# BENCHMARKS FOR MUSSEL, OYSTER, SCALLOP, AND SEAWEED CULTURE IN MAINE

**Carole Engle, Jonathan van Senten, Michael Schwarz, Christian Brayden, and Sebastian Belle**

**July, 2020**

**Report produced by**

**In partnership with**

## Table of Contents


EXECUTIVE SUMMARY Page 2

- Key Findings Page 2
- Recommendations Page 4
- Conclusions Page 5

LIST OF FIGURES Page 6

LIST OF TABLES Page 10

INTRODUCTION Page 15

- Literature Review Page 15
- Potential Benefits to Shellfish Producers from Benchmarking Page 19
- Study Goals and Objectives Page 20

METHODS Page 20

- Survey Page 20
- Benchmark Calculation and Subsequent Analysis Page 21
- Oysters Page 22
- Raft-cultured Mussels Page 24
- Seaweed Page 25
- Scallops Page 26

RESULTS Page 27

- Survey Page 27
- Oysters Page 32
- Mussels Page 40
- Seaweed Page 47
- Recommendations for Use of Benchmarks Page 51

CONCLUSIONS Page 54

- Key Findings Page 55
- Recommendations Page 56

REFERENCES Page 58

FIGURES

TABLES

APPENDIX: Questionnaire used in survey

## EXECUTIVE SUMMARY

Aquaculture in Maine has grown rapidly in recent years, particularly in terms of shellfish production and with interest in seaweed production. Business growth, however, requires capital to support both the long-term capital assets required as well as to cover operating expenses. This report presents results of the development and calculation of a series of benchmarks that can serve as guidance for prospective Maine shellfish and seaweed producers for use in their business planning as well as by lenders in the evaluation of loan applications.

A survey was launched in 2018 of shellfish and seaweed producers in Maine to collect farm-level data from the 2017 to 2019 seasons that were used to tabulate the types of risks and problems faced by Maine shellfish and seaweed farmers and to calculate a series of benchmarks. Benchmarks developed were selected from a review of the scientific literature as well as from benchmarking programs used by some farm management associations in the U.S. and EU. Benchmarks were calculated for the following categories: production, expenses, breakeven prices and yields, profitability, financial, loan repayment, and efficiency (labor, capital, financial). All benchmarks were calculated for oysters, mussels, and seaweed farms. Scallop production in Maine is in an early, experimental phase and there were insufficient data from which to calculate numerical benchmarks. Oyster benchmarks were further separated into the categories of established (> 5 years in business) suspended culture farms, established bottom culture farms, and startup (< 5 years in business) suspended culture farms, given differences identified in on-farm cost structures. Mussel benchmarks were developed only for raft culture, not bottom mussel culture, due to insufficient numbers of bottom culture mussel farms to maintain confidentiality of farm information. A series of graphical analyses were performed to search for benchmarks that appeared to be related to the profitability of each type of aquaculture business and to its cash flow.

This study developed:

- Summaries of the types of risks and overall problems faced by Maine shellfish and seaweed producers.
- Summary of the workforce structure on Maine shellfish and seaweed farms.
- Identification of the major costs of production for Maine oyster, mussel, and seaweed farms.
- Estimates of the startup costs for Maine oyster, mussel, and seaweed production.
- Values for 15 production benchmarks, 18 expense benchmarks, 9 cost and breakeven price/yield benchmarks, 16 profitability benchmarks, 12 financial and repayment benchmarks, and 14 efficiency benchmarks for Maine oyster, mussel, and seaweed farms.

### Key Findings

Benchmarking:

- Three-fourths of respondents indicated interest in a confidential benchmarking web site that would allow them to compare their production and financial performance with benchmarks of other, similar farms.

For oyster farms:

- Larger oyster farms showed greater productivity, producing more oysters per acre than did smaller farms.
- Larger oyster farms used labor more efficiently than did smaller farms.
- Larger oyster farms used investment capital more efficiently than did smaller farms.
- Cost structures differed among established (> 5 years in business) suspended culture oyster farms, established bottom culture oyster farms, and startup suspended culture oyster farms.
- The greatest costs on established suspended culture oyster farms were labor (62%), marketing (10%), depreciation (8%), management (5%), and insurance (4%).
- The greatest costs on established bottom culture oyster farms were labor (48%), insurance (13%), depreciation (11%), seed (8%), repairs (6%), and marketing (3%).
- The greatest costs on startup oyster farms were depreciation (28%), seed costs (20%), labor (16%), repairs (8%), and insurance (5%).
- On established suspended culture farms, profitability decreased with longer growout time from seed to market size.
- Working capital decreased with decreasing quantities harvested of oysters harvested.
- For startup farms, profitability decreased with decreasing working capital.

For raft-culture mussel farms:

- The major costs on mussel farms were: labor (40%), repairs (11%), insurance (7%), management (7%), depreciation (6%), and marketing (5%).
- While gross margins for raft-culture mussel farming on average were positive, when non-cash costs of depreciation were included, the net margins that reflect long-term profitability were negative, on average.
- Some indication of economies of scale were found in mussel production.
- The most profitable mussel farm had the greatest volume of production per foot of line and the greatest labor efficiency (lb harvested per hour of labor).
- Profitability decreased as working capital decreased.

For seaweed farms:

- The greatest costs in seaweed production were: labor (64%), depreciation (7%), marketing (6%), and rent (6%).
- Only one of the seaweed farms responding to the survey showed long-term profitability (including non-cash costs of annual depreciation).
- There appear to be some economies of scale in seaweed farming.
- Losses increased with decreasing efficiency of use of labor and investment capital.
- There is a strong need for research and extension support to identify the sources of variation in seaweed yields and to assist producers to stabilize yields at a higher level on their lease site to be able to operate profitably.

## Recommendations

- Aquaculture businesses exhibit a great deal of variability from farm to farm. Management and finance decisions need to be based on a holistic analysis of the farm (from production to marketing) and not on a single benchmark. Thus, benchmark values should be used **as guides only**[1], not as absolute values, within the context of an analysis of the overall business model and performance.
- It is important to pay attention to the variability of individual benchmark values: the greater the coefficient of variation, the greater the variability, and the less reliable the average values. This is true for all species.

For established oyster farms:

- Evaluate historical data for the farm annually.
- For loan applications, review 3 years of balance sheets, profit and loss statements, and monthly cash flow statements.
- To decide whether new borrowing is feasible, examine debt/asset ratio from balance sheet to ensure that the additional financial risk is acceptable (debt/asset ratio less than 50% for medium risk level).
- To seek ways to improve profitability, examine the percent of major costs and compare with benchmark values, with especial attention to labor, depreciation and any other major costs.

For startup oyster farms:

- Have adequate startup capital, but manage borrowing to keep the farm within an acceptable (debt/asset ratio less than 50%) level of financial risk. If financial risk is excessive, start slowly with oysters as a side business and build equity before assuming greater debt burden.
- Develop a 3-year monthly pro forma cash flow budget, to be able to plan for surviving periods of cash deficits, particularly in the early years before full production is achieved and revenue received. Account for production risks and shortfalls when deciding to borrow capital.
- The quantity of oyster seed purchased in the early years of the farm business should be a moderate quantity. There is a learning phase during which new oyster farmers learn to manage and operate their farm efficiently on that particular lease site to be able to achieve productivity levels that are financially advantageous. It is better to purchase fewer oyster seed and incur less expense during the early years in which the owner/manager is more prone to experience setbacks and problems due to inexperience.

[1] Many types of aquaculture are in the early stages of development. Unlike other types of agriculture for which consistent and fairly standardized, calibrated practices have been developed over decades of research and on-farm trial, many types of aquaculture are still in a trial phase in which new techniques and practices are being developed. Thus, there is a great deal of variability among farms, many of which are viable enterprises for which a strict benchmark interpretation from another farm may not be relevant. These benchmarks should be used to provide a general range of potential values and some perspective as to what the top performance might look like in specific production or financial categories.

- Once in oyster production, monitor mortalities carefully, track harvest quantities per acre for each site, and monitor efficiency of use of labor and capital as per benchmark guidance.

For mussel farms:

- Monitor labor efficiency and sales revenue per hour of labor. If sales revenue per hour of labor is less than hourly wage rates, the farm is losing money with every hour of wages paid.
- The most profitable mussel farm harvested 2.3 lb of mussels per ft of growout line.

For seaweed farms:

- Seaweed farming is in a developmental stage in which farmers are learning how and where seaweed will grow well.
- Prospective producers should enter slowly and learn how seaweed grows on his/her site before incurring financial liabilities through borrowing or attempting to raise seaweed as the basis for a full-time business.
- Risk of total crop loss was found to be high (it should be noted that the sample size of seaweed producers was small in this survey). Given that seaweed production is in its infancy, such risks would be expected to diminish as producers learn how to protect crops from various types of losses.
- Cost estimates must include the percentages used for seaweed of the costs of the vessel and winch or hoist for harvesting, mooring gear, buoys, and other fixed capital assets.
- Develop an extension verification program for seaweed producers in which extension personnel monitor key parameters (i.e., seed density on spools, growth of seaweed), and key environmental parameters (i.e., water temperature, nutrients) to assist producers to obtain greater yields per foot of line.

For scallops:

- Scallop production in Maine is experimental and in a developmental stage.
- Scallop producers will need to experiment with production technologies and marketing strategies.
- Prior business and marketing experience is recommended.
- Prospective scallop producers should contact and take advantage of the various resources and support services available, such as from the Maine Aquaculture Association, NOAA Sea Grant, and Coastal Enterprises, Inc., prior to investment in scallops.
- Prior experience farming less-sensitive shellfish such as oysters is recommended.
- Labor and capital costs likely to be greater for scallops than for oysters and mussels.

## Conclusions

Aquaculture is growing rapidly in Maine with increasing interest in aquaculture production from prospective producers and various governmental and non-governmental agencies. Aquaculture in Maine includes a number of well-established shellfish producers of oysters and mussels who

have developed successful businesses that have been sustained for many years. The success of these businesses has attracted new, prospective producers who seek to develop similarly successful aquaculture businesses.

A successful aquaculture business requires careful attention to many details related not only to efficient production of high-quality products but also to marketing strategies, costs, and financial outcomes. Successful businesses are those for which owners and managers make the correct decisions related to all facets of the business and most often are those who monitor all phases of the business on a continuous basis. The benchmarks developed in this report offer a means for individual businesses to compare the performance of their aquaculture business with that of other, similar types of aquaculture businesses across production, marketing, and financial perspectives. Such comparisons offer a means to identify changes likely to improve profitability of the business.

## LIST OF FIGURES

Figure 1. Levels of crop losses reported as detectable by survey respondents, 2019 survey, Maine shellfish and seaweed producers.

Figure 2. Frequency of mention of various types of quality attributes for oysters, 2019 survey, Maine shellfish and seaweed producers.

Figure 3. If a confidential web site were developed that would allow you (at no cost to your farm) to compare your farm's production and financial performance information with averages of other similar-sized farms in the region, in a way that would preserve the confidentiality of your farm's individual data, would you be interested in participating?

Figure 4. Mean area planted (acres) in oysters by production scale, oyster farms.

Figure 5. Productivity (mean number of oysters harvested per acre planted) by production scale, oyster farms.

Figure 6. Labor efficiency (number of oysters harvested per hour of labor) by production scale, oyster farms.

Figure 7. Investment capital efficiency ($ of investment capital per oyster harvested) by production scale, oyster farms.

Figure 8. Cost structures on oyster farms (percentage breakdown of expenses) on: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms.

Figure 9. Mean net farm income per single oyster by: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 10. Economies of scale, measured as breakeven price above total costs per single oyster for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 11. Mean net farm income per single oyster by length of growout (months from spat to market size) for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 12. Mean net farm income per single oyster by breakeven price above total costs (BEP, TC) for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 13. Mean net farm income per single oyster by working capital ($/farm) for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 14. Mean working capital ($/farm) for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 15. Mean working capital ($/farm) vs acres planted for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 16. Mean working capital ($/farm) vs quantity harvested (oysters/acre) for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 17. Mean working capital ($/farm) vs quantity harvested (oysters/farm) for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms, oyster farms.

Figure 18. Mean working capital ($/farm) vs seed purchased per acre for: a) established suspended culture farms; b) established bottom culture farms; and c) startup suspended culture farms, oyster farms.

Figure 19. Cost structure, mussel farms.

Figure 20. Net farm income ($/foot of line), mussel farms.

Figure 21. Economies of scale measured as breakeven price above total costs per lb of mussel harvested.

Figure 22. Net farm income ($/foot of line) by total mussels harvested per farm, mussel farms.

Figure 23. Net farm income ($/foot of line) by weight harvested (lb/foot of line), mussel farms.

Figure 24. Net farm income ($/foot of line) by labor efficiency (lb harvested/hour of labor), mussel farms.

Figure 25. Net farm income ($/foot of line) by sales revenue/hour of labor, mussel farms.

Figure 26. Working capital ($/farm), mussel farms.

Figure 27. Working capital ($/farm) vs net farm income ($/foot of line), mussel farms.

Figure 28. Working capital ($/farm) by total weight (lb) of mussels harvested/farm, mussel farms.

Figure 29. Working capital ($/farm) by labor efficiency (lb mussels harvested/hour of labor), mussel farms.

Figure 30. Working capital ($/farm) by sales revenue/hour of labor, mussel farms.

Figure 31. Cost structure, seaweed farms.

Figure 32. Net farm income ($/foot of line), seaweed farms.

Figure 33. Economies of scale measured as breakeven price above total costs per lb of seaweed, seaweed farms.

Figure 34. Net farm income ($/foot of line) by total weight (lb) of seaweed harvested (lb/farm), seaweed farms.

Figure 35. Net farm income ($/foot of line) by labor cost ($/lb harvested), seaweed farms.

Figure 36. Net farm income ($/foot of line) by labor efficiency (lb harvested/hour of labor), seaweed farms.

Figure 37. Net farm income ($/foot of line) by sales revenue/hour of labor, seaweed farms.

Figure 38. Net farm income ($/foot of line) by capital efficiency (lb/$ investment capital), seaweed farms.

Figure 39. Working capital ($/farm), seaweed farms.

Figure 40. Working capital ($/farm) vs labor efficiency (lb harvested/hour of labor), seaweed farms.

Figure 41. Working capital ($/farm) vs sales revenue/hour of labor, seaweed farms.

Figure 42. Harvest of farm raised marine algae in Maine in wet pounds (lbs.) and USD ($).

## LIST OF TABLES

1. Benchmark metrics calculated, definition and calculations.

2. List frame and response rate for shellfish and seaweed producers in Maine.

3. Number and acreage of leases of respondents, 2019 survey, Maine shellfish and seaweed producers.

4. Number and acreage of leases in production by aquaculture product, 2019 survey, Maine shellfish and seaweed producers.

5. Types of collateral used for loans, as reported by respondents, 2019 survey, Maine shellfish and seaweed producers.

6. Frequency of occurrence of various types of risk, 2019 survey, Maine shellfish and seaweed producers. Values are the reported severity of losses (in terms of percentage of volume of sales) for each frequency of risk for each source of loss. N=number of respondents to each type of risk.

7. Other sources of risk reported, 2019 survey, Maine shellfish and seaweed producers.

8. Greatest problems mentioned by oyster producers. Data are percentages of respondents, 2019 survey, Maine shellfish and seaweed producers.

9. Greatest problems mentioned by mussel producers. Data are percentages of respondents, 2019 survey, Maine shellfish and seaweed producers.

10. Greatest problems mentioned by seaweed producers. Data are percentages of respondents, 2019 survey, Maine shellfish and seaweed producers.

11. Greatest problems mentioned by scallop producers. Data are percentages of respondents, 2019 survey, Maine shellfish and seaweed producers.

12. Specific regulatory problems mentioned as “other” regulatory problems, 2019 survey, Maine shellfish and seaweed producers.

13. Types and characteristics of employment of family labor and non-family employment, 2019 survey, Maine shellfish and seaweed producers. Values are means $\pm$ standard deviation.

14. Responses to question whether survey respondents were concerned about market saturation, 2019 survey, Maine shellfish and seaweed producers.

15. Additional comments from oyster respondents related to concerns over market saturation, 2019 survey, Maine shellfish and seaweed producers.

16. Additional comments from mussel and scallop respondents related to concerns over market saturation, 2019 survey Maine shellfish and seaweed producers.

17. Additional comments from seaweed respondents related to concerns over market saturation, 2019 survey, Maine shellfish and seaweed producers.

18. Determinants of quality of oyster products, 2019 survey Maine shellfish and seaweed producers.

19. Determinants of quality of end mussel products, 2019 survey, Maine shellfish and seaweed producers.

20. Determinants of quality of seaweed products, 2019 survey, Maine shellfish and seaweed producers.

21. Top six costs (ranked by percentage contribution to total cost) of **oyster** production by **farm size**, 2019 survey, Maine **oyster** farms.

22. Startup cost benchmarks by **farm size**, 2019 survey, Maine **oyster** farms.

23. Top six costs (ranked by percentage contribution to total cost) of **oyster** production by the three categories of established suspended, established bottom culture, and startup suspended oyster farms.

24. **Production** benchmarks for established (> 5 years in business) suspended culture **oyster** farms. Mean areas planted were 7.8 $\pm$ 7.0 acres for established suspended farms.

25. **Production** benchmarks for established (> 5 years in business) bottom culture **oyster** farms. Mean areas planted were 7.8 $\pm$ 6.9 acres for established bottom culture farms.

26. Production benchmarks for **startup** (< 5 years in business) suspended culture **oyster** farms.

27. **Expense** benchmarks (direct operating/variable costs and ownership/fixed/overhead costs) for established (> 5 years in business) suspended culture oyster farms.

28. **Expense** benchmarks (direct operating/variable costs and ownership/fixed/overhead costs) for established (> 5 years in business) bottom culture oyster farms.

29. Expense benchmarks (direct operating/variable costs and ownership/fixed/overhead costs) for **startup** (< 5 years in business) suspended culture **oyster** farms.

30. **Total annual costs, breakeven price, and breakeven yield** benchmarks for established (> 5 years in business) suspended culture oyster farms.

31. **Total annual costs, breakeven price, and breakeven yield** benchmarks for established (> 5 years in business) bottom culture oyster farms.

32. **Total annual costs, breakeven price, and breakeven yield** benchmarks for **startup** (< 5 years in business) suspended culture oyster farms.

