.4	$180.5	$120.5	66.75%
Sales revenue per hour of labor and management	$/hr.	$97.68	$24.68	$265.4	$97.38	$64.63	66.37%
Labor costs as % of $ output from farm	%	17.42%	0.00%	50.14%	17.45%	15.18%	86.99%
Labor and management costs as % of farm output	%	23.17%	0.00%	100.3%	32.41%	33.16%	102.3%

Market saturation and product quality

When asked, only 15.3% of participants indicated that they had concerns about market saturation (**Table 13, Appendix**). Growers also noted that obtaining "clean product with limited or no biofouling" was the most important determinant of quality (**Table 14, Appendix**).

Startup cost analysis

Growers spent a median of $32,925 to set up their farm, or a median of $3.07 per foot of seeded grow line (**Table 15**). It is important to note that these are one-time costs deployed either in the first year of cultivation or during a ramp up in production scale.

Table 15. Startup and investment costs

Benchmark	Unit	Median	Min	Max	Average	SD	CV
Startup costs per farm	$ / farm	$32,925	$2,397	$212,080	$52,771	$54,273	102.9%
Startup costs per farm	$ / ft. of planted longline	$3.07	$0.53	$48.86	$8.54	$12.83	150.3%

Financial benchmarks

We observed a median farm net worth of $32,833. The range, between $2,397 and $212,080, reflects the buildup of capital equipment required to scale from a series of LPAs to a multi-acre standard lease (**Table 16**).

Table 16. Financial benchmarks

Benchmark	Unit	Median	Min	Max	Avg	SD	CV
Net worth (owner's equity)	$ / farm	$32,833	$2,397	$212,080	$52,759	$54,277	103%

Financial efficiency

The operating expense ratio measures how much is spent to generate income. Across all farms, the median operating expense ratio was 0.41 (**Table 17**). The depreciation-expense ratio tracks the amount of income required to maintain the equipment being used. Any value higher than 0.15 indicates that the farm may be overcapitalized or wearing out its equipment too quickly. We observed that all farms had a median depreciation-expense ratio of 0.17, placing them right on the margin of businesses that are utilizing machinery "efficiently" (**Table 17**). This is likely due to the fact that most growers use lobster boats, which may be slightly larger than necessary and contain equipment not custom sized for kelp farming. The net farm income from operations ratio represents the ratio of net farm income from operations to gross revenue. The median across all businesses was 0.2, but ranged from -1.61 to 0.85, indicating that while most farms were able to achieve positive margins, there was wide variability within the dataset (**Table 17**).

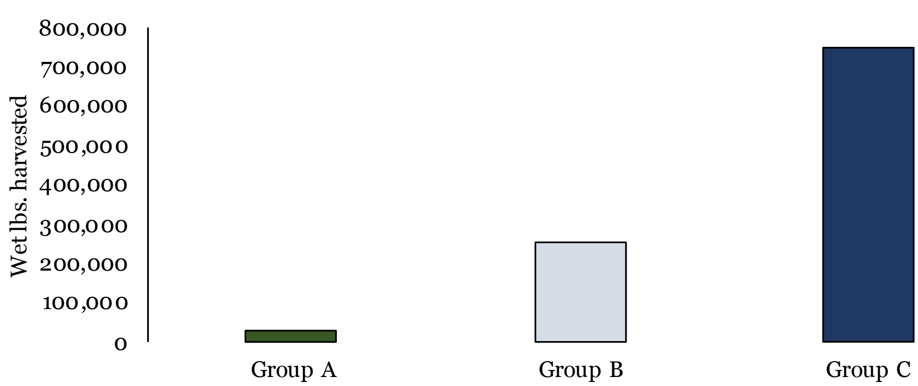
Table 17. Financial efficiency

Benchmark	Description/Unit	Median	Min	Max	Average	SD	CV
Operating expense/revenue ratio	Annual operating expenses divided by annual revenue	0.41	0.09	1.87	0.51	0.44	85.03%
Depreciation expense ratio	Ratio of annual depreciation of assets to total (ownership and variable) expenses	0.17	0.02	0.36	0.18	0.09	52.34%
Net farm income from operations ratio	Net farm income from operations/gross revenue	0.2	-1.61	0.85	0.06	0.66	1085%

Results: distinct farm size analysis

We combined the data from our interviews into groups "A", "B", and "C", based on annual harvest quantities (lbs. wet weight). Farms in Group A harvested ≤ 10,000 lbs., farms in Group B harvested between 10,000 and 75,000 lbs., and farms in Group C landed > 75,000 lbs. It should be noted once again that by international standards, even Maine's largest seaweed farms (here, Group C) are considered "micro farms." Key benchmarks were recalculated separately for farms within each size grouping to identify differences between operations at various scales. The benchmarks are presented in the following order: harvest, lease, and license data, sales, labor and labor efficiency, expense (total cost, breakeven price, and breakeven yield), profitability, financial, and financial efficiency benchmarks. Group C farms harvested 72% of the seaweed included in this study, Group B farms harvested 25%, and Group C farms harvested 3% (**Figure 9**).

