

**JANUARY  
2023**

# **RESEARCH, DEVELOPMENT, AND EDUCATION PRIORITIES**

**For the Aquaculture Sector in Maine**



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# R&D Priorities



## EXECUTIVE SUMMARY

The Maine aquaculture research, development and education priorities survey is an ongoing initiative coordinated by the Maine Aquaculture Innovation Center in collaboration with University of Maine, Aquaculture Research Institute, the Maine Aquaculture HUB, and Maine Sea Grant. The survey has been conducted biennially since 2012. This report is based on the 2022 research priorities survey of Maine's aquaculture community, and when appropriate, trends are compared with data from the 2012, 2016, and 2019 surveys.

While there have been some changes in the prioritization of needs since 2020, many of the same research, development, and education (R&D&E) challenges identified in 2012 still persist. As expected, priorities differ between sub-sectors, however, the survey identified the ***priorities in the Executive Summary*** that are relevant across Maine's entire aquaculture sector:

The survey data is available on a data dashboard developed by the Atlantic Corporation using Microsoft Power BI. ***Scan this QR code to access the dashboard.***





# R&D Priorities

Full Report



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

- Research on biofouling and invasive species management, including the associated economic and environmental costs
- Automation technology to cut costs, reduce labor, and improve efficiency across culture methods
- Economic and market research
- Research on farm management strategies to mitigate the impacts of environmental change

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

- Continue to develop public information materials for use and dissemination by the aquaculture community
- Education to improve farmer awareness of opportunities for accessing finance and capital
- Reducing the timeline associated with the lease process
- Accessibility to green technologies, reduced plastics, and reusing working waterfront infrastructure
- Building a more equitable seafood industry and maintaining opportunities for all people to enter the industry
- Market strategy for food traceability
- Leveraging the Maine brand to promote local, sustainable, farm-raised seafood

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

- Public education strategy for high school students, including Marine Science teachers
- Develop curricula regarding environmental stewardship and best management practices
- Program development to understand and address Riparian owner concerns

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

- Biofouling management research
- Developing farm and business management strategies for small farm infrastructure
- Shellfish disease research
- Vibrio detection research
- Addressing issues associated with maturation of newer farms such as accessing workforce, understanding financing and capitalization, and the timeline associated with the leasing process

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

- Streamlining the regulatory process
- Identifying and developing new high-value-added products (food and non-food)
- Nursery & seeding, harvesting, and processing technology
- Research to understand consumers and markets

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

- Management of Invasives, parasites, pests, & diseases
- Streamlining the regulatory process
- Innovations for effluent treatment
- Community relations and communication strategies

# INTRODUCTION

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As a large rural state (~30,000 mi<sup>2</sup>, population ~1.3 million)<sup>1</sup> Maine ranked 32nd in the nation for per capita income in 2022, with an economy heavily dependent on natural resources and human capital. Marine resources are a crucial asset in the state, supporting a wide range of interdependent sectors, from seafood harvesting and processing to tourism and boatbuilding. Within the marine economy, the aquaculture sector has potential to transform the seafood economy in the face of economic and environmental change, while also increasing climate resilience and supporting the cultural and economic traditions of coastal communities. These communities are the nexus of complex social-environmental interactions. While there are ongoing challenges to Maine's marine economic heritage, there is the possibility to create a diverse seafood economy that integrates aquaculture, wild caught fisheries and eco-tourism with the conservation of marine ecosystems and tribal interests. Maine has the opportunity to be a part of a global expansion of aquaculture, and the national effort to reduce seafood trade deficits. To achieve this there is a need for investment in research, development, and education that increases sustainable aquaculture growth in the region and incorporates collaboration across all parts of the sector.