33. **Profitability** benchmarks for **established** (> 5 years in business) suspended culture **oyster** farms.

34. **Profitability** benchmarks for **established** (> 5 years in business) bottom culture **oyster** farms.

35. **Profitability** benchmarks **for startup** (< 5 years in business) suspended culture **oyster** farms.

36. Number and percentage of respondents who reported payments on loans by **established** (> 5 years in business) or **startup** (< 5 years in business) **oyster** farms. Values in percentage of respondents, 2019 survey, Maine shellfish and seaweed producers.

37. **Financial** benchmarks for **established** (> 5 years in business) suspended culture **oyster** farms.

38. **Financial** benchmarks for **established** (> 5 years in business) bottom culture **oyster** farms.

39. **Financial** benchmarks for **startup** (< 5 years in business) cage culture **oyster** farms.

40. Repayment analysis benchmarks for **established** (> 5 years in business) suspended culture vs. bottom culture **oyster** farms.

41. Repayment analysis benchmarks for **startup** (< 5 years in business) suspended culture **oyster** farms.

42. **Efficiency** benchmarks for **established** (> 5 years in business) suspended culture **oyster** farms.

43. **Efficiency** benchmarks for **established** (> 5 years in business) bottom culture **oyster** farms.

44. Efficiency benchmarks for **startup** (< 5 years in business) suspended culture **oyster** farms.

45. Production benchmarks for **mussel** farms. All seed obtained from wild sets.

46. Expense benchmarks (direct operating/variable costs and ownership/fixed/overhead costs) for **mussel** farms. All seed obtained from wild sets.

47. Total annual costs, breakeven price, and breakeven yield benchmarks for **mussel** farms.

48. Profitability benchmarks for **mussel** farms.

49. Number and percentage of **mussel** producer respondents who reported payments on loans, 2019 survey, Maine shellfish and seaweed producers. Values in percentage of respondents.

50. Financial benchmarks for **mussel** farms.

51. Repayment analysis benchmarks for **mussel** farms.

52. Efficiency benchmarks for **mussel** farms.

53. **Mussel** benchmarks compared to available benchmarks for EU aggregated values for Spain mussel raft culture and bottom mussel culture in The Netherlands.

54. Cost comparison (% of total costs) on oyster, mussel, and seaweed farms.

55. Production benchmarks for **seaweed** farms.

56. Expense benchmarks (direct operating/variable costs and ownership/fixed/overhead costs) for **seaweed** farms.

57. Total annual costs, breakeven price, and breakeven yield benchmarks for **seaweed** farms.

58. Profitability benchmarks for **seaweed** farms.

59. Number and percentage of **seaweed** producer respondents who reported payments on loans, 2019 survey, Maine shellfish and seaweed producers. Values in percentage of respondents.

60. Financial benchmarks for **seaweed** farms.

61. Repayment analysis benchmarks for **seaweed** farms.

62. Efficiency benchmarks for **seaweed** farms.

# INTRODUCTION

The state of Maine has shown rapid growth in terms of the number of aquaculture producers and the value of products sold from aquaculture farms, particularly for shellfish and seaweed. Shellfish production in Maine is expected to continue to grow due to a variety of factors. Market demand appears to be strong for farmed shellfish generally. Maine is considered to have several competitive advantages that include: proximity to major population areas in the Northeast U.S. where shellfish consumption is high, good growing conditions, and room for expansion. In addition, consumer preferences and price premiums exist for the cold-water oysters grown in Maine that add to expectations for additional growth for Maine shellfish (Hale Research Group 2016). Seaweed production is a relatively new aquaculture endeavor for the Western Hemisphere. Seaweed production has grown in Maine as a secondary source of income especially for fishermen, lobstermen, and shellfish producers who have boats and other types of necessary gear for seaweed production.

The market growth that will be required for Maine oysters to meet demand will require expansion of existing oyster businesses and entry of new oyster farming businesses. Such expansion will require access to sufficient capital for investment in facilities and for operation. The financing community in Maine, however, is generally unfamiliar with aquaculture farming and would benefit from financial tools such as benchmarks against which loan application financial projections could be compared. Such benchmarking information is of special value for startup shellfish and seaweed farms. For shellfish farms, it may be 3 to 5 years before the business is in full production with full revenue, whereas seaweed production is in its infancy during which producers will need to learn from trials and experiences of other producers how to manage seaweed farms efficiently.

Adequate financing through the first 5 years of a shellfish farm is essential for its success. Insufficient investment and operating capital are a major cause of failure of new aquaculture businesses (Engle 2010, 2019), but obtaining sufficient capital for aquaculture businesses is challenging (Lockwood 2017). Aquaculture continues to be viewed as a new, high-risk type of farming in spite of a history of economic success that extends for more than a century. The lack of personal experience by lenders, even in regions with well-established aquaculture industries, is compounded by the lack of readily available benchmarking information. Most applicants for financing must develop their own information or use that which was developed in a different geographic region, often with conditions that differ substantially from those in Maine. The difficulty of obtaining sufficient capital is a barrier to entry to many prospective aquaculture businesses in Maine.

## Literature Review of Benchmarking and Shellfish Economics

### Benchmarking

Benchmarks are business tools that have been used to provide a basis for one business to compare its performance with other similar businesses for any given year as well as over a period of years. Benchmarks provide a basis for a business to track which aspects of its business (i.e., various production and cost efficiencies) meet, exceed, or fall below industry averages. Financial

lenders and investors also use benchmarks to identify thresholds likely to predict financial success or failure of a startup business. In some industries, individual businesses can subscribe to services that tabulate benchmarks periodically for evaluation and comparison. Benchmarks also provide a basis for making industry-wide comparisons over time. In addition to formal benchmarking programs, there are a variety of Extension education materials available on the internet that list and explain various farm financial ratios and benchmarks (See Kohl, as modified by Blonde 2005 for an example).

Much of the available information on benchmarking for agriculture is in the form of industry support materials from farm organizations or from extension personnel. No examples have been found for aquaculture benchmarks that are in use by industry. Moreover, there is little peer-reviewed scientific literature on benchmarking for agriculture generally or aquaculture in particular.

Various farm management associations, a number of which are located in the north central states of the U.S. participate in FINBIN (available at www.finbin.umn.edu.), an online benchmarking database and service developed and maintained by the Center for Farm and Financial Management at the University of Minnesota. FINBIN is one of the largest and most accessible sources of farm financial and production benchmark information in the world. Farmer participants upload financial data each year into databases that allow program participants to generate detailed benchmarking reports that compare their farm to other similar farms at the whole farm and crop/livestock unit levels based on a series of production and financial benchmark metrics.

Another widely recognized benchmarking initiative in agriculture is that of the Agri Benchmark program, based in Germany. Agri Benchmark began in 2002 as an effort to standardize methods for global farm-level benchmarking (Deblitz et al. 1998; Deblitz 2010; Deblitz 2013) and relies heavily on pre-existing farm networks in several different countries (de Roest 2006; Richardson et al. 2009; and Sarzeaud et al. 2009). Crops such as beef and dairy cattle, sheep, swine, poultry, horticulture, cereals, oilseeds, and sugar are included in the Agri Benchmark database. The approach used for the database is based on the identification of “typical farm” categories, chosen based on farm size structures and key production factors that differ among production systems (Deblitz and Zimmer 2007). Survey data collected from existing farms provide the most appropriate basis of identification of the most appropriate categories of farms.

The Agri Benchmark database includes background farm information such as land size and stocking numbers. Market prices are tracked along with key performance metrics. For beef cattle, for example, performance indicators include: daily weight gain, finishing period, and productivity (calves per cow; cows and calves per ha; weight per ha). Additional metrics provide cost breakdowns of land and feed costs across the farm and, for beef cattle, per 100 kg of carcass weight while labor production and cost are tracked in kg beef per hour and return per unit of labor cost. Profitability is measured as total returns and margins over cash costs. Land productivity is measured in carcass weight per hectare and short- and medium- term profitability is measured per 100 kg of carcass weight. Capital productivity metrics use information on opportunity costs and depreciation. Participating farms are then encouraged to seek to match the

performance levels of the top-performing farms. The data are complex and detailed, but provide a basis for international comparisons across a large number of metrics.

In addition to the online agricultural benchmarking services, a number of farm business management associations work with producers to report individual farm financial information in a confidential format that then allows each to compare their data to other similar types of farms. Statistics reported often include the average, minimum, and maximum of other farms that raise similar types of crops on similar scales. Other approaches report benchmarking indicators by percentile, such as the lowest 20% and the highest 20%.

A wide array of benchmarking indicators is used by these associations. As one example, the Southwest Minnesota Farm Business Management Association and the Northwest Farm Credit Services Business Tools (available at: www.northwestfcs.com/Resources/business-tools) reports metrics such as: average net farm income, gross cash income, return on assets, net worth, net worth growth, debt/asset ratio, working capital, debt repayment capacity, ending equity, yields, and net farm income liquidity metrics such as current assets, current liabilities, current ratio, working capital, working capital rule, and size distributions at harvest (Nordquist et al. 2017).

In one of the few scientific articles on benchmarking in agriculture, Koketsu et al. (2010) reviewed the application of benchmarks for commercial hog farms. The study analyzed a variety of specific benchmarks and identified herd financial performance (in particular return on assets, net profit margin and asset turnover ratio), growth of pigs in growout, and reproductive productivity of sows as most important.

There are far fewer examples of the development of benchmarks for aquaculture. In the U.S., the Southern Regional Aquaculture Center in the U.S. developed a series of benchmark indicators for catfish and for baitfish farms in the U.S. (SRAC 1998; Engle et al. 2000). These benchmarks, however, have not been further developed into on-going databases used by industry.

In Australia, CDI Pinnacle Management (2010) developed a set of benchmarks for the Australian oyster industry. The software was set up to report a minimum, maximum, and an average value for each. Key performance indicators included: revenue (total income, total sales, total sales per leased ha, and total sales per developed ha, total cost of goods sold (COGS), COGS per leased ha, COGS per developed ha, gross profit, gross profit per leased ha, gross profit per developed ha, and gross profit margin, net profit, net profit per leased ha, net profit per developed ha, net profit margin, total income per dozen, total oyster income per dozen, COGS per dozen, gross profit per dozen, and net profit per dozen. Expense benchmarks included: total expenses per leased ha, total expenses per developed ha, COGS per dozen, expenses per dozen, licenses and lease fees per dozen, repair and maintenance costs per dozen, spat cost per dozen, and wages and costs per dozen. Other tables reported the percentage that various expense items composed of total costs. Other, non-financial benchmarks included: average dozens per leased ha, average dozens per developed ha, average dozens per man hour, average sales revenue per FTE, average costs per FTE, total production, % of total production of various sizes of oysters, total leased hectares, total developed hectares, dozens per leased hectare, dozens per developed hectare, dozens per man hour, oyster sales revenue per FTE, and oyster costs per FTE.

In the CDI example analysis, labor and spat composed the greatest costs, with labor 49% of total costs and spat 14% of all costs; repairs and maintenance composed 8% of costs. The top four categories of costs composed 77% of all costs. The example included the size distribution of harvest as one metric. They also found that reducing growout time from 24 to 18 months can improve efficiencies. Nevertheless, no evidence has been found that this benchmarking program has been implemented with commercial oyster producers.

In one of the few peer-reviewed scientific publications on benchmarking in aquaculture, Lasner et al. (2017) followed the agri benchmark approach of defining "typical" types of farms for which to calculate benchmarks related to profitability, productivity, and energy efficiency of rainbow trout farming in Denmark, Turkey, and Germany. Cash cost metrics were developed for feed, fingerlings, wages, energy, interest, veterinary costs, administration, maintenance, and others. Depreciation, opportunity cost, and returns similarly were measured in $/kg live weight, while labor was measured in kg live weight added per hour of labor.

**Shellfish Economics**

The shellfish economics literature is relatively sparse. Much of it examines overall feasibility such as that of scallop culture in Florida (Adams et al. 2001), bioeconomic models (Choi et al. 2006; Johnston et al. 2019), economic impact (Cole et al. 2016; Northern Economics 2013), and broader industry overviews (Department of Fisheries and Oceans 2006; Hudson and Murray 2016).

For oysters, several recent studies have examined production efficiencies. For example, Scuderi and Chen (2018) found that production efficiency of Maine, New Hampshire, and Massachusetts (U.S.) oyster farms increased from 2013 to 2015, but that there was room for continued improvements in efficiencies. Farm locations in Maine were found to contribute to greater farm-level efficiencies. Other studies have examined effects of production scale on production efficiency (Samonte-Tan and Davis 1998 in the Philippines; Huang et al. 2013; and Huang and Lee 2014 in Taiwan). In Hawaii, Chen et al. (2017) showed negative net returns from oyster production in small-scale traditional Hawaiian fish ponds.

Coffen and Charles (1991) found that capital investment, labor and experience significantly affected the output of oysters in Atlantic Canada. In Taiwan, Huang et al. (2013) found that labor costs accounted for 37% of total costs of oyster production. Similarly, Chen et al. (2017), showed that the cost of labor and wage rates constituted a major cost of production on small-scale oyster farms in Hawaii. Labor productivity was identified as especially meaningful for oyster farmers in France due to the importance of labor as a major cost of production, but land productivity was also found to be a meaningful determinant of profitability (Girard and Pérez Agúndez 2014).

Extension support materials have been developed in the U.S. in support of economic and financial analysis of oyster farms. For example, Haight (2007) developed a complete financial and economic analysis of a model oyster farm for Alaska. The workbook developed includes detailed lists of investment and operating costs as well as pro forma profit and loss statements, farm development plans, and sales and revenue.

In more recent work, budgeting tools have been developed for oyster production in Maryland (Parker et al. 2013a, b) and in North Carolina (Turano 2013). The Maryland oyster cost analysis spreadsheets include separate spreadsheets for bottom and container culture (Available at: https://extension.umd.edu/aquaculture/resources). The Maine Aquaculture Association has developed a series of generic business and production plans (Brayden In Press).

A few studies from France, Canada, and Denmark have examined the economics of mussel production. Mongruel and Perez-Agundez (2006) compared the economic dynamics of oyster and mussel farming in Mont St. Michel Bay, France, where mussels are raised in mussel beds, with cords strung from posts. Detailed analysis of respective production costs showed that mussel farming was more profitable than oyster farming at that time. In Prince Edward Island in Canada, the Department of Fisheries and Oceans (2006) compiled an economic impact study of long-line mussel production. However, no annual costs and returns were included in the analysis. In Denmark, Nguyen et al. (2013) estimated costs associated with a "smart-farm" system of suspended mesh ropes for mini-mussel production. The advantage identified of mini-mussel production was to reduce labor costs as compared to traditional systems, thereby improving profitability. The lack of profitability of traditional blue mussel culture in Denmark was attributed to the labor-intensive nature of mussel farming.

Even fewer studies have examined the economics of seaweed production. One of the few is that by Valderrama et al. (2015) that examined the economic performance of seaweed farms in six Asian and Latin American countries. Differences in economic performance were attributed to differing scales of operation and farm prices. Alternative seaweed processing standards and costs were compared by Wakamatsu and Miyata (2015) for the Japanese market. Production cost estimates of seaweed as a biofuel in the U.S. ranged from $21 to $150 per metric ton of dried seaweed (Chynoweth 2002; Reith et al. 2009; and Oilgae 2010). Finally, offshore production of seaweed in the North Sea was found to be economically infeasible (van den Burg et al. 2016).

## Potential Benefits to Shellfish Producers from Benchmarking

Benchmarks for shellfish farming in Maine would provide a series of potential benefits. The immediate benefit would likely be the value to the financial community. Shellfish benchmarks would assist lenders to better understand shellfish businesses and to be more comfortable approving loans for shellfish farming.

There would likely also be benefits to shellfish producers as well. Benchmarks are often used in other business sectors, including farming, as a way for farms to compare the performance of their farm to that of other similar farms. It may be that a particular farm is well above average for some metrics but below average in others. Such comparisons suggest areas for improvement that can be quite beneficial.

Finally, benchmarks for aquaculture can potentially be used to assess risk management strategies. Benchmarking databases could be used, for example, to develop actuarial tables necessary for development of different types of insurance products. Overall, financial benchmarks for Maine aquaculture have potential to improve accessibility of Maine aquaculture

producers to adequate and financially-responsible funding for new startup businesses and for expansion of existing businesses.

### Study Goals and Objectives

The goal of this study was to develop a series of benchmarks to assist and support startup shellfish and seaweed farms particularly during the early years as well as to assist and support growth of established companies. Specific objectives include:

1. To develop production, cost-efficiency, profitability, performance, and financial benchmarks for oysters, mussels, and seaweed for Maine.

2. To develop a summary of results for Maine shellfish and seaweed farming that will provide a basis for lenders and loan officers to better evaluate business plans and loan proposals.

## METHODS

The project was developed in four phases. Phase 1 focused on development of data collection forms along with background research of secondary data and existing literature on benchmarking and shellfish economics. A comprehensive literature review of existing financial and economic data and literature on oysters was conducted in Phase 1 and summarized in the "Literature Review of Benchmarking and Shellfish Economics" section of this report. A preliminary list of financial benchmarking metrics was developed and reviewed by the Financial Advisory Committee[2] for the project. Input on ranking systems for the benchmarks suggested that a statistical type of ranking (reporting average, minimum, and maximum values) was preferable. Table 1 presents the final list of benchmarks selected and their definitions.

Phase 2 consisted of the survey and field data collection. Data were analyzed in Phase 3, and benchmarks calculated in Phase 4. The methods are discussed first for the survey conducted to collect the farm-level data required to develop farm benchmarks. Given the substantial differences in terms of industry structure, production scales, and available technologies, the methods used to organize and analyze the data prior to calculation of benchmarks are discussed under each species heading (i.e., oysters, mussels, and seaweed).

### Survey

Data collection forms were designed and assembled in the form of a questionnaire that drew upon previous and on-going surveys of shellfish producers on the Pacific and Atlantic coasts. The final survey included questions and tables designed to collect the data necessary to calculate the benchmarks selected (Table 1). The survey collected data on: 1) production (planting and harvesting); 2) expenses categorized by operating (variable) and ownership (fixed) costs; 3) market prices and sales volumes; 4) quantities and value of labor and management on each farm; 5) investment expenditures on facilities and equipment; and 6) types of loans and lending terms.

