Research, Development and Education Priorities

for the Aquaculture Sector in Maine

Maine Aquaculture Innovation Center

January 2020

Research, Development and Education Priorities for the Aquaculture Sector in Maine

TABLE OF CONTENTS

Executive Summary 1
Introduction 2
Methodology 4
Results and Discussion 7
Conclusions and Recommendations 47
References 48

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Damariscotta oysters Photo by Chris Davis

EXECUTIVE SUMMARY

The research priorities survey has been an ongoing initiative coordinated by the Maine Aquaculture Innovation Center in collaboration with Maine Aquaculture Association, Maine Sea Grant, and the University of Maine's Aquaculture Research Institute since 2012. This report is based on the research priorities survey conducted in June 2019 of Maine's aquaculture community, and is compared with surveys from 2012 and 2016 to look at trends.

There have been some changes in the prioritization of needs since 2016, but many of the same research, development, and education (R&D&E) needs persist and remain unaddressed. As expected, there are different R&D&E priorities for different aquaculture sectors. The survey found the following needs across the aquaculture cluster and within specific sectors:

Recommended R&D foci to maximize impact across multiple aquaculture sectors include:

- Research on methodologies for invasive species management
- Research on biofouling control methods
- Research on pest and predator management strategies
- Climate change predictive models with a focus on aquaculture production
- Improving understanding of the beneficial impacts of aquaculture on water quality/ecosystem
- Streamlining distribution

Recommended Sector Development foci to maximize impact across multiple aquaculture sectors include:

- Accessibility to water quality data
- Development of public information materials for use and dissemination by the aquaculture community
- Marketing campaign for Maine farmed seafood
- Market development
- Development of Best Management Practices for shellfish and sea vegetable sectors

Recommended Education foci to maximize impact across multiple aquaculture sectors include:

- Training for growers on community relations and communication strategies
- Public education strategy
- Career education programs for schools
- High school internship programs

Recommended R&D foci to maximize impact across the shellfish aquaculture sectors include:

- Seed collection strategies (sea scallop and mussel growers)
- Nursery/hatchery technology(sea scallop and mussel growers)
- Shellfish disease research (oyster growers)
- Farm/business management strategies to reduce revenue losses caused by biotoxin closures (sea scallop growers)

Recommended R&D foci to maximize impact across the sea vegetable aquaculture sector include:

- The development of new value-added products (food and non-food),
- Processing infrastructure
- Regulation

Recommended R&D&E foci to maximize impact across the finfish aquaculture sector include:

- Sea lice management
- Workforce development
- Access to capital

The Maine Aquaculture Innovation Center in collaboration with the University of Maine's Aquaculture Research Institute, Maine Sea Grant, and the Maine Aquaculture Association will continue to conduct these surveys on a biennial basis. The findings from this 2019 report will be reported at the 2020 Maine Aquaculture Research, Development and Education Summit (January 17th, 2020)

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INTRODUCTION

Maine's coastal communities, a nexus of complex, dynamic, social-environmental systems, face many serious challenges to their long-standing economic and cultural traditions. They range from the impacts of accelerated coastal tourism and recreation (~37 million visitors/year)[1], the integration of fisheries and aquaculture, and the conservation of marine ecosystems. These challenges are further complicated by the uncertainty caused by environmental change.

As a large rural state (~30,000mi^2, population ~1.3million)[2] ranked 31st in the nation for per capita income in 2018[3] Maine's economic prosperity is dependent on its geography, physical and natural resources, and human capital. In this context, Maine's coastline, working waterfronts, and marine resources represent a crucial asset, supporting a wide spectrum of interdependent sectors. Within this spectrum, the aquaculture sector has demonstrated its potential for transformative, knowledge-based economic, social and environmental opportunities, while also conserving and building upon the vital cultural and economic traditions of rural, coastal communities.

According to the Maine Aquaculture Economic Impact Report[4]:

- Maine's aquaculture sector has a direct economic impact of $73.4 million in output, 571 in employment, and $35.7 million in labor income in 2014
- Including multiplier effects, Maine's aquaculture sector generates a statewide annual economic contribution of $137.6 million in output (i.e., sales revenue), 1,078 full- and part-time jobs, and $56.1 million in labor income based on 2014 data
- Between 2007 and 2014, the total economic impact of aquaculture almost tripled from $50 million to $137 million dollars
- The majority of jobs related to aquaculture production are full-time, year-round positions. Less than 30% of employment is seasonal
- The top three species — in terms of 2014 sales— are Atlantic salmon, blue mussels and Eastern oysters.
- Thirty-nine percent of the respondents reported $0 revenue, likely indicating a large number of new businesses

Sea scallop Photo by Chris Davis

In 2015, the landed value of oysters, mussels, and scallops in the U.S. was roughly $700 million[5]. Maine accounted for approximately 4% of that total, delivering $24 million to harvesters. Of the landed shellfish total, Maine aquaculture accounted for 25%, producing a landed value of approximately $6.5 million. Maine's existing shellfish aquaculture industry may generate a total economic benefit of over $15 million[5].

The vast majority of Maine's aquaculture businesses have common characteristics such as:

- Small size
- Small workforce
- Reduced capacity for staff development and training
- Reduced capacity for research and development

These characteristics can hinder growth both as a business and a sector.

The aquaculture sector is fortunate to have a well-established research and innovation ecosystem to support Maine's community of small aquaculture-related businesses and maximize growth, organizations.

These organizations include:

- Maine Aquaculture Innovation Center
- Maine Sea Grant
- Maine Aquaculture Association
- University of Maine, Aquaculture Research Institute
- Downeast Institute
- Coastal Enterprises Inc
- Island Institute
- Maine Technology Institute
- Gulf of Maine Research Institute
- University of New England
- Gulf of Maine Research Institute
- University of Maine Darling Marine Center
- University of Maine Center for Cooperative Aquaculture Research

An understanding of the research, development, and education needs of Maine's aquaculture sector is essential for these organizations to collaborate, and to direct resources to maximize benefits to the sector.

The research priorities survey has been an ongoing initiative coordinated by the Maine Aquaculture Innovation Center in collaboration with Maine Aquaculture Association, Maine Sea Grant, and the University of Maine's Aquaculture Research Institute since 2012. This report is based on the research priorities survey of Maine's aquaculture community conducted in June 2019.

METHODOLOGY

The main purpose of this study was to elicit and prioritize the research, development, and education needs of the aquaculture sector in Maine.

There is no single database in Maine of people involved in the aquaculture sector. To ensure comprehensive inclusion of Maine aquaculture growers, service providers, researchers, students, educators, and other personnel, a survey mailing list was compiled from the following sources, and duplicates were removed.

- A list of Maine registrants to the Northeast Aquaculture Conference & Exposition held in 2019
- The Maine Aquaculture Association membership list
- The University of Maine's Aquaculture Research Institute mailing list
- A list of limited purpose aquaculture license holders
- A list of aquaculture lease-holders

A survey was created in Survey Monkey using the 2016 "Maine Aquaculture Research Priorities" survey as a basis.

The survey was emailed to 851 separate email addresses. Of these:

- 545 were opened (64.0%)
- 271 were unopened (31.8%)
- 30 bounced (3.5%)

A reminder email was sent to people who had not responded after 14 days.. A Thank You email was sent to everyone who completed the survey.

In total there were 208 responses:

- 160 complete (76.9%)
- 48 partial (23.1%)

As some of the questions were conditional, respondents did not see every question.

A range of question styles were used:

- Multiple choice
- Likert scale
- Open-ended.

To prioritize research topics, respondents were asked to rate the importance of a list of research areas on a 5 point Likert-scale (urgently important to not important). Respondents could also select a "Not Relevant to Me" option. The responses were weighted, and a weighted average was generated. In this report, weighted averages were interpreted as follows:

- < 2 = urgently important
- 2.01 - 3.99 = moderately important
- 4.00 - 5 = not important

Scallop juveniles Photo by Hugh Cowperthwaite

The weighted average was calculated by Survey Monkey as follows, where:

w = weight of answer choice (1 = urgently important, 5 = not important)

x = response count for answer choice

$$\frac{x1w1 + x2w2 + x3w3 \ldots xnwn}{\text{Total}}$$

"Not Relevant to Me" responses were not factored into the weighted average.

A qualitative, thematic analysis was used to examine themes or patterns of meaning within the responses to open questions.

NOTE OF CAUTION:

The results of this survey represent the individuals responding, and while the results provide some insight into the demographics and structure of Maine's aquaculture sector, there may be elements that are not represented by survey respondents.

When results have been filtered for growers, there may have been more than one response per aquaculture business entity.

Kelp harvest Photo by Chris Davis

RESULTS and DISCUSSION

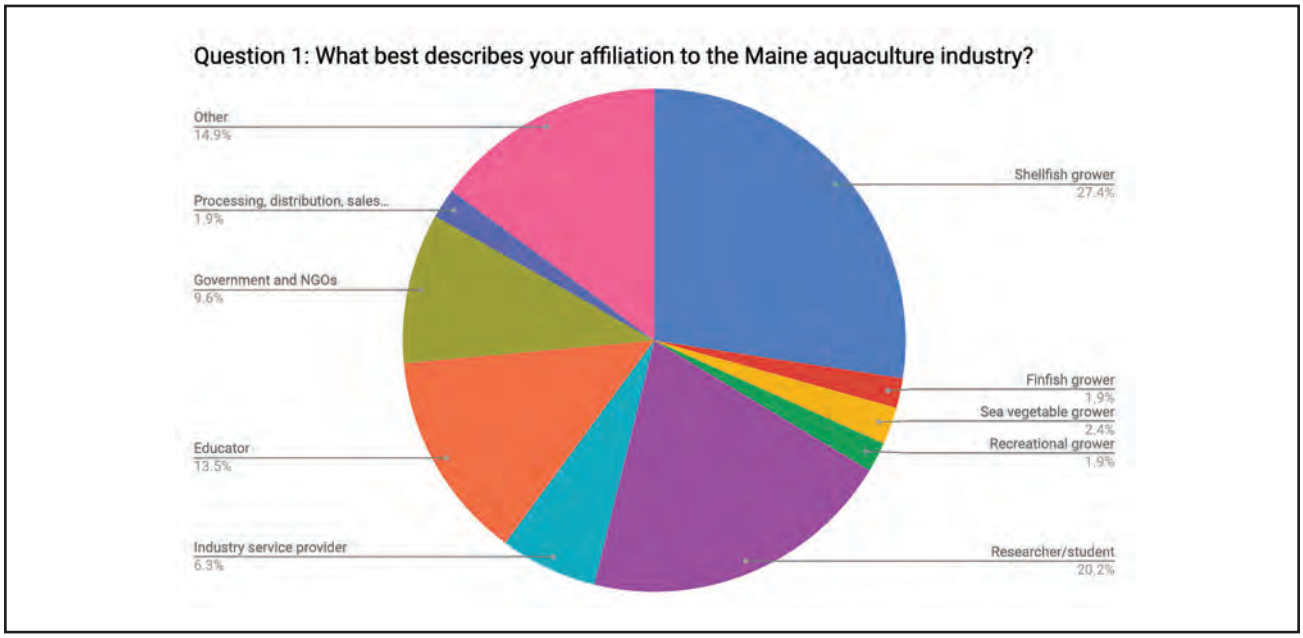
A total of 208 people responded to the survey, with an average completion rate of 76%.
The typical time spent on the survey was just over 12 minutes, with newer growers taking slightly longer to reply (almost 16 minutes) and completing more of the survey (85%).

Question 1. What best describes your affiliation to the Maine aquaculture industry?

2019 Survey: Answered: 208; Skipped: 2

At over a quarter of respondents, shellfish growers were the largest population represented. Researchers and students were the second largest group of respondents (Figure 1).

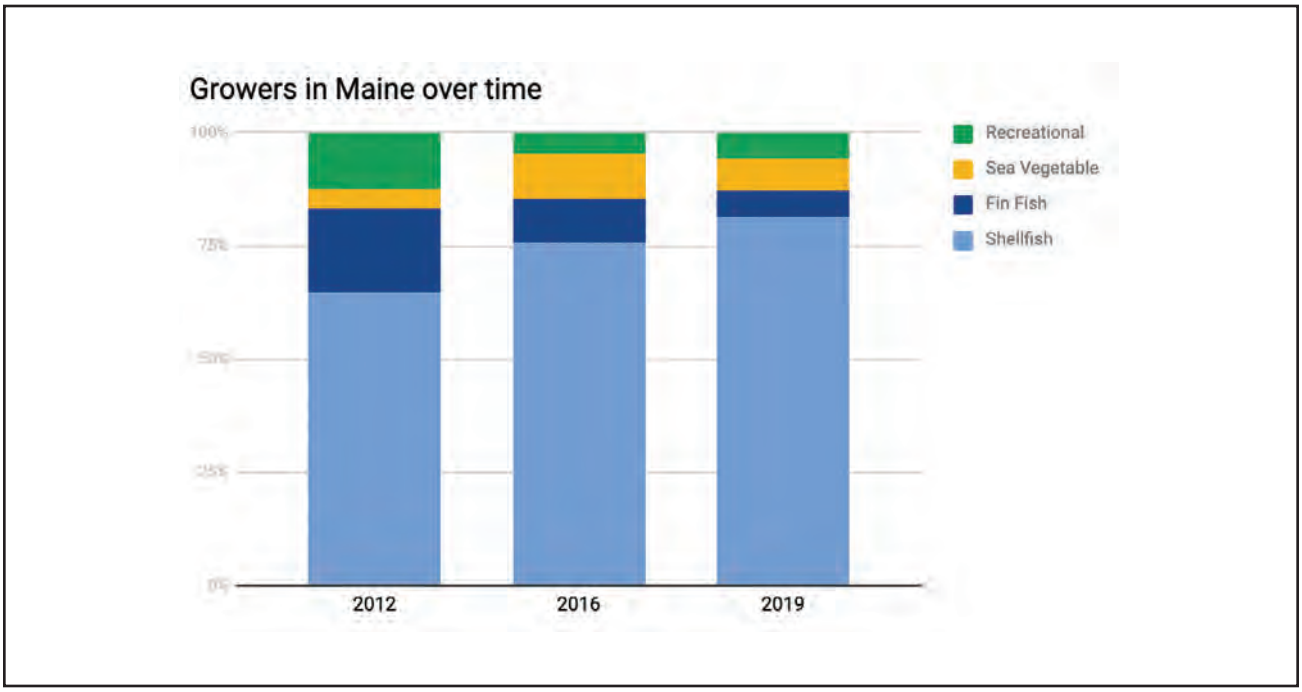
FIGURE 1: Affiliations of survey respondents in 2019 (n=208)



This is similar to the results of the previous R&D Priorities survey conducted in 2016 (n=170) where 26.8% of the respondents were shellfish growers, and the second largest group of respondents were researchers and students (25%). In the 2012 R&D Priorities Survey (n=90), the respondents had a higher proportion of shellfish growers (34%), but the number of researchers and students was similar (25.56%). The population of finfish growers was higher in 2012 (10%) most likely due to the pool of respondents being smaller.

The total number of responding growers (finfish, shellfish, sea vegetable and recreational growers) has increased over time (2012 n=45; 2016 n=62; 2019 n=70). In addition, when considering only growers, representation of the different aquaculture sectors in Maine has changed over time (Figure 2). This reflects the growth of Maine's aquaculture sector, and in particular the growth of the sea vegetable and shellfish sectors.

FIGURE 2: Changes in Production Sector distribution since 2012

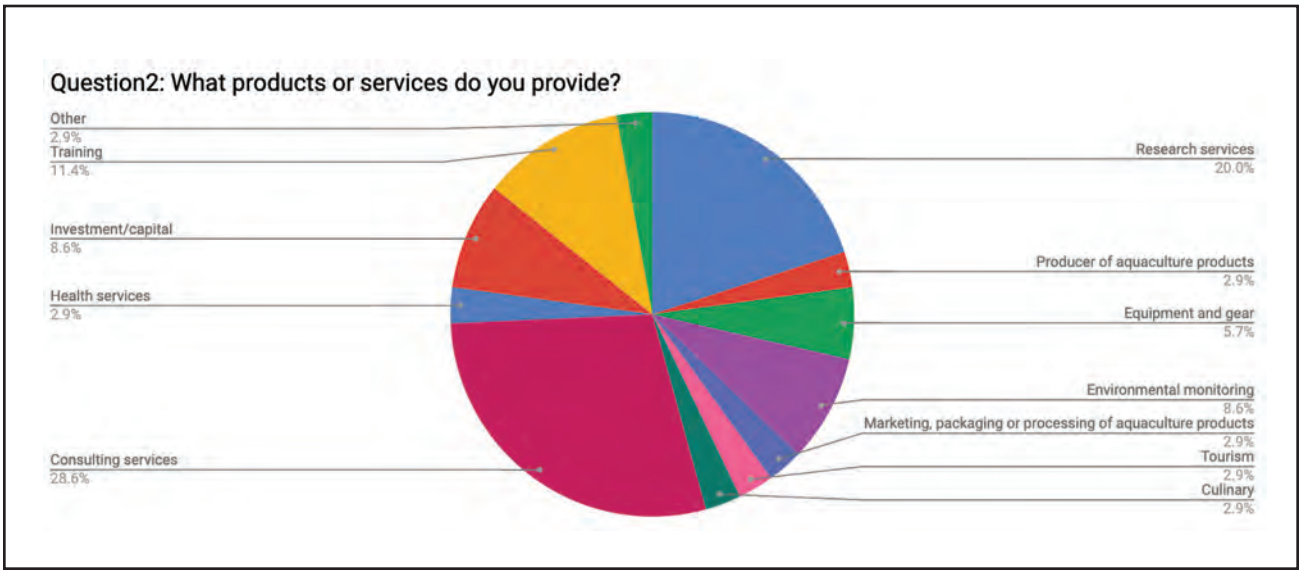


Question 2. What products or services do you provide? (check all that apply)

2019 Survey: Answered: 13; Skipped: 197

Only industry service providers were guided to this question, and as such there were only 13 responses. Industry service providers mostly provide consulting and research services to the aquaculture sector in Maine (Figure 3).