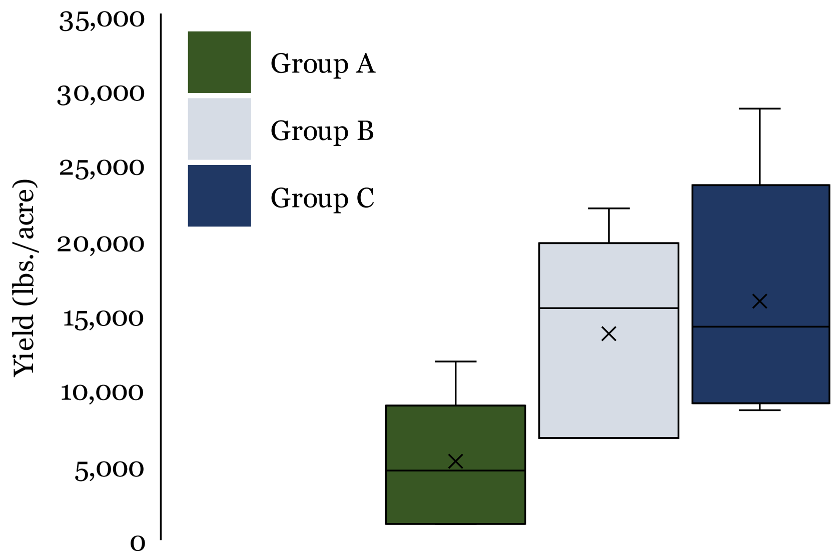
Figure 9. Total lbs. harvested by farm size



Production benchmarks by farm size: harvest, lease, and license data

The median leased acreage per business in each of the three size groupings ranged from 0.08 acres per farm for Group A to 10 acres per farm for Group C (**Table 18**). Farms of all sizes seeded a similar amount of grow line per acre, with the median between 2,644 ft./acre for Group A farms and 3,250 ft./acre for both Group B and C farms (**Table 19, Appendix**). However, yields differed greatly between size groupings. On a per acre basis, Group B and C farms produced a median of over three times as many pounds as Group A farms (15,375 and 14,167 vs. 4,548 lbs./acre) (**Table 19; Figure 10**). This trend was likely driven by the difference in linear yield (lbs./ft.) between farms of varying sizes (**Figure 11, Appendix**). It takes time to expand into a 10-acre farm footprint, and transitioning from LPAs to a standard or experimental lease could take up to 3 years. In that time, farmers typically gain knowledge and experience, which is likely one factor that drove yield improvements with farm size.

Figure 10. Yield per acre by farm size



All Group B and C farms sold 100% of harvested seaweed to a value-added processor, while Group A farms sold an average of 87% of harvested seaweed to a value-added producer (**Table 20, Appendix**). It was clear that most farms, especially larger farms, are predominately selling their crop to 1 or 2 processors in the state. Only a small portion of Group A farms are experimenting with producing their own value added (typically dried, flaked etc.) products.

Table 18. Lease acreage by farm size

Total acres	A	B	C	Total leases	A	B	C	Total LPAs	A	B	C
Total acreage	15.2	21.15	50.04	Total leased acres	15.00	21.00	50.04	Total unadjusted LPA acres	0.2	0.15	0
Median	0.08	4.03	10	Median acreage per farm	7.5	4.5	10	Median acreage per farm	0.06	0.08	NA
Min	0.01	0.12	8	Minimum acreage per farm	5	4	8	Minimum acreage per farm	0.01	0.03	NA
Max	10	8	12.04	Maximum acreage per farm	10	8	12.04	Maximum acreage per farm	0.08	0.12	NA
Average per business	2.53	4.23	10.01	Average lease size (acres)	7.5	5.25	10.01	Average size (acres)	0.05	0.08	NA
SD	4.16	2.82	1.14	SD	3.54	1.89	1.14	SD	0.04	0.06	NA
CV	164.2%	66.65%	11.39%	CV	47.14%	36.06%	11.39%	CV	71.18%	84.85%	NA
				Total #	4	6	12	Total #	24	15	NA
				Median number per business	2	1.50	2	Median number per business	2.50	7.5	0
				Average	2	1.5	2.4	Average	4	7.5	NA
				SD	0	0.58	1.14	SD	3.16	6.36	NA
				CV	0.00%	38.49%	47.51%	CV	79.06%	84.85%	NA
*This column includes data for all farmers - those who held LPAs and/or leases				*This column includes data only for farmers who held leases				*This column includes data only for farmers who held LPAs			

Labor costs and labor efficiency by farm size

Harvest was the most labor-intensive production step for farms in all three size groupings. For Group B and C farms, more hours were logged during harvest than during the rest of the growing process combined (**Table 21**). However, the differences in the time requirement between harvest, seeding, and maintenance were less pronounced for Group A farms (**Table 21**). This likely reflects the labor learning curve, as well as the lack of harvest/seeding infrastructure on smaller farms that is typically found on larger farms.