[2] The Financial Advisory Committee consisted of representatives of commercial lending, Farm Credit Service, and community development financial institutions.

The survey instrument included questions to elicit other information important to lenders, including details of the various types of risk (i.e., weather, diseases, theft, etc.) and degree of risk (frequency and severity of losses for each type) faced by shellfish and seaweed producers in Maine. Respondents were asked about the greatest problems that they faced as well as the types of factors that affected the quality of the products sold.

Every effort was made to streamline the survey instrument so as to minimize the response burden on the part of producers, while still collecting the data necessary to calculate the benchmark indicators listed in Table 1. An early draft of the questionnaire was reviewed by the Maine Aquaculture Association for feedback on whether: 1) the terms used were those typically used by Maine producers; 2) the questions were worded clearly and unambiguously for Maine producers; 3) the questions could be answered by Maine producers in the format proposed; 4) there were faster or easier ways to request the various types of data; 5) there was a better way to order the questions in terms of encouraging responses; and 6) whether there were important omissions. Following review and revision, the questionnaire was pre-tested with five shellfish and one seaweed producer in Maine with a few additional revisions made following the pre-test.

Prior to the launch of the survey, the Maine Aquaculture Association sent an initial introductory description of the project to producers. This initial correspondence served to introduce the economists conducting the survey to producers and to solicit participation. Individual contacts were then made to schedule appointments for direct, personal interviews. Follow-up activities were conducted to make every attempt to obtain sufficient numbers of observations for the analysis. Refusals constituted 3% and no responses 23% of the list frame, for a final response rate of 74% (Table 2).

Data were entered into a spreadsheet by observation. Following data entry, quality control procedures were completed for which all observations were checked for: 1) accuracy of data entry by double checking with original data records; and 2) reliability and consistency within and across observations (such checks can reveal other errors that require corrective action). Descriptive summaries of survey data were developed and summarized into separate tables by species (i.e., oysters, mussels, and seaweed).

## Benchmark Calculation and Subsequent Analysis

Data were first sorted into separate spreadsheets by species, following which the proposed benchmarks (Table 1) were calculated for each observation in each species dataset. The average, standard deviation, minimum, and maximum values (based on the statistical rating system selected based on input from the Financial Advisory Committee) were then calculated for each benchmark. Given the degree of variability found in the data, the median value was also identified for each benchmark. The median is the middle value of the numbers reported. The benchmarks were compiled into the following sets of tables by species: 1) production benchmarks; 2) expense benchmarks; 3) total annual cost categories, breakeven price, and breakeven yield benchmarks; 4) profitability benchmarks; 5) types of loans; 6) financial benchmarks; 7) repayment analysis benchmarks; and 8) efficiency benchmarks (including labor, capital, and financial efficiency).

Lenders must take into consideration a variety of factors when deciding whether to approve a loan proposal or not. Two of the most critical factors, however, are: 1) whether the business overall is profitable and likely to survive in the long term; and 2) whether there is sufficient cash flow for the business to be able to pay bills when they come due, including principal and interest payments on loans. Thus, a series of graphical analyses were conducted on the benchmarks for each species that searched for benchmarks that showed some relationship to profitability (as measured by net margins, or net farm income) and cash flow (as measured by working capital). While the relatively small number of observations precluded quantitative analyses of relationships, graphing data points of various benchmarks revealed some trends among a few benchmarks that appear to be related. Managing financial position and the associated financial risk is also important for long-term success of businesses. Unfortunately, the survey data included small numbers of observations of farms that borrowed money. Thus, in most cases, there were too few observations to adequately assess financial position and the related financial risk; thus, the analysis focused on profitability and cash flow benchmarks.

## Oysters

A descriptive analysis was conducted first of the oyster data collected. The key production output unit used was that of the number of single oysters harvested per year. The scale of production often affects many production and cost metrics in aquaculture. Thus, an initial descriptive analysis of effects of production scale was developed from the oyster data. To do so, the individual observations from oyster farms were sorted by the number of single oysters sold. These values were graphed and examined to identify groupings of similar farm sizes by noting the breaks in the graph developed. Farm sizes identified were those that sold: < 100,000; 100,000 to 249,999; and > 250,000 single oysters per year. Additional graphs were then developed that compared each of the following benchmarks by scale of production: 1) mean area planted (in acres) in oysters by each production scale; 2) mean productivity (mean number of oysters harvested per acre planted); 3) labor efficiency (number of oysters harvested per hour of labor); and 4) investment capital efficiency ($ of investment capital per oyster harvested). In addition, the top six greatest contributors to cost of oyster production were identified by farm production scale in terms of the mean cost per oyster harvested for each cost item. Mean startup investment costs were compared by farm, by acre planted and by single oyster harvested across the three production scales.

A second descriptive analysis was then developed of the oyster data to examine whether there were differences due to years in production. This second analysis was done because oysters are a crop that in some ways resembles that of an orchard in that it takes several years for the initial investment in an oyster farm to result in sales and revenue to the farm business. Oysters require several years to reach market size; thus, the startup years of an oyster farm pose different challenges than those experienced by established farms, due to the lack of revenue in the early years. To account for these differences, the oyster benchmark data were sorted into two groups of farms: 1) established farms, those that had been in business for more than 5 years; and 2) startup farms, those that had been in business for less than 5 years. Cost structures were examined by calculating the relative proportions of line-item costs. The comparison of cost structures revealed substantial differences between startup and established oyster farms. The various line item expenditures were ranked from greatest to smallest and were graphed

separately for established and startup farms. Further examination of various benchmarks revealed that cost structures were also affected by the gear type used on established oyster farms. Whereas all startup oyster farm respondents used suspended gear, there was a sub-set of established farms that planted oysters directly on the bottom with others using suspended gear.

Due to the different cost structures found, the oyster benchmarks were sorted into the following three categories: 1) established suspended culture farms; 2) established bottom culture farms; and 3) startup suspended culture farms. These three categories were then used for all subsequent analyses and data summaries for oysters.

The benchmarks calculated were summarized by the following categories: production and marketing, expenses (direct operating/variable and ownership/fixed/overhead), total annual costs, breakeven prices, and breakeven yields, profitability, financial, repayment, and efficiency (labor, capital, financial). Within each of these benchmarking categories, the values calculated for established (both suspended and bottom culture) and startup oyster farms were compared based on the average values. Average values were reported as the means plus or minus standard deviations. There was a great deal of variability across the benchmarks calculated. Thus, the median was also calculated for each. The median is the middle value of the numbers reported. While the variability among values decreased after sorting the data into the three categories, some benchmarks continued to show greater variability than others. To account for this variability when using the benchmarks calculated, the coefficient of variation (CV) was calculated for each set of benchmark values. The CV is a measure of variability that is calculated by dividing the standard deviation by the mean and multiplying by 100 for each benchmark calculated. The range of values between the minimum and maximum values also provides additional indications of the degree of variability for each benchmark.

The analysis did not account for variability among farms in terms of size differences in the oysters harvested. Different sizes and qualities of oysters yield different prices, with lower prices paid for smaller, or “down-graded” oysters. The survey data allowed us to calculate a weighted average price, based on the relative volumes sold of different size categories of oysters, but the data were too variable to be able to sort and make direct comparisons based on the percentage of “down-graded” oysters.

Further analyses were developed to seek additional insights into the economics and financial performance of oyster farms. Average cost per oyster harvested was graphed for established suspended and bottom culture and for startup suspended farms to determine if economies of scale were present. In addition, graphical analyses were done to search for benchmarks that showed some relationship to profitability (as measured by net margins, or net farm income per oyster harvested) and to cash flow (as measured by working capital). Within each of the three categories (established suspended and bottom culture and startup suspended culture), the observations were sorted and ranked in terms of decreasing profitability and cash flow within each category.

Graphs were then developed with net farm income per oyster harvested on one vertical axis and the second vertical axis of each of the following benchmarks: acres planted, total quantity of seed purchased per farm and per acre, time (in months) from planting spat to market size, total

quantity of oysters harvested per farm and per acre, percent of harvest sold of cocktail size, breakeven price above variable and above total cost, total variable and total fixed cost as a percent of total cost, and working capital (in $/farm). To search for benchmarks with some relationship to cash flow, the datasets for each of the three categories (established suspended and bottom culture and startup suspended culture) were again sorted but in terms of decreasing working capital ($/farm). The relationships with the same benchmarks as those analyzed for profitability were then examined by graphing the working capital ($/farm) on one of the vertical axes and each of the benchmarks listed above on the second vertical axis.

Finally, the use of benchmarks in analyzing data from an individual farm was illustrated through an analysis of those farm observations that were not profitable (negative net farm income). The benchmarks for each observation were used to identify root causes of the lack of profitability as well as to identify strategies likely to improve profitability on each farm.

## Raft-Cultured Mussels

The data used to calculate and analyze benchmarks for mussels were obtained from the survey of Maine shellfish and seaweed producers. The overall survey methods are described above in the "Methods" sub-section entitled "Survey." The text below will present the methods used to analyze the mussel survey data, calculate benchmarks for mussels, and analyze the mussel benchmarks calculated. The benchmarks calculated for mussels were restricted to those of raft culture only. There were too few producers of bottom cultured mussels in Maine to be able to report them and maintain the confidentiality of individual farm data.

Cost structures of mussel farms were examined by calculating the relative proportions of line-item costs. The various line item expenditures were ranked from greatest to smallest and were graphed separately. If average cost of production decreases as production scale increases, then economies of scale are present. If average cost of production increases with increasing production scale, then diseconomies of scale are determined to be present.

The data from mussel farms were pulled out of the overall dataset into a separate worksheet file and further organized into the following groups of benchmarks: 1) production benchmarks; 2) expense benchmarks; 3) total annual cost categories, breakeven price, breakeven yield benchmarks; 4) profitability benchmarks; 5) types of loans; 6) financial benchmarks; 7) repayment analysis benchmarks; and 8) efficiency benchmarks (including labor, capital, and financial efficiency). Each benchmark was calculated separately for each individual observation from which the statistical ratings of average plus or minus standard deviation, minimum, and maximum values were calculated. The resulting benchmark statistics were summarized into tables as follows: production (acres planted, numbers of rafts); expense (direct operating/variable costs and ownership/fixed/overhead costs); total annual costs, breakeven prices, and breakeven yields; profitability; financial; repayment analysis; and efficiency (of labor, capital, and finances).

The first round of calculations of mussel benchmarks included all respondents who raised mussels. The results, however, were highly variable. Closer examination revealed that many of the benchmark metrics were skewed by one particular observation of a farm that was in the

startup phase of production. The accuracy of the values was verified through further discussion with the farmer, but the lack of data at full production resulted in the data from this farm not being consistent with that of other observations. Thus, the data from this observation was dropped from the dataset of mussel benchmarks. The farm was in a scale-up phase with high costs as compared to a low volume of sales, given that much of the crop had not yet reached market size, distorting the overall results.

Further analysis of the mussel benchmark results was done as described in the "Methods" sub-section under the heading of "Oysters." Average costs of production (breakeven price above total costs were graphed by farm size to search for evidence of economies of scale. As with the oyster benchmark metrics, graphs were developed with net farm income per pound of mussel harvested on one vertical axis and the second vertical axis corresponded to each of the following benchmarks: total weight of mussels harvested per farm, total pounds of mussels harvested per foot of line, years in business, labor cost ($/lb), labor efficiency (lb/hour of labor and lb/$ of labor), sales revenue per hour of labor, depreciation ($/lb harvested), long-term capital efficiency (lb/$ of investment capital). and working capital (in $/farm). To search for benchmarks with some relationship to cash flow, the mussel benchmark metrics were again sorted but in terms of decreasing working capital ($/farm). The relationships with the same benchmarks as those analyzed for profitability were then examined by graphing the working capital ($/farm) on one of the vertical axes and each of the benchmarks listed above on the second vertical axis.

As a basis of comparison with a broader number of mussel farms that had been in production for some time, data from Salz (2009) were used to compare as many of the benchmark indicators as possible with equivalent metrics from raft mussel production in Spain and bottom culture of mussels in The Netherlands. The EU dataset included data from 2,065 mussel raft farms in Spain and 55 bottom culture mussel farms in The Netherlands. The Salz (2009) report included only aggregated values for costs and revenues, assets and liabilities, employment, legal status, and sales volume, but without farm-level means and standard deviations. Moreover, the Salz (2009) data did not include production metrics such as acreage, numbers of rafts, etc., that would allow for calculation of productivity metrics. Thus, not all benchmark metrics evaluated in this study could be calculated for mussel production in Spain and The Netherlands. In addition, the values reported in Salz (2009) were for the year 2006 and were reported in Euros. The EU Consumer Price Index (available at: www.inflationtool.com; accessed February 6, 2020) was used to inflate all monetary values (other than market price) to 2018 values before conversion to U.S. dollars using the 2018 exchange rate (available at: www.statista.com; accessed February 6, 2020).

## Seaweed

The data used to calculate and analyze benchmarks for seaweed were obtained from the survey of Maine shellfish and seaweed producers. The overall survey methods are described above in the "Methods" sub-section under the heading of "Survey." The text below will present the methods used to analyze the seaweed survey data, calculate benchmarks for seaweed, and analyze the seaweed benchmarks calculated.

Cost structures of seaweed farms were examined by calculating the relative proportions of line-item costs. The various line item expenditures were ranked from greatest to smallest and were

graphed separately. In addition, to examine whether there are economies of scale in seaweed production, the average cost of production (break-even price above total costs, in $/lb) was calculated and graphed against the production scale (total quantity of seaweed sold). If average cost of production decreases as production scale increases, then economies of scale are present. If average cost of production increases with increasing production scale, then diseconomies of scale are determined to be present.

The data from seaweed farms were pulled out of the overall dataset into a separate worksheet file and further organized into the following groups of benchmarks: 1) production benchmarks; 2) expense benchmarks; 3) total annual cost categories, breakeven price, breakeven yield benchmarks; 4) profitability benchmarks; 5) types of loans; 6) financial benchmarks; 7) repayment analysis benchmarks; and 8) efficiency benchmarks (including labor, capital, and financial efficiency). Each benchmark was calculated separately for each individual observation from which the statistical ratings of average plus or minus standard deviation, minimum, and maximum values were calculated. The resulting benchmark statistics were summarized into tables as follows: production (acres planted, quantity of feet of line); expense (direct operating/variable costs and ownership/fixed/overhead costs); total annual costs, breakeven prices, and breakeven yields; profitability; financial; repayment analysis; and efficiency (of labor, capital, and finances).

Further analysis of the seaweed benchmark results was conducted as described in the "Methods" sub-section under the heading of "Oysters." As with the oyster benchmark metrics, graphs were developed with net farm income per foot of line harvested on one vertical axis and the second vertical axis with each of the following benchmarks: total pounds of seaweed harvested per farm, total pounds of seaweed harvested per foot of line, years in business, labor cost ($/lb), labor efficiency (lb/hour of labor and lb/$ of labor), sales revenue per hour of labor, depreciation ($/lb harvested), long-term capital efficiency (lb/$ of investment capital), and working capital (in $/farm).

To search for benchmarks with some relationship to cash flow, the seaweed benchmark metrics were again sorted but in terms of decreasing working capital ($/farm). The relationships with the same benchmarks as those analyzed for profitability were then examined by graphing the working capital ($/farm) on one of the vertical axes and each of the benchmarks listed above on the second vertical axis.

## Scallops

Several respondents to the survey raised scallops, but on a small, experimental basis. Further consultation with technical experts on scallop farming in Maine revealed that the few producers attempting to develop scallop enterprises were using different types of gear and targeting different products for different markets. Such differing business models will have different costs and efficiencies, but with such small numbers, it would not be possible to report such data in a way that protects the confidentiality of individual farm businesses. Thus, no benchmarks were calculated for scallops. The section of this report entitled, "Recommendations for Use of Benchmarks," includes some qualitative discussion and suggestions related to the emerging scallop businesses developing in Maine.

# RESULTS

## Survey Results

Survey responses included 47 standard and experimental leases and 27 Limited Purpose Aquaculture (LPA) leases with a total acreage of 266 acres in standard and experimental leases and 0.27 acres in LPAs (Table 3). The average number of standard/experimental leases per farm was 1.6 and 1.0 LPA per farm. Total acreage leased per farm averaged 9.2 acres $\pm$ 9.7 acres of standard/experimental leases and 0.01 acres for LPAs. It is of note that, while the average size of leased area was 9.2 acres, the median was only 5.4 acres, indicating that there was a proportionately greater number of smaller-sized than larger-sized farms.

Of the 29 respondents to the survey, 83% raised oysters (Table 4). Another 21% raised seaweed with 14% each raising mussels and scallops. Twenty-one percent of respondents raised more than one aquaculture crop. Total acreage reported in the survey was greatest for oyster production. Mussels composed the second-greatest amount of acreage in the dataset, followed by seaweed and then a very small amount for scallops.

In comparison, the most recent Census of Aquaculture (USDA 2019) data for Maine showed that 78% of reported shellfish producers raised oysters and 24% of shellfish producers raised mussels. No macroalgae or sea vegetables (seaweed) were reported in Maine in the Census of Aquaculture. Thus, with the exception of seaweed producers, the proportions of oyster and mussel farmers in this survey were roughly proportionate to that reported in the Census of Aquaculture. Nationally, oyster farms accounted for 79% of all shellfish farms in the U.S. with mussels accounting for only 4% of all shellfish farms in the U.S. Thus, on a national level, oysters are a major industry whereas mussels are a small, although measurable, segment of the industry. Scallop production in the U.S. was not great enough to be itemized in the census data and likely was included in the "other mollusk" category in the census.

Mussel farms in Maine, on average, tended to be about 50% larger than oyster farms, while seaweed farms, on average, tended to be nearly 50% smaller than the average size of oyster farms (Table 4). Scallops in Maine were produced only on an experimental basis on LPAs with very small average sizes of production area per farm.

### Types of collateral used for loans by shellfish and seaweed producers in Maine

The most frequently mentioned type of collateral used for loans by survey respondents was that of equipment and buildings (44% of respondents) (Table 5). Specific mentions of boats, motors, floats, and rafts were included in the category of "equipment and buildings." Vehicles, such as cars and trucks, were mentioned by 16% of respondents as collateral for loans, followed by 16% of respondents who reported "everything outside of the business" and another 12% who reported "everything." Mention of the use of homes or a "personal guarantee" was included in the category of "everything outside of the business." Land as collateral was mentioned by only 8% of respondents, and the inventory of oysters on the farm was reported as serving as collateral by only 4% of respondents with loans.