FIGURE 3: Services Provided by Service Providers in 2019 (n=13)



When compared to the previous R&D surveys conducted in 2016 (question respondents n=29) and 2012 (question respondents n=41), there were some changes in the types of service providers represented by the respondents.

- In 2016 and 2012 there was a much higher proportion of service providers involved in marketing, packaging and/or processing aquacultured products (19.5% in 2012; 20.7% in 2016; 2.9% in 2019)
- The proportion of responding aquatic animal health services providers has fluctuated (4.8% in 2012; 20.7% in 2016; 2.9% in 2019)
- In the 2012 survey, wholesale sales of aquacultured products was chosen by 21.9% of question respondents but not represented at all in 2019
- Distribution and transport of aquaculture products and Retail sales of aquaculture products were not represented at all in 2019. No Feed service providers were represented in 2019, but were in 2016 (3.4%) and 2012 (4.8%)
- Training and investment capital were not included as survey options in 2016 and 2012, although education and innovation support were mentioned in comments. These were included as multiple-choice options in 2019 and were selected by 11.4% (training) and 8.6% (investment and capital) of respondents
- For the 1st time, SBIR support services were reported in 2019

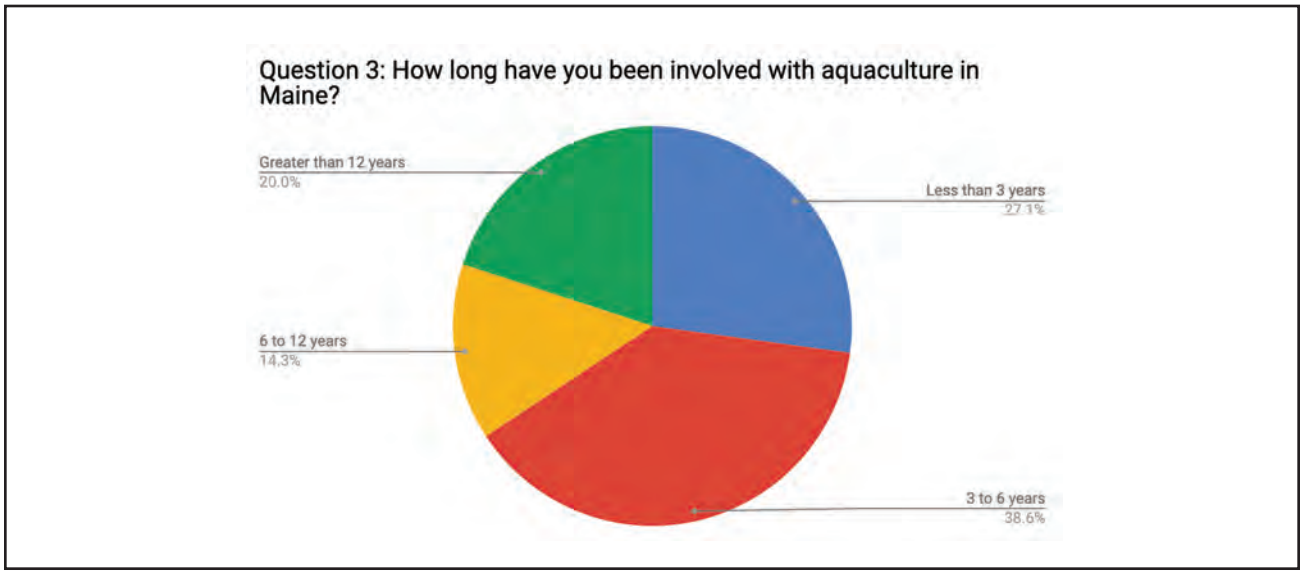
Question 3. How long have you been involved with aquaculture in Maine?

2019 Survey: Answered: 70; Skipped: 140

Only responding growers (shellfish, finfish, sea vegetable and recreational growers) were guided to this question, and all answered the question.

The majority of respondents were relatively new to aquaculture, with 65% involved in Maine aquaculture for less than 6 years (Figure 4).

FIGURE 4: Amount of time that responding growers had been involved in Maine Aquaculture in 2019 (n=70)



All finfish growers have been involved in aquaculture for longer than 3 years, and most for more than 12 years (Figure 5).

Most of the new entries to aquaculture are shellfish growers; 82% of those involved in aquaculture for less than 6 years are shellfish growers; 6.5% sea vegetable growers; 8.7% finfish growers; and 2.7% recreational growers (Figure 6).

FIGURE 5: Frequency Distribution of Years in Business for Aquaculture Producers in Maine Aquaculture, 2019 by sector (n=70)

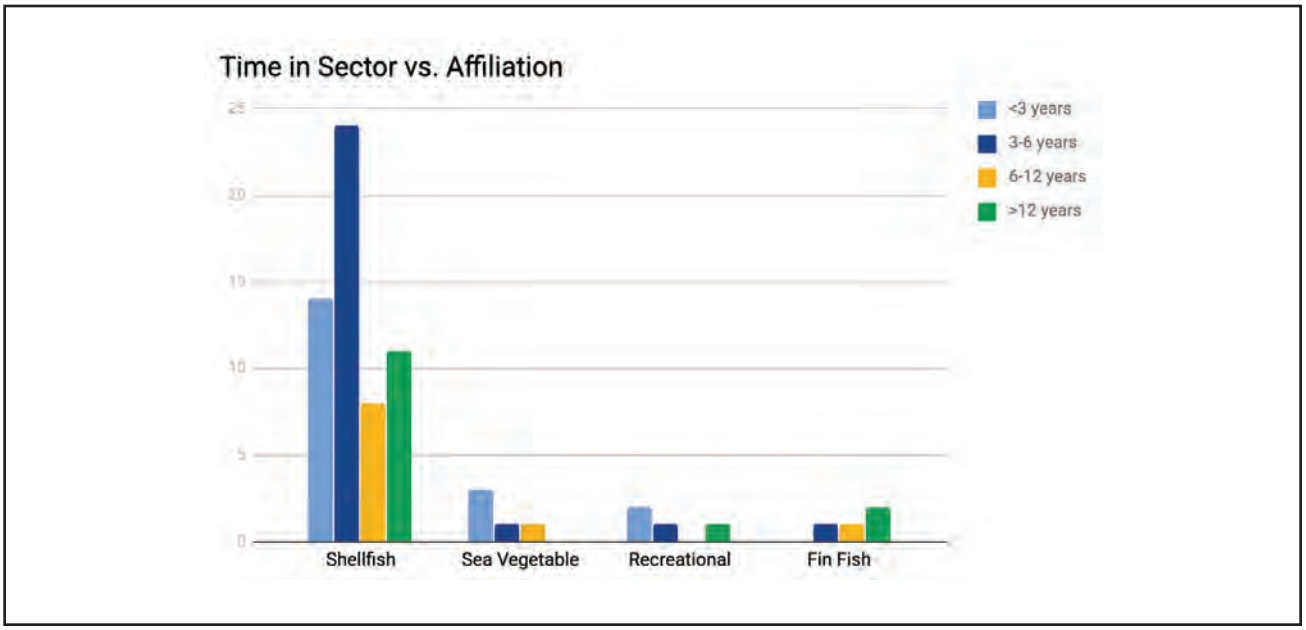
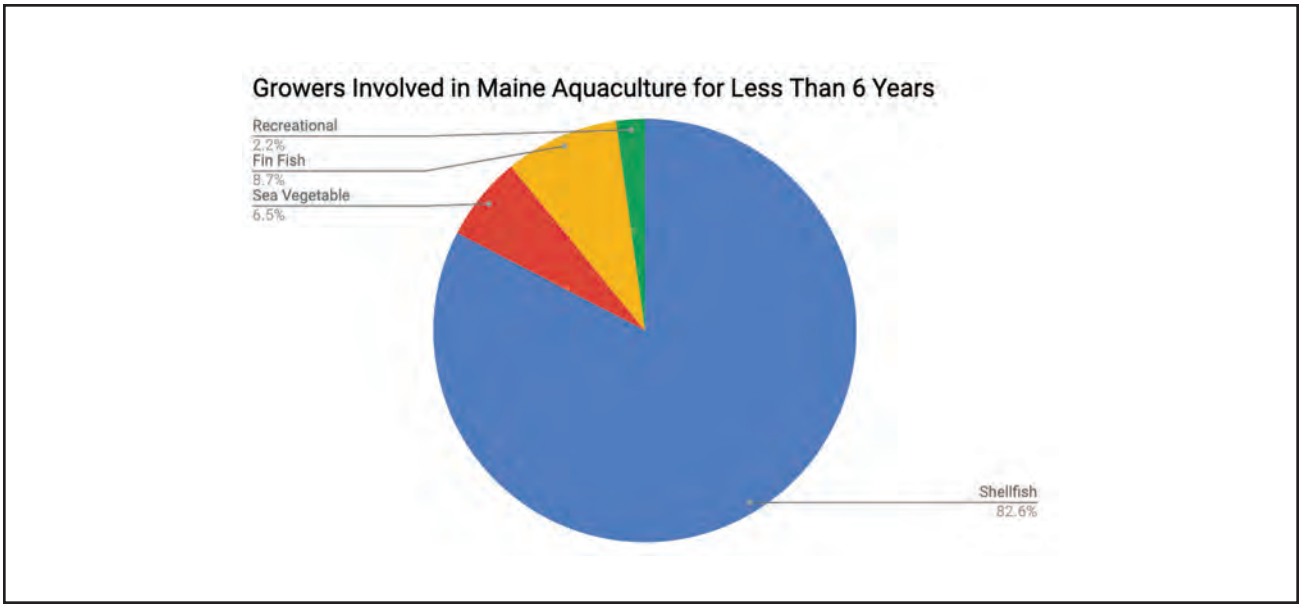


FIGURE 6: Sector affiliations of newer growers in 2019 (n=46)



The number of new entries into Maine's aquaculture sector has changed over time. In 2012, (n=45) 45% of growers were involved in Maine's aquaculture sector for more than 10 years (Figure 7).

FIGURE 7: Amount of time that respondents had been involved in Maine Aquaculture in 2012 (n=45)

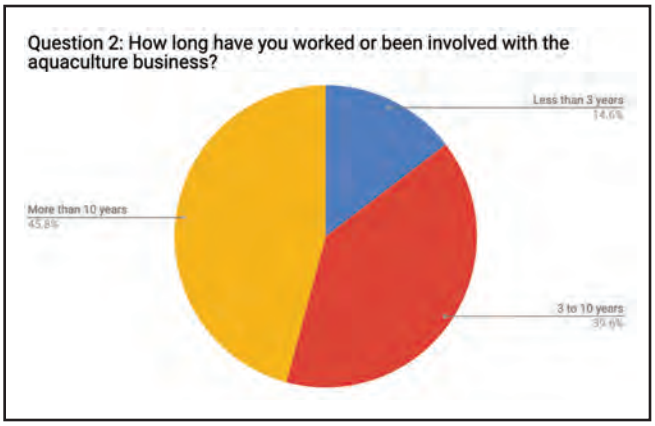
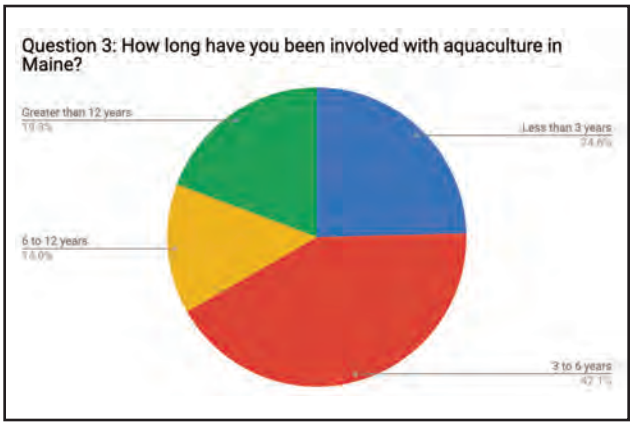
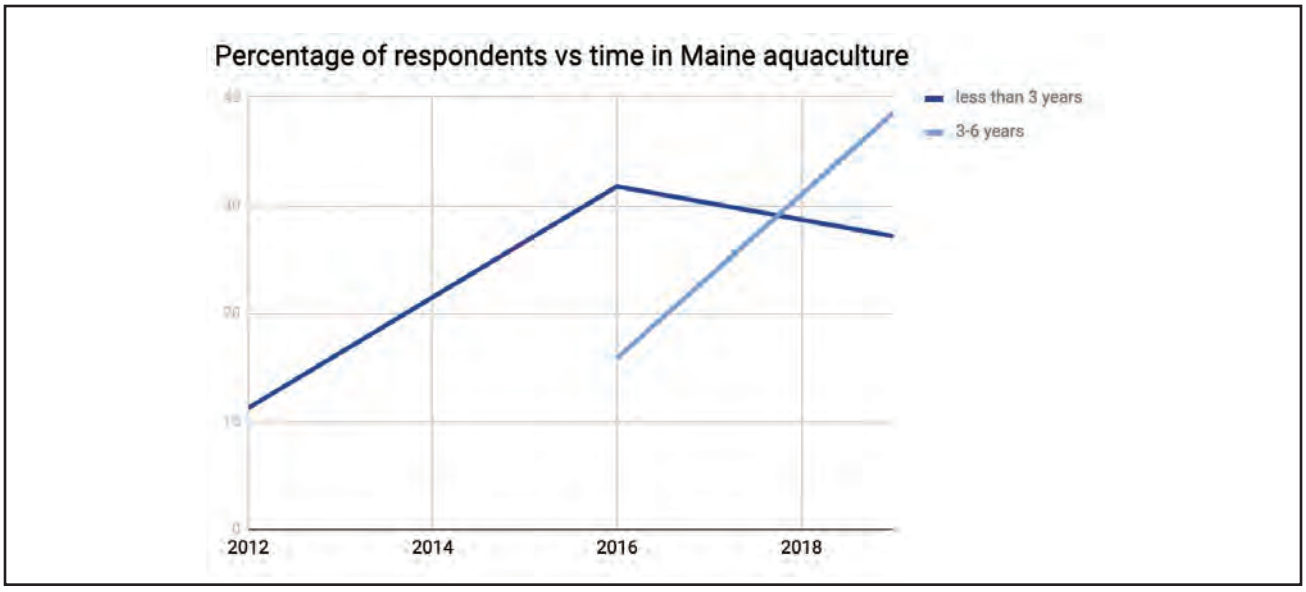


FIGURE 8: Amount of time that responding shellfish growers had been involved in Maine Aquaculture in 2019 (n=57)



The percentage of the responding grower population that was involved in Maine aquaculture for less than 3 years peaked in 2016 (Figure 9).

FIGURE 9: Amount of time that respondents had been involved in Maine Aquaculture (%)



In 2019, a third of the responding shellfish growers have been involved in Maine aquaculture for more than 6 years (Figure 8). However, the shellfish sub-sector also has a large number of respondents who are newer farmers (less than 6 years) (Figure 8). Reflecting the nascent nature of the sea scallop sector, all responding scallop growers have been involved in Maine aquaculture for less than 6 years (Figure 11).

More than two-thirds of responding oyster growers have been involved in the sector for 6 years or less (Figure 10) reflecting the recent growth in this sector.