The median total paid labor ranged from $726.9 on Group A farms to $18,800 on Group C farms, while median wages ranged from $20.00 to $32.22/hr. for Group A and C farms, respectively. Owner/operators logged a median of between 58.50 hours/year on Group A farms to 524.0 hours/year on Group C farms (**Table 22**).

Table 21. Labor input by farm size

	Median			Average			SD		
Task	A	B	C	A	B	C	A	B	C
Total Person Hours Worked									
Gear installation	10	32	126	25	51.2	117	32.12	66.36	33.21
Seeding	30	45	102	36.67	56.4	109.5	29.84	18.88	60.69
Maintenance	28.5	13.5	182	25.08	24.3	223	22.14	31.33	185.2
Harvest	51.5	272.	765	58	265.2	683.5	38.99	96.39	401.7
Total person hours worked	126.3	380	880	141.8	404.1	906.4	107.2	162.4	695.2
Total Hired Labor Hours									
Gear installation	6.67	0	84	14.22	25.6	72	17.44	36.83	55.81
Seeding	4	22.5	46	13.33	23.1	57	18.01	15.22	45.06
Maintenance	0	0	48	6	0	72	13.42	0	85.42
Harvest	23.88	200	404	32.29	180.4	369.5	37.21	91.79	183.6
Total Hired Labor Hours	72	200	591	85.01	229.1	570.5	78.87	131.9	167.87
Owner Hours Worked									
Gear installation	16	32	64	22	42.67	59	15.87	33.31	26
Seeding	28	40	46	27	31.7	48.5	20.49	14.39	29.41
Maintenance	55	18.75	146	55	30.38	151	35.36	32.6	123.7
Harvest	32	96	292	33.25	84.8	305	21.28	19.27	243.3
Owner Hours Worked	58.5	181.5	524	69.5	166.4	563.5	69.91	62.6	404

One of the greatest differences we observed between farms of various sizes was the discrepancy in labor efficiency. Farms in Group A harvested a median of 76.77 pounds of seaweed per hour of labor, while farms in Groups B and C harvested 215.8 and 259.1 pounds per hour of labor, respectively (**Figure 12; Table 23**). Group A farms spent a median of $0.23 of paid labor per pound harvested, which also does not account for the opportunity cost of an unpaid owner-operator. Farmers in Groups B and C, on the other hand, spent almost half as much on labor per lb. harvested, $0.10/lb. (**Table 23**). However, when labor and management costs were considered, the costs per lb. harvested more than tripled for farms in Group B ($0.46), but remained stagnant for farms in Group C ($0.10).

Table 22. Wages and employees by farm size

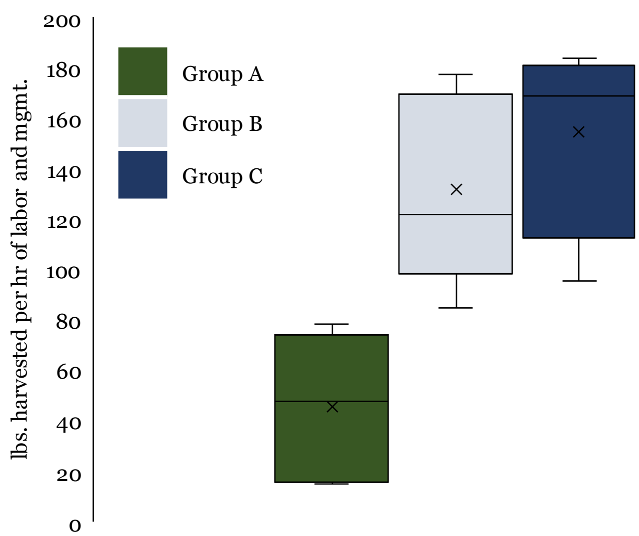
	Median			Average			SD		
Metric	A	B	C	A	B	C	A	B	C
Total paid labor	$726.9	$3,560	$18,800	$1,280	$6,292	$15,173	$1,607	$7,559	$10,578
Hourly wage	$20.00	$20.00	$32.22	$14.56	$24.05	$32.99	$11.48	$24.31	$9.31
Employee age	21.5	42.5	38.5	23.67	46.25	36.75	24.01	13.15	4.57

Table 23. Labor efficiency by farm size

	Median			Average			SD		
Metric	A	B	C	A	B	C	A	B	C
Pounds of seaweed harvested per hour of labor	76.77	215.8	259.1	71.1	266.2	287.7	29.14	121	81.87
Pounds of seaweed harvested per dollar of labor	3.44	8.06	9.04	3.23	11.86	8.74	1.54	11.06	2.47
Pounds harvested per hour of labor and management	48.08	122.2	169.2	45.53	131.7	154.5	29.35	37.51	40.2
Labor cost per lb. harvested	$0.23	$0.10	$0.10	$0.27	$0.12	$0.09	$0.31	$0.12	$0.06
Labor and management costs per lb. harvested	$0.23	$0.46	$0.10	$0.27	$0.39	$0.17	$0.31	$0.32	$0.20
Sales revenue per hour of labor	$98.25	$129.5	$194.5	$123.9	$196.98	$230.7	$94.56	$142.2	$121.85
Sales revenue per hour of labor and management	$41.67	$97.11	$101.6	$78.39	$89.14	$131.4	$69.62	$26.85	$91.75
Labor cost as % of $ output from farm	21.85%	17.41%	17.44%	18.92%	19.28%	13.87%	16.04%	20.11%	10.73%
Labor and management costs as % of farm output	21.85%	71.43%	17.44%	18.92%	53.61%	27.38%	16.04%	41.88%	34.38%