**Risks**

All businesses face risk of one sort or another, and farming businesses are no exception, facing not only market and financial risks but also risks related to the weather, predators, diseases and parasites, and closure of production areas, among others. Successful shellfish and seaweed farmers must be able to overcome the challenges created by exposure to these various types of risk. In addition, input to the survey instrument from the Financial Advisory Committee pointed to the need to explore various types of specific risks experienced by shellfish and seaweed farmers in Maine. As a result, several questions were asked of respondents related to various types of events that result in risk to the shellfish or seaweed farm as well as the frequency and severity of losses associated with various risky events.

Farmers were first asked about the level of crop loss that they could detect on their farms. Given that shellfish and seaweed are crops grown under the water, observing and monitoring such crops pose special challenges. The mean response to this question was that a crop loss rate of 5.7% $\pm$ 4.7% (median of 3%) was detectable. Responses to this question did not differ among the various species raised by respondents. The most frequent response was that they could detect a loss of 1% to 5% of the crop (Figure 1). The second most frequent response was detection at a level of 6% to 10% loss of the crop, while the least frequent response was that they could detect losses only at rates greater than 10% of the crop. Only one mussel and one seaweed producer responded to this question; both responded that they could detect a loss of from 1% to 5% on their farms. The other respondents to this question were all oyster producers. It should be noted, however, that 48% of respondents did not respond to this question.

Table 6 reports responses to a question related to the frequency of occurrence of various types of risks and the severity of losses for each risky event. The most frequently mentioned type of risk was that of the weather, reported by 38% of respondents (N=11). Of these respondents, 64% indicated that weather-related problems occurred infrequently but caused losses of 49% of their crop when a weather-related event happened. Another 18% of these respondents indicated that weather-related risks were frequent and caused losses of 70% of their crop. The remaining 18% indicated that weather-related risks were frequent but caused only minor losses of 9% of the crop.

The next most frequently mentioned type of risk was that of predators (N=9), mentioned by 31% of respondents (N=9), followed by disease/parasites (14% of respondents, N=4)), closure/toxins (14% of respondents, N=4), markets (10% of respondents, N=3), and theft (7% of respondents, N=2). Of those respondents to each type of risk, the majority of those experiencing predator risk, disease/parasite risk, and theft indicated that these types of risky events occurred infrequently but caused major losses (from 9% of the crop to theft to 81% of the crop from disease/parasites) when this type of event occurred. Two-thirds of the respondents who experienced market risk indicated that these risks occurred frequently and resulted in major losses (56% of crop sales). Of these, only one respondent who reported market risk raised oysters while the others raised mussels or seaweed. Three-fourths of those who reported experiencing risks associated with closures or toxins indicated that such events occurred frequently, but resulted in minor losses (14% of the crop). Only oyster producers reported risk of losses due to diseases and predators. A notably greater percentage (40%) of mussel producers reported that weather problems occurred

frequently and resulted in major losses. Nearly one-third of respondents provided additional comments on the risks associated with production of their crops. Table 7 itemizes the additional comments made. Examples included damage to mussel rafts due to weather or due to someone else's float coming loose and damaging the farm. Predators were mentioned to reduce yields by 50% on oyster farms. Biofouling problems on mussel and scallop farms were mentioned as a source of loss by several respondents as well as losses due to invasive tunicates.

**Problems reported by aquaculture producers**

The responses to questions related to the greatest problems experienced by Maine shellfish and seaweed producers were organized by type of crop. For oysters, the most frequently mentioned problem was that of other regulations" (reported as "always a problem" by 50% of respondents and sometimes a problem by the other 50%), followed by acquiring leases/permits (reported as always a problem by 25% of respondents and sometimes a problem by another 30% of respondents) (Table 8). These problems were followed in descending order of frequency of mention by: death of crops, bottom type, market price, lack of available loans, market availability, poor/slow growth, and theft of crops. Sixty percent of respondents also mentioned "other problems" as "always a problem". These included finding labor, human error in harvesting and loading, working in a new industry in a new field, and water quality issues from overboard discharge. Theft of crops, availability of seed, and poor/slow growth were reported to be "never a problem" by 73%, 73%, and 50% of oyster respondents, respectively.

Table 9 lists the types of problems reported by mussel producers. Acquiring leases/permits was reported as "always a problem" by 20% of respondents, with an additional 60% of respondents reporting it as "sometimes a problem." Market price and market availability were also reported as "always a problem," by 20% of respondents, but another 40% of respondents reported that these were "never a problem." Availability of seed, poor/slow growth, lack of available loans, other regulations, and death of crops were reported as "sometimes a problem" by 60%, 40%, 40%, 33%, and 20% of mussel respondents, respectively. Other problems mentioned by respondents included marketing and promotion.

Seaweed producers reported that "other regulations" and leases/permits were the greatest problems, with 100% indicating that "other regulations" were "always a problem" and 50% that leases/permits were "always a problem" (Table 10). The other 50% of seaweed respondents indicated that leases/permits were "sometimes a problem." Other types of issues that were rated as "sometimes a problem" included: availability of seed (75% of respondents), market price (67% of respondents), lack of available loans (50% of respondents), and market availability (33% of respondents). Pollution of the water and theft of the crop were considered as "never a problem" by all respondents.

Respondents who were experimenting with scallop production mentioned only three problems (Table 11). These included the availability of seed, theft of crop, and the death of crops, all of which were categorized as "sometimes a problem" by scallop respondents.

Other regulatory problems were mentioned by a number of oyster respondents as well as mussel and seaweed respondents. These other regulatory problems are listed in Table 12. Most of the

other regulations referred to by oyster respondents were related to the time and expense of licensing and leasing. The current system was viewed by one respondent as being too restrictive and not flexible enough for a new industry in which producers are attempting to work through effective production and marketing practices. Other comments by oyster producers referred to some regulators being unrealistic and out of touch, while still other comments mentioned problems with summer management of vibrio, the volume of product on the market every fall, and marking lease sites properly. For mussels, the reference to other regulatory problems involved the complexity of the regulations that made it difficult for growers and for the department to track. Seaweed producers reported water quality (particularly as related to overboard discharge), infrequent testing by DMR, and the huge areas that are closed to seaweed production, limiting where they can go and grow seaweed.

**Workforce**

More than one-third (38%) of respondents relied upon unpaid family labor and 45% on paid family labor as part of their overall workforce (Table 13). In addition, 36% percent of respondents had full-time, non-family employees, but nearly three-fourths of respondents hired non-family employees on a part-time, often seasonal, basis. While family members worked most weeks of the year (37 to 40 weeks/year, on average), unpaid family members worked an average of 11 hours/week as compared to 26 hours/week worked by paid family members. The average age of employees across survey respondents was 35 $\pm$ 11 years of age. There was no clear difference in the average age of employees by type of species raised.

**Concerns about market saturation[3]**

Given the growth of shellfish and seaweed production generally in the U.S. and specifically in Maine, respondents were asked whether they were concerned about the market becoming saturated. Approximately two-thirds (68%) of oyster respondents to the survey indicated that they were concerned about saturation of the market for oysters (Table 14). Only half of mussel respondents reported concerns over market saturation, while the other half did not. Three-fourths of seaweed respondents were not worried about saturation of markets, but one-fourth indicated that there were concerns sometimes over market saturation for kelp. Given that scallop production was a small and experimental part of overall shellfish businesses, there were no explicit ratings related to concerns over market saturation.

Respondents offered a variety of additional comments related to their perceptions of market saturation. Oyster farmers who were not worried about market saturation commented that prices seemed to be going up generally with the exception of the seasonal price decline each fall when many oysters come on the market (Table 15). Another respondent commented that it takes a while to scale up production and that the market potential was expanding, with increasing human population numbers. Oyster respondents who were concerned with market saturation referred to

[3] The survey done for this study was completed prior to the onset of the COVID-19 pandemic. The ensuing shutdown of restaurants and businesses in early 2020 in the interest of public health resulted in a sudden and severe contraction of seafood markets. The long-term impacts of COVID-19 on demand and distribution channels for aquaculture products have yet to be fully understood.

seasonal decreases in price that correspond to the fall supply glut. Some respondents viewed the low fall prices as an early signal of market saturation. Others pointed to concerns over the increasing supply from new farms entering the business, resulting in prices that were either constant or decreasing over time. Without a corresponding increase in demand, markets were viewed by some as becoming flooded, dropping prices, and driving some people out of business. Further comments were made that greater attention needs to be paid to supply and demand factors, especially for smaller producers.

Mussel respondents who reported not being concerned over market saturation indicated that, for the present, they believed that there were out-of-state markets that could be supplied with good product (Table 16). Other mussel respondents indicated that they were beginning to see signs of saturation in the mussel market. Scallop respondents indicated that market saturation was not yet a problem, but others were worried that scallops would be pulled into the lower-priced "meat" market[4].

Some seaweed respondents were not concerned about the market, but others were (Table 17). Those not concerned over the market indicated that people were "begging" them to grow more seaweed and that there was "no worry" for seaweed markets. Others, however, reported that processors limit what can be sold due to limitations in processing capabilities. Still others commented that there was a lack of identifiable markets for seaweed, and they were sometimes concerned over market saturation for kelp.

**Determinants of product quality reported by aquaculture producers**

Respondents were asked to describe the determinants of quality of their products. For oyster producers, the most frequently mentioned quality attribute was that of taste and flavor (25%) (Figure 2). Taste/flavor was followed by the overall appearance (18%), the meat-to-shell ratio (14%), the oyster having a deep cup (14%), the size and shape of the oyster (13%), and that the oyster had a hard shell (11%). Other quality attributes mentioned included the shelf life, the meat condition, and that the oyster had a plump belly (Table 18). Air drying and tumbling were reported to be processes that enhance quality and consistency. Some oyster producers reported having a quality control program in place, with individuals who know how to grade oysters well while another respondent mentioned constant handling to produce a better oyster. A number of oyster producers mentioned various types of marketing messages and efforts. Marketing messages focused primarily on taste attributes, with frequent mentions of descriptors such as "briny, salty, or "tastes like a beach," or "rich, sweet meat." Others referred to the cold, crisp waters and unique taste profiles of specific bays or locations, including references to Maine. Some respondents referred to the finish as "clean without an after taste," or as a "cucumbery finish." Marketing efforts mentioned included efforts to brand the product and use of social media for promotion and messaging.

For mussels, product quality attributes mentioned were similar to those reported by oyster producers. A mild taste and succulent, tender texture were reported as important quality attributes as were the meat yield and meat-to-shell ratio (Table 19). The appearance of the

[4] The traditional, higher volume market for scallop meat is for the adductor muscle. Markets for the whole scallop and roe on scallop are higher-valued markets for scallops.

mussels was also reported as an important quality attribute by several respondents. Specific components of the appearance of mussels included the cleanliness of the shells, shells that were "pretty," whole, unbroken and un-cracked shells and clean mussels with no grit or sand in the lot. Hard shells were reported to be preferred by customers. Other important attributes mentioned included the freshness, shelf life, and consistency of mussels sold.

Given that seaweed is a newer crop with fewer long-term producers, there were fewer responses by seaweed producers to the question on determinants of seaweed product quality. Several attributes mentioned included the freshness and tenderness of product in addition to purported environmental benefits from seaweed production (Table 20).

Several benchmarking programs have been developed for other agricultural crops. Survey respondents were asked whether they would be interested in participating long-term in a confidential web-based benchmarking program. Such a program would require participants to enter their farm production and financial data to a web site that would then generate a report that compared the benchmark values of that farm with averages and ranges of other similar farms. Seventy-two percent of survey respondents indicated that they would be willing to participate in such a program (Figure 3). Fourteen percent of respondents were not interested, and another 14% did not respond to this question.

## Oysters

Results of the analyses done with the oyster farm data will be summarized below. Some key over-arching results related to scales of production will be presented first. A discussion of differing cost structures identified will be presented that show the need to evaluate the performance of oyster farms separately for established (>5 years in production) suspended culture and bottom culture farms as well as startup (<5 years in production) suspended culture farms. The benchmarks calculated will then be presented, followed by a discussion of apparent relationships of several benchmarks with profitability and with cash flow. Finally, an example is presented of the use of benchmark metrics to pinpoint sources of financial difficulties for unprofitable farms from which intervention strategies can be developed.

### Farm Size Analysis

Many types of aquaculture exhibit economies of scale and there is some evidence for economies of scale in oyster production (see Engle and van Senten 2018 for Maryland oyster production). To search for potential effects of farm size and/or production scale, oyster farm observations were sorted by farm size and several benchmarks compared across the farm size/production scales identified in the study. Figure 4 shows the magnitude of differences in the mean area planted (in acres) by larger farms as compared to smaller farms. Larger farms (those harvesting more than 250,000 oysters/year), on average, planted 10 times more acres than did the farms in the smallest farm size category (those harvesting < 100,000 oysters/year). In addition, the largest sizes of farms were more productive than smaller farms in terms of harvesting greater numbers of oysters per acre (Figure 5). While there was little difference in productivity between the two smaller farm sizes, the largest farms, on average, produced approximately three times more per acre than did the two smaller farm size groups.

Individual line-item costs were compared across farm size groups in terms of the percentage contribution of each to total costs. Labor costs were found to be the greatest contributor to total cost of oyster production in Maine for all farm sizes (Table 21), although depreciation was the greatest cost on the very smallest farms. The second-greatest cost of oyster production varied by farm size. For the two smallest farm size groups, depreciation was the second-greatest cost, but marketing costs were second-greatest for the large farm size. On the smallest farm size, seed was the third-greatest cost followed by repairs, insurance, and lease/permit fees. On the medium-farm size, depreciation was the second-greatest cost followed by marketing, insurance, seed, and repairs. Insurance, depreciation, repairs, and management were the third, fourth, fifth, and sixth greatest costs on the largest farm size.

The importance of labor costs in oyster production indicates the importance of paying close attention to the efficiency of its use. In general terms, more efficient use of an input, labor in this case, results in greater production of oysters per hour of labor, thereby reducing labor costs per oyster produced. Figure 6 shows that labor efficiency (in this case measured as the number of oysters harvested per hour of labor) increased with increased farm size. Each hour of labor used on the largest oyster farms resulted in more oysters harvested and sold than on the smaller farm sizes, and resulted in correspondingly lower labor cost per oyster.

Total startup costs increased with farm size as would be expected, but startup cost per oyster harvested was substantially (approximately three times) greater on the smallest farm size when compared to the larger farm sizes (Table 22). Thus, capital costs appear to be especially important on smaller farm sizes. This was also evident in the importance of depreciation costs as the second-greatest cost of production on the two smaller farm sizes. It is thus important to pay attention to the efficiency of use of capital resources, especially for farms in the two smaller farm sizes. Figure 7 shows that investment capital was used more efficiently on the larger farm sizes. The dollars of investment capital per oyster harvested (a capital efficiency benchmark) were, on average, approximately four times less on the largest farm size than on the smallest farm size.

**Established suspended, bottom culture versus startup suspended farms**

The original set of benchmarks calculated were those across all oyster observations. While some clear differences and effects were found in terms of farm size and production scale as described above, there was a great deal of variability in the benchmarks calculated. While the degree of variability may reflect inherent differences in farm location, condition, financial circumstances, business models, etc., they may also reflect more structural types of differences. The dataset included a number of relatively new oyster farms, for example, that would likely have different cost structures than would more established farms. In addition, the set of farms that had been in business for a number of years included those moving to suspended culture systems as well as those that have continued to raise oysters with more traditional bottom culture practices. Thus, the dataset was divided into three groups for analysis first of cost structures and then for comparison and analysis of the benchmarks calculated. The three groups were identified as: 1) established farms (that had been in production for more than 5 years) using primarily suspended culture methods; 2) established farms (that had been in production for more than 5 years) using primarily bottom culture methods; and 3) startup farms (that had been in production for less than

5 years). All startup farms responding to the survey used suspended culture practices. The following designations will be used throughout this report for these three groups of oyster farms: established suspended culture farms, established bottom culture farms, and startup suspended culture farms.

**Cost structures on established suspended culture, established bottom culture, and startup suspended culture farms**

A cost structure analysis was developed to determine if there were sufficient differences among established suspended culture, established bottom culture, and startup suspended culture farms to warrant presentation of benchmarks separately for each. Costs of all line item expenditures reported by oyster respondents were tabulated as percentages of total costs, with values for each line-item expenditure averaged within each of the three farm categories. Pie charts were developed to illustrate the resulting cost structures (Figures 8a, b, c). Labor costs constituted the greatest percentage of the total cost of production on both categories of established farms. On established suspended farms, however, labor costs were proportionately greater (62% of total costs) than on established bottom culture farms (46%). Marketing expenses (10%) were the second-greatest cost on established suspended culture farms, but insurance (13%) was the second-greatest contributor to total costs for established bottom culture farms.

Table 23 directly compares the top six contributors to cost across the three categories of shellfish farms. While labor costs were the greatest cost on the established oyster farms, it was the third-greatest cost on startup oyster farms. Seed cost was the second-greatest cost on startup suspended culture farms, but seed cost was only the fourth greatest cost on established bottom culture farms and the sixth greatest cost on established suspended culture farms. Lease and permit fees also constituted proportionately greater costs on startup suspended farms (sixth greatest cost) whereas lease and permit fees were not in the top six costs of the established oyster farms. While depreciation costs composed a greater percentage of total costs on established bottom culture farms than on established suspended culture farms, the absolute cost per oyster was not greater. Overall costs, especially labor costs, per oyster were lower on established bottom culture farms. Bottom culture oyster farms still require a truck, boats, docks, cold storage, winches, and hoists, although less direct production gear is required than with suspended culture techniques.

The cost structure analysis showed clear differences in cost structures among the three categories of farms analyzed. Moreover, the benchmark calculations showed substantial reductions in variability for benchmarks when dis-aggregated into these three categories. As a result, the use of separate benchmarks for established suspended culture farms, established bottom culture farms, and startup suspended culture farms is recommended and will be used throughout the presentation and analysis of oyster benchmarks.