In contrast, even though the mussel sector is small, it has been active in Maine for many years, and the responding mussel growers have all been involved in aquaculture for more than 6 years, and most for more than 12 years (Figure 12).
The finfish farming sector has been active in Maine for many years although there has been recent diversification (see Question 5) of species and production technology. The responding finfish growers have all been involved in aquaculture for more than 3 years, and most for more than 12 years. (Figure 13)

FIGURE 10: Time that responding oyster growers had been involved in Maine Aquaculture (n=44)

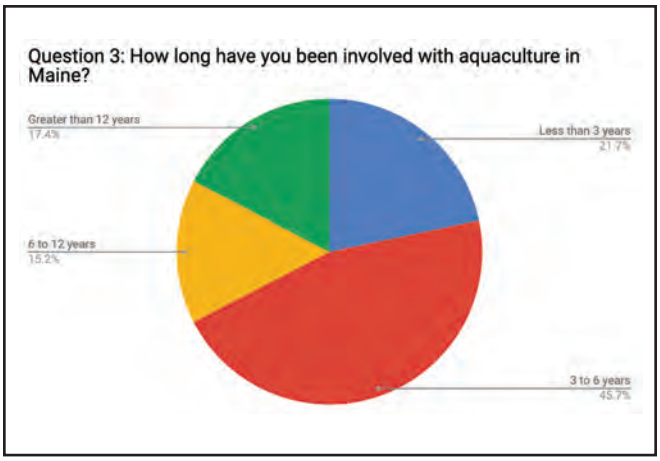


FIGURE 11: Amount of time that responding scallop growers had been involved in Maine Aquaculture (n=6)

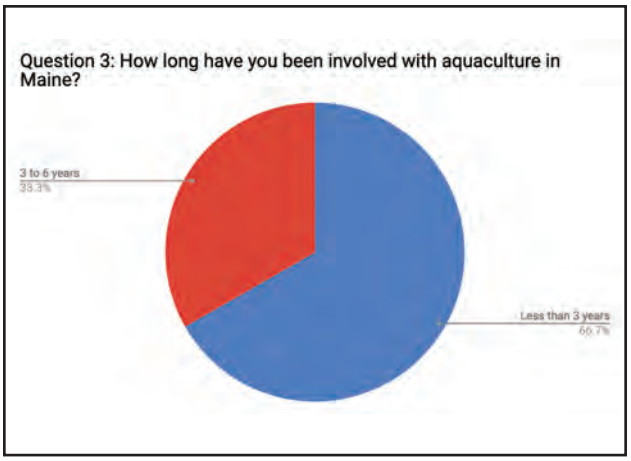


FIGURE 12: Amount of time that responding mussel growers had been involved in Maine Aquaculture (n=3)

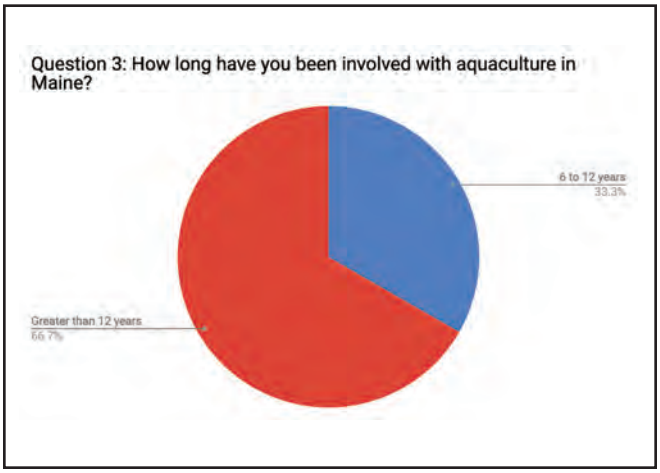


FIGURE 13: Amount of time that responding Finfish growers had been involved in Maine Aquaculture (n=4)

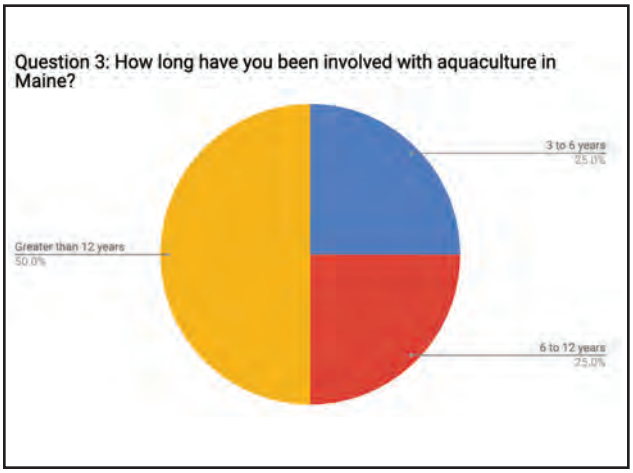
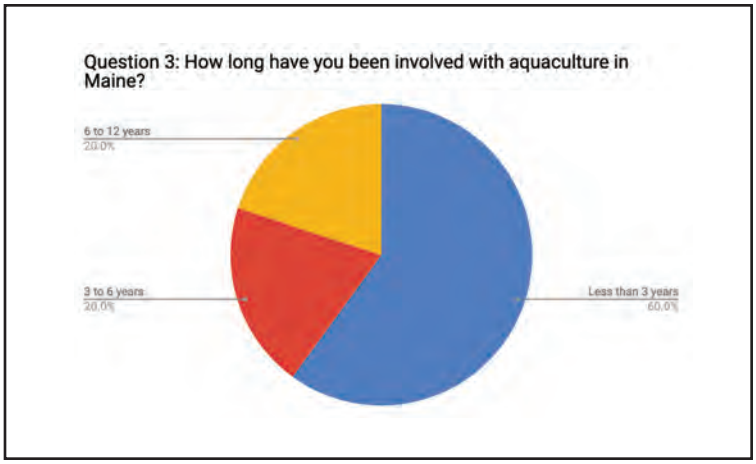


FIGURE 14: Amount of time that responding sea vegetable growers had been involved in Maine Aquaculture (n=5



The sea vegetable farming sector is relatively new and this is reflected in the length of time sea vegetable farmers have been involved in Maine aquaculture; most of the responding sea vegetables growers have been involved in aquaculture for less than 3 years. (Figure 14)

Question 4. Which of the following culture systems do you work with? (check all that apply)

2019 Survey: Answered: 69 Skipped: 141

All responding growers (total n=70) were guided to this question but 1 grower chose not to answer (shellfish n=57, finfish n=4, sea vegetable n=5 and recreational growers n=3).

Surface cages are the most commonly used culture system and are used by shellfish growers, recreational growers, and sea vegetable growers.

Recirculating Aquaculture Systems (RAS) are used by all sectors.

FIGURE 15: Frequency Distribution of Culture Systems used by Responding Producers in 2019

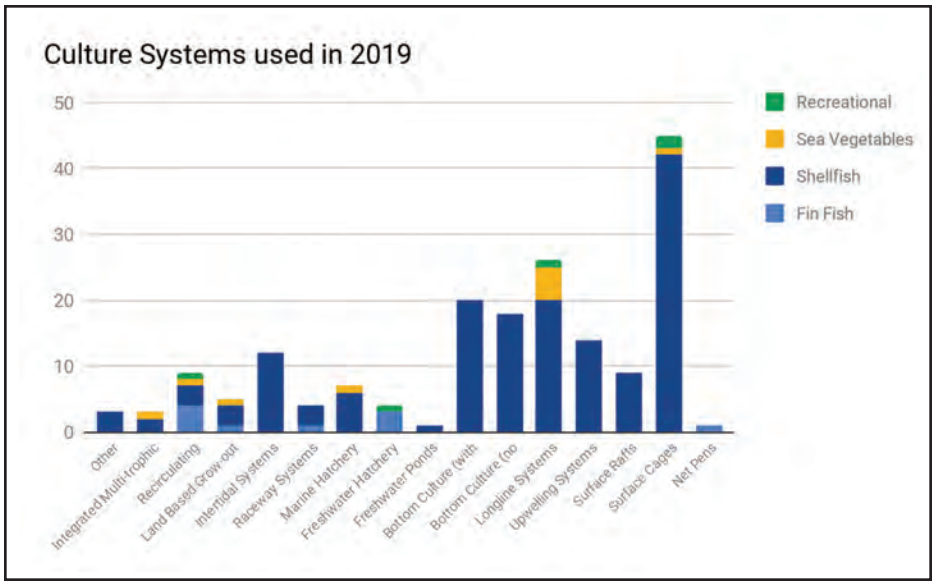


FIGURE 16: Frequency Distribution of Culture Systems used by Responding Producers in 2016

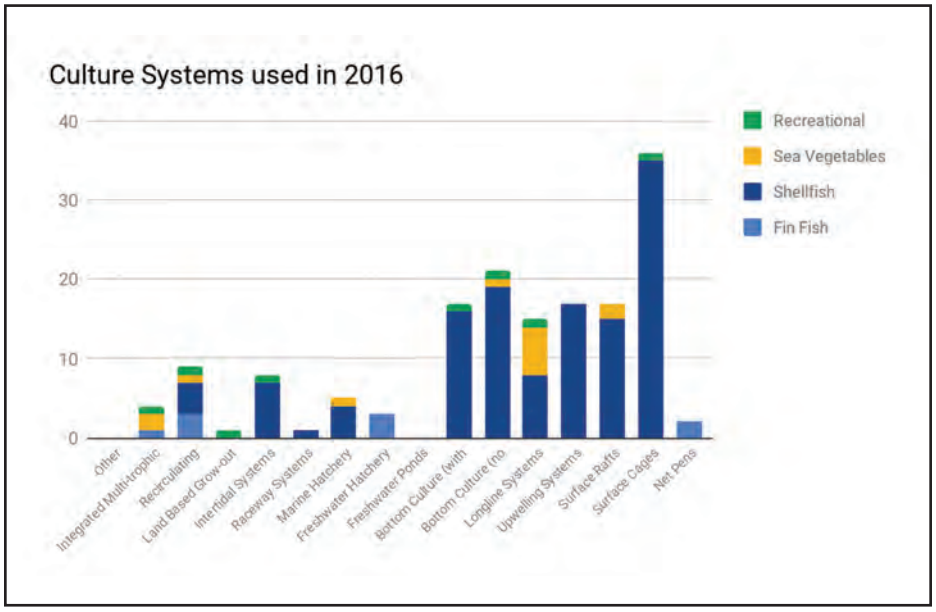


FIGURE 17: Frequency Distribution of Culture Systems used by Responding Producers in 2012

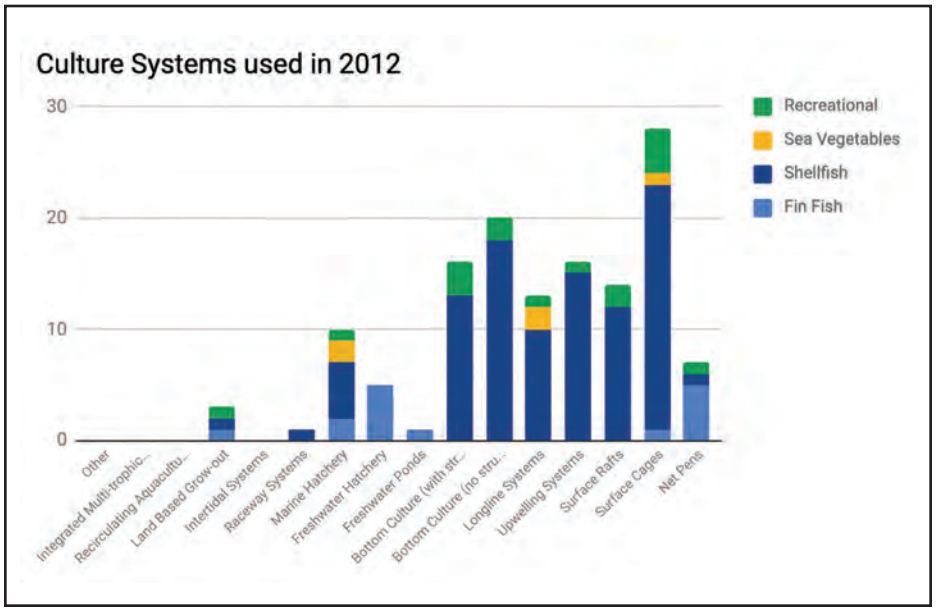


Table 1: Aquaculture Culture Systems in Maine (as represented by survey respondents)

Culture System	2012	2016	2019
Net Pens	✓	✓	✓
Surface Cages	✓	✓	✓
Surface Rafts	✓	✓	✓
Upwelling Systems	✓	✓	✓
Longline Systems	✓	✓	✓
Bottom Culture (no structures)	✓	✓	✓
Bottom Culture (with structures)	✓	✓	✓
Freshwater Ponds	✓		✓
Freshwater Hatchery	✓	✓	✓
Marine Hatchery	✓	✓	✓
Raceway Systems	✓	✓	✓
Intertidal Systems		✓	✓
Land Based Grow-out Systems	✓	✓	✓
Recirculating Aquaculture Systems		✓	✓
Integrated Multi-trophic Systems		✓	✓
Other			✓

The culture systems used by growers have changed only slightly over time (Table 1; Figures 15-17). The following systems were not reported by survey respondents in 2012:

- Integrated Multi-trophic Aquaculture Systems
- Recirculating Aquaculture Systems
- Intertidal Systems

This diversification may be a consequence of the culture of emerging species (see Question 5), an increase in experimentation by Maine growers, or gear innovations nationally and globally.

Question 5. Please indicate the principal species you culture (check only one box).

2019 survey: Answered: 69 Skipped: 141

All growers (total n=70) were guided to this question but 1 grower choose not answer (shellfish n=57, finfish n=4, sea vegetable n=5 and recreational growers n=3).

FIGURE 18: Principal Species Cultured by Maine Growers in 2019

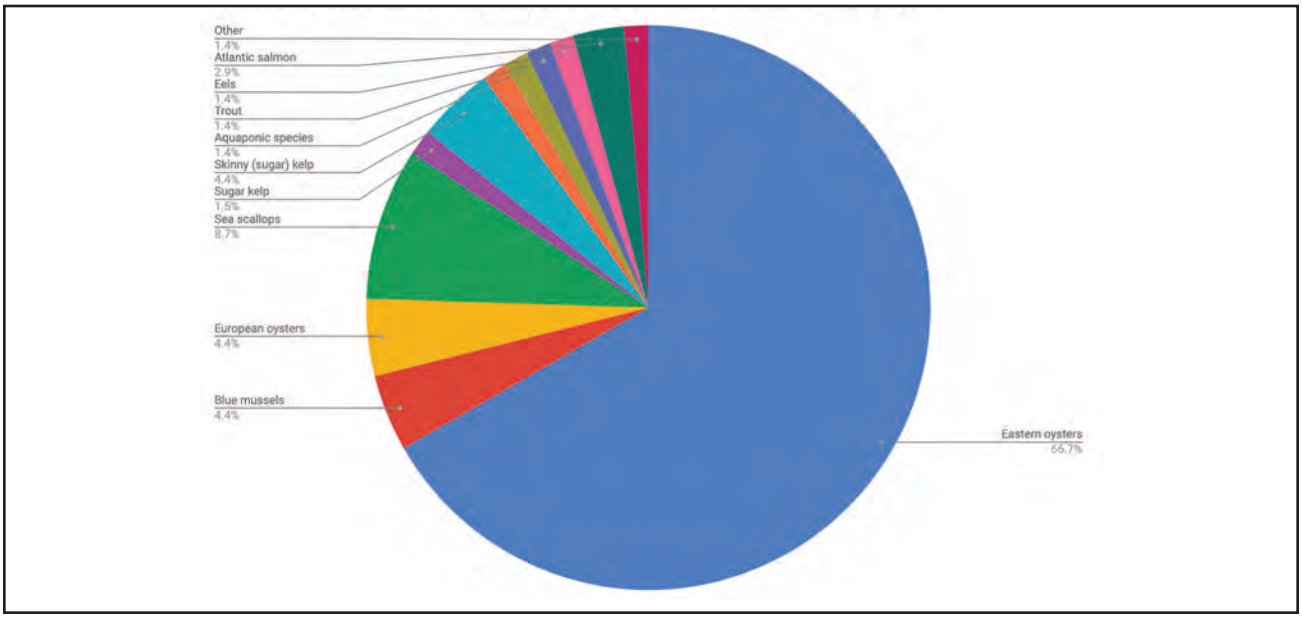
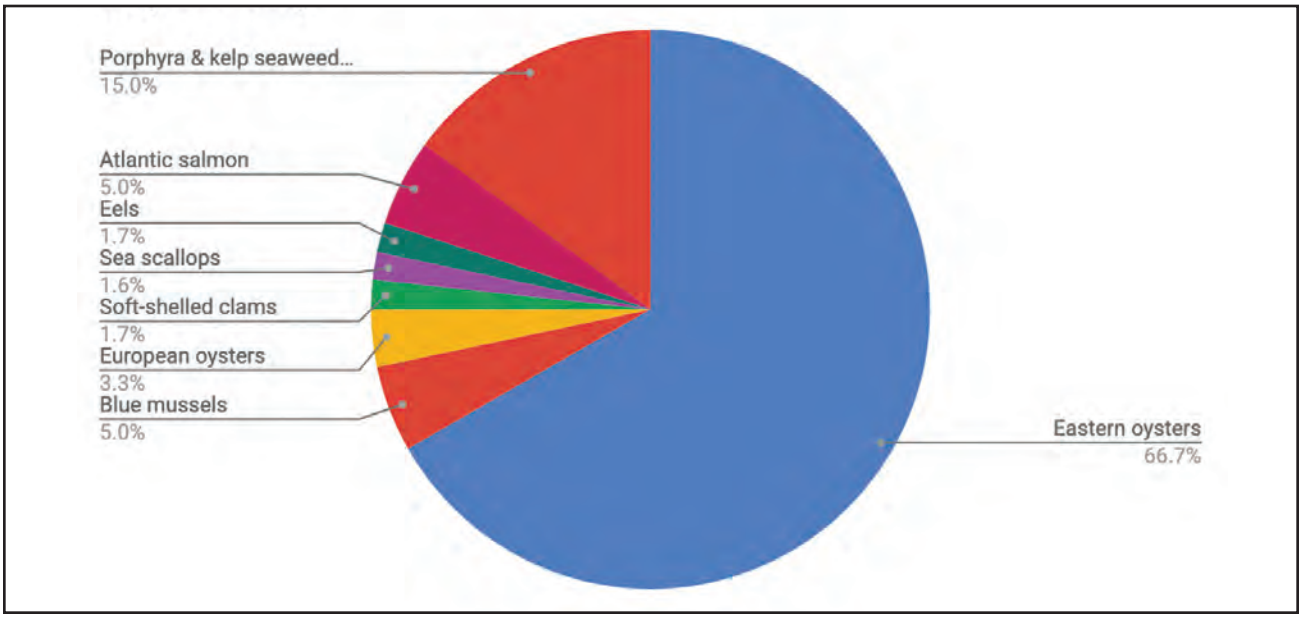


FIGURE 19: Principal Species Cultured by Maine Growers in 2016



There have been changes in the diversity of "main crop" species represented in the research priorities surveys over time (Table 2).