These values highlight the ways in which higher levels of production thinly spread fixed overhead costs, such as management, across total costs on a per unit basis. It also highlights the tough financial balance that medium sized farms must strike as owner-operators may begin to draw a salary while needing to simultaneously reinvest proceeds towards critical infrastructure to facilitate growth (anchors, longlines, etc.).

Figure 12. Labor efficiency by farm size



Expense benchmarks by farm size

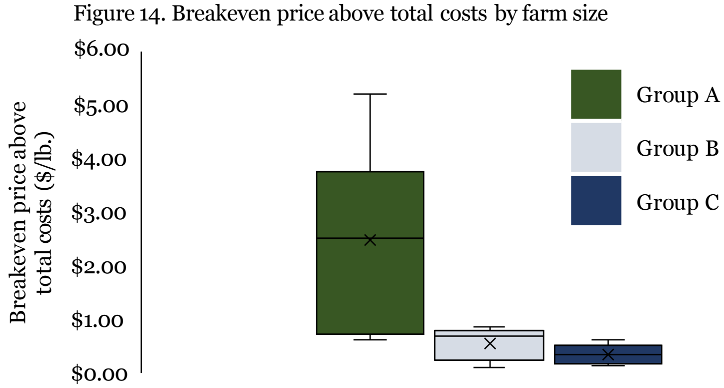
Operating and fixed costs as a percentage of total costs were similar for enterprises in Groups A through C. However, we observed an increase in fixed costs as a percentage of total costs for farms in Group B (**Table 24**). Total costs per planted acre varied significantly. Group B and C farms reported a median between $4,000 and $5,000 per acre, while farms in Group A reported a median of $8,602 per acre (**Table 24**).

Table 24. Cost, breakeven price, and breakeven yield by farm size

	Median			Average			SD		
Metric	A	B	C	A	B	C	A	B	C
Variable (operating) cost as % of total costs	64.95%	44.71%	71.07%	62.58%	42.87%	65.55%	12.43%	22.11%	20.52%
Ownership (fixed) cost as % of total costs	35.05%	55.29%	28.93%	37.42%	57.13%	34.45%	12.43%	22.11%	20.52%
Cost of Goods Sold (COGS) per acre	$1,062	$1,109	$2,475	$1,404	$1,805	$2,143	$1,279	$1,709	$1,718
Total cost (variable and ownership) per acre	$8,602	$4,780	$4,036	$14,409	$7,934	$5,109	$15,926	$7,217	$2,657
Breakeven price above variable cost ($/lb.)	$1.50	$0.20	$0.20	$1.54	$0.19	$0.22	$1.20	$0.10	$0.11
Breakeven price above total cost ($/lb.)	$2.54	$0.70	$0.36	$2.50	$0.56	$0.36	$1.74	$0.30	$0.19
Breakeven yield above variable cost (lbs./acre)	3,061	2,438	5,159	6,151	3,568	4,832	$6,923	2,540	2,565
Breakeven yield above total cost (lbs./acre)	5,980	7,968	6,726	9,008	10,473	8,101	9,208	7,260	5,070
Breakeven yield above variable cost (lbs./foot of grow-line)	2.17	0.95	1.59	2.4	1.18	1.41	1.95	0.79	0.59
Breakeven yield above total cost (lbs./foot of grow-line)	3.25	4.25	2.02	3.95	3.41	2.29	3.42	2.08	1.01

Similarly, breakeven price above total costs ranged widely between larger and smaller farms. Median breakeven price above total costs for farms in Groups B and C was $0.70 and $0.36/lb., respectively, but was $2.54/lb. for the smaller farms in Group A (**Figure 14**). The median breakeven yield above total costs for farms in Group C was well within the range of observed yields on kelp farms in Maine today at just over 2 lbs. per foot. However, the smaller farms, those in Groups A and B, would need to produce nearly 3.25 – 4.25 lbs./ft. to break even, a mark which only could be achieved by some, especially more experienced, farmers (**Table 24**).

Figure 14. Breakeven price above total costs by farm size



Profitability benchmarks by farm size

Profitability varied between farms of different sizes. Although farms in Group A received a median market price roughly twice that of the other farms, none of these operations were profitable (**Table 25**). This trend was likely driven by the notable differences in yield per foot of line (2.63 vs. 4.73 lbs. vs. 5.67 lbs.) and efficiency of labor ($-1.70 vs. $44.50 vs. $123.20 of net farm income earned per hour of labor) for farms in Groups A, B, and C, respectively (**Table 19, Appendix**; **Table 25**).