**Oyster benchmarks**

Oyster benchmarks will be presented in the following order: production and marketing, expense, total cost/breakeven price/yield, profitability, financial, repayment, and efficiency benchmarks.

<u>Production and marketing benchmarks, oysters</u>

The production benchmarks calculated for established suspended and bottom culture oyster farms are presented in Tables 24 and 25 and those for startup suspended culture farms in Table 26. Established oyster farms were larger and planted approximately seven times more acres than did startup oyster farms, on average. Acreage planted was similar between established suspended and bottom culture farms, at 7.8 acres. Planting rates, however, measured as the number of seed purchased and planted per acre, were approximately one-third lower on both categories of established farms than on startup suspended farms, although planting rates on startup suspended farms were especially variable.

The average reported time from planting to market size was greatest on startup suspended culture farms (33 months) than on established farms (27 months for suspended culture farms and 24 months for bottom culture farms). Survival rates of oyster seed cohorts from planting to harvest were not calculated[5]. The average volume of oysters harvested per acre on average was greater on established suspended culture farms (66,625 oysters/acre) as compared to the other two farm categories. Harvesting rates were relatively similar on established bottom culture farms (39,597 oyster/acre) than on startup farms (33,941 oysters/acre).

Most (68% to 100%) of the oysters sold in all three farm categories were sold to wholesalers or distributors (Tables 24, 25, 26). Startup suspended farms reported selling a greater percentage of the harvest volume directly to end customers than did either category of established farm. All farm categories sold greater percentages of their crop as "selects", followed closely by percentages of harvest sold as "cocktails." Much smaller percentages of crops were sold as "jumbos." The percent of harvested oysters reported to be unmarketable due to poor quality (less desirable size, shape, appearance) averaged 0.4% for established suspended farms, 0% for established bottom culture farms, and 2.9% for startup suspended farms. Startup costs per acre were reported to be greatest on startup suspended culture farms (averaging $50,971/acre), followed by those on established suspended culture farms (averaging $40,395/acre), and lowest on established bottom culture farms (averaging $21,566/acre).

<u>Expense benchmarks (direct operating/variable costs and ownership/fixed/overhead costs), oysters</u>

Expense benchmarks of line-item direct operating/variable and ownership/fixed/ overhead costs were calculated and are presented for established suspended and bottom culture farms in Tables 27 and 28 and for startup suspended culture oyster farms in Table 29. These benchmark costs are expressed as $ per single oyster harvested and generally reflect the cost structure differences (calculated as the percent each line item composed of total cost) described above for the three oyster farm categories. Labor costs were the greatest cost on both established oyster farm categories, followed by marketing expenses, depreciation, management, and insurance on the established suspended culture farms and depreciation, insurance, seed, and repairs on the established bottom culture farms. On startup suspended farms, depreciation costs were the greatest cost, followed by seed, labor, repairs, marketing, and insurance. The cost of seed on

[5] The questionnaire asked respondents to report the number of seed planted in 2018 and the volume of production sold in 2018. Following planting, oysters are harvested over a period of years; thus, we were not able to calculate an annual survival rate for each cohort of oyster seed planted.

startup suspended farms was 10 to 20 times greater per oyster harvested than on established farms (Tables 27 and 28). Startup suspended farms purchased relatively more seed per acre planted than did established farms (Table 26).

Depreciation costs were a major cost on both established and startup farms, but were five times greater on startup suspended farms than on the established farms. In spite of the differences in production gear types, the depreciation costs per single oyster harvested were similar between established suspended and bottom culture farms. Bottom culture farmers must also have boats, a truck, a dock, some form of cold storage, winches, hoists, and, in some cases, upweller depreciation costs that are spread across a lower volume of oysters harvested per acre than for suspended culture farms. Insurance costs were surprisingly high, especially on established bottom culture and startup suspended farms, at $0.05 per oyster harvested. Management costs were not a major cost on oyster farms, and were reported only on established suspended farms. Lease/permit fees (per $/single oyster harvested) similarly were not a major cost for any farm group, but were four times greater on startup suspended farms as compared to either category of established farms. It should be noted that these costs do not include costs the grower incurred to apply for leases. The costs associated with a lease application can be substantial depending on the degree of controversy related to a specific lease application.

Total annual costs, breakeven prices, and breakeven yield benchmarks, oysters

Benchmarks for total annual cost, breakeven price, and breakeven yield are presented for established farms in Tables 30 and 31 and in Table 32 for startup suspended farms. The benchmarks for the relative percentages of total variable and total fixed costs are noticeably different between the startup suspended farms and the two established farm categories. For startup suspended farms, total variable costs accounted for only 55% of total costs as compared to 71% for established bottom culture farms and 82% for established suspended culture farms. Thus, total fixed costs compose a much greater percentage of total costs on startup suspended culture farms. For farms with relatively high percentages of fixed costs, a key strategy to reduce overall costs of production is to intensify production and produce more with a given amount of capital and equipment assets.

The Cost of Goods Sold (COGS) per oyster sold on startup suspended farms was nearly double that of the two established farm categories. The breakeven prices above total costs reflect the same pattern of breakeven price above total cost on startup suspended culture farms that is nearly double that on the established farm categories.

Profitability benchmarks, oysters

Profitability benchmarks are presented in Tables 33 and 34 for established farms and in Table 35 for startup suspended farms. The average market price, weighted across sizes of oysters sold was similar for all three farm categories with relatively lower coefficients of variation than many other benchmarks calculated. Gross cash income per oyster sold was similar for both established farm categories but greater on startup oyster farms, reflecting greater sales directly to consumers on startup farms. Gross margins per oyster sold on average, however, were negative on startup suspended farms, but were positive on average for both categories of established farms.

Net margins per oyster harvested were greater on established bottom culture farms than on established suspended culture farms, but were negative for startup suspended oyster farms. Per hour of labor, the difference was even more striking, with net margins per hour of labor more than 10 times greater on established farms than on the startup suspended farms. On the other hand, net margins per dollar of investment capital were similar on startup as compared to the established farm categories. Nevertheless, the rate of return on farm assets was negative for startup suspended culture farms, but was positive and high for both categories of established farms.

Financial and repayment analysis benchmarks, oysters

Table 36 shows that more than half of oyster respondents had no outstanding loans. Only 10% and 20% of established suspended and bottom culture farms, respectively, had operating loans, whereas 25% of startup suspended farm respondents had operating loans. Somewhat greater percentages of established farms (20% of suspended culture and 40% of bottom culture) had equipment or real estate loans, whereas 37% of startup suspended culture farms had equipment or real estate loans.

The low incidence of borrowing on oyster farms likely indicates that oyster farms rely primarily on equity capital for both equipment and operating expenses. The lack of reports of loan payments may also reflect a general lack of capital available for oyster farming and perhaps reluctance on the part of lenders to approve loans for oyster farming.

Financial benchmarks for established suspended and bottom culture farms are presented in Tables 37 and 38 and those for startup suspended culture farms in Table 39. Overall liquidity metrics are positive with positive current ratios, on average, for all farm categories, likely reflecting a relatively low rate of borrowing and a comparatively low level of liabilities. Net worth similarly was generally positive for all farm categories with favorable debt-asset, debt-equity, and equity-asset ratios. There was one exception of a startup oyster farm for which net worth was negative that led to a negative det-equity ratio for startup suspended farms. Given the limited numbers of observations of farms with loans, the repayment analysis benchmarks presented in Tables 40 and 41 are of limited value due to the lack of sufficient data.

Efficiency benchmarks, oysters

Tables 42 and 43 presents the efficiency benchmarks calculated for established suspended and bottom culture oyster farms, and Table 44 presents efficiency benchmarks for startup suspended oyster farms. Labor efficiency (measured as the number of oysters harvested per hour of labor, per dollar of labor, and sales revenue per hour of labor) were similar between the two established farm categories, whereas the same labor efficiency values were lower on startup suspended farms. Labor costs as a percent of the dollars of output on the farm were approximately one-third greater on startup suspended farms as compared to the two established farm categories. It appears that established farms used labor more efficiently than did startup suspended farms. The cost of investment capital per volume of harvested product was noticeably greater on startup farms than on the established farms.

**Further analysis of oyster benchmarks**

Benchmarks associated with profitability, oysters

Profitability of oyster farms in Maine will be discussed primarily in terms of net farm income per oyster sold (also referred to as net margin per oyster sold) in conjunction with other benchmarks that may be associated with profitability[6]. This analysis was done to search for a small set of benchmarks that would be best for lenders to evaluate when reviewing oyster loan proposals.

Figures 9a, b, and c show net farm income per oyster sold for established suspended farms, established bottom culture farms, and startup suspended farms, respectively. All three figures show wide variability in profitability, although all established bottom culture oyster farms were found to be profitable whereas 57% of established suspended culture farms and only half of startup suspended farms showed profits. It should be noted that the established farms are those that have survived the initial 5 years of the startup phase and those for which successful business plans have been developed and implemented. It is also important to note that net farm income includes the non-cash cost of annual depreciation in determination of profitability. Long-term, businesses must be able to replace equipment and other capital goods at the end of the useful life, or the business will not survive in the long term.

While economies of scale for oyster production have been documented for oyster production in other states (Engle and van Senten 2018), no clear evidence of economies of scale were found for established suspended farms (Figure 10a) or for startup suspended farms (Figure 10c). Results of Figure 10b must be interpreted with caution because there were only five respondents, but the graph shows evidence of economies of scale up to approximately 230,000 oysters per farm, with diseconomies of scale at greater scales of production. Nevertheless, additional data are needed to arrive at definitive conclusions. For the startup suspended farms, the range of farm sizes of 0.18 acres to 2.25 acres may not have included a sufficient range to measure economies of scale. There clearly was a sufficient range of production scales on the established suspended farms to observe economies of scale if these existed. Other factors may have greater influence on profitability than do scale effects for this oyster farm category. The largest farm in the dataset did have the lowest average cost of production per oyster, but this may reflect a very efficiently managed operation more so than economies of scale.

Net farm income ($/oyster harvested) was then graphed against 13 other benchmarks (listed in the "Methods" section) for each oyster farm category. The following will discuss only those benchmarks that appeared to exhibit some type of relationship to net farm income. Figure 11a shows that profitability tends to be greater with shorter length of growout (months from seed to market size) for established suspended culture farms. The relationship was not clear for startup suspended culture farms (Figure 11c) but the three most unprofitable farms had the longest growout time. Figure 11b does not show a relationship between net farm income and months of growout time for established bottom culture farms. The less profitable bottom culture farms had much greater labor costs than did the more profitable farms. While faster turnover of a crop

[6] There were too few observations in any of the farm categories analyzed to conduct quantitative statistical analyses of relationships among benchmarks. Graphical analyses that suggest similar movement of benchmarks and a potential relationship with net farm income are presented.

typically is associated with greater profits, the differing labor structures on these farms may explain the lack of a clear relationship between profitability and growout time.

Net farm income appeared to be negatively related to breakeven price above total cost, as would be expected. (Figures 12 a, b, c). Working capital was directly related to net farm income for startup suspended farms, but not for the other farm categories (Figure 13 a, b, c). Sufficient quantities of working capital may be relatively more important for startup farms to weather the financial challenges of gearing up production to full sales.

Benchmarks associated with cash flow, oysters

The ability to repay loans is vital to the financial success of a business. To continue to search for a smaller set of benchmarks that could be used by lenders and financial advisors for oyster loan applicants, the same benchmarks as described above were graphed against working capital. Working capital was shown to decrease with net farm income for startup suspended farms in Figure 13c. Figure 14 shows that, similar to net farm income, working capital varies by established suspended and bottom culture farms, but remained positive for all farms in both the established oyster farm categories (Figures 14 a, b). Two startup farms, however, exhibited negative working capital, indicating cash flow problems (Figure 14c) and likely debt repayment problems.

Working capital declined as the quantity of acres planted declined for established cage farms as would be expected, but was more variable and less consistent for established bottom culture and startup cage culture farms (Figures 15 a, b, c). The two established suspended and bottom culture farms that respectively had the greatest quantities harvested per acre were associated with the greatest levels of working capital. The other farms with similar but lower quantities harvested per acre also had similar (and lower) quantities of working capital (Figures 16 a,b). On startup suspended culture farms, however, there appeared to be little relationship between the quantity harvested per acre and working capital (Figures 16c). On a per-farm basis, however, the quantity harvested per farm generally declined with working capital for the established farm categories (Figures 17a,b). For the startup suspended farm category (Figures 17c), the two farms that harvested the second and third-greatest quantities per farm were associated with greater working capital. The farm with the greatest quantity harvested per farm also had high costs and a greater debt load than the other farms that resulted in negative working capital. The volume of seed purchased per acre mirrored working capital for the established farms, but on startup suspended farms, the number of seed purchased per farm first declined with working capital but was greater at lower levels of working capital (Figure 18 a, b, c). It is possible that some startup farms purchased more seed than was optimal, incurring greater expenditures that resulted in working capital difficulties.

In summary, those farms that tended to plant more acres and who harvested more per acre were those associated with greater working capital. It is important to note that working capital is not necessarily related to loans. It is calculated as the difference between current assets and current liabilities. Some people with loans have lower working capital than those without, depending on the magnitude of the payments due in relation to the value of oysters expected to be harvested in that same period of time. However, farms that do have loans with associated loan payments that

are less than the value of oysters to be harvested in the same time period can have adequate levels of working capital. Simply borrowing more money does not guarantee adequate working capital. It is important to conduct a financial review and analysis prior to seeking a loan to understand the effects on working capital as well as other metrics related to liquidity and solvency.

Use of benchmarks to analyze economic and financial feasibility of oyster farms

A qualitative examination of those farms with negative net farm income sheds some light on the key metrics that explain the losses. Of the established suspended culture farms, there were three farms that were not profitable in the study year. Of these, all three required more time than average for spat to reach market size, harvested fewer oysters per acre, and had greater breakeven prices above total costs. All established bottom culture farms were profitable.

In the startup category, four observations had negative gross and net margins. All four had working capital levels less than the average startup farm. Three of four observations with negative net farm income exhibited the following characteristics:

a. Required more months for oysters to grow from spat to market size than the average startup farm
b. Harvested fewer oysters per acre than the average startup farm
c. Had greater breakeven prices above total costs than average startup farms
d. Had greater total variable costs per acre than the average startup farm

Two of the four startup farms with negative net farm income had:

a. Planted more per acre than the average startup farm
b. Higher startup costs/acre than average startup farms
c. Negative working capital and a current ratio less than 1
d. Greater seed costs per acre than the average startup farm

## Mussels

Mussel production in the U.S. is a small part of overall U.S. aquaculture. Nationally, only 4% of all U.S. shellfish farmers raised mussels (USDA 2019). In Maine, there was a somewhat greater proportion of shellfish farmers raising mussels (24% of shellfish producers) than that nationally (USDA 2019). Nevertheless, it is still a small segment with low numbers of farms and total production. While overall demand for mussels in the U.S. is much less than that for oysters, there appears to be growing interest in mussels by U.S. consumers (GSGislason & Associates Ltd. 2006).

There were four respondents in the survey who farmed mussels, representing 11% of the total number of survey respondents (Table 4). One of the respondents was in a startup phase and had not yet reached full production. The productivity and cost data from this startup farm did not reflect what it likely will be when full production and sales are reached. To avoid skewing the benchmarks with an observation that was not comparable to the others that had been in full

production for a number of years, the startup farm observation was dropped from the benchmark calculations.

The data from the few farms that raise mussels in Maine are quite variable and reflect to a large degree the trial and error necessary for farms to work through how to farm a new species within the constraints of the approved lease sites, workforce skillsets, and other available farm resources. If mussel production continues to expand in Maine, benchmarking values across mussel farms over time would be expected to begin to converge and exhibit somewhat greater uniformity. It must be recognized, however, that even in well-established segments of U.S. aquaculture, such as U.S. catfish farming in which most farmers sell to a relatively small number of processing plants, studies continue to show a great deal of variability in farm management practices, cost structures, and economic outcomes (Kumar et al. 2020).

The following benchmarks for mussels must be interpreted in light of the limited number of farm observations obtained in this study and should be used **only as general guides**[7], not as absolute thresholds for decisions related to farm financing. Each individual application for financing should be evaluated on its own financial merits. The benchmarks developed should provide some sense of the potential range of values that can be observed in Maine as well as some sense of which benchmark values may have the greatest impact on profitability and cash flow as related to the loan repayment ability of the applicant.

### Cost Structures

An analysis of the cost structure of mussel farms was used to identify the major categories of costs that contributed to the total cost of mussel production in Maine. Line item cost expenditures reported by mussel respondents were tabulated as percentages of total costs. Similar to the cost structures developed for established oyster farms, labor accounted for the greatest percentage of total cost, although at a somewhat lower percentage (46%) of total costs (Figure 19). The second-greatest contributor to total costs was that of repairs (11%), followed by insurance and management, each at 7% of total costs, and then depreciation (6%).

### Mussel benchmarks

Mussel farmed acreage on average was approximately 50% greater than the average acreage on oyster farms (Table 4). Maine mussel farmers used 2.7 $\pm$ 1.6 rafts per acre (ranging from 1 to 4.2 rafts per acre) that equated to 4,364 $\pm$ 2,474 square feet of raft per acre (Table 45). On average, there were 15,625 $\pm$ 1,474 feet of line per raft, with a range of from 14,000 to 16,875 linear feet per raft. Of these farm size metrics (i.e., rafts/acre, lines/raft, and feet of linear/raft), the most consistent metric across respondents was that of linear feet/raft. The coefficient of variation for

[7] Many types of aquaculture are in the early stages of development. Unlike other types of agriculture for which consistent and fairly standardized, calibrated practices have been developed over decades of research and on-farm trial, many types of aquaculture are still in a trial phase in which new techniques and practices are being developed. Thus, there is a great deal of variability among farms, many of which are viable enterprises for which a strict benchmark interpretation from another farm may not be relevant. These benchmarks should be used to provide a general range of potential values and some perspective as to what the top performance might look like in specific production or financial categories.

linear feet per raft was only 9% as compared to 60% for the number of rafts per acre, and 57% for the square feet of raft per acre.