Finfish species represented in the surveys have continued to include Atlantic salmon, but the marine species Atlantic cod and Atlantic halibut were only represented in the 2012 survey. Eels, trout, and aquaponic species are all now represented by the 2019 research priorities survey.

Hard-shell clams, soft-shelled clams, and green sea urchins were represented in previous research priorities but are no-longer represented as principal cultured species in 2019. In contrast, sea scallops are now clearly represented in the research priorities reported by growers for 2019.

Macro- and micro-algae species are represented in 2019. Only kelp species are represented as principal species..

FIGURE 20: Principal Species Cultured by Maine Growers in 2012

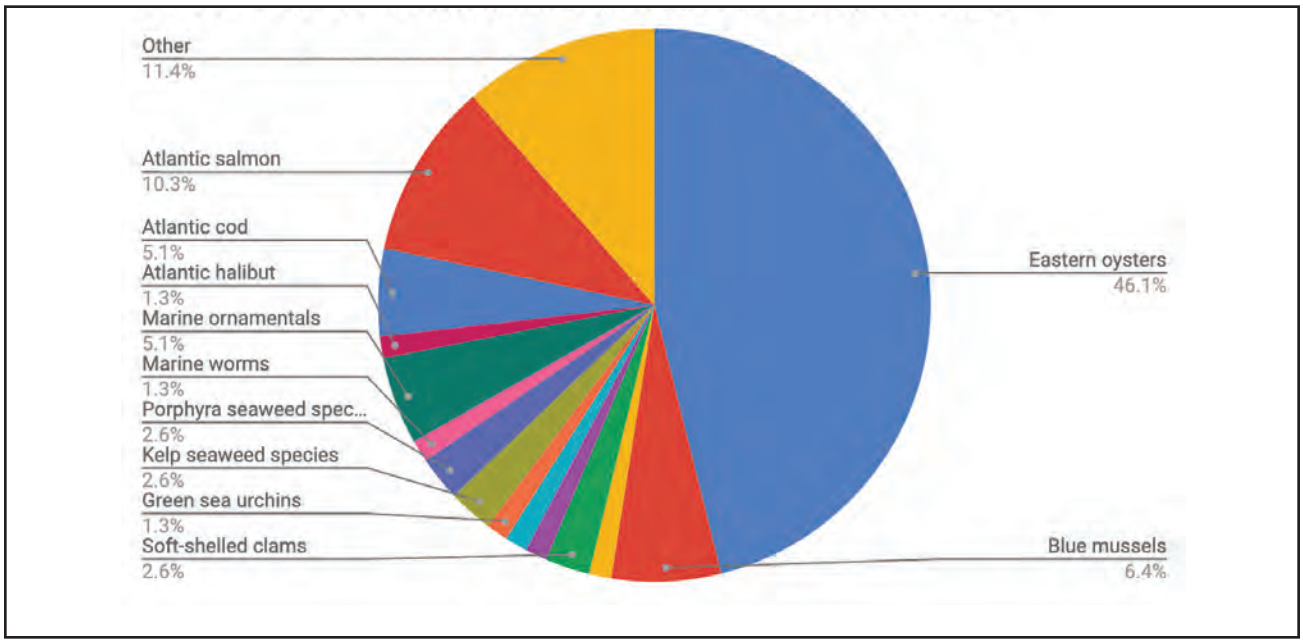


Table 2: Species Cultured in Maine (as represented by responding growers)

Principal Species	2012	2016	2019
Atlantic salmon	✓	✓	✓
Atlantic cod	✓		
Atlantic halibut	✓		
Eels		✓	✓
Trout			✓
Baitfish			
Aquaponics species			✓
Ornamental species	✓		
Eastern oysters	✓	✓	✓
European oysters	✓	✓	✓
Blue mussels	✓	✓	✓
Hard clams	✓		
Soft-shelled clams		✓	
Razor clams			
Surf clams			
Arctic surf clams			
Sea scallops		✓	✓
Bay scallops			
Green sea urchins	✓		
Marine worms			
Sugar kelp	✓ (kelp species not presented as separate species in the 2012 survey)	✓ (sea vegetables not presented as separate species in the 2016 survey)	✓
Skinny sugar kelp			✓
Winged kelp			✓
Horsetail kelp			
Dulse			
Irish moss			
Porphyra species			
Other			✓ (microalgae)

Question 6. What is the single greatest barrier to your success?

2019 Survey: Answered: 62; Skipped: 148

All growers (shellfish, finfish, sea vegetable and recreational growers) were guided to this question and 8 skipped the question. This was an open question, and a qualitative, thematic analysis was carried out.

Overarching themes in 2019: Several cross-cutting themes were identified as barriers by more than one sector in 2019:

- Regulations and the lease process (in particular the time required to obtain a standard lease)
- Access to capital
- Crop loss

Overarching themes over time: Access to funding, capital, shellfish health (although not expressed as crop loss), and regulations were also common themes in 2016, indicating that these barriers are still experienced by the aquaculture sector in Maine.

Access to capital and shellfish disease are also identified as urgently important topics in the survey questions in 2016 and 2019 (see question 9).

Seedstock/hatchery production was a common barrier in 2012 but did not come up as a barrier on 2016 or 2019. Similarly, predation was a theme in 2012 that did not recur in 2016 and 2019. However, nursery priorities and the management of invasive species/predators/biofouling are identified as urgently important research priorities in 2019.

Finfish growers identified 3 key barriers to business success in 2019:

- Infrastructure. For finfish growers this was expressed as a trained workforce
- Crop-loss due to parasites
- Access to capital

Feedback: "Workforce development and making sure training programs are in place so that we can hire local people"

"Sea lice and lack of approved treatment options"

Sea vegetable growers identified 2 key barriers to business in 2019:

- Infrastructure. For sea vegetable growers, this referred to processing infrastructure
- Regulations

Feedback: "Processing/drying facilities"

"Open grow areas"

Shellfish growers identified a greater number of barriers due to the higher number of respondents.
Key barriers included:

- Access to information. A lack of easy access to up to date, reliable information was identified as a barrier
- Community acceptance. This was mentioned in relation to bad press generated by recent high profile lease applications, but also potential conflict with other water users (e.g. lobstermen, and riparian landowners)
- Market. This was in reference to both anxiety about local market saturation, and how to identify markets as a new grower
- Regulation. This was sometimes referred to as "red tape", and there were mentions of regulations to prevent growth of the industry
- Access to capital was mentioned mostly as a barrier for new growers starting out with a need for expensive equipment
- Crop-loss (particularly overwintering losses)
- Time. This was mostly in relation to time to work the farm, and time to balance workloads, but also referred to the delay between investment and income
- Business planning/growth. Many growers identified the need for support to scale up their business. This included support for paperwork, lease applications etc, as well as a need for business planning knowledge

Feedback: "Regulations meant to stop our industry"

"Bad press that new lease application explosion is causing ..."

"Local market saturation (related: price drops, bottlenecks for getting product direct to customers or sold out of state"

"Potential conflicts with lobstermen & shorefront owners"

"A centralized source for information on oyster culture, trouble-shooting etc."

"I have too much going on to tend it all "

In addition to these overarching barriers to business success, there were some species-specific barriers identified by different shellfish sectors.

Sea scallop growers identified biotoxins, and seed supply as barriers to business success.

Feedback: "Obtaining seed"

"Cost of biotoxin testing"

Oyster growers identified overwintering as a barrier to business success.

Feedback: "High mortality during overwintering"

Question 7. What do you see as the greatest opportunity to succeed in your venture?

2019 Survey: Answered: 55; Skipped: 155

All growers (shellfish, finfish, sea vegetable and recreational growers) were guided to this question and 15 skipped the question. This was an open question, and a qualitative, thematic analysis was carried out.

Overarching themes: Marketing was a cross-cutting theme identified by many sectors as the greatest opportunity for success. This theme incorporated the importance of name recognition and the Maine brand, and also the opportunities associated with the expansion of markets and products. The opportunities associated with expanding markets and sales, and product diversification were also common themes in previous surveys (in 2016 and 2012).

Additional themes included the opportunities to succeed related to:

- Choosing a good site (e.g. a high quality growing area)
- Securing appropriate resources (e.g. for new equipment)
- Product diversification (e.g. diversifying species that are farmed, as well as exploring non-traditional revenue streams)
- Good public relations/community cooperation
- The wisdom of "don't overreach" (i.e. don't try to grow too quickly as a new business)

Feedback: "To integrate into a community"

"The market wants fresh farmed shellfish from Maine, and I believe there are a few species that aren't farmed yet that have significant potential"

"The quality of Maine grown shellfish and recognition of Maine brand"

"Product quality and excellent name recognition for Maine seafood"

"Species diversification and not-traditional revenue streams"

"Diversification of revenue streams through new products and species"

"Good riparian relations"

Unlike question 6 (identifying barriers), there was little variation in the responses to question 7 (identifying opportunities for success) that could be attributed to species.

The only species-specific opportunities for success that were identified were for sea scallops and related to sales of product.

Feedback: "Direct to consumer sales"

"Ability to sell live product"

Question 8. Please indicate all the species you are currently involved with (check all that apply).

2019 Survey; Answered: 183; Skipped: 27. All survey respondents were guided to this question.

By jointly analyzing responses to questions 5 and 8, including responses filtered for growers or non-growers, it was possible to identify primary commercial species, secondary commercial species, and non-commercial species (Table 3).

Table 3: Aquacultured Species in Maine, 2019 (as represented by survey respondents)

Principal Commercial Species	Only Secondary Commercial Species	Only Commercial Species	Only Non-commercial
Atlantic salmon	✓		
Eels	✓		
Trout	✓		
Aquaponic spp	✓		
Atlantic cod			✓
Atlantic halibut			✓
Baitfish			✓
Ornamentals			✓
Blue mussels	✓		
Eastern oysters	✓		
European oysters	✓		
Sea scallops	✓		
Hard clams		✓	
Surf clams		✓	
Softshell clams		✓	
Razor clams		✓	
Bay scallops		✓	
Arctic surf clams			✓
Sugar kelp	✓		
Skinny kelp	✓		
Winged kelp	✓		
Horsetail kelp		✓	
Irish moss		✓	
Dulse		✓	
Porphyra spp		✓	
Green sea urchin		✓	
Marine worms		✓	
Other	microalgae	Wild set macroalgae	

Twelve different species were identified as "main crop" species by survey respondents. An additional twelve species were identified as "secondary crop" species. As such, the research, development, and education priorities identified in the 2019 survey represent those 24 species.

Shellfish Sector Priorities

Question 9. How would you rate the importance of research in each of these shellfish sector areas:

Survey respondents were asked to rate a list of sector research areas using a 5 point Likert-scale (urgently important to not important). Respondents could also select a "Not Relevant to Me" option. Although all respondents were guided to this question, the following results have been filtered for shellfish growers only. The analysis includes parsing the priorities of different shellfish sectors (oysters, scallops, mussels), and newer vs. more experienced growers.

Table 4: Top 3 R&D Priorities for the Shellfish Sectoras rated by all shellfish growers (n=54)

Importance	Topic	Weighted Average*
Urgently Important	Shellfish Diseases	1.78
Moderately Important	Crop Protection	2.11
Moderately Important	*Vibrio* Detection/Resistance	2.14

*Lower numbers indicate higher priorities

Collectively, shellfish growers identify shellfish diseases as the most important research priority (Table 4). All the other listed areas were scored as moderately important research priorities (Figure 21). Research on probiotics was rated as of the lowest priority (Figure 21).

At 77% of responding shellfish growers, Eastern oyster farmers are driving the importance of the shellfish diseases, crop protection, and *vibrio* detection/resistance research priorities (Table 5; Figure 22). Responding scallop (Table 6; Figure 23) and mussel (Table 7; Figure 24) growers identified alternative research priorities.

Table 5: Top 3 R&D Priorities for the Shellfish Sector as rated by all Eastern oyster growers (n=43)

Importance	Topic	Weighted Average*
Urgently Important	Shellfish Diseases	1.63
Moderately Important	*Vibrio* Detection/Resistance	2.02
Moderately Important	Crop Protection	2.07

*Lower numbers indicate higher priorities

Table 6: Top 3 R&D Priorities for the Shellfish Sector as rated by all scallop growers (n=6)

Importance	Topic	Weighted Average*
Urgently Important	Direct Sales	1.67
Urgently Important	Seed Collection	1.8
Urgently Important	Selective Breeding Crop Protection Biofouling Control	2.0

*Lower numbers indicate higher priorities

Scallop growers identified direct sales and seed collection as the two most important research priorities for their businesses. Selective breeding, crop protection, and biofouling control were also identified as urgently important (Table 6).

All other listed research areas were ranked as moderately important, with probiotics rated as being of lowest priority (Figure 23).

Table 7: Top 3 R&D Priorities for the Shellfish Sector as rated by all mussel growers (n=3)

Importance	Topic	Weighted Average*
Urgently Important	Site Selection	1.67
Urgently Important	Seed Collection	1.8
Urgently Important	Reducing Grow-out Period Nursery Technology Biofouling Control	2.0

*Lower numbers indicate higher priorities

Mussel farmers identified site selection and seed collection as the two most important research priorities for their businesses. Reducing the grow-out period, nursery technology, and biofouling control were also identified as urgently important (Table 6).

Several listed research areas were ranked as moderately important (Figure 23).

Probiotic research, *vibrio* detection and resistance, direct sales from farms, and selective breeding were rated by mussel farmers as not important research areas (Figure 23).

Vibrio detection and resistance was only rated by oyster growers as a priority, not by mussel and scallop farmers.

Seed collection strategies were rated as urgently important priorities by both mussel and scallop farmers, as unlike oyster farmers, mussel and scallop farmers rely on wild seed.

Biofouling control was also rated as urgently important priorities by both mussel and scallop farmers.

Newer vs. More Experienced Growers:

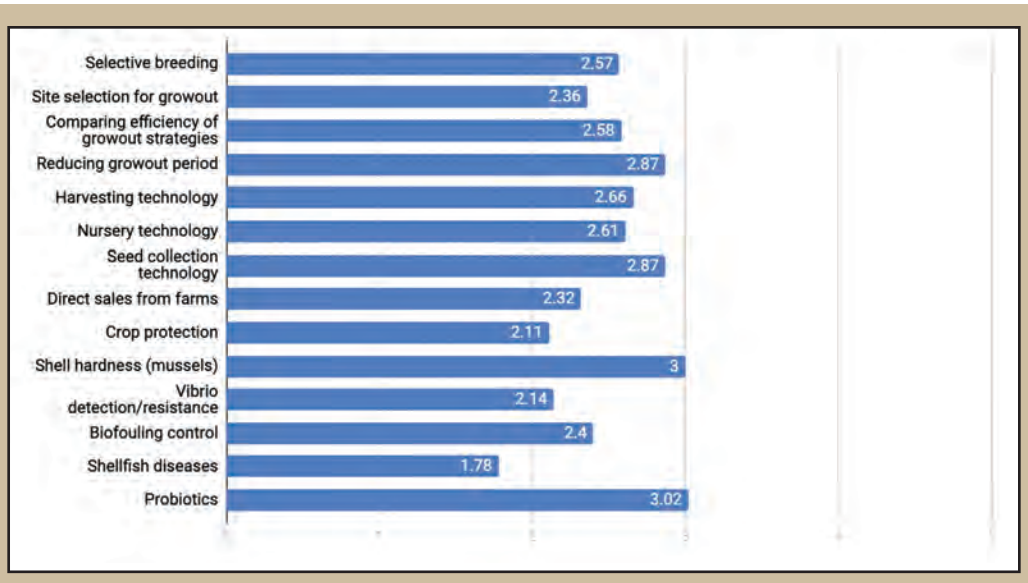
Scallop grower priorities did not change according to the time growers have been involved in aquaculture, because all scallop growers have been involved in aquaculture for LESS than 6 years (Table 8).