Table 25. Profitability benchmarks by farm size

	Median			Average			SD		
Metric	A	B	C	A	B	C	A	B	C
Market price	$1.50	$0.60	$0.60	$1.47	$0.69	$0.78	$0.53	$0.20	$0.40
Gross cash revenue (lease)	$6,231	$9,225	$11,175	$13,129	$10,213	$11,193	$17,567	$7,814	$4,667
Grass cash revenue (harvest)	$1.70	$0.60	$0.60	$1.95	$0.60	$0.80	$1.17	$0.00	$0.38
Gross cash revenue (linear)	$3.00	$2.80	$3.00	$5.85	$3.10	$4.20	$6.15	$1.81	$3.16
Gross margin (lease)	$465.9	$4,371	$6,380	$3,281	$7,870	$8,136	$14,050	$7,732	$5,095
Gross margin (harvest)	$0.50	$0.40	$0.40	$0.41	$0.50	$0.60	$1.36	$0.26	$0.43
Gross margin (linear)	$0.50	$1.40	$1.70	$1.62	$2.30	$3.30	$3.97	$1.89	$3.19
Net margin, Net farm income (lease)	-$487.0	$1,534	$4,429	-$1,280	$2,279	$6,084	$16,022	$3,948	$6,192
Net margin, Net farm income (harvest)	-$0.49	$0.18	$0.24	-$0.55	$0.14	$0.41	$1.80	$0.24	$0.49
Net margin, Net farm income (linear)	-$0.90	$0.50	$1.20	-$1.29	$0.60	$2.70	$4.81	$1.10	$3.33
EBITDA (lease)	$146.4	$2,102	$6,046	$1,719	$2,939	$6,758	$14,441	$3,789	$6,153
EBITDA (harvest)	$0.10	$0.20	$0.30	$0.08	$0.20	$0.50	$1.46	$0.22	$0.48
EBITDA (linear)	$0.40	$0.70	$1.60	$0.62	$0.80	$2.90	$3.81	$1.01	$3.34
Net margins (net farm income) per hour of labor	-$1.70	$44.50	$123.2	$6.94	$51.92	$145.05	$97.33	$80.53	$152.3
Net margins (net farm income) per hour of labor and mgmt.	-$1.10	$20.00	$59.90	$18.48	$21.19	$85.87	$50.00	$39.64	$99.18
Net margins per $ of investment capital	-$0.04	$0.23	$0.17	$0.08	$0.41	$1.05	$0.37	$0.58	$1.56
Rate of return on farm assets (ROA)	-$0.04	-$0.31	$0.17	$0.08	-$0.35	$0.52	$0.37	$1.31	$2.31
Rate of return on farm equity (ROE)	-$0.04	-$0.31	$0.17	$0.08	-$0.35	$0.52	$0.37	$1.31	$2.31
Operating profit margin	-$0.22	$0.17	$0.40	-$0.37	$0.20	$0.44	$0.83	$0.40	$0.37
Net income ratio	$0.27	$0.19	$0.69	-$6.27	$0.22	$0.63	$16.32	$0.55	$0.41

For farms in Groups B and C, the inclusion of management hours notably reduced net margins per hour of labor (**Table 25**). Farms in Group A (the smallest farms) actually reported an increase in net margins when management hours were included, as these farms technically lost *less* money per hour when owner/operator time was included. It is worth noting that despite the impacts on profitability, management costs are direct payments to the owner/operators. In other words, the owner/operators of the farms in Group A did not take any pay and still experienced negative net farm incomes, while some owner/operators in Groups B and C managed to take a salary draw and benefit from positive net farm incomes (**Table 25**). The operating profit margin benchmarks highlighted the advantages of scale in seaweed farming. Farms in Group A reported -$0.22 of profit margin per lb. harvested, while the larger farms in Groups B and C earned $0.17 and $0.40 per lb. harvested, respectively (**Table 25**).

Financial benchmarks by farm size

The larger farms in Group C accumulated nearly twice the amount of net worth compared to farms in Groups A and B (**Table 26**). Given that it takes multiple years to receive the lease space required to grow >75,000 lbs. of seaweed, it is no surprise that more mature farms, have accumulated a greater quantity of assets.

Table 26. Financial benchmarks by farm size

	Median			Average			SD		
Metric	A	B	C	A	B	C	A	B	C
Net worth	$25,200	$32,666	$69,875	$29,310	$37,803	$95,855	$25,990	$24,309	$78,653

Financial efficiency by farm size

Farms in Group A had nearly double the median operating expense to revenue ratio compared to those of farms in both Groups B and C, placing them near the high-cost producer category above 75% (**Table 27**). We also observed a negative net farm income from operations ratio for farms in Group A, and positive ratios for the larger Group B and C farms. Furthermore, both the average and median net farm income from operations ratio was much higher for the larger farms in Groups B and C than the average across all farms in the previous study, -9.8 (Engle et al., 2020). This is a strong market growth signal and indicates that it makes sense to continue investing time and money in such businesses.