The volume of production harvested, calculated as pounds of mussels produced per total farm acres (including those used for set and for growout), averaged 37,322 ± 29,127 lb/acre with a wide range of 3,745 lb/acre to 55,795 lb/acre (Table 45). Calculated on a per-raft basis for the growout phase only, production volumes averaged 19,828 ± 13,037 lb/raft (CV=66%), with a range of from 6,317 lb/raft to 32,330 lb/raft. These are averages that will vary with the natural set of mussels. Per linear foot of line (growout only), harvested volumes averaged 1.33 ± 0.97 lb/linear foot of line (CV = 73%) (range of 0.37 to 2.31). On average, mussel farms sold 52% ± 47% of their harvest to wholesalers, 33% ± 58% to wholesaler/distributors, and 9% ± 9% to restaurants (Table 45). No direct sales to consumers were reported.

Startup costs averaged $190,066 ± $107,290 per farm, and ranged from $69,145 per farm to $273,866 per farm (Table 45). Labor accounted for the greatest cost of mussel production (Table 46), averaging $1.11 ± $0.13/lb. The next greatest costs were, in descending order, repairs (0.27 ± 0.27), insurance (0.18 ± 0.10), management (0.16 ± 0.14), and depreciation (0.15 ± 0.01).

The majority of annual costs on mussel farms were total variable costs that accounted for 62% ± 10% of total costs as compared to total fixed costs that accounted for 38% ± 10% of total costs (Table 47). On average, the Cost of Goods Sold was variable (CV = 78%); when calculated on a per-acre basis, COGS/acre averaged 67,336 ± 52,633 lb/acre. When calculated on a per-lb basis, however, the values were more consistent (CV = 1%) and averaged $1.80 ± $0.01/lb.

Breakeven price above variable cost averaged 1.48 ± 0.15 and when calculated above total costs was $2.43 ± $0.56/lb (Table 47). Breakeven prices were relatively consistent with coefficients of variation of 9% for breakeven price above variable cost and 23% for breakeven price above total cost. Breakeven yields were much more variable whether calculated on a per-acre (CV = 75% to 77%), per-raft (CV = 50% to 62%), and per foot of line (CV = 57% to 69%) basis. Per raft, breakeven yield above total cost averaged 12,237 ± 6,091 lb/raft (range of from 5,502 lb/raft to 17,360 lb/raft). Per-line, breakeven yields averaged 0.81 ± 0.46 lb of mussels harvested per total (set and growout) foot of line and ranged from 0.33 to 1.24 lb/foot of line.

The market price that respondents sold mussels for was 2.12 ± 0.08 (Table 48) and quite consistent (CV = 4%). Gross cash income calculated per acre was quite variable (CV = 79%), averaging $79,362 ± $62,388/acre but much more consistent (CV=4%) when calculated per pound. Gross and net margins as well as the other profitability benchmarks calculated were highly variable due to negative values of some respondents. Only one respondent had positive gross and net margins. One respondent had positive gross margins but negative net margins, while the other two respondents had negative gross and net margins. Since the other profitability benchmarks use many of the same values, the other profitability benchmarks reflect the lack of profitability of several mussel respondents, even after removing the farm that was not yet in full production.

All mussel respondents had some type of loan (Table 49), in contrast to oyster farm respondents of which the majority reported no loans. Half of mussel respondents reported having an

operating loan, half reported an equipment loan, and 25% reported a mortgage for real estate. Total interest paid (of which 88% was for long-term loans, primarily equipment) were the sixth-greatest cost on mussel farms (Table 46).

Mussel farms indicated favorable liquidity with current ratios of 3.35 ±1.23 (Table 50), and ranged from 2.06 to 4.50. Working capital averaged $51,280 ± 38,377/farm, but was variable (CV = 75%). The solvency benchmarks were highly variable, although net worth was positive and less variable (CV = 39%). The average interest coverage ratio was negative, reflecting the losses on some farms (Table 51).

Labor efficiency was calculated in two ways: 1) as the pounds of mussels harvested per hour of labor; and 2) pounds harvested per dollar of labor (Table 52). The labor efficiency benchmarks calculated were much less variable than the financial benchmarks overall, with coefficients of variation that ranged from 11% to 19%. On average, there were 12 lb of mussels harvested per hour of labor. Labor costs were a major cost of production, at $1.11/lb of mussel sold, and mussel farmers harvested 0.91 ± 0.11 pounds of mussels per $ of labor spent. Sales revenue per hour of labor averaged $25/hour for mussel respondents, as compared to $45 per hour for established oyster farms.

The efficiency of use of capital was measured by: 1) volume of harvested product per $ of investment capital; and 2) cost of investment capital per lb of harvested product. On average, the capital invested (mostly in equipment) cost $6.60 ± $4.19 per pound of mussel harvested (Table 52). Conversely, 0.19 ±0.09 pounds of mussels were harvested for every dollar of investment capital, only 21% of the amount of mussels harvested per dollar spent on labor.

**Mussel benchmarks in Maine as compared to mussel benchmarks in the EU**

Table 53 compares the benchmark metrics for which data were available from Salz (2009) on EU production of mussels, for raft culture in Spain and bottom culture in The Netherlands. Given that the Salz (2009) data did not report area planted, numbers of rafts, or length of lines for mussel production, the productivity benchmarks could not be calculated and compared. Those benchmark metrics listed in Table 53 were those for which Salz (2009) reported values.

Labor and management were the greatest costs reported for EU mussel as in Maine mussel production (Table 53). Costs of labor and management per pound in the EU countries, however, were much lower than those calculated in this study[8]. This may reflect the much greater scale of production both for raft culture in Spain (four times as large as the average production scale in this study) and bottom culture in The Netherlands (30 times larger than the average production scale in this study). Thus, economies of scale in mussel production may contribute to the substantial difference in cost per pound of the major production cost, labor and management.

The cost structures of mussel production in the EU appear to differ from those found in this study of Maine mussel producers (Table 53). In the EU, total variable costs constituted a greater percentage (84% to 96%) of total costs than on the mussel farms in Maine (53% to 74%), with

[8] The EU values were adjusted to be comparable to the 2019 values in this study.

annual fixed costs constituting a correspondingly greater percentage of total costs in Maine than the mussel farms in the EU. The greater percentage of annual fixed costs in Maine may suggest that there are economies of scale in mussel farming that will need to be captured to reduce production costs and improve capital efficiency.

The profitability benchmark metrics reported in Table 53 suggest lower market prices per pound generally for mussel production in the EU, but much higher prices in Maine as observed in the comparison of gross cash income per pound. Nevertheless, the profitability metrics show positive profits from the aggregated EU data but losses on average for Maine mussel farms (although the data show profits on some farms).

The labor efficiency values calculated for mussel production in Maine demonstrated substantially lower efficiency of the use of labor than shown by the benchmarks from the EU and correspondingly greater costs of labor and management as a percentage of farm output.

Mussel farming in Maine is a small industry (although perhaps increasing) as compared to the EU that has had substantial demand and a large industry for many years. As industries mature and markets develop, farms tend to become more efficient through optimizing production methods for specific lease sites and marketing strategies.

**Further analysis of mussel benchmarks**

Benchmarks associated with profitability, mussels

The key profitability benchmark, net farm income, was negative for three of the four mussel observations (Figure 20). Figure 20 includes one startup farm not yet in full production at the time of this study. Thus, it was important to attempt to identify which other benchmarks were related to and may affect net farm income on mussel farms. Graphs were developed that contrasted net farm income with the following benchmarks: volume harvested (in both total lb of mussels harvested and lb of mussels per linear foot of line), years in business, labor cost (in $/lb of mussels harvested), labor efficiency (lb of mussels harvested per hour and per $ of labor), sales revenue per hour of labor, depreciation ($/lb of mussels harvested), and long-term capital efficiency (lb of mussels harvested per $ of investment capital). Of these, only those that showed some sort of relationship have been included in the figures in this report (Figures 21 to 30).

Figure 21 graphs average costs of production per pound of mussels harvested and demonstrates economies of scale. Average costs of production declined most rapidly between the very small and small farm size. The largest farm size still exhibited slightly lower average costs of production, without indication of the development of diseconomies of scale at that size. Further evidence for economies of scale can be observed in Figure 22, in which net farm income decreased with decreasing volumes of mussels harvested per farm. Economies of scale in mussel production may explain, at least in part, the lack of long-term profitability of mussel production. Economies of scale exist when there are fixed costs that, when spread across greater volumes of production, result in a lower average cost of production (measured as breakeven price above total costs). Examples of the types of fixed costs than can contribute to economies of scale include the

capital costs of equipment (such as a large barge for harvesting), buildings for packing and cold storage, and can also include those of a salaried manager.

Profitability was also affected by productivity in terms of lb of mussels harvested per foot of line (Figure 23). Labor constituted the greatest cost in mussel production; therefore, it is not surprising that profitability decreased with decreasing efficiency of use of labor (measured as lb of mussels harvested per hour of labor) (Figure 24). A different way to look at the relationship of labor efficiency to net farm income is to compare it with sales revenue per hour of labor. Sales revenue per hour of labor also decreased as net farm income decreased (Figure 25). Sales revenue per hour of labor provides a metric that can be compared with wages paid. If sales revenue per hour of labor is less than wages paid per hour of labor, the farm is losing money with each additional hour of labor hired.

Benchmarks associated with cash flow, mussels

The key cash flow benchmark of working capital was further examined by graphing the benchmarks listed above against working capital on mussel farms. Only those graphs that show some degree of relationship with working capital are included in the figures and presented here. Working capital varied among the mussel farm respondents, but was positive for three of the four respondents (Figure 26). As would be expected, working capital declined as net farm income declined (Figure 27) and also declined as the scale of production declined (measured as total lb of mussels harvested per farm) (Figure 28). Labor efficiency, whether measured by lb harvested per hour of labor (Figure 29) or by sales revenue per hour of labor (Figure 30) also declined as working capital declined.

Use of benchmarks to analyze economic and financial feasibility of mussel farms

One of the important uses of benchmarks is to provide a basis of comparison with other farms to search for either clues to why a farm is losing money or if the farm is profitable, to examine ways to improve financial performance. In the case of mussels, two of the three farm respondents were not profitable, exhibiting negative net farm income. One of these two had negative gross margins, a more serious financial situation. A qualitative examination of those farms with negative net farm income was used to search for the sources of financial problems.

The farm with negative gross margins had a cost structure in which the percentage of fixed costs was noticeably greater than that of the other mussel respondents. The breakeven price above variable cost was $0.18 to $0.27/lb greater than that of the other respondents, indicating less efficient use of variable inputs than the other two farms. The breakeven price above total costs for the farm with negative gross margins was proportionately greater than that of the other two farms ($0.78 to $1.08/lb greater), indicating that in addition to higher variable costs per lb of production, that fixed costs/lb were also greater than the other two farms. In all, the following costs were greater than those of the other farms: labor cost/lb, management cost/lb, “other” costs/lb, and lease/permit fees/lb. The labor efficiency benchmarks showed that labor was used much less efficiently on this farm than the other mussel farms. In addition, repair costs and total interest costs per pound were substantially greater on the farm with negative gross margins than on the other farms. The financial solvency benchmarks shed some light on the difficulties of this farm. The greater debt-to-asset and debt-to-equity ratios and the lower equity-to-asset ratios

indicate that the farm was carrying much greater debt loads than the other two farms. The greater total interest expenses paid provide further support for the greater debt loads. The very high repair cost suggests either that the farm had experienced some adverse event that required substantial repairs or that the farm had acquired additional assets that required repairs, possibly for which loans were taken out to cover the expenses. There are other indications that this farm may have attempted to expand too rapidly, incurring debt in the process without expanding the volume of harvest at a level commensurate with the increased expenditures. The lower-than-average capital efficiency benchmarks provide support for this. The second farm that was not profitable had positive gross margins, but the higher management, insurance, marketing and rental costs resulted in negative net farm income.

Both farms with negative net farm income received prices for their mussels that were less than those of the profitable farm. This, combined with greater marketing costs per pound indicate that these farms may be experiencing difficulties in developing a market that is adequate for the business model developed. Overall, the lower prices and greater costs contributed to the economic losses on these farms.

The profitable farm reported no costs for management. Not only did this farm receive the highest price for mussels, but also controlled costs, as exhibited by the number of different line-item costs that were less than those of the two unprofitable farms.

This overall analysis suggests there may be economies of scale in mussel production that should be taken into consideration by prospective producers, but only with strong evidence of adequate growth in market demand for mussels. While expansion of farming enterprises to achieve economies of scale can be important, the expansion process can entail substantial financial risk, particularly if individual farms attempt to expand too quickly and assume debt loads that put the farm into a high-risk financial position. Such examples are common in many industries and there have been many such examples in aquaculture. Some of the negative economic indicators measured in this study for mussel farms in Maine likely reflect attempts to expand too rapidly. Careful financial planning with especial attention to cash flow throughout the expansion process is essential. To avoid excessive financial risk, it may be necessary to base expansion plans more on equity than on debt capital and to plan for a slow expansion commensurate with market and sales growth rather than a quick startup that entails much greater levels of financial and marketing risk.

**Cost comparison of oyster and mussel farms**

Table 54 presents a comparison of the relative costs among shellfish and seaweed producers in Maine. Across the types of aquaculture analyzed in this study, labor was one of the largest costs of production, constituting the greatest single cost category for all but the startup oyster farms, for which seed was the greatest cost. Mussel farms collect seed from the wild and have no direct purchase expenditures for seed, although a percentage of labor and capital costs for the rafts and lines used to collect the seed would accrue. Depreciation was also a substantial cost across all aquaculture products considered. Thus, it is important for shellfish and seaweed producers in Maine to pay especial attention to hiring practices and use of labor to ensure that labor costs result in returns to labor that are greater than the wages paid. Similarly, the importance of

depreciation calls for attention to be paid to productivity of the use of capital in these aquaculture enterprises.

## Seaweed

The seaweed benchmarks are based on data from 6 respondents who reported on the 2017 harvest season. The 2017 seaweed aquaculture industry in Maine consisted of 8 producers who harvested a total of 45,023 wet lbs. of seaweed (Maine DMR 2019; Piconi et al. 2020). Several of these growers were new entrants into the seaweed sector, and operated on a small scale with only a handful of lines. By comparison, Maine's 2020 seaweed sector consists of at least 28 growers, many of whom have scaled up to larger operations. Figure 42 demonstrates the growth of the seaweed sector from 2015-2019. In total, the sector is estimated to have harvested over 500,000 wet lbs. of seaweed in 2020. It is expected that economies of scale have been achieved through this growth, and that the economics of the industry have likely shifted significantly. Furthermore, we understand that efficiencies have been found that may have significantly reduced the cost of setting up farming operations. Given the industry's nascency, and the anecdotal evidence that we have received that suggests profitability on many of the new and larger farms, we believe that the data received from the 2017 growing season may no longer represent the current trends of the industry writ-large in Maine. As a result, we plan to revisit this benchmarking study to analyze the new economic realities in this growing industry.

Seaweed farming is a much newer crop in Maine than oysters or mussels. There is a steep learning curve for anyone entering into a new type of farming activity, particularly one for which there is little commercial experience in the U.S. As is to be expected for a new type of endeavor, the benchmarks calculated for seaweed farms showed a great deal of variability, with high coefficients of variation. Over time, as long as robust markets for seaweed are developed in the U.S., some percentage of those who seek to develop seaweed farms will begin to develop the most efficient and least-cost ways to raise seaweed on their leases. For now, the degree of variability in the benchmarks calculated indicate that a great deal of caution should be used in their evaluation. The final section of this report outlines a series of recommendations for lenders in terms of effective ways to review and evaluate loan proposals for each of the various crops discussed in this report.

### Cost structure, seaweed

An analysis of the cost structure of seaweed farms was used to identify the major categories of costs that contributed to the total cost of seaweed production in Maine. Line item cost expenditures reported by seaweed respondents were tabulated as percentages of total costs. The greatest cost on seaweed farms was that of labor, accounting for 64% of total costs (Figure 31). Depreciation was second, accounting for 7% of total production costs. Other costs included rent and marketing costs, each at 6% of total costs, followed by insurance, repairs, and total interest paid, each at 2% of total costs. The cost structure identified for seaweed likely reflects the experimental, developmental nature of seaweed production in which several respondents had low yields. If seaweed production increases and the apparent production risks are reduced through additional research and development, the subsequent cost structure would be expected to be quite a bit different, with greater variable costs related to seed, repairs, and other inputs.

**Seaweed benchmarks**

Table 55 lists the production benchmarks calculated for seaweed. On average, farmers planted 13,240 ± 14,624 feet of line per acre; 89 ± 86 spools per acre; and 0.007 ± 0.004 spools per foot of line. Coefficients of variation for the above planting benchmarks ranged from 96% to 110%. Volumes of seaweed harvested averaged 16,169 ± 15,201 lb/acre (CV = 94%) and 2.7 ± 1.8 lb/linear foot of line (CV = 67%). In terms of harvest, the most appropriate benchmark likely is the pounds of seaweed harvested per linear foot of line planted. It was somewhat less variable, but it should be noted that the volume harvested ranged from complete crop losses to a maximum of 4.5 lb/foot of line. It is of note that, of the six respondents who raised seaweed, two reported complete losses in the reporting year. In one case, the loss was due to another shellfisherman inadvertently catching the anchor for the seaweed line and pulling it out, causing the lines to collapse. In the other case, the farmer lost 80% of the crop in the water and the remaining 20% that was harvested was unmarketable. One of these respondents later submitted data for the most recently completed crop year that was used in the calculations of the benchmarks reported in the tables. Thus, the benchmarks reported in the tables include only one farm with a complete loss. Without that observation (with 100% loss), the average yield would be 3.2 lb of seaweed per linear foot of line. The graphs developed included only the five observations of producers who did not experience a total loss because the observation with a total loss showed metrics that were so negative it was difficult to see patterns for those that did not have a total loss. Lenders will need to ensure that yield estimates are conservative and that contingency financial plans are in place for an occasional complete crop loss.

Much of the seaweed sold was to a single processor that also performs wholesale and distribution functions for seaweed. Respondents reported selling 33% ± 50% of their crop to a wholesaler and 17% ± 41% to a distributor (Table 55). Startup costs were similarly variable, averaging $13.9 ± $7.9 per linear foot planted (CV = 56%).

The greatest overall cost was the labor cost, followed by depreciation costs for boats, moorings, and lines necessary for production (Table 56). These were followed by rental costs of facilities and marketing costs, insurance, repairs and total interest paid. It is of note that the magnitude of the various costs and expenses were highly variable, with all but two expense items exhibiting coefficients of variation greater than 100%.