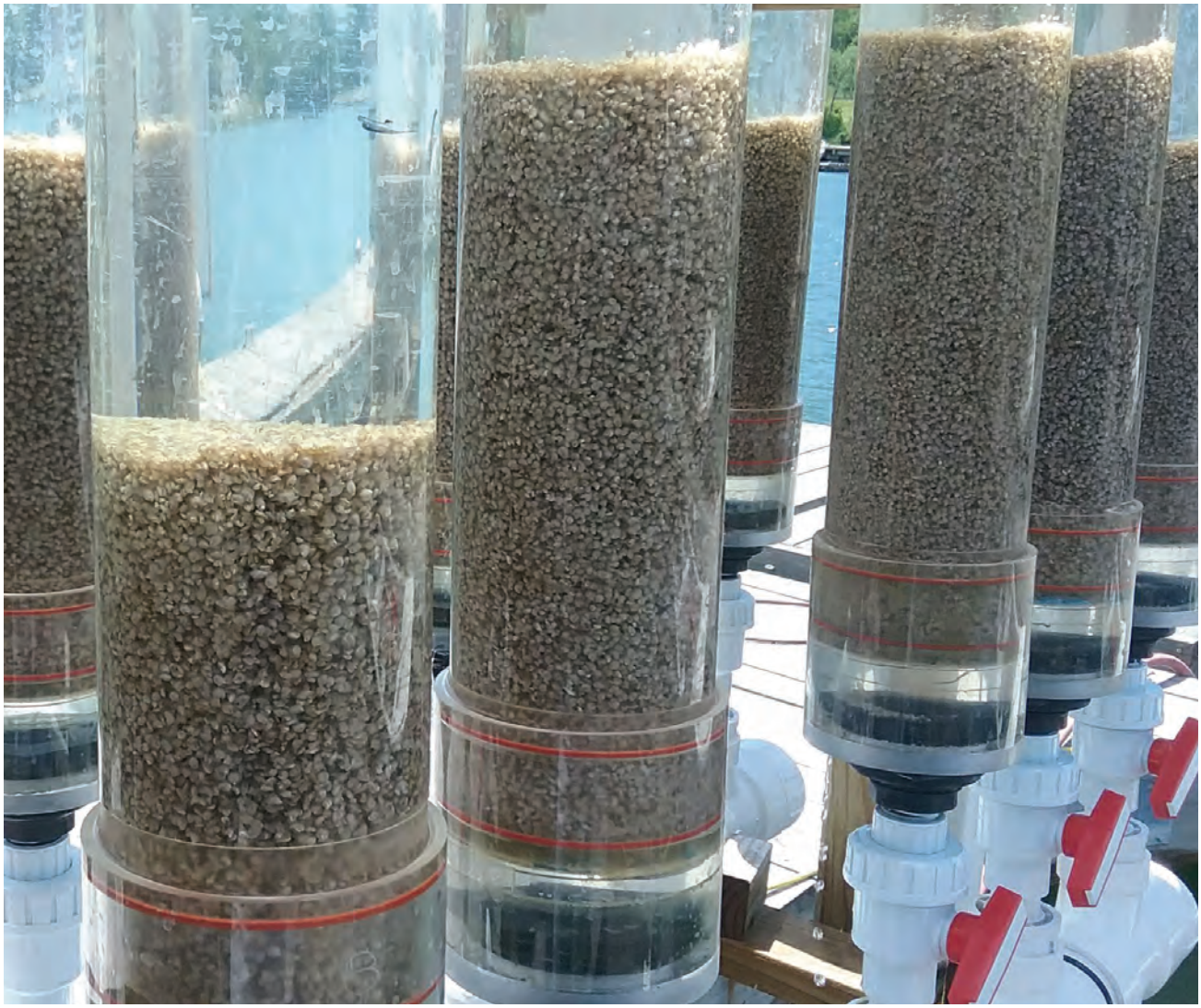
Mussel grower priorities did not change according to the time growers have been involved in aquaculture, because all mussel growers have been involved in aquaculture for MORE than 6 years (Table 8).

When looking at the whole shellfish sector, there were only subtle differences in the priorities identified by newer vs. more experienced growers (Table 9, Figure 25, Figure 26), and again this appears to be driven by oyster growers (Table 10, Figure 27, Figure 28).

An interesting difference that can be seen between newer vs. more experienced shellfish growers is that, generally, newer growers rate priorities as higher priority (Table 9, Figure 25, Figure 26)

FIGURE 21: Shellfish Sector R&D Priorities* in 2019 (all shellfish growers) (n= 54)





BUPSY Oyster Seed System Photo by Anne Langston Noll

FIGURE 22: Shellfish Sector R&D Priorities* in 2019 (Eastern oyster growers) (n=43)

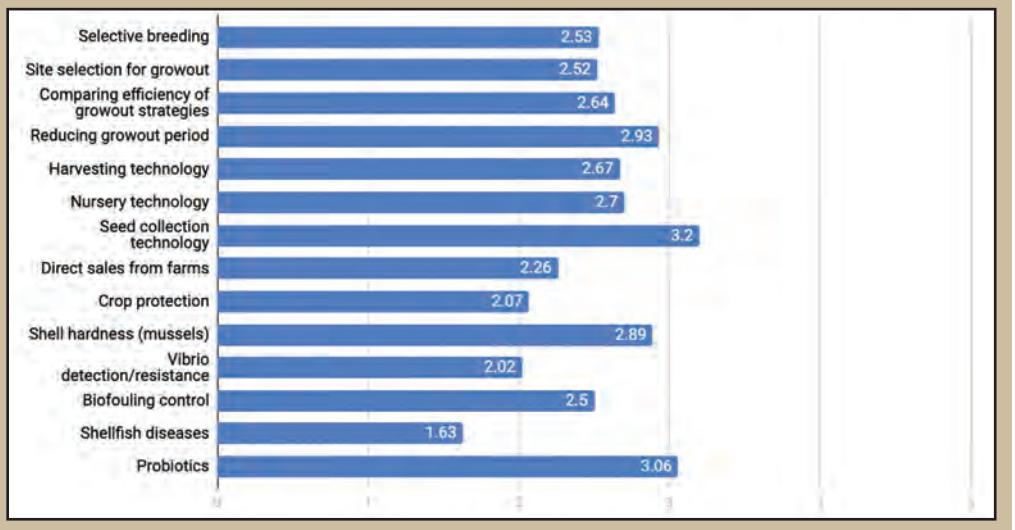


FIGURE 23: Shellfish Sector R&D Priorities* in 2019 (scallop growers) (n= 6)

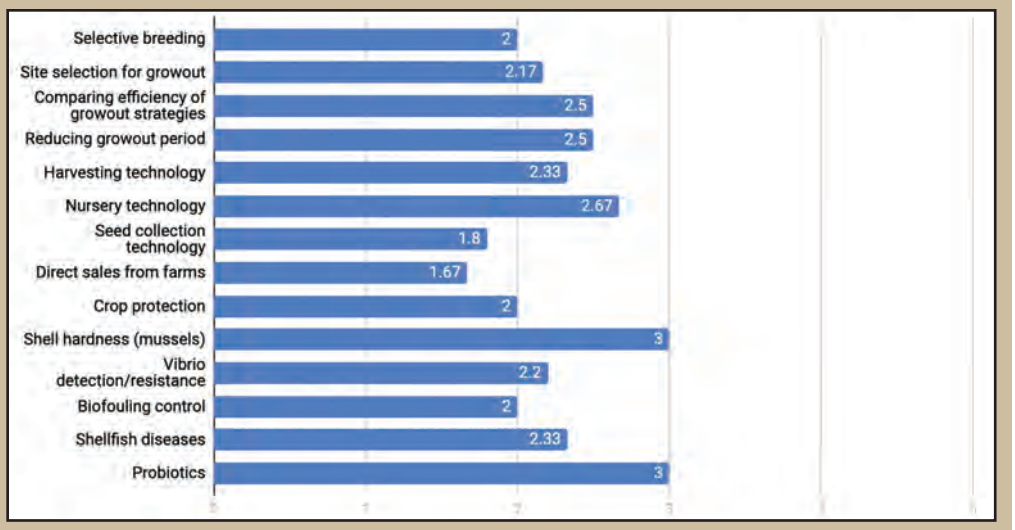
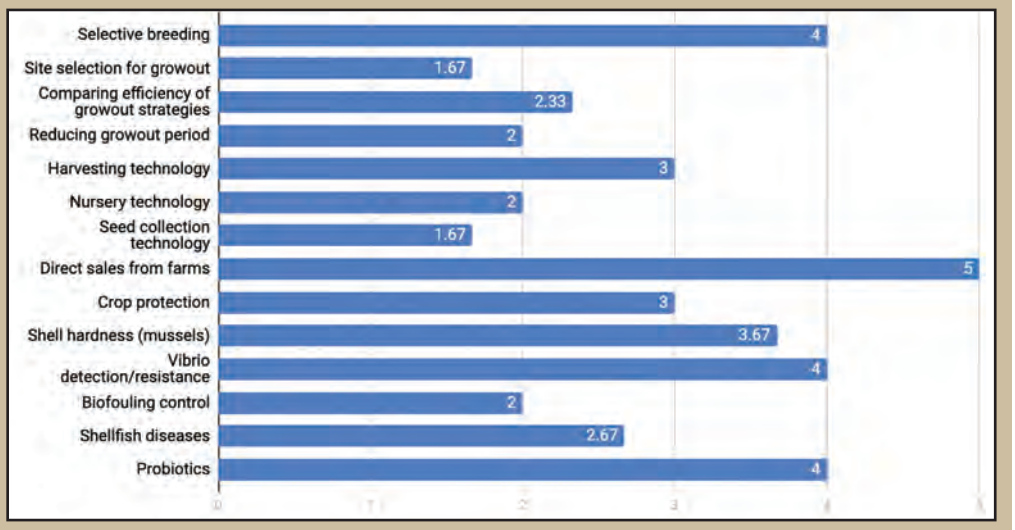


FIGURE 24: Shellfish Sector R&D Priorities* in 2019 (mussel growers) (n=3)



*Lower numbers indicate higher priorities

Table 8: Newer vs More Experienced Responding Growers

	All shellfish grower	Oyster growers	Scallop growers	Mussel growers
Newer Growers **<6 years in the the sector**	66% of all shellfish growers have been in the sector for less than 6 years	67% of all oyster growers have been in the sector for less than 6 years	100% of scallop growers have been in the sector for less than 6 years	None
Newer Growers **>6 years in the the sector**	34% of all shellfish growers have been in the sector for more than 6 years	33% of all oyster growers have been in the sector for more than 6 years	None	100% of mussel growers have been in the sector for more than 6 years

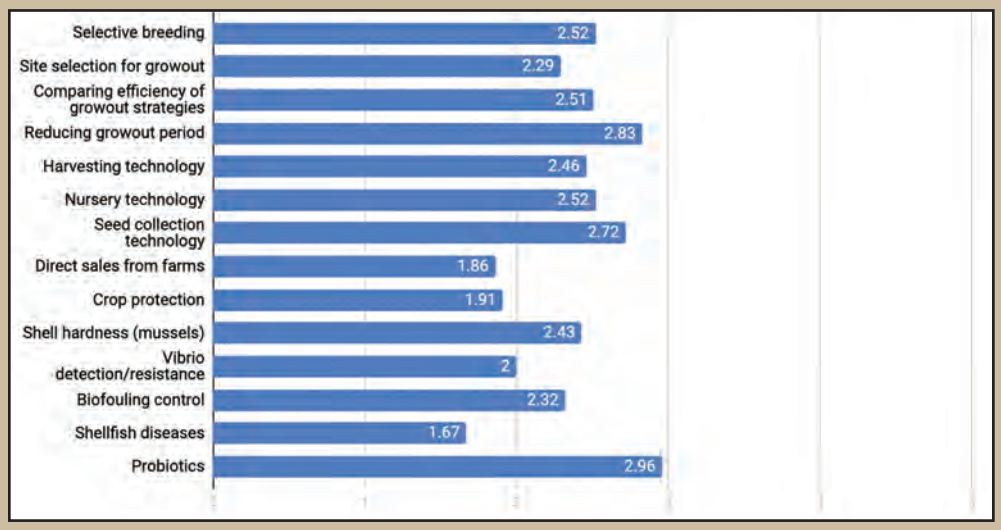
Table 9: Top 3 R&D Priorities for the Shellfish Sector
Newer vs experienced

	Combined	Newer growers <6 years in the sector	Scallop growers > 6 years in the sector
1	Shellfish Diseases Urgently important	Shellfish Diseases Urgently important	Shellfish Diseases Urgently important
2	Crop Protection Moderately important	Direct Sales from Farms Urgently important	*Vibrio* Detection/Resistance Moderately important
3	*Vibrio* Detection/Resistance Moderately important	Crop Protection Urgently important	Crop Protection Moderately important

Table 10: Top 3 R&D Priorities for the Oyster Sector
Newer vs experienced

	Combined	Newer growers <6 years in the sector	Scallop growers > 6 years in the sector
1	Shellfish Diseases Urgently important	Shellfish Diseases Urgently important	Shellfish Diseases Urgently important
2	*Vibrio* Detection/Resistance Moderately important	Crop Protection Urgently important	*Vibrio* Detection/Resistance Moderately important
3	Crop Protection Moderately important	Direct Sales from Farms Urgently important	Selective Breeding Moderately important

FIGURE 25: Shellfish Sector R&D Priorities* in 2019 (newer shellfish growers) (n=36))



IGURE 26: Shellfish Sector R&D Priorities* in 2019 (more experienced shellfish growers) (n=18)

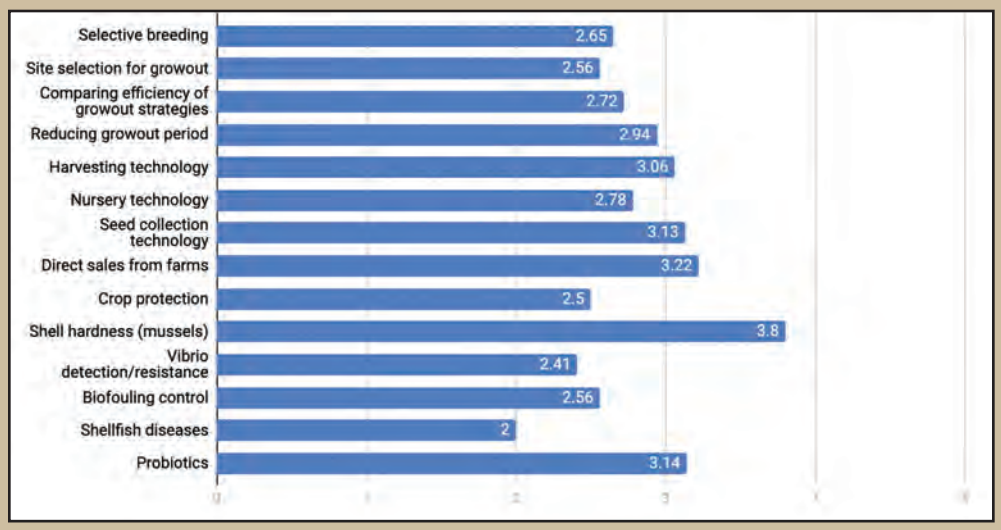
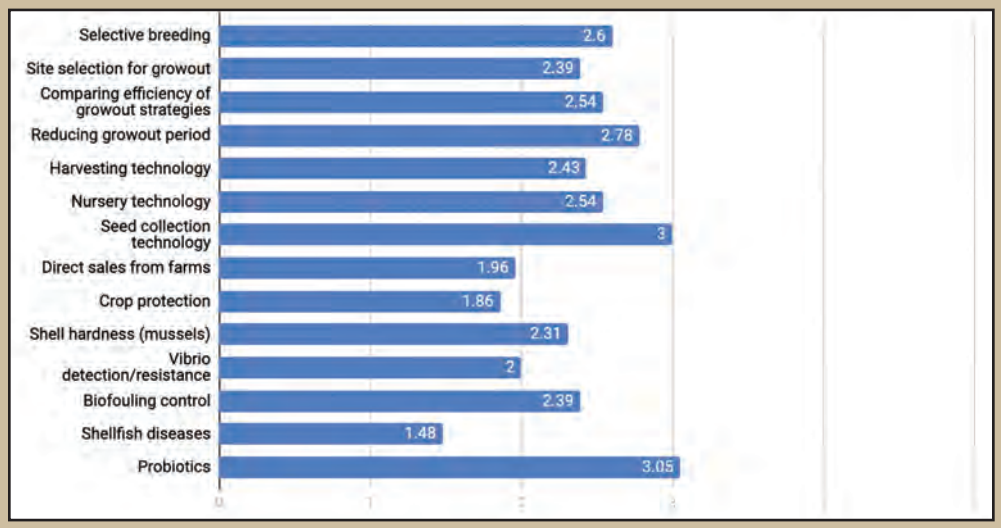
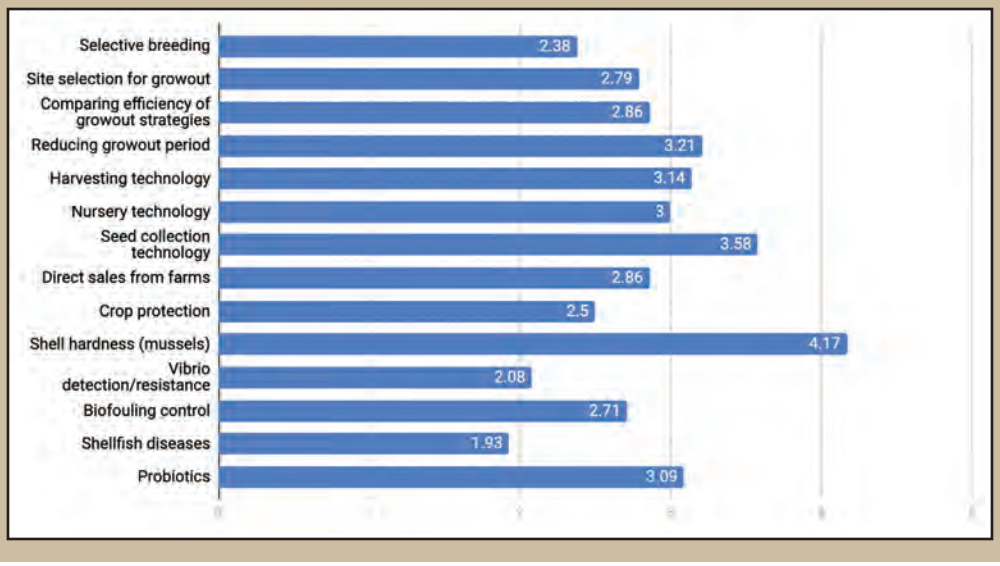


FIGURE 27: Shellfish Sector R&D Priorities* in 2019 (newer oyster growers) (n=29)



*Lower numbers indicate higher priorities

FIGURE 28: Shellfish Sector R&D Priorities* in 2019 (more experienced oyster growers) (n=14)



*Lower numbers indicate higher priorities

Finfish Sector Priorities:

Question 10. How would you rate the importance of research in each of these finfish sector areas:

Survey respondents were asked to rate a list of sector research areas using a 5 point Likert-scale (urgently important to not important). Respondents could also select a "Not Relevant to Me" option. Although all respondents were guided to this question, the following results have been filtered for finfish growers only.