Table 27. Financial efficiency by farm size

	Median			Average			SD		
Benchmark	A	B	C	A	B	C	A	B	C
Operating expense/revenue ratio	0.68	0.35	0.34	0.83	0.31	0.33	0.55	0.55	0.21
Depreciation expense ratio	0.22	0.14	0.16	0.24	0.15	0.15	0.09	0.09	0.08
Net farm income from operations ratio	-0.22	0.17	0.40	0.-37	0.20	0.44	0.83	0.40	0.37

Comparison between 2017 and 2022 benchmarks

In an effort to track the potential improvements that have been made in the Maine seaweed sector since the 2017 harvest season (Engle et al., 2020), we drew a direct comparison between key benchmarks from both the 2020 report and this study. We focused on metrics related to yield, labor costs and efficiency, breakeven price/yield, profitability, and financial efficiency. For this comparison, we used the "aggregated" benchmarks which were calculated using the 2022 harvest data from all 16 farms included within the study.

Farmers harvested a median of 0.94 more lbs. of kelp per foot of grow line in the 2022 harvest season than in the 2017 season (**Table 28**). Yield is one of the strongest predictors of financial and production success for not only seaweed farms, but also other shellfish/finfish aquaculture operations (Kite-Powell et al., 2022). The nearly 28% median increase (58% average increase) in linear yields is an incredibly encouraging sign of improvement. We also observed that the farms in this study spent nearly 97% less, on a $ per lb. basis on labor, and that labor efficiency (lbs. harvested per hour of labor and management) also markedly improved by a factor of almost 14x (**Table 28**).

Table 28. Comparison of key benchmarks between 2017 and 2022 Maine seaweed harvest seasons

Metric	'17 Median	'22 Median	'17 Avg ± SD	'22 Avg ± SD
Yield (lbs./ft of grow-line)	3.7	4.24	2.7 ± 1.8	4.25 ± 2.13
Labor cost contribution ($/lb.)	$3.35	$0.11	$2.90 ± $2.95	$0.18 ± $0.21
Labor efficiency (lbs. harvested per hr of labor + management)	7.55	103.76	22.14 ± 32.89	107.45 ± 58.77
Breakeven price above variable cost ($/lb.)	$4.97	$0.29	$3.86 ± $3.14	$0.71 ± $0.97
Breakeven price above total cost ($/lb.)	$6.89	$0.66	$4.86 ± $3.74	$1.22 ± $1.45
Breakeven yield above total cost (lbs./ft.)	12.64	2.69	16 ± 16.67	3.26 ± 2.41
Net margin ($/lb.)	-$6.41	$0.16	-$4.38 ± $3.78	-$0.04 ± $1.16
Operating expense/revenue ratio	13.8	0.41	9.8 ± 8.2	0.51 ± 0.44
Depreciation expense ratio	0.6	0.18	0.7 ± 0.4	0.18 ± 0.09
Net farm income from operations ratio	-13.4	0.20	-9.8 ± 8.7	0.06 ± 0.66

As a function of improved yields, scale, and efficiencies, breakeven prices dropped precipitously from the values reported in the 2020 study. Across all 16 farms we analyzed in 2022, the average breakeven price above total costs was $0.66/lb. harvested, a 90% decrease from the values calculated from the 2017 harvest season data ($6.89/lb. harvested) (**Table 28**). The decrease in production costs was mirrored by the increase in the number of profitable of farms. As mentioned above, only 1 of the 6 farms included in the 2020 study was profitable, while nearly 57% of farms (9 out of 16) generated positive net margins in this study (**Table 28**).

Lastly, we observed greatly improved financial efficiency between the farms included in the two studies. In the present analysis, farmers spent less money to generate revenue (operating expense/revenue ratio), and still generated positive margins (net farm income from operations ratio) (**Table 28**). However, we did observe that the median depreciation/expense ratio was three times the value recorded in 2017, indicating that capital expenditures may be straining the bottom line of kelp businesses (**Table 28**).

In the time since the 2017 harvest, the farmed seaweed sector in Maine has grown by nearly 7,000% (DMR, 2022). Therefore, it should come as no surprise that we recorded substantial upgrades in the financial performance of both individual farms and the sector as a whole. Tracking the chronological improvements in the industry can provide insight into the trajectory of this emerging market, a useful metric for farmers, processors, researchers, and investors.

Contextualizing Maine seaweed benchmarks

How the tides have changed: summary of progress between 2017 – 2022

Increases in extension support, efficiencies, and economies of scale have brought new economic realities to Maine's seaweed sector. Since 2017, median farm acreage has grown from 1.8 acres to 5 acres, and median yields have grown from 3.3 lbs. to 4.24 lbs. per foot, a 28% increase. Just as in 2017, seaweed farmers sold the vast majority, 95%, of their product to a value-added processor in 2022. However, farmers in 2017 had significantly higher amounts of unmarketable biomass, ~50%, compared to only ~1% in this study. In 2022, farmers received a median price of $0.60 per lb., compared to a median price of $0.48 in 2017. It is clear that a 25% increase in farm-gate prices, a 27% increase in yield, and a 1,274% increase in labor efficiency have combined to generate much higher levels of profitability.