In 2021, the total landed value of wild caught and farmed oysters and mussels in the U.S. was approximately \$227 million.<sup>3</sup> Maine accounted for approximately 5.8% of that total, delivering \$13.2 million of farmed shellfish.<sup>3</sup> A large proportion of Maine's landings are from aquaculture. Pre-pandemic aquaculture landings in Maine, for oysters and mussels, totaled \$13.6 million.<sup>4</sup>

The diversity of farmed species in Maine is increasing, representing Maine's leadership in innovation and diversification. In 2020, the following species were harvested from aquaculture leases and licenses in Maine:<sup>4</sup>



## Farmed Species in Maine

- 1 species of finfish, Atlantic Salmon (*Salmo salar*)
- 8 species of shellfish
- American/Eastern Oyster (*Crassostrea virginica*),
- Arctic Surf Clam (*Mactromeris polynyma*),
- Blue Mussel (*Mytilus edulis*),
- European Oyster (*Ostrea edulis*),
- Hen Clam (*Spisula solidissima*),
- Northern Quahog (*Mercenaria mercenaria*),
- Sea Scallop (*Placopecten magellanicus*),
- Soft Shell Clam (*Mya arenaria*), and
- 3 species of macroalgae
- Strap/Skinny Kelp (*Saccharina angustissima*),
- Sugar Kelp (*Saccharina latissima*),
- Winged Kelp (*Alaria esculenta*)

The vast majority of Maine's aquaculture businesses have common characteristics such as: small footprint (roughly 7.4 acres per lease), small workforce, low capacity for staff development, training, and R&D. These characteristics can hinder growth both in individual businesses and the sector.

There is a need to better understand Maine's current blue economy landscape. The last Maine Aquaculture Economic Impact Report was completed in 2014 when the total economic impact of aquaculture had almost tripled between 2007 and 2014 from \$50 million to \$137 million. These numbers are out of date and there is an urgent need to gather quality data on the latest direct economic impacts, the effects of a global pandemic, the federal regulatory environment, statewide multiplier effects and accurate labor statistics.

Maine aquaculture is fortunate to have a well-established research and extension ecosystem to support aquaculture-related businesses.

These organizations include:

- Maine Aquaculture Innovation Center
- University of Maine
- Bigelow Laboratory for Ocean Sciences

- Maine Sea Grant
- Downeast Institute
- Gulf of Maine Research Institute
- Island Institute

There is also great capacity in Maine for business and entrepreneurial support specific to marine resources and aquaculture. Those organizations include:

- Maine Aquaculture Innovation Center
- Maine Aquaculture Association
- Coastal Enterprises Inc
- Maine Technology Institute
- SEAMaine
- Gulf of Maine Research Institute
- Island Institute

Finally, there is a large and diverse education and training ecosystem supporting workforce development for Maine's aquaculture sector which can be explored in more detail at this link. A new Seafood Educators' Network was launched in 2022 to support communication and collaboration for important, ongoing workforce development activities. To find out more or to join this network, reach out to Anne Langston Noll at Maine Aquaculture Innovation Center, or Keri Kaczor at Maine Sea Grant.

The dynamic nature of Maine's aquaculture sector necessitates a frequently updated survey of its research, development, and education needs. These data are essential for these organizations to continue to collaborate, and direct resources to maximize benefits to the sustainability of the sector. To this end, the R&D and Education priorities survey is an ongoing biennial initiative coordinated by the Maine Aquaculture Innovation Center in collaboration with Maine University of Maine's Aquaculture Research Institute, Maine Sea Grant, and the Maine Aquaculture Association since 2012. This report is based on the research priorities survey of Maine's aquaculture community conducted April through July of 2022.

# METHODOLOGY

**The main purpose of this study was to elicit an understanding of barriers and opportunities for Maine’s aquaculture businesses and to prioritize the research, development, and education needs of the aquaculture sector in Maine.**

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 2022;
- The Maine Aquaculture Association membership list;
- The University of Maine’s Aquaculture Research Institute mailing list;
- A list of limited purpose and commercial aquaculture leaseholders.
- 

A survey was created in Survey Monkey using the 2020 “Maine Aquaculture Research Priorities” survey as a basis.

The survey was directly emailed to 513 separate email addresses. A reminder email was sent to people who had not responded after 14 days. Two additional reminder emails followed. Of these:

- 351 were opened (68.4%)
- 108 were unopened (21.1%)
- 45 bounced (8.8%)

Additional outreach was done via link sharing through ARI’s e-newsletter (757 subscribers), social media posts on ARI’s and MAIC’s instagram and facebook pages, and announcements at the April, 2022 NACE/MAS conference in Portland, ME.

In total there were 202 responses:

- 147 complete (73%)
- 55 partial completion (data included) (27%)
- 180 were Maine residents
- 22 were not Maine residents and not considered in these analyses.