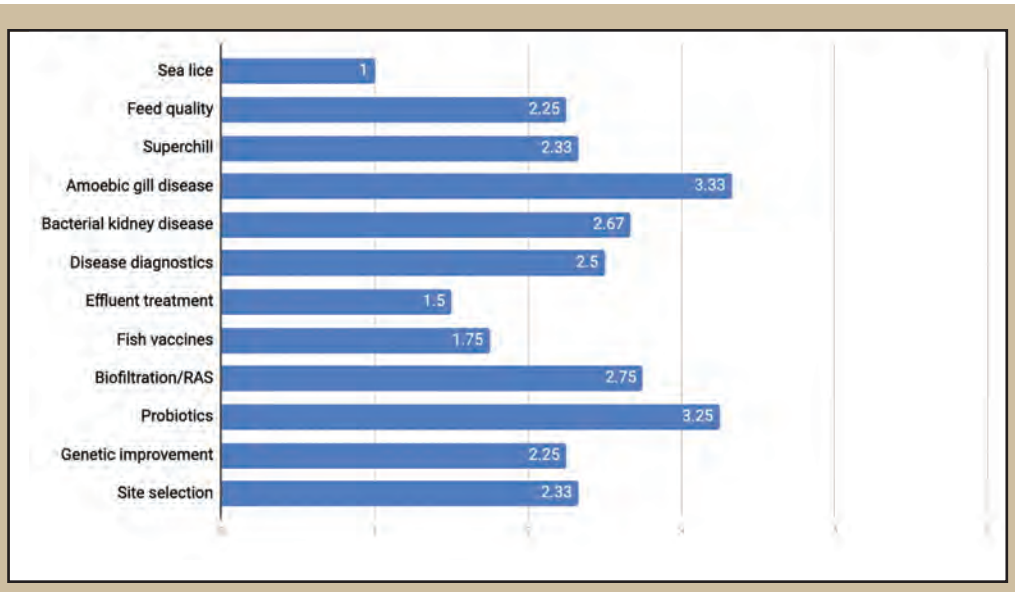
Due to the small number of finfish grower respondents, it is not appropriate to parse results for species-specific priorities nor the priorities of newer vs. more experienced growers.

Table 11: Top 3 R&D Priorities for the Finfish Sector (n=4)

Importance	Topic	Weighted Average
Urgently Important	Sea Lice	1.00
Urgently Important	Effluent Treatment	1.50
Urgently Important	Fish Vaccines	1.75

Sea lice, effluent treatment and fish vaccine were all identified by responding finfish growers as urgently important research priorities. All the other listed areas were scored as moderately important research priorities. Amoebic Gill Disease was rated as of lowest importance.

FIGURE 29: Finfish Sector R&D Priorities* (n=4)



*Lower numbers indicate higher priorities

Sea Vegetable Sector Priorities:

Question 11. How would you rate the importance of research in each of these sea vegetable areas:

Survey respondents were asked to rate a list of sector research areas using a 5 point Likert-scale (urgently important to not important). Respondents could also select a "Not Relevant to Me" option. Although all respondents were guided to this question, the following results have been filtered for sea vegetable growers only.

Due to the small number of sea vegetable grower respondents, it is not appropriate to parse results for species-specific priorities nor the priorities of newer vs. more experienced growers.

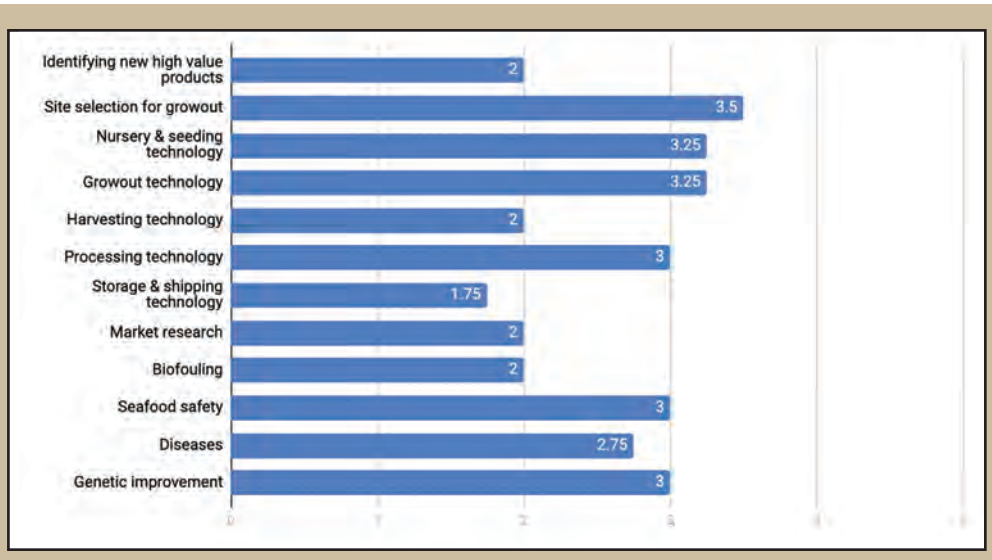
Table 12: Top 3 R&D Priorities for the Sea Vegetable Sector (n=4)

Importance	Topic	Weighted Average
Urgently Important	Storage & Shipping Technology	1.75
Urgently Important	Identifying New High Value-added Products	2.0
	Harvesting Technology	
	Market Research	
	Biofouling	2.0

Storage and shipping technology was the most important research priority identified by sea vegetable growers. Identifying New High Value-added Products, Harvesting Technology, Market Research, and Biofouling were also identified as urgently important priorities (Table 12).

All the other listed areas were scored as moderately important research priorities (Figure 30).

FIGURE 30:
Sea Vegetable Sector R&D Priorities* (n=4)



*Lower numbers indicate higher priorities

General Aquaculture Priorities:

Question 12. How would you rate the importance of R&D in each of these areas:

Table 13: Top 3 General Aquaculture R&D Priorities (responding growers) (n=62)

Importance	Topic	Weighted Average
Urgently Important	Access to working waterfront	1.67
Urgently Important	Water quality monitoring and accessing water quality information	1.9
Urgently Important	Social acceptability	1.95

*Lower numbers indicate higher priorities

Although the above were the Top 3 priorities (Table 13), there were two additional areas that were also identified as urgently important by all responding growers:

- Seafood safety
- Management of invasive species, predators & biofouling

All the other listed areas were scored as moderately important research priorities (Figure 31).

There are no differences in the priorities identified by newer growers vs more experienced growers.

When filtering by sector (Shellfish vs Finfish vs Sea Vegetable growers) some differences in priorities become apparent (Table 14).

- Shellfish growers identified 7 urgent priorities
- Finfish growers identified 2 urgent priorities
- Sea vegetable growers identified 4 urgent priorities

Sea vegetable growers rated waste utilization and effluent reduction (weighted average 4.0) as not important, whereas in contrast finfish growers identified it as urgently important (weighted average 1.75).

The following topics were rated by finfish growers as not important, whereas shellfish and sea vegetable growers identified them as moderately important:

- Inter-tidal aquaculture (Finfish weighted average 4.0; shellfish 2.46; sea vegetable 3.0)
- Biofouling control (Finfish weighted average 4.5; shellfish 2.44; sea vegetable 2.75)
- Identification of new candidate species (Finfish weighted average 4.75; shellfish 2.7; sea vegetable 3.0)

Table 14: Urgently Important Priorities
General Aquaculture
Shellfish vs Finfish vs Sea Vegetable

	Shellfish (n=51)	Finfish (n=4)	Sea Vegetable (n=4)
1	Access to working waterfront (weighted average 1.58)	Waste utilization and effluent reduction (weighted average 1.75)	Access to working waterfront (weighted average 1.5)
2	Management of invasive species, predators & biofouling (weighted average 1.75)	Training and professional development (weighted average 2.0)	Information materials for the general public (weighted average 1.75)
3	Water quality monitoring and accessing water quality information (weighted average 1.76)		Offshore aquaculture (weighted average 2.0)
4	Social acceptability (weighted average 1.88)		Policy & Regulations (weighted average 2.0)
5	Seafood Safety (weighted average 1.92)		
6	Management of impacts of environmental change (weighted average 1.94)		
7	Policy & Regulations (weighted average 1.96)		

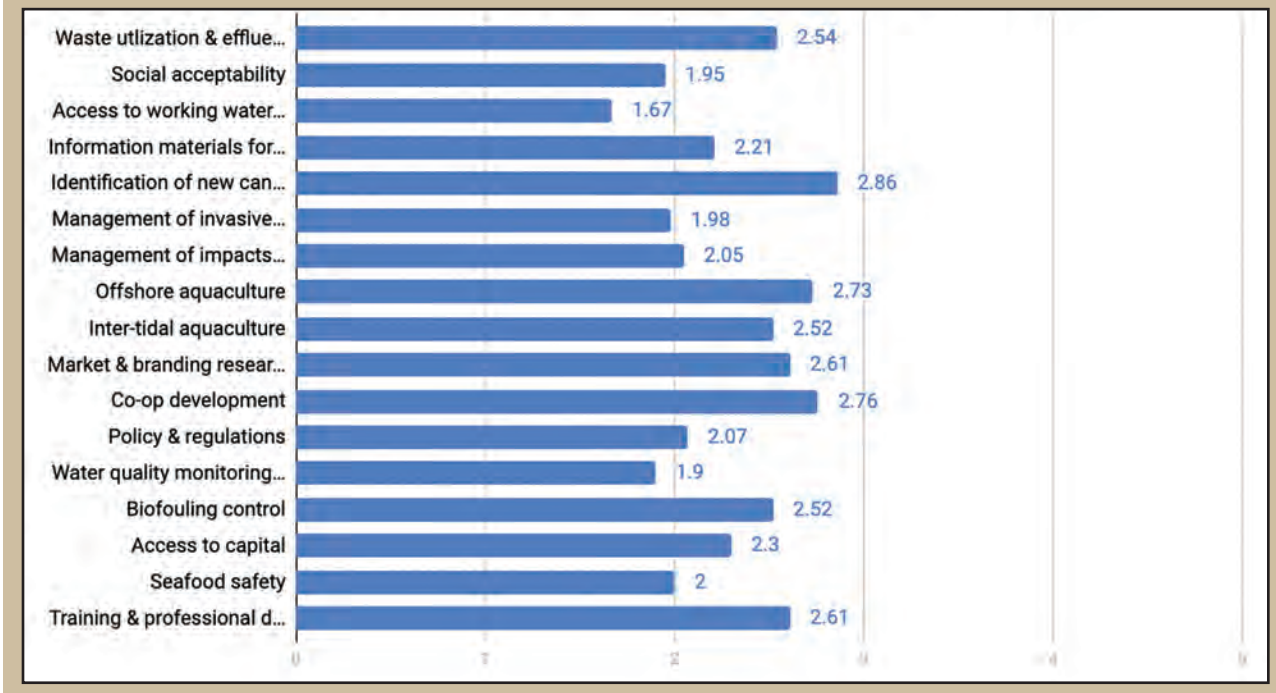
When differentiating between shellfish sub-sectors (scallop vs mussel vs oyster growers), more differences in priorities become apparent (Table 15).

Mussel growers rated coop development (weighted average 4.67) and market & branding research (weighted average 4.0) as not important, whereas in contrast finfish growers identified these as urgently or moderately important.

Table 15: Urgently Important Priorities
General Aquaculture
Scallop vs Mussel vs Oyster

	Scallop (n=6)	Mussel (n=3)	Oyster (n=41)
1	Seafood Safety (weighted average 1.33)	Policy & Regulations (weighted average 1.0)	Access to working waterfront (weighted average 1.7)
2	Water quality monitoring and accessing water quality information (weighted average 1.33)	Social acceptability (weighted average 1.0)	Water quality monitoring and accessing water quality information (weighted average 1.77)
3	Access to working waterfront (weighted average 1.33)	Access to working waterfront (weighted average 1.33)	Management of invasive species, predators & biofouling (weighted average 1.78)
4	Access to capital (weighted average 1.67)	Information materials for the general public (weighted average 1.33)	Seafood Safety (weighted average 1.95)
5	Coop development (weighted average 1.67)	Management of invasive species, predators & biofouling (weighted average 1.33)	Social acceptability (weighted average 1.95)
6	Offshore aquaculture (weighted average 1.67)	Biofouling control (weighted average 1.67)	Management of impacts of environmental change (weighted average 2.0)
7	Management of impacts of environmental change (weighted average 1.67)	Seafood Safety (weighted average 2.0)	
8	Social acceptability (weighted average 1.67)	Water quality monitoring and accessing water quality information (weighted average 2.0)	
9	Management of invasive species, predators & biofouling (weighted average 1.83)		
10	Policy & Regulations (weighted average 1.83)		
11	Information materials for the general public (weighted average 2.0)		
12	Training and professional development (weighted average 2.0)		

FIGURE 31: General Aquaculture R&D Priorities* (responding growers) (n=62)



*Lower numbers indicate higher priorities

Processing & Product Development Priorities:

Question 13. How would you rate the importance of research in each of these areas:

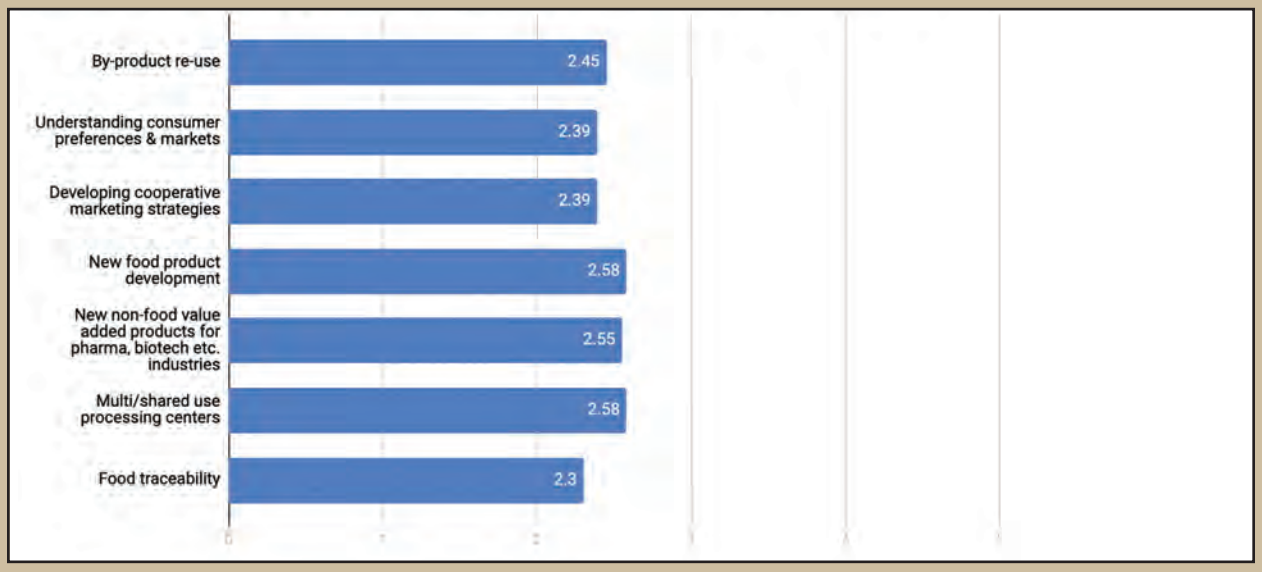
Table 16: Top 3 Processing & Product Development R&D Priorities (responding growers) (n=61)

Importance	Topic	Weighted Average
Moderately Important	Food traceability	2.30
Moderately Important	Understanding consumer preferences and markets	2.39
Moderately Important	Developing cooperative marketing strategies	2.39

*Lower numbers indicate higher priorities

All the other listed areas were also scored as moderately important research priorities.

FIGURE 32: Processing & Product Development R&D Priorities* (responding growers) (n=61)



*Lower numbers indicate higher priorities

Although the above were the Top 3 priorities (Table 16), all the listed areas were scored as moderately important research priorities (Figure 32).

There are no differences in the priorities identified by newer growers vs more experienced growers.

When filtering by sector (Shellfish vs Finfish vs Sea Vegetable growers) some differences in priorities become apparent (Table 17). Sea vegetable growers were the only group to identify any processing and product development topics as urgently important priorities (Table 17). In particular, sea vegetable growers rated food and non-food product development as urgently important.