Total variable costs, on average, accounted for 74% of total costs, and total fixed (ownership) costs accounted for 26% of total costs, on average (Table 57). Values reported by respondents were more consistent than for some other benchmarks, with coefficients of variation of 27% for total variable and 79% for total annual fixed costs as a percentage of total costs. The per-lb cost of production (breakeven price above total cost) ($4.86/lb) exceeded the average market price paid for seaweed ($0.48/lb). While variable, even the minimum cost per lb ($0.44/lb) was close to the market price per lb of $0.48. In line with these results, the breakeven yield, expressed as lb of seaweed harvested per foot of line to cover all costs was 16 lb/foot of line, on average. To cover only variable costs, the breakeven yield averaged 12 lb/foot of line. The minimum breakeven yield, if only variable costs are considered per foot of line in the dataset was 1.38 lb of seaweed per foot of line, indicating that at least one seaweed producer was able to produce a sufficient amount to cover at least the variable costs of production; however, none were able to

produce sufficient amounts of seaweed per foot of line to cover all costs of production at current market prices.

Table 58 presents the profitability benchmarks for seaweed production. Only one seaweed producer who responded to the survey was profitable, when all expenses were accounted for (i.e. net farm income was negative for all respondents). One additional seaweed producer had positive gross margins, indicating that they were able to cover variable costs of production but not all annual fixed costs. The remaining producers showed negative gross and net margins, indicating the inability to cover even variable costs of production. The overall lack of profitability on most seaweed farms was mirrored by the negative values for the average ROA (only one farm had a positive ROA) and ROE (two seaweed farms had positive ROE).

Relatively greater percentages of seaweed producers reported loans than did oyster farms. Eighty-three percent of seaweed respondents reported operating loans (83%) and 50% reported equipment/real estate loans (Table 59). These loans were reported for the seaweed portion of their business.

Current ratios measured for seaweed producers were strong (3.43 $\pm$ 5.69) but highly variable (CV = 166%), with the minimum current ratio of 0.0 (Table 60). Net worth was positive, on average, on seaweed farms, but debt-asset and debt-equity ratios were quite variable. The average debt-asset ratio indicated a medium level of financial risk, but the maximum value in the data exhibited very high risk.

The interest coverage ratio on seaweed farms was negative (Table 61) as compared to the positive value for oysters. The interest coverage ratio for mussels was also negative, but substantially less than that for seaweed. The negative interest coverage ratios reflect the negative profitability as measured by EBITDA.

Given that labor is the greatest variable cost of producing seaweed, efficiency benchmarks related to labor are especially important. On average, seaweed farms harvested 22.1 lb of seaweed per hour of labor, which generated $11.70 of sales revenue per hour of labor (Table 62). Given that seaweed respondents reported paying an average of $17.75 an hour for full-time employees and $15.21 an hour for part-time employees, the value of the seaweed harvested does not cover the cost of labor. In contrast, oyster farm respondents generated $45 of oyster revenue per hour of labor and mussel farmers $25 of mussel revenue per hour of labor.

**Further Analysis of Seaweed Benchmarks**

Only one of the seaweed respondents to the survey was profitable, exhibiting a positive net farm income, while the others had negative net farm incomes (Figure 32). There appear to be economies of scale in seaweed farming, with the largest farm of those responding having the lowest costs of production (breakeven price above total cost, in $/lb) (Figure 33). When profits (measured as net farm income per foot of line) were graphed against the total weight of seaweed harvested, the largest farm size showed a profit while the second-largest farm size had fewer losses than did the smaller farms (Figure 34), consistent with the previous figure that showed

economies of scale. Decreasing net farm income was associated with increasing labor costs[9] (Figure 35). The one profitable farm had the greatest labor efficiency in terms of lb harvested per hour of labor, and the farm with fewer losses had the second greatest amount of seaweed harvested per hour of labor (Figure 36). A similar trend can be observed with greater sales revenue per hour of labor on the farms with the greatest net farm income (Figure 37). Capital efficiency was also greater on the profitable farm and the farms with fewer losses (Figure 38), as would be expected with depreciation cost being the second-greatest cost on the seaweed farms participating in this survey. The importance of labor and capital costs in seaweed production suggests that paying close attention to the efficient use of labor and capital is an important consideration to increase profitability of seaweed farming.

For seaweed farming, research has shown that it is possible to achieve much greater yields per foot of line. While one respondent indicated that yields of 5 to 7 lb per ft. of line were possible, yields harvested and sold, on average, were half of these levels. In two cases, respondents lost entire crops in a given year. Research and extension support appears to be needed to identify why yields appear to be variable and provide assistance to seaweed producers to be able to more consistently produce greater yields per foot of line. Greater yields per foot of line would increase the efficiency and productivity of use of both labor and capital.

One seaweed respondent had positive working capital whereas working capital on the other farms was negative (Figure 39). The two respondents with the most favorable working capital also had substantially greater labor efficiency benchmarks than the other respondents, including lb harvested per hour of labor (Figure 40), and sales revenue per hour of labor (Figure 41).

A recent study on the economic feasibility of seaweed farming in California also showed very high breakeven prices, of $1.75/lb to $5.19/lb (Ladner et al. 2018). The lowest cost ($0.68/lb) seaweed species in that study was that of *Laminaria setchellii*. The study was based on seaweed growth rates reported from research studies that most commonly have yields that are greater than those obtained on commercial farms (Engle 2019). The production costs reported in Ladner et al. (2018) were greater than market prices reported on the west coast for wild-harvested seaweed and those paid for farmed seaweed on the east coast. Thus, the lack of profitability found in these benchmark analyses of Maine seaweed farms is supported by the results of Ladner et al. (2018).

Comments from some seaweed farmers support results of the benchmark analysis that seaweed farming is not generally profitable at the current time. One seaweed respondent said that, “It's a good hobby. If I pretend my boat doesn't cost anything, and I think if I don't add in the mast and boom, I either broke even or maybe lost about $500. Not bad." Another farmer found that the total weight of seaweed being harvested requires additional equipment, such as a mast, boom and winch that will cost an additional $6,500 that was not included in the benchmark metrics. Finally, another respondent lost his crop when a scallop dragger pulled a screw out of the bottom and bent it in half, resulting in his lines being pinched into a “v” shape. He has not been able to get the lines straightened out in a way that it will stay and has been unable to find a diver willing

[9] Note: There is a labor cost for the two smaller farm scales difficult to discern due to the range of values in the graph, but much less per pound of seaweed than on the larger farms.

to go replace and re-anchor the screw. The conclusion of this seaweed respondent is that, “"If it all goes wrong, I could be out 20 grand." There have been other reports of producers who have had issues with gear from other people on the water taking out entire sections of their farm.

The data from the few responding seaweed farms in Maine were quite variable and reflect the trial and error necessary for farms to learn how to farm a new species on their particular lease, with the set of skills that they possess and with their available farm resources. As seaweed farming expands in Maine, benchmarking values over time will begin to converge and exhibit somewhat greater uniformity. Even in well-established segments of U.S. aquaculture, however, studies continue to show a great deal of variability in farm management practices, cost structures, and economic outcomes (Engle et al. 2019; van Senten 2020; Kumar et al. 2020).

Seaweed production in Maine has developed primarily as a secondary source of income for fishermen, lobstermen, and shellfish producers. Such individuals already own much of the equipment necessary for seaweed farming, including boats, buoys, mooring gear, and a mast/beam/winch. For such individuals, the total new investment in this business model of seaweed farming is likely to be minimal with benchmark values more positive than those reported here. The benchmark values reported account fully for all costs, including non-cash costs (in proportion to the use of each piece of equipment in seaweed production). Nevertheless, individuals who already own the equipment required to raise seaweed should develop a 10-year annual cash flow budget to plan for the capital necessary to replace each piece of equipment when necessary. In addition to reduced capital costs, fishermen and lobstermen may be able to reduce labor costs by attending to seaweed lines on their way to and from other activities on the water. Regardless of the availability or lack of necessary equipment, each individual considering developing a seaweed farm should develop a well thought out and comprehensive financial plan tailored to his/her individual situation but that accounts for either acquiring or replacing all equipment needed when necessary.

Use of benchmarks to analyze economic and financial feasibility of seaweed farms

In the case of the seaweed respondents, gross margins were negative for all but two respondents. Thus, farms on average were not covering the direct operating costs much less the fixed and total costs. There were several clear reasons for this. Two of the farms lost their entire crop for the reporting year, and thus had no revenue to cover expenses. The smallest of the farms bought a quantity of seed spools that cost more per pound of seaweed harvested than the market price of seaweed. The farmer likely expected to produce a much greater weight of seaweed than what was produced and sold. For two additional farms, the marketing costs per pound were greater than the market price per pound of seaweed. Overall, the seaweed producers who responded to this survey were not able to consistently produce and harvest the weight of seaweed per foot of line that has been reported by researchers and some producers. There appears to be a clear need to determine what the factors are that contribute to variability in seaweed yield, and to work with producers to address those sources of variability to be able to operate profitably. There also is a need for continued monitoring of benchmarks for seaweed production. Seaweed production in Maine has continued to grow since this survey was conducted and on-going monitoring of production and economic benchmarks will provide useful guidance as the seaweed industry evolves in Maine. Seaweed benchmarks calculated five years after this study was completed will undoubtedly be quite different from those in this report as the industry matures and develops.

## Recommendations for Use of Benchmarks

The benchmarks developed in this analysis should be used with caution. As with many types of aquaculture, there is a great deal of variability in farm-level data due to different business models, different management practices, likely differences in the lease sites in terms of productivity, different labor patterns on farms (unpaid family versus hired employees), and other factors. This inherent variability among farms is compounded by the small sample sizes in this study that reflect overall small numbers of producers of these various aquaculture products. When consulting the benchmark values, attention should also be paid to the coefficient of variation (CV). The higher the CV, the greater the variability, and the less reliable are the specific values. The range of values reported provides additional detail on the potential variability for each benchmark for each species.

It is critical that the benchmark values calculated 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 provide some indication of which loan applications may be more feasible than others. However, the bottomline in terms of whether the prospective borrower will be able to pay off a loan and maintain a profitable and feasible shellfish or seaweed farm will depend more on the interaction of a series of factors rather than a single benchmark value. Thus, each loan application must be scrutinized for its financial viability across a set of benchmark values.

The following steps are recommended for evaluating loan applications for oysters (established and startup), mussels, and seaweed.

<u>Established oyster farms</u>

Established oyster farms will have historical data that can be scrutinized, and the evaluation of their application should be relatively straight forward. The complete loan application should include the previous three years of balance sheets, profit and loss statements, and a 3-year monthly cash flow budget. From these three statements, the lender can quickly look at the profitability of the farm over the past several years, look at the patterns of cash flow with an eye towards those months in which there typically are cash deficits, and use the cash flow statement to assess the feasibility of having cash available to meet scheduled loan payments. The degree of financial risk already present in the farm business can be readily assessed with the debt-to-asset ratio calculated from the balance sheet.

The benchmarks calculated in this study can also be used to suggest ways to improve profitability, cash flow, or financial position on the farm going forward. The first step in such an analysis would be to look at the percentage of labor, depreciation, and any other major costs for the farm under consideration. In this study, labor accounted for 62% of total costs on suspended culture oyster farms and 48% of total costs on bottom culture farms. Depreciation costs that are relatively greater than the percentage costs estimated in this analysis could be a sign that a farm is over-capitalized. Marketing expenses should be evaluated based on the overall marketing strategy for the business; some strategies require greater levels of direct marketing costs than

others with a strategy of selling primarily to wholesalers and distributors. Examining other costs that compose a noticeably greater percentage of total costs than those measured in this study may indicate areas where greater cost control may be important.

This study showed that few established oyster farms had borrowed capital; most used equity capital and built their businesses slowly.

Startup oyster farms

The benchmark values provide some indication of the amount of investment capital that will be required for a successful farm. Loan applications with investment capital levels less than those presented in this study likely will be under-capitalized and suffer from various types of inefficiencies and higher costs as a result. An over-capitalized farm will have greater repair and depreciation costs that may result in financial difficulties, particularly if a substantial portion of the capital is debt capital.

The costs per pound of various inputs should be compared with the average, minimum and maximum levels measured in the benchmark values, to see if any particular costs may be under-estimated. It is vital that a startup oyster farm adequately account for all capital that is needed to operate at an efficient level and not under-estimate costs when planning for the financial resources needed for the early years. Estimates of breakeven prices above total costs should be compared with expected market prices to evaluate the potential profitability of the farm. Additional important benchmarks to examine for startup oyster farms include the anticipated length of time from seed to market size, and projected working capital, that all appear to be related to the profitability of a startup oyster farm. A comprehensive cash flow budget will show the likelihood of making loan payments, and the debt-to-asset ratio will indicate the extent of financial risk that will be imposed on the business for the level of borrowing proposed.

Once the farm begins to grow oysters, monitoring mortalities and harvest quantities per acre will be important. Tracking actual harvests over time with those proposed in the initial loan application will provide information on how well the farm is performing from a production point of view. The benchmarks for established oyster producers can be used as guidance for monitoring production performance over time.

Mussel farms

Only one mussel farm responding to the survey was profitable (note that this measure of profitability includes non-cash depreciation costs that must be covered for a business to be profitable in the long run). In the short run without consideration of the need for sufficient profit to be able to replace capital assets when they wear out, mussel farms on average were profitable (short-run profitability was measured as gross margins). There appeared to be substantial economies of scale in mussel production related primarily to the type of boats required to handle the harvesting. It appears that, to take advantage of economies of scale, that a minimum production scale will be about 50,000 lb a year. Nevertheless, only the very largest farm in the dataset was profitable. Other benchmark values that would be important to review include the weight of mussels harvested per foot of line. The profitable farm harvested 2.3 pounds of

mussels per growout foot of line, as compared to the next best farm that harvested only 1.3 pounds of mussels per foot of growout line and was unprofitable. Given the importance of labor as the greatest cost of producing mussels, the labor efficiency benchmarks are important. An easy way to develop an initial estimate of the efficiency of labor is to calculate the sales revenue per hour of labor. If this value is less than the hourly wages paid, then the farm will lose more money with every hour of labor used. Working capital, as a measure of cash flow, was related to the total weight of mussels harvested per farm and to the labor efficiency benchmarks as well.

Seaweed farms

The analysis of seaweed farm benchmarks shows that seaweed farming currently entails a number of risks that include that of total crop loss. It would strongly behoove anyone considering seaweed farming to enter slowly and try out a few lines in different locations to get a good feel as to what production levels are likely to be. Expansion should be very slow at first. Low levels of investment would be preferable until the farmer develops a good basis of understanding what costs and production volumes are likely to be over time. Assuming debt capital at a time when seaweed farming is clearly in a developmental stage with many un-answered production and marketing questions appears to be unwise. This is especially true for an individual whose family income would depend on such a new and risky crop. The data from this study do not support going into seaweed production on a full-time basis to support a family until yields on the lease stabilize at a level that, on average, is much greater than those reported in this study. Seaweed production may have potential as a secondary source of income for fishermen and lobstermen who own most of the equipment required. Nevertheless, long-term planning for repairs and replacement costs for major capital expenses of boats, buoys, rope, and mooring gear would still be needed. Approaching seaweed production as an experimental crop would still be advisable, with an initial step of gaining experience with several test lines in the first year or two.

Scallop farms

Several individuals in Maine have been experimenting and raising scallops on an experimental basis. While scallops have potential to be a high-value shellfish product, the production and marketing technologies are still in a developmental phase with producers working to develop the best way to grow and market scallops. Technological assistance and support services are available to scallop producers from a variety of sources, including the Maine Aquaculture Association, NOAA Sea Grant, and Coastal Enterprises, Inc. Moreover, several producers have been cooperating with each other in their efforts to develop scallop farming businesses. Cooperative efforts have supported technology transfer from other countries, sharing of expensive equipment, and more rapid movement of producers along the learning curve for scallop production.

In terms of production costs relative to other types of shellfish, scallops likely will require greater labor and possibly greater capital investment than do oysters or mussel production. In addition to risks expressed by shellfish producers in this report, scallops also are more susceptible to biofouling that can pose difficult problems for the business. Prospective scallop producers should further be aware that testing for biotoxins will require additional expense to ensure the safety of scallops raised, especially if planning to sell animals in the live market.

Prospective scallop producers will need to either own or acquire a vessel with a hoist or winch for harvesting heavy loads as well as equipment to clean and remove biofouling of scallops, typically done onboard. In addition, previous experience farming shellfish would be advantageous because scallops require more careful handling than do oysters or mussels.

## CONCLUSIONS

Aquaculture is growing rapidly in Maine with increasing interest in aquaculture production from prospective producers and various governmental and non-governmental agencies. Aquaculture in Maine includes a number of well-established shellfish producers of oysters and mussels who have developed successful businesses that have been sustained for many years. The success of these businesses has attracted new, prospective producers who seek to develop similarly successful aquaculture businesses. The following presents key results, findings, and recommendations for Maine shellfish and seaweed farmers based on the development and analysis of benchmarks for these segments of Maine aquaculture.

This study developed:

- Summaries of the types of risks and overall problems faced by Maine shellfish and seaweed producers.
- Summary of the workforce structure on Maine shellfish and seaweed farms.
- Identification of the major costs of production for Maine oyster, mussel, and seaweed farms.
- Estimates of the startup costs for Maine oyster, mussel, and seaweed production.
- Values for 15 production benchmarks, 18 expense benchmarks, 9 cost and breakeven price/yield benchmarks, 16 profitability benchmarks, 12 financial and repayment benchmarks, and 14 efficiency benchmarks for Maine oyster, mussel, and seaweed farms.

### Key Findings

Benchmarking:

- Three-fourths of respondents indicated interest in a confidential benchmarking web site that would allow them to compare their production and financial performance with benchmarks of other, similar farms.

For oyster farms:

- Larger oyster farms showed greater productivity, producing more oysters per acre than did smaller farms.
- Larger oyster farms used labor more efficiently than did smaller farms.
- Larger oyster farms used investment capital more efficiently than did smaller farms.