Visibility of survey questions was conditional upon self-identification at the beginning of the survey (e.g. shellfish farmer, researcher, educator, etc.), therefore respondents did not see every question.

A range of question styles were used:

- Multiple choice
- Likert scale
- Open-ended

To prioritize research, respondents were asked to rate the importance of a list of research topics 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:

- $\leq 2$  = urgently important
- 2.01 - 3.99 = moderately important
- 4.00 - 5 = not important

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

$$\frac{x_1w_1 + x_2w_2 + x_3w_3 \dots x_nw_n}{\text{Total}}$$

\*“Not Relevant to Me” responses were not factored into the weighted average.

A qualitative, thematic analysis was used to examine themes and patterns within the responses to open questions with NVivo software (SE International Pty Ltd, 2020)<sup>6</sup> and Excel. Each response was tagged with one or more themes, as appropriate. Analysis of themes was based on the number of times a theme occurred.



#### 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.

It is possible that multiple respondents may represent the same business entity and its interests.

# RESULTS & DISCUSSION

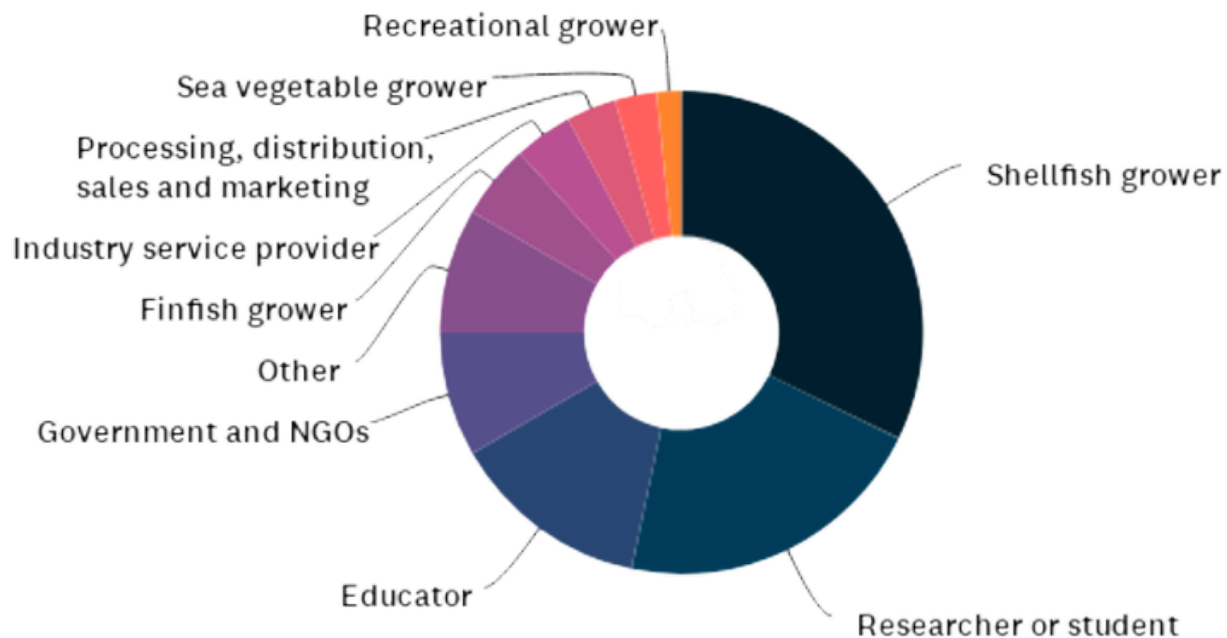
A total of 202 people responded to the survey, with an average completion rate of 73%. The typical time spent on the survey was just over 12 minutes. Of the 202 respondents, 180 declared Maine residency. Given the scope of this report, the following data will only account for Maine residents.

## QUESTION 1: What best describes your affiliation to the Maine aquaculture industry?

2022 Survey: Answered: 180; Skipped: 0; Not Applicable\*: 0  
\*“Not applicable” is abbreviated to N/A from the remainder of the report

At nearly a third of respondents, shellfish growers were the largest population represented. Researchers & students were the second largest group of respondents (Figure 1).