Table 17: Urgently Important Priorities
Processing & Product Development
Shellfish vs Finfish vs Sea Vegetable

	Shellfish (n=50)	Finfish (n=4)	Sea Vegetable (n=4)
1	None. All priorities were rated as moderately important	None. All priorities were rated as moderately important	New non-food value added products for pharma, biotech etc industries (weighted average 1.5)
2			New food product development (weighted average 1.67)
3			By-product re-use (weighted average 2)

*Lower numbers indicate higher priorities

An in-depth analysis into shellfish sub-sectors (scallop vs mussel vs oyster growers) more differences in priorities become apparent (Table 18).

Mussel growers did not rate processing and product development topic areas as urgently important, and all the topic areas scored 3+ (i.e. of moderate priority but erring towards not important). Food traceability was rated by mussel growers as not important (weighted average 4.0).

Scallop growers in contrast rated food traceability as an urgently important research priority (weighted average 1.83). Understanding consumer preferences and markets, and multi/shared-use processing centers were also rated as urgently important by scallop growers (Table 18).

Table 18: Urgently Important Priorities
Processing & Product Development

	Scallop vs. Mussel vs. Oyster		
	Scallop (n=6)	**Mussel (n=3)**	**Oyster (n=40)**
1	Understanding consumer preferences & markets (weighted average 1.67)	None. All priorities were rated as moderately important or not important	None. All priorities were rated as moderately important
2	Food traceability (weighted average 1.83)		
3	Multi/shared-use processing centers (weighted average 2.0)		

*Lower numbers indicate higher priorities

Farm Operations Technology:
Question 14. How would you rate the importance of research in each of these areas

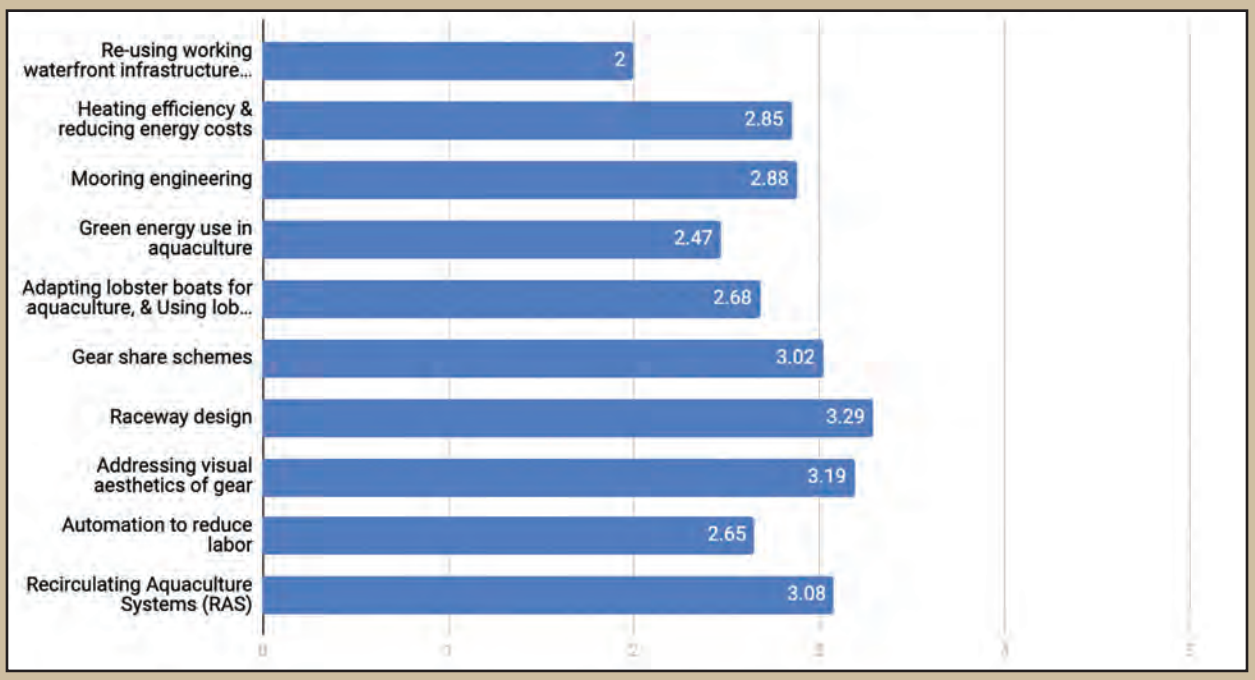
Table 19: Top 3 Farm Operations Technology R&D Priorities
(responding growers) (n=59))

Importance	Topic	Weighted Average*
Urgently Important	Re-using working waterfront infrastructure for aquaculture	2.00
Moderately Important	Green energy use in aquaculture	2.47
Moderately Important	Automation to reduce labor	2.65

*Lower numbers indicate higher priorities

All the other listed areas were scored as moderately important research priorities.

FIGURE 33: Farm Operations Technology R&D Priorities* (responding growers) (n=59)



*Lower numbers indicate higher priorities

Although the above were the Top 3 priorities (Table 19), all the listed areas were scored as moderately important research priorities (Figure 33).

There was one difference in the priorities when comparing newer growers (n=39) vs more experienced growers (n=20); newer growers rated re-using working waterfront infrastructure as urgently important (weighted average 1.87) rather than moderately important (more experienced growers had a weighted average of 2.29).

When filtering by sector (Shellfish vs Finfish vs Sea Vegetable growers) some differences in priorities become apparent (Table 20).

- Shellfish growers rated re-using working waterfront infrastructure for aquaculture as urgently important (weighted average 1.82) where as finfish growers and sea vegetable growers rated this as moderately important (weighted average 3.33 and 2.5 respectively)
- Finfish growers rated 4 topic areas as not important:
  - Adapting lobster boats for aquaculture, & Using lobster pounds for aquaculture (weighted average 4.0)
  - Raceway design (weighted average 4.0)
  - Gear share schemes (weighted average 4.5) and
  - Addressing visual aesthetics of gear (weighted average 4.5)
- Sea vegetable growers rated 3 topic areas as not important:
  - Automation to reduce labor (weighted average 4.0)
  - Gear share schemes (weighted average 4.5) and
  - Addressing visual aesthetics of gear (weighted average 4.67)

Table 20: Urgently Important Priorities, Farm Operations Technology

	Shellfish vs Finfish vs Sea Vegetable		
	Shellfish (n=48)	**Finfish (n=4)**	**Sea Vegetable (n=4)**
1	Re-using working waterfront infrastructure for aquaculture (weighted average 1.82)	None. All priorities were rated as moderately important or not important	None. All priorities were rated as moderately important

*Lower numbers indicate higher priorities

When drilling down into shellfish sub-sectors (scallop vs mussel vs oyster growers) more differences in priorities become apparent (Table 21).

Raceway design was scored as "not relevant to me" by all responding mussel growers. In addition, mussel growers rated gear share schemes as not important (weighted average 4.5).

In contrast, several farm operations topic areas were rated as urgently important by mussel growers (Table 21).

Oyster growers only identified one farm operations topic area as an urgently important research priority. All other farm operations topic areas were rated as moderately important by oyster growers.

Scallop growers rated several farm operations topic areas as urgently important (Table 21). All other farm operations topic areas were rated as moderately important by scallop growers.

Table 21: Urgently Important Priorities, Farm Operations Technology

	Scallop vs Mussel vs Oyster		
	Scallop (n=6)	**Mussel (n=3)**	**Oyster (n=39)**
1	Re-using working waterfront infrastructure for aquaculture (weighted average 1.67)	Automation to reduce labor (weighted average 1.0)	Re-using working waterfront infrastructure for aquaculture (weighted average 1.94)
2	Gear share schemes (weighted average 1.67)	Green energy use in aquaculture (weighted average 1.0)	
3	Moring engineering (weighted average 1.83)	Moring engineering (weighted average 167)	
4	Green energy use in aquaculture (weighted average 2.0)	Re-using working waterfront infrastructure for aquaculture (weighted average 1.67)	
5	Adapting lobster boats for aquaculture, & Using lobster pounds for aquaculture (weighted average 2.0)		

*Lower numbers indicate higher priorities

Education & Training:

Question 15. How would you prioritize target audiences for outreach and education?

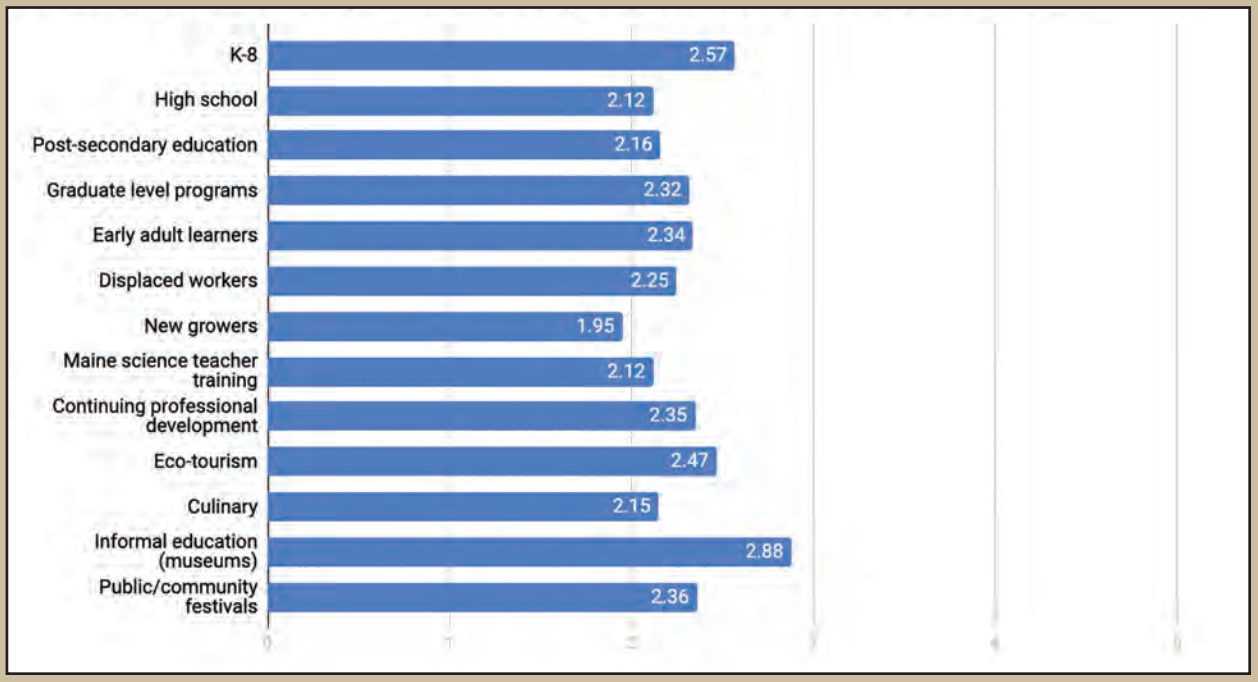
Table 22: Top 3 Target Audiences: Education Priorities (n=163)*

Importance	Topic	Weighted Average**
Urgently Important	New growers	1.95
Moderately Important	High schoolers Maine science teachers	2.12
Moderately Important	Culinary Post-secondary	Scored 2.15 and 2.16 respectively

*All respondents were guided to this question.
**Lower numbers indicate higher priorities

New growers were highlighted as the top priority target audience by the entire population of respondents. This does not appear to be driven by growers. When selecting for growers only (n=58), the target audience priorities shift to culinary (2.13), Maine science teachers (2.20), and public/community festivals (2.23).

FIGURE 34: Education Priorities*:Target Audiences (as scored by all respondents) (n=163)



*Lower numbers indicate higher priorities

Question 16. How would you prioritize curricula and training needs?

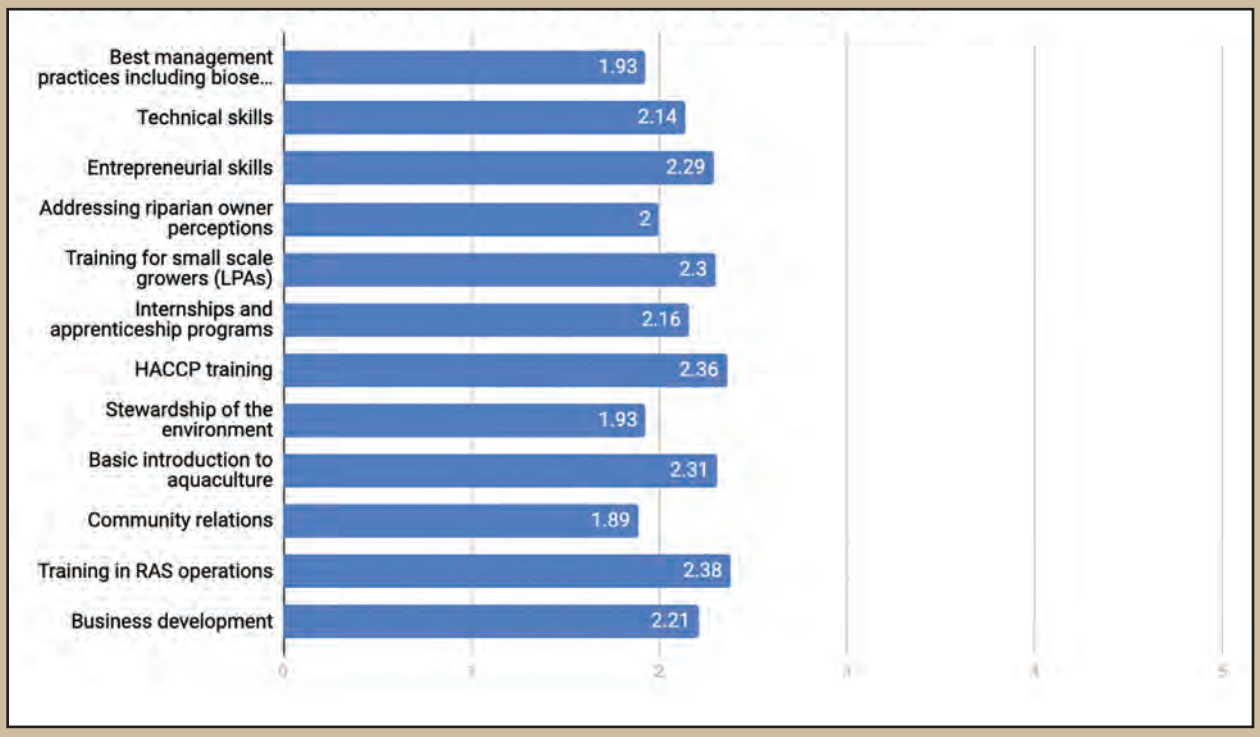
Table 23: Top 3 Curricula: Education Priorities (n=161)*

Importance	Topic	Weighted Average**
Urgently Important	Community relations	1.89
Urgently Important	Best management practices Stewardship of the environment	Both scored 1.93
Urgently Important	Addressing riparian owner concerns	2.00

*All respondents were guided to this question.
**Lower numbers indicate higher priorities

Community relations and Addressing riparian concerns were both scored as urgently important by the entire population of respondents. The same curricula scored as important when selecting for just growers (n=57): Community relations (1.93), Addressing riparian owner concerns (1.96) scored as most important, with Best management practices (2.05) and Stewardship of the environment (2.06) also scoring as urgently important.

FIGURE 35: Education Priorities*: Curricula (as scored by all respondents) (n=161)



*Lower numbers indicate higher priorities

Question 17. Other education and outreach needs. Do we need programs to address the following?