- Cost structures differed among established (> 5 years in business) suspended culture oyster farms, established bottom culture oyster farms, and startup suspended culture oyster farms.
- The greatest costs on established suspended culture oyster farms were labor (62%), marketing (10%), depreciation (8%), management (5%), and insurance (4%).
- The greatest costs on established bottom culture oyster farms were labor (48%), insurance (13%), depreciation (11%), seed (8%), repairs (6%), and marketing (3%).
- The greatest costs on startup oyster farms were depreciation (28%), seed costs (20%), labor (16%), repairs (8%), and insurance (5%).
- On established suspended culture farms, profitability decreased with longer growout time from seed to market size.
- Working capital decreased with decreasing quantities harvested of oysters harvested.
- For startup farms, profitability decreased with decreasing working capital.

For raft-culture mussel farms:

- The major costs on mussel farms were: labor (40%), repairs (11%), insurance (7%), management (7%), depreciation (6%), and marketing (5%).
- While gross margins for raft-culture mussel farming on average were positive, when non-cash costs of depreciation were included, the net margins that reflect long-term profitability were negative, on average.
- Some indication of economies of scale were found in mussel production.
- The most profitable mussel farm had the greatest volume of production per foot of line and the greatest labor efficiency (lb harvested per hour of labor).
- Profitability decreased as working capital decreased.

For seaweed farms:

- The greatest costs in seaweed production were: labor (64%), depreciation (7%), marketing (6%), and rent (6%).
- Only one of the seaweed farms responding to the survey showed long-term profitability (including non-cash costs of annual depreciation).
- There appear to be some economies of scale in seaweed farming.
- Losses increased with decreasing efficiency of use of labor and investment capital.
- There is a strong need for research and extension support to identify the sources of variation in seaweed yields and to assist producers to stabilize yields at a higher level on their lease site to be able to operate profitably.

## Recommendations

- Aquaculture businesses exhibit a great deal of variability from farm to farm. Management and finance decisions need to be based on a holistic analysis of the farm (from production to marketing) and not on a single benchmark. Thus, benchmark values should be used **as**

**guides only**[10], not as absolute values, within the context of an analysis of the overall business model and performance.

- It is important to pay attention to the variability of individual benchmark values: the greater the coefficient of variation, the greater the variability, and the less reliable the average values. This is true for all aquaculture products analyzed.

For established oyster farms:

- Evaluate historical data for the farm annually.
- For loan applications, review 3 years of balance sheets, profit and loss statements, and monthly cash flow statements.
- To decide whether new borrowing is feasible, examine debt/asset ratio from balance sheet to ensure that the additional financial risk is acceptable (debt/asset ratio less than 50% for medium risk level).
- To seek ways to improve profitability, examine the percent of major costs and compare with benchmark values, with especial attention to labor, depreciation and any other major costs.

For startup oyster farms:

- Have adequate startup capital, but manage borrowing to keep the farm within an acceptable (debt/asset ratio less than 50%) level of financial risk. If financial risk is excessive, start slowly with oysters as a side business and build equity before assuming greater debt burden.
- Develop a 3-year monthly pro forma cash flow budget, to be able to plan for surviving periods of cash deficits, particularly in the early years before full production is achieved and revenue received. Account for production risks and shortfalls when deciding to borrow capital.
- The quantity of oyster seed purchased in the early years of the farm business should be a moderate quantity. There is a learning phase during which new oyster farmers learn to manage and operate their farm efficiently on that particular lease site to be able to achieve productivity levels that are financially advantageous. It is better to purchase fewer oyster seed and incur less expense during the early years in which the owner/manager is more prone to experience setbacks and problems due to inexperience.
- Once in oyster production, monitor mortalities carefully, track harvest quantities per acre for each site, and monitor efficiency of use of labor and capital as per benchmark guidance.

For mussel farms:

[10] Many types of aquaculture are in the early stages of development. Unlike other types of agriculture for which consistent and fairly standardized, calibrated practices have been developed over decades of research and on-farm trial, many types of aquaculture are still in a trial phase in which new techniques and practices are being developed. Thus, there is a great deal of variability among farms, many of which are viable enterprises for which a strict benchmark interpretation from another farm may not be relevant. These benchmarks should be used to provide a general range of potential values and some perspective as to what the top performance might look like in specific production or financial categories.

- Monitor labor efficiency and sales revenue per hour of labor. If sales revenue per hour of labor is less than hourly wage rates, the farm is losing money with every hour of wages paid.
- The most profitable mussel farm harvested 2.3 lb of mussels per ft of growout line.

For seaweed farms:

- Seaweed farming is in a developmental stage in which farmers are learning how and where seaweed will grow well.
- Prospective producers should enter slowly and learn how seaweed grows on his/her site before incurring financial liabilities through borrowing or attempting to raise seaweed as the basis for a full-time business.
- Risk of total crop loss was found to be high (it should be noted that the sample size of seaweed producers was small in this survey). Given that seaweed production is in its infancy, such risks would be expected to diminish as producers learn how to protect crops from various types of losses.
- Cost estimates must include the percentages used for seaweed of the costs of the vessel and winch or hoist for harvesting, mooring gear, buoys, and other fixed capital assets.
- Develop an extension verification program for seaweed producers in which extension personnel monitor key parameters (i.e., seed density on spools, growth of seaweed), and key environmental parameters (i.e., water temperature, nutrients) to assist producers to obtain greater yields per foot of line.

For scallops:

- Scallop production in Maine is experimental and in a developmental stage.
- Scallop producers will need to experiment with production technologies and marketing strategies.
- Prior business and marketing experience is recommended.
- Prospective scallop producers should contact and take advantage of the various resources and support services available, such as from the Maine Aquaculture Association, NOAA Sea Grant, and Coastal Enterprises, Inc., prior to investment in scallops.
- Prior experience farming less-sensitive shellfish such as oysters is recommended.
- Labor and capital costs likely to be greater for scallops than for oysters and mussels.

A successful aquaculture business requires careful attention to many details related not only to efficient production of high-quality products but also to marketing strategies, costs, and financial outcomes. Successful businesses are those for which owners and managers make the correct decisions related to all facets of the business and most often are those who monitor all phases of the business on a continuous basis. The benchmarks developed in this report offer a means for individual businesses to compare the performance of their aquaculture business with that of other, similar types of aquaculture businesses across production, marketing, and financial perspectives. Such comparisons offer a means to identify changes likely to improve profitability of the business.

## REFERENCES


Adams, C.M., L. Sturmer, D. Sweat, N. Blake, and B. Degner. 2001. The economic feasibility of small-scale commercial culture of bay scallops (*Argopectan irradians*). Aquaculture Economics & Management 5(1/2):81-98.

Brayden, C. In press. Business and Production Plans for Aquaculture. Maine Aquaculture Association, Hallowell, Maine.

CDI Pinnacle Management Pty Ltd. 2010. Australian Seafood Cooperative Research Centre Project No. 2009/701, Oyster Benchmarking Program, Milton, QLD, Australia.

Chen, J.Q., M.C. Haws, Q. Fong, and P-S Leung. 2017. Economic feasibility of producing oysters using a small-scale Hawaiian fishpond model. Aquaculture Reports Aquaculture Reports 5:41-51.

Choi, J.D., S.L. Larkin, and T.H. Spreen. 2006. A bioeconomic model for cham scallop (*Patinopecten yessoensis*) aquaculture in Korea. Aquaculture Economics & Management 10(2):125-146.

Chynoweth, D.P. 2002. Review of biomethane from marine biomass. University of Florida, Gainesville, Florida. 207 pp.

Coffen, S. S., and A.T. Charles. 1991. Production economics of shellfish aquaculture in Atlantic Canada: A preliminary analysis. Aquaculture and Fisheries Management 22:193–202. http://doi.org/10.1111/j.1365-2109.1991.tb00509.x.

Cole, A., A. Langston, and C. Davis. 2016. Maine Aquaculture Impact Report, Aquaculture Research Institute, University of Maine, Orono, Maine.

Deblitz, C. 2010. Agri benchmark: Benchmarking Beef Farming Systems Worldwide. Thünen Institute of Farm Economics, Braunschweig, Germany.

Deblitz, C. 2013. Global meat production, drivers and challenges. Global Forum agri benchmark beef and sheep conference 2013. Agri benchmark, Thünen Institute of Farm Economics, Braunschweig, Germany.

Deblitz C, and Y. Zimmer. 2007. Agri benchmark beef: a standard operating procedure to define typical farms. Braunschweig: FAL, 20 pages. Available on the Internet at http://www.agribenchmark.org/beef_typical_farms_definitions.html.

Deblitz, C., T. Hemme, F. Isermeyer, R. Knutson, and D. Anderson. 1998. The International Farm Comparison Network (IFCN): Objectives, Organisation, First Results on Dairy Production. Institute of Farm Economics, Bundesforschungsanstalt für Landwirtschaft (FAL), Braunschweig, Germany.

Department of Fisheries and Oceans. 2006. An economic analysis of the mussel industry in Prince Edward Island. Policy and Economics Branch, Gulf Region, Moncton, New Brunswick, Canada.

Engle, C.R. 2010. Aquaculture Economics and Financing: Management and Analysis. Blackwell Scientific, Ames, Iowa.

Engle, C.R. 2019. Aquaculture Businesses: A Practical Guide to Economics and Marketing. 5M Publishing, UK.

Engle, C.R. and J. van Senten. 2018. Economic Analysis of Oyster Production in Maryland. Report submitted to Maryland Sea Grant, University of Maryland, College Park, Maryland.

Engle, C.R., N. Stone, and E. Park. 2000. An analysis of production and financial performance of baitfish production. Journal of Applied Aquaculture 10(3):1-15.

Engle, C.R., J. van Senten, and G. Fornshell. 2019. Regulatory costs on U.S. salmonid farms. Journal of the World Aquaculture Society 50(3):522-549. doi.org/10.1111/jwas.12604.

Girard, S. and J.A. Pérez Agúndez. 2014. The effects of the oyster mortality crisis on the economics of the shellfish farming sector: Preliminary review and prospects from a case study in Marennes-Oleron Bay (France). Marine Policy 48:142-151.

GSGislason & Associates Ltd. 2006. The Canadian farmed mussel industry benchmark analysis for the US market. Final report prepared by GSGislason & Associates Ltd for Agriculture & Agri-Food Canada, Ottawa, Ontario.

Haight, G. 2007. Economic model for optimum Alaska shellfish oyster farm. Alaska Sea Grant Marine Advisory Program, Anchorage, Alaska.

Hale Research Group. 2016. Maine farmed shellfish market analysis. Gulf of Maine Research Institute, Maine.

Huang, J. F. and J.M. Lee, J. 2014. Production economics and profitability analysis of horizontal rack culture and horizontal rack culture coupled with raft-string culture methods: A case study of Pacific oyster (Crassostrea gigas) farming in Chiayi and Yunlin Counties, Taiwan. Aquaculture International, 22(3):1131–1147. http://doi.org/10.1007/s10499-013-9733-7.

Huang, J-F, J-M Lee, and P-C Sun. 2013. Prolonged culture period on production cost and factor input: a case from the Pacific oyster, *Crassostrea gigas*, farming industry in Yunlin County, Taiwan. Journal of the World Aquaculture Society, 44(6):795–804. http://doi.org/10.1111/jwas.12085

Hudson, K. and T. Murray. 2016. Virginia shellfish aquaculture situation and outlook report. VIMS Marine Research Report No. 2016-4, Virginia Institute of Marine Science/College of William and Mary.

Johnston, B., D. Hine, P. Kishore, and P. C. Southgate. 2019. Cost–benefit analysis of two culture methods that influence pearl production from the black-lip pearl oyster, *Pinctada margaritifera*. Journal of the World Aquaculture Society 50(3):510–521. Available at: https://onlinelibrary.wiley.com/doi/10.1111/jwas.12594

Kohl, D. 2005. Agricultural Economist, Virginia Tech University. Modified by Greg Blonde, 2009. Waupaca County UW-Extension Agriculture Agent. Available at: www.grainnet.com/pdf/FarmFinancialRatiosBenchmarks.pdf. Accessed May 11, 2019.

Koketsu, Y., Y. Sasaki, H. Ichikawa, and M. Kaneko. 2010. Benchmarking in animal agriculture: concepts and applications. Journal of Veterinary Epidemiology 14(2):105-117.

Kumar, G., C. Engle, S. Hegde, and J. van Senten. 2020. Economics of U.S. catfish farming practices: profitability, economies of size, and liquidity. Journal of the World Aquaculture Society. doi.org/10.1111/jwas.12717.

Ladner, I., I. Su, S. Wolfe, and S. Oliver. 2018. Economic feasibility of seaweed aquaculture in southern California. M.S. thesis, U. of California, Santa Barbara.

Lasner, T., A. Brinker, R. Nielsen, and F. Fad. 2017. Establishing a benchmarking for fish farming – profitability productivity and energy efficiency of German, Danish and Turkish rainbow trout grow-out systems. Aquaculture Research 48:3134-3148.

Lockwood, G. 2017. Aquaculture: Will it rise to its potential to feed the world? Blurb Publishers. Available at Amazon.com.

Maine Department of Marine Resources (DMR). 2019. Harvest of Farm-Raised Marine Algae in Maine. Augusta, Maine. Available at: https://www.maine.gov/dmr/aquaculture/harvestdata/documents/marinealgae2015-19.pdf

Mongruel, R. and J.A. Perez Agundez. 2006. Comparing economic dynamics of oyster and mussel farming, with particular emphasis on their profitability: an application in the Mont-Saint-Michel Bay (France). Proceedings of IIFET 2006. Portsmouth, United Kingdom.

Nguyen, T.T., M. A. van Deurs, L. Ravn-Jonsen, and E. Roth. 2013. Assessment of financial feasibility of farming blue mussel in the great belt by the 'smart farm system'. Department of Environmental and Business Economics (IME) Report 15/13, University of Southern Denmark, Esbjerg, Denmark.

Nordquist, D.W., D. L. Nitchie, G. J. Paulson, T. L. Knorr and C. Mahnken. 2017. Southwestern Minnesota Farm Business Association 2016 Annual Report. Staff Paper #P17-3. Department of Applied Economics, University of Minnesota, St. Paul, Minnesota.

Northern Economics. 2013. The economic impact of shellfish aquaculture in Washington, Oregon, and California. Prepared for the Pacific Shellfish Institute, Olympia, Washington.

Northwest Farm Credit Services Business Tools. Understanding Financial Ratios and Benchmarks. Available at: www.northwestfcs.com/Resources/business-tools. Accessed May 25, 2019.

Oilgae. 2010. Oilgae guide to fuels from macroalgae. Tamil Nadu, India.

Parker, M., S. Dill, D. Webster and D. Meritt. 2013a. Bottom culture cost analysis. Oyster aquaculture technology series. University of Maryland Extension, College Park, Maryland.

Parker, M., S. Dill, D. Webster and D. Meritt. 2013b. Contained culture cost analysis. Oyster aquaculture technology series AGNR-EM-14-07. University of Maryland Extension, College Park, Maryland.

Piconi, P., R. Veidenheimer, and B. Chase. 2020. Edible Seaweed Market Analysis. Island Institute, Rockland, Maine. Available at: http://www.islandinstitute.org/edible-seaweed-market-analysis-2020

Reith, J.H., W. Huijjen, J. van Hal, and J. Lenstra. 2009. Seaweed potential in the Netherlands. Macroalgae-Bioenergy Research Forum, Plymouth, UK.

Richardson J.W., J.L. Outlaw, G.M. Knapek, J.M. Raulston, B.K. Herbst, D.P. Anderson, and S.L. Klose. 2009. Representative Farms Economic Outlook for the December 2009 FAPRI/AFPC Baseline, Briefing Paper 09-4, December 2009, Agricultural and Food Policy Center, Texas A&M University. Available on the Internet at http://www.afpc.tamu.edu/pubs/3/535/BP09-4%20paper.pdf.

Roest de, K. and C. Montanari. 2006. Quanto è costato produrre carne bovina nel 2005. Rif.: Informatore Agrario 2006, v. 62(48) p. 25-28. Available on the internet at: http://www.crpa.it/media/documents/crpa_www/Settori/Economia/Download/Archivio-23/48025.pdf.

Salz, P. 2009. Review of the EU aquaculture sector and results of costs and earnings survey. Framian BV, The Netherlands.

Samonte-Tan, G. P. B. and G.C. Davis. 1998. Economic analysis of stake and rack-hanging methods of farming oysters (Crassostrea iredalei) in the Philippines. Aquaculture, 160(3–4):239–249. http://doi.org/10.1016/S0044-8486(97)00231-7.

Sarzeaud P, J. Belvèze, L. Echevarria, M. Kentzel. 2009. Résultats 2007 des exploitations bovins viande; Synthèse nationale des données des réseaux d'élevage, Etude du Département

Actions Régionales (DAR), ISBN 978-2-84148-704-2, Réf. T1856-0950103, details at http://www.inst-elevage.asso.fr/html1/spip.php?page=article_lib&id_article=17444.

Scuderi, B. and X. Chen. 2018. Production efficiency in New England's oyster aquaculture industry. Aquaculture Economics & Management 23(1):45-64.

SRAC. 1998. SRAC Eleventh Annual Progress Report. Southern Regional Aquaculture Center, Stoneville, Mississippi. Available at: https://srac.msstate.edu/Project%20PDFs/Baitfish%20Culture%20Practices.pdf.

Turano, M. 2013. Shellfish production methods and economics. NC Aquaculture Development Conference, North Carolina.

van den Burg, S., A. P. van Duijin, H. Bartelings, M.M. van Krimpen, and M. Poelman. 2016. The economic feasibility of seaweed production in the North Sea. Aquaculture Economics & Management 20(3):235-252.

Valderrama, D., J. Cai, N. Hishamunda, N. Ridler, I.C. Neish, A.Q. Hurtado, F.E. Jsuya, M. Krishnan, R. Narahanakumar, M. Kronen, D. Robledo, E. Basca-Leyva, and J. Fraga. 2015. The economics of *Kappaphycus* seaweed cultivation in developing countries: a comparative analysis of farming systems. Aquaculture Economics & Management 19(2):251-277.

van Senten, J., C.R. Engle, B. Hudson, and F.S. Conte. In press. Regulatory costs on Pacific coast shellfish farms. Aquaculture Economics & Management.

Wakamatsu, H., and T. Miyata. 2015. Reforming wakame aquaculture in Japan with relaxed processing standards: from consumer and producer viewpoints. Aquaculture Economics & Management 19(4):387-403.