FIGURE 1: Affiliations of survey respondents in 2022 (n=180)



These results are similar to the results of the previous R&D Priorities survey conducted in 2019 (n=208) where 27.4% of the respondents were shellfish growers, and 20.2% were researchers and students (20.2%). The 2016 R&D Priorities Survey (n=175) showed a similar breakdown - (shellfish growers 26.9%; researchers and students 25.14%). Overall, since 2016, the most consistent change in respondent demographics has been the increased representation of shellfish growers.

The total number of responding growers (all species) has increased over time (2016 n=62; 2019 n=70; 2022 n=75) but proportional representation of the different aquaculture sub-sectors in Maine has changed very little.

## QUESTION 2: Yes or no: I am a Maine Resident

2022 Survey: Answered: 22; Skipped: 1; N/A: 157

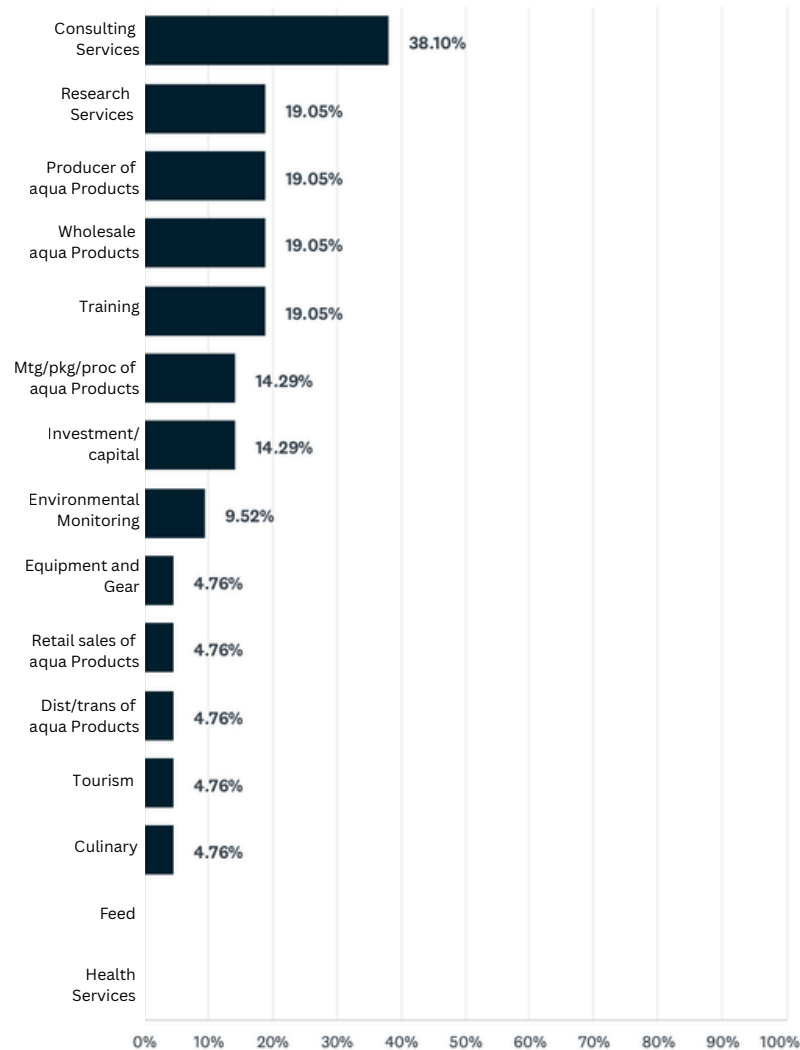
Of the 202 total respondents, each identified their residence status. All questions in this survey have been filtered to only include Maine residents (n=180).

### QUESTION 3: What products or services do you provide? (check all that apply)

2022 Survey: Answered: 22; Skipped: 1; N/A: 157

Only 23 industry service providers and respondents who self-described as “other” were guided to this question, with one choosing to skip it. Industry service providers mostly provide consulting, research services, and training to the aquaculture sector in Maine (Figure 2). Eight respondents indicated “other” as the type of service provided and self-described themselves as providing mooring services, industry advocacy/representation, engineering services, water quality services, or education.

FIGURE 1: Services Provided by Service Providers in 2022 (n=21)



When compared to the previous R&D surveys conducted in 2019 (2016 n=29; 2019 n=13), there were some changes in the types of service providers represented by the respondents.