All of the farms included in our analysis had a median breakeven price above total costs that was lower than the median value recorded in 2017 ($6.89). In the previous study, only one farm was profitable. In this study, 9 of the 16 farms generated positive net income, a metric that was positively correlated with production scale (**Figure 6**). It is important to note that net farm income included the non-cash cost of annual depreciation, a practice that accounts for the replacement cost of equipment and other capital goods at the end of their useful life. On an EBITDA basis, 12 of 16 farms had positive earnings.

The lack of loans reported by seaweed farmers, coupled with sparse information on current/long term debt financing, prevented us from including debt/interest payments in our analysis. It was clear that most farmers were financing their seaweed businesses through either personal investment or off the books of another marine related business (such as fishing). This has allowed owner/operators to avoid paying for the cost of capital, likely contributing to the rosy profitability outlook we observed. As a hypothetical exercise, if we included an operating loan with a 6.75% interest rate, a 7-year payback period, and a present value equal to 20% of the operating expense budget into the cost calculations for each business, the same number of farms (9 of 16) would still be profitable on a net margin basis. This is a strong signal that the seaweed farming business model may be robust enough to withstand the cost of capital (at least used for operating expenses) in the future. However, whether or not individuals who do not already own seaweed assets (such as a lobster boat) would be able to use debt financing to start a kelp aquaculture business remains to be seen.

We also observed changes in the cost structure of seaweed business between 2017 and 2022. Operating costs comprised 74% of total costs in the 2020 report, and only 64% in this report. This is most likely due to the fact that some owner-operators took a draw to pay themselves in 2022 (reported here as management costs in the fixed expenses category), while none took a draw in 2017. This could also be a product of increases in labor efficiency. Seeding and harvest efficiencies have clearly helped reduce per unit labor costs, and thus operating costs. In the 2020 study, farmers were spending a median of $3.35 on labor per lb. harvested. We found that farmers only spent a median of $0.11 on labor per lb. harvested in 2022. This trend is likely due to a combination of both higher yields per foot of grow line and more farmer experience, an encouraging signal for the sector.

Perceptions of risks on Maine seaweed farms and potential mitigation strategies

Despite the notable improvements in efficiency, we also observed various sources of risk that still impact seaweed farming in Maine. We recorded a substantial reduction in the average biomass lost annually on farms between the 2020 and 2022 studies. However, multiple growers emphasized that, in 2022, lost seaweed was still an issue. Gear failure and tangled lines were the most consistent, and often most impactful, sources of loss, with growers relaying that when line to line interactions occurred, it usually resulted in a near total crop loss for the affected lines. Tangled lines and gear failure are often linked to a combination of lack of line tension, improper depth management, and adverse weather. Part of the improvement we observed in both yield (lbs./ft.) and biomass loss may be attributed to the fact that farmers are becoming more familiar with their sites, and are thus better able to manage tension, spacing, and buoyancy. It was also interesting to note that some growers plan to actually reduce the amount of grow-line planted per acre in an effort to mitigate tangling. While kelp growth rates are an important sector benchmark, simply reducing loss is a powerful strategy to increase overall per acre yields and efficiency.

In addition to line-to-line interaction, farmers consistently referenced seed failure as a source of production risk. One farmer we spoke with had to remove and reseed their entire farm in a previous growing year due to twine not properly taking to the grow line. "Seed failure", as defined here, can likely be attributed to a combination of handling and biology. A diverse nursery broodstock sourced annually from wild beds can lead to variation in growth performance both within and between farms. Similarly, when twine-wrapped spools leave the nursery, growers can influence the performance of seed through handling, including exposure to variable salinity and air temperatures. Just as growers are optimizing farm layouts for their specific sites, seed production/handling is an active area of learning across the sector as a whole.

Farmers also emphasized that grazers and biofouling impact both yield and product quality. The calculus on optimal harvest timing takes into account biomass growth, fouling, and (often) leasing constraints. Notably, we also observed that farmers sometimes struggled with a lack of personnel to help with harvest. This combination of factors indicates that as growers and processors work together to maximize both the quantity and quality of product grown on farms in Maine, labor bottlenecks may hinder further expansion. If farmers are unable to access part- or full-time labor during harvest, delays could lead to fouling, deterioration, and product loss. Multiple organizations across the state have highlighted the continued importance of a robust aquaculture workforce, including the Maine Aquaculture Innovation Center, The Gulf of Maine Research Institute, Educate Maine, FocusMaine, The University of Maine, and The Maine Aquaculture Association. This continues to be an important area of investment for the emerging seaweed sector. Resources include the Maine Aquaculturist Job Board, the Aquaculture Pioneers Internship Program, the Aquaculture Research Institute's Externship Program, and the Maine Aquaculture Association's Apprenticeship Program.