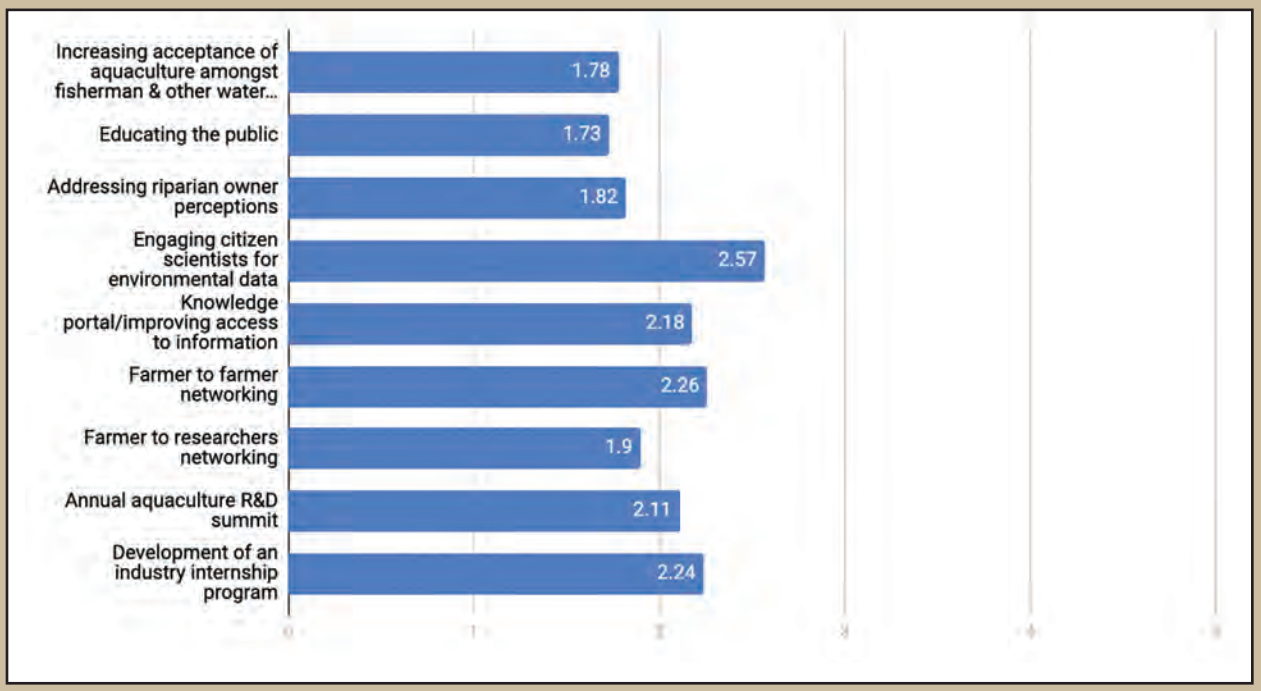
Table 24: Top 3 Programs: Education Priorities (n=161)*

Importance	Topic	Weighted Average**
Urgently Important	Educating the public	1.73
Urgently Important	Increasing acceptance of aquaculture	1.78
Urgently Important	Addressing riparian owner concerns	1.82

*All respondents were guided to this question.
**Lower numbers indicate higher priorities

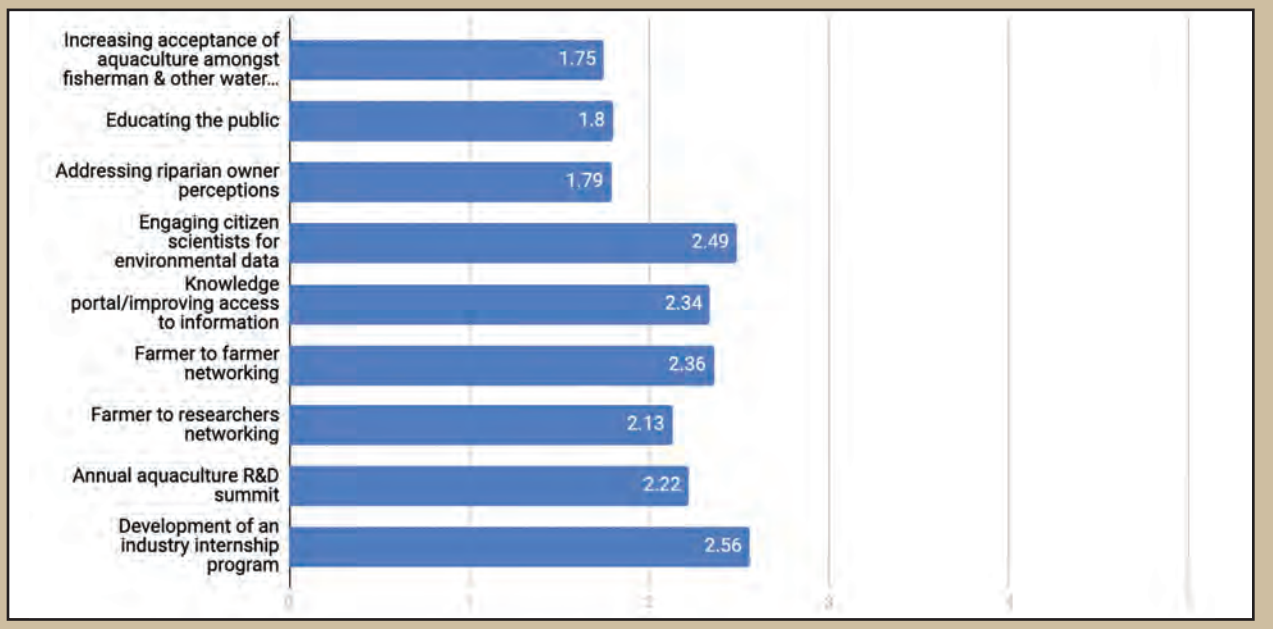
The Top 3 Programs identified by the entire respondent population all concerned public and riparian education.
All other listed programs also scored urgently or moderately important.
When selecting for just growers, these education program priorities did not change.

FIGURE 36: Education Priorities*: Programs (as scored by all respondents) (n=161)



*Lower numbers indicate higher priorities

FIGURE 37: Education Priorities*: Programs (as scored by growers)



*Lower numbers indicate higher priorities

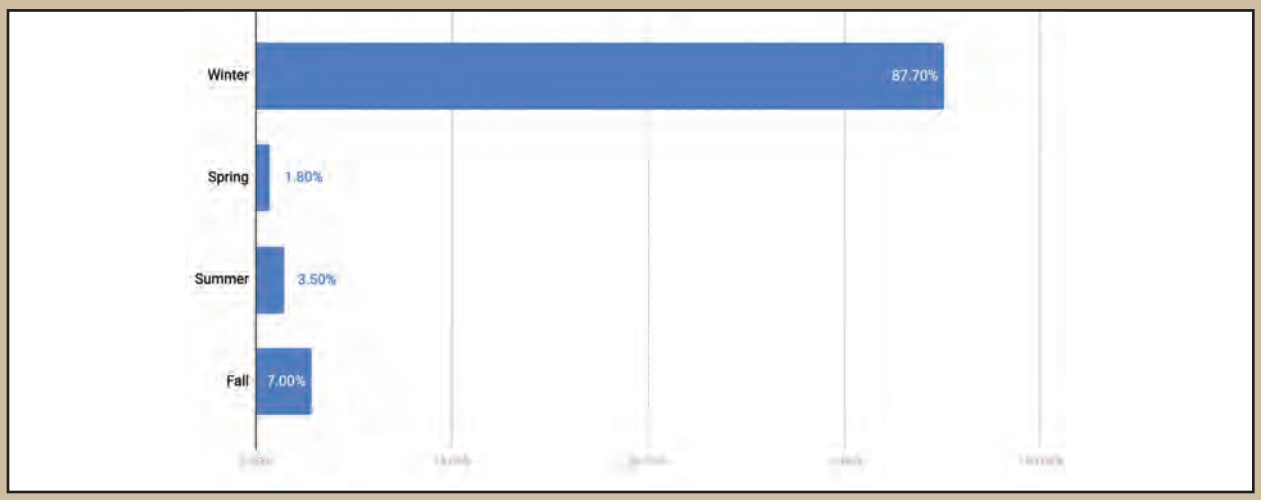
Question 18. Which time of year would be best for you to attend training sessions?

2019 Survey: Answered: 158; Skipped: 52

Winter was identified by over 70% of respondents as the best time of year to attend training sessions.

When selecting just growers, the preference for winter training sessions rose to 88% of the respondents.

FIGURE 38: Timing of Training Sessions



Community Identified Research Needs

Question 19. If a $25,000 seed grant were available to address a critical issue facing your venture in Maine, what would be your most important priority?

2019 Survey: Answered: 129; Skipped: 81

All respondents were guided to this question; 129 answered and 81 skipped the question. This was an open question, and a qualitative, thematic analysis was carried out.

Overarching themes for 2019: Overall the dominating themes were related to seed grants for:

- Workforce development
- Public education
- Improving technology/gear/equipment/mechanization

Shellfish growers (n=40) put forward a wide range of suggestions for seed grants including:

- Understanding the beneficial impacts of aquaculture on water quality/ ecosystem
- Biofouling control
- Pest/predator management
- Nursery protocols for sea scallops (including use of probiotics)
- Developing a rapid result biotoxin assay
- Intertidal aquaculture

The two most common suggestions were:

- A state-wide marketing campaign for Maine farmed seafood
- Understanding the impact of climate change and ocean acidification on production.

Feedback: "Marketing of Maine grown aquaculture products"

"Climate change predictive models with focus on production"

Finfish growers (n=4) suggested 4 topics for seed grants:

- RAS waste stream utilization
- Sea lice reduction methods
- Automated processing equipment / training
- Water quality

Sea vegetable growers (n=3) suggested 3 topics for seed grants:

- Food safety
- Advertising/marketing
- New technology to enable scaling of harvest

Educators (n=10) suggested two key initiatives:

- High school internship program development (pipeline development and general help with farm)
- Career education in Middle/High School

Question 20. If you could direct a $1,000,000 research initiative, what would be its focus?

2019 Survey: Answered: 129; Skipped: 81

All respondents were guided to this question; 129 answered and 81 skipped the question. This was an open question, and a qualitative, thematic analysis was carried out.

Overarching themes for 2019: Overall the dominating themes related to $1million initiatives included:

- Understanding environmental impacts of aquaculture
- Marketing campaign for Maine farmed seafood
- Distribution and processing
- Workforce development
- Technology development (in particular RAS systems, processing technology, growing technology)
- Sector expansion (including product diversification, site selection)
- Public outreach and education hugely important

When selecting for growers only (n=48), the most common suggestion was a marketing campaign for Maine farmed seafood.

Feedback: "Support the ideas of growers to advance the industry"

Shellfish growers (n=39) suggested several topics for large scale research investment:

- Climate change research
- Pest/predator management
- Marketing
- Product diversification
- Developing and/or testing new growing technology

Scallop growers (n=5) suggested investment in:

- Biotoxin testing,
- Farm management strategies to cope with biotoxin closures,
- Spat collection or husbandry, and
- Exploring opportunities to make aquaculture more accessible to people in year round coastal communities

Feedback: "Biotoxins, mapping historic biotoxin closure and create production plans with biotoxin constraints built in"

Finfish growers (n=3) suggested several topics for large scale research investment:

- RAS workforce development
- Sea lice reduction methods
- Experimental offshore farm
- Streamlining distribution
- Removal of phosphorus from wastewater

Feedback: "Streamlining distribution (traceability tech, shipping logistics, tracking improvements, order processing, cold-chain distribution."

Sea vegetable growers (n=3)

- Product diversification
- Design and testing of kelp harvesting barge

Feedback: "Uses for sea vegetables other than food"

Many educators (n=11) indicated they would like to see investment in education, and specifically:

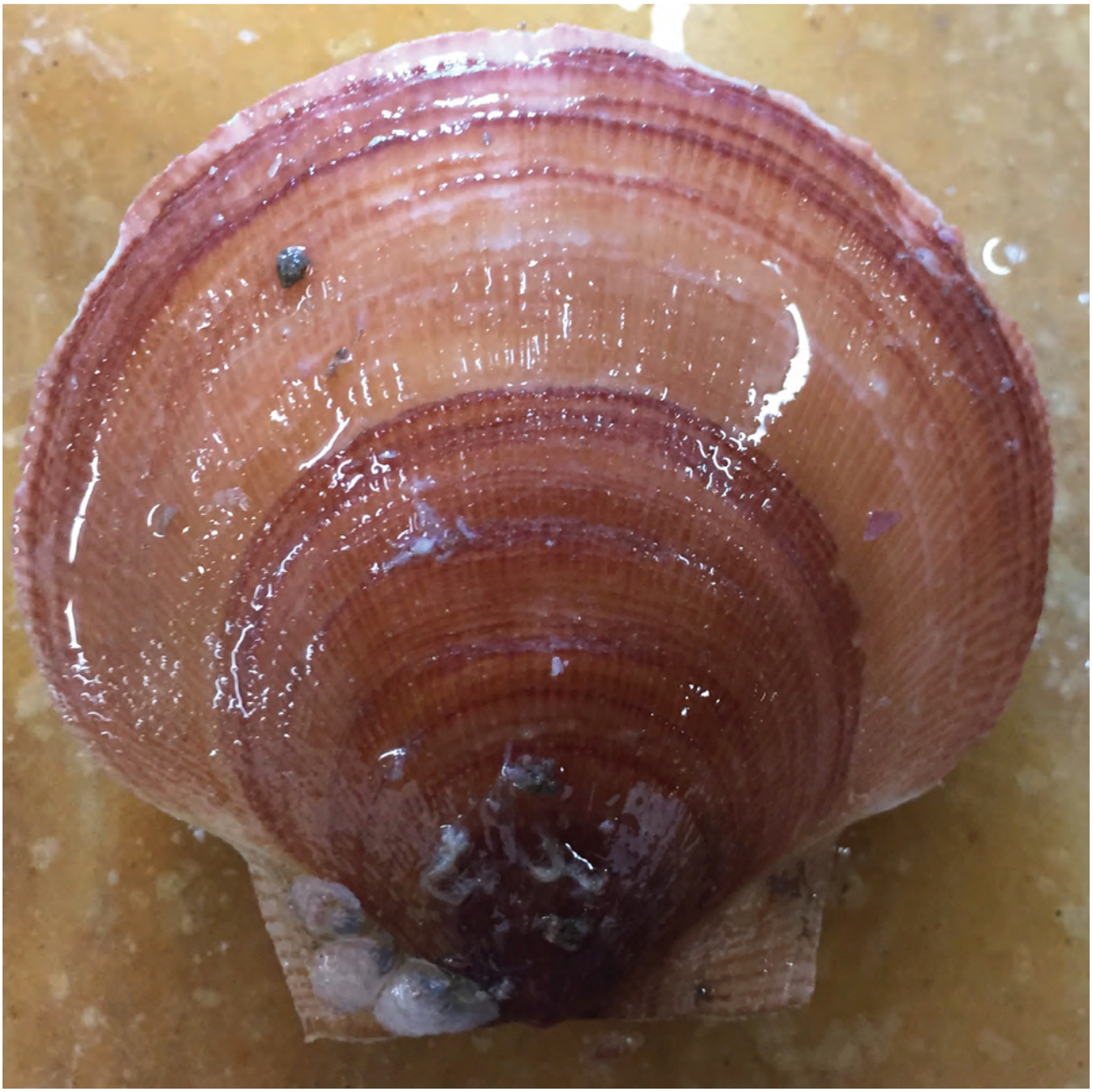
- Outreach/Practical sharing of knowledge with communities

Feedback: "Organizing a coalition to create positive publicity and to educate the public about the vast potential benefits if we (the state of Maine) invest in and encourage aquaculture in Maine; from small-scale up through large industrial scale. We have the infrastructure to do both and the jobs created can only benefit this state and hopefully encourage young people to stay in a young and growing industry."

In 2012 the range of initiative suggestions was smaller, possibly due to the smaller number of respondents (n=38). Initiative suggestions included:

- site selection
- species and product diversification
- climate change (although not as dominant as in 2019)
- seedstock/hatchery/breeding programs
- disease and breeding for disease resistance
- polyculture
- predation management

Eels Photo by Meggan Dwyer



Top: Sea Farm Buoys Photo by Anne Langston Noll; **Scallop** Photo by Hugh Cowperthwaite

CONCLUSIONS and RECOMMENDATIONS

Parsing sectors:

Examining priorities by sector, and especially analyzing open questions, is important to identify specific research needs, and to ensure urgent needs for emerging or smaller sectors are not missed.

Newer vs More Experienced Growers:

There are some differing research and development needs between newer and more experienced growers, but the differences are less apparent than in 2016 when there was a higher proportion of growers who had been involved in the sector for less than 3 years.

Parsing research priorities for sectors:

In future surveys it would be helpful to follow-up the survey with one-to-one interviews to clarify the research needs of different sectors. For example, in this 2019 survey it is possible that different sectors understood "Effluent treatment" in different ways. Was it perceived as a question about overboard discharges and opening up shellfish areas, or as treatment of aquaculture discharges?

Feedback: "I have participated in shared waters class and the island institute boot camp! Both EXCELLENT!"

The difference between research and development:

There are differences between research and development that are not easily ascertained for responses to a survey and require interpretation. In the context of aquaculture in Maine we are referring to research and development to innovate and introduce new products and processes, but also this survey has identified topics for sector development (strategies for promoting economic growth).

Recommended R&D foci for Cross-Sector Impact:

- Research on methodologies for invasive species management,
- Research on biofouling control methods,
- Research on pest and predator management strategies,
- Climate change predictive models with focus on aquaculture production,
- Improving understanding of the beneficial impacts of aquaculture on water quality/ ecosystem,
- Streamlining distribution

Recommended Sector Development foci:

- Accessibility to water quality data,
- Development of public information materials for use and dissemination by the entire aquaculture community,
- Marketing campaign for Maine farmed seafood,
- Market development,
- Development of Best Management Practices for shellfish and sea vegetable sectors

Recommended Education foci:

- Training for growers on community relations and communication strategies
- Public education strategy
- Career education programs for schools
- High school internship program(s)

Recommended R&D foci to maximize impact across the shellfish aquaculture sectors:

- Seed collection strategies (sea scallop and mussel growers)
- Nursery/hatchery technology(sea scallop and mussel growers)
- Shellfish disease research (oyster growers)
- Farm/business management strategies to reduce revenue losses caused by biotoxin closures (sea scallop growers)

Recommended R&D foci to maximize impact across the sea vegetable aquaculture sector:

- The development of new value-added products (food and non-food)
- Processing infrastructure
- Regulation

Recommended R&D&E foci to maximize impact across the finfish aquaculture sector:

- Sea lice management
- Workforce development
- Access to capital

The Maine Aquaculture Innovation Center and the University of Maine's Aquaculture Research Institute (ARI) are the state's primary public resources for applied aquaculture research and act as a conduit between academia and aquaculture stakeholders. The ability to respond to stakeholders' research, education, and training needs using academic-industry partnerships to resolve aquaculture bottlenecks and challenges are key to the viability and economic growth and output of the sector and in creating resilient rural, coastal economies. These biennial surveys and the resulting summits are an invaluable tool for strengthening these connections.

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Oyster mesh bags Photo by Anne Langston Noll

Cooke Aquaculture Photo by Emily Tarr

Maine Aquaculture Innovation Center

Aquaculture Research Institute

Sea Grant Maine at the University of Maine

The Maine Aquaculture Association