As growers look to advance from multiple LPAs or an experimental lease to a larger standard lease, and add additional grow-lines and infrastructure, careful budgeting and planning is necessary. However, a common thread that we observed was the lack of a clear timeline to move a lease application through the state's aquaculture leasing process. Currently, it can take upwards of three years to receive a decision on a standard lease application in Maine. Given that there exist clear economies of scale in seaweed farming, decreasing the time from application submission to final decision should be one of the highest priority objectives for state regulators,

The role of seaweed farming in Maine

Seaweed production in Maine has remained primarily a secondary source of income for fishermen, aquaculturists, and others who work on the water. One farmer said:

> "Tell new farming people that they can make this a part of their living. But likely not their whole living."

Others made comments such as:

> "If it wasn't for lobstering, kelp wouldn't even be an option. Lobster pays all the bills and kelp uses the stuff we already have. We have almost everything else for fishing. If you had to go buy a boat to do this with, it wouldn't work. At least at the scale we're at. You couldn't make the boat payments on this [from kelp alone]."

Respondents reported a median of $3.07 per foot of planted longline for startup and investment costs, while the median net margin per foot of planted longline, a metric that reflects long-term profitability, was only $0.85/ft. While long-term profitability can be achieved, the data indicate that seaweed farming is not a get-rich-quick scheme. However, improvements in efficiency and profitability are promising signs of seaweed's ability to diversify Maine's working waterfront. We observed that some farmers were able to obtain a worthwhile supplementary minimal (~30 days) time input. To put it in perspective, one respondent added:

> "It is less costly and more profitable to go kelping than it is to go lobstering. Lobster traps this year cost more than all 3 seaweed fields put together. If anyone has an opportunity to get into this, I would jump into it. It's only going to get better."

The role of Atlantic Sea Farms (ASF), a value-added processor in Maine who contracts with farmers, cannot be overlooked. ASF has, in many ways, shaped the business models of many kelp farms in Maine through the distribution of free seed spools and the commitment to buy unprocessed kelp back from growers at the dock. Just as with ocean farming, there are large overhead costs and economies of scale associated with kelp nursery production and processing. None of the farmers we interviewed incurred any seed costs in the Fall of 2021. For other aquaculture sectors in Maine, seed is often one of the largest costs for individual businesses. Similarly, ASF purchases unprocessed seaweed from growers at a set price. This eliminates the need for growers to assume any processing costs, and reduces many of the market uncertainties associated with selling seafood. These factors have likely contributed to the scenario we observed in our study, in which growers operating on small (8 - 12 acre) farms are able to profitably grow and sell seaweed.

Leveraging benchmarks to analyze the economic feasibility of seaweed farms

It is critical that the benchmark values calculated here NOT be used as absolute thresholds for decisions made related to approval of loan applications. Rather, the range of benchmark values developed in this analysis provides some indication of which loan applications may be grounded in reality more than others. However, whether a prospective borrower will be able to pay off a loan by building and maintaining a profitable seaweed business will depend more on the interaction of a series of factors rather than alignment with individual benchmark values.

Yield and labor costs were two of the most important determinants of financial performance across all 16 interview participants. When analyzing prospective business models during the underwriting process, we recommend that particular attention be paid to the applicant's estimates of both spatial (lbs./acre) and linear (lbs./ft.) yield estimates, as well as the assumptions regarding annual labor costs. There was a strong correlation between farm size and yield. This was likely a product of farmer experience and learning by doing. The benchmarks presented here can be used to project the rate at which a farmer may reduce loss, increase product quality, and improve efficiencies as they grow their farm.

Ultimately, many of the farmers we interviewed had financed their seaweed business using the proceeds and equipment from existing working waterfront businesses, such as fishing. Access to capital remains one of the strongest barriers facing the growth of the seaweed and shellfish aquaculture sectors in North America (Kim et al., 2019). Quality industry benchmarking data can help de-risk this emerging industry by providing accessible information to enable risk-adjusted decision making. Continuously updating the data presented here will help traditional and non-traditional lenders confidently asses seaweed business plans, thereby increasing the flow of capital into an industry that can drive lasting change for Maine's working waterfront communities.

Recommendations for use of benchmarks

The benchmarks developed in this analysis should be used with caution. We observed a great deal of variability in the farm-level data due to disparate business models, management practices, lease sites, and labor dynamics. When consulting the benchmark values, attention should be paid to the coefficient of variation (CV). The higher the CV, the greater the variability, and the less reliable the specific values. The range of values reported provides additional detail on the potential variability for each benchmark.

While we observed dramatic improvement in efficiency, yield, and profitability when compared to the 2020 study, we also urge caution. There was a clear learning curve with respect to yield and labor, necessitating calculated expansion. The results of this analysis can help inform future R&D efforts, serve as a guide for prospective farmers who are developing business plans, allow existing farmers to optimize their operations, and serve as a record of long-term improvement for the sector as a whole. As seaweed farming expands in the Gulf of Maine, maintaining an understanding of both the farm level and sector wide health of the sector will be critical.

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