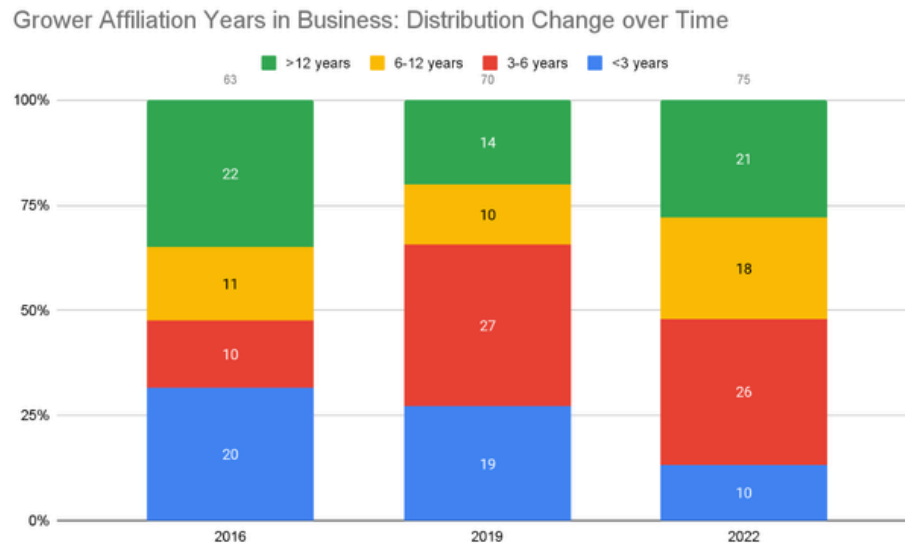
- Training (22.7%) and research services (22.7%) were the most commonly-reported services for this survey in 2022.
- Aquatic animal feed and aquatic animal health services were not represented in 2022 as opposed to past years;
- Seafood wholesale returned for the first time since 2016, representing 18% of the cumulative responses;
- Other products and services identified by respondents include:
  - Mooring services
  - Industry advocacy & representation
  - Engineering services
  - Education
  - not applicable (n=2)

## QUESTION 4: How long have you been involved with aquaculture in Maine?

2022 Survey: Answered: 75; Skipped: 0; N/A: 105

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

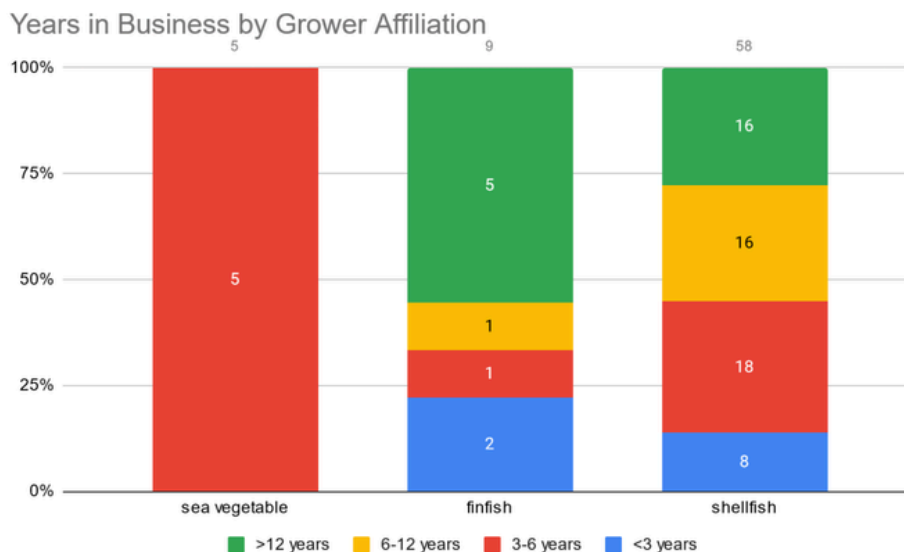
FIGURE 3: Amount of time that responding growers have been involved in Maine Aquaculture: distribution change over time (n=58)



Compared to the 2019 report, the proportion of newer growers (<6 years) has decreased from 66% to 48%, while the proportion of their more experienced counterparts (>6 years) has increased from 34% to 52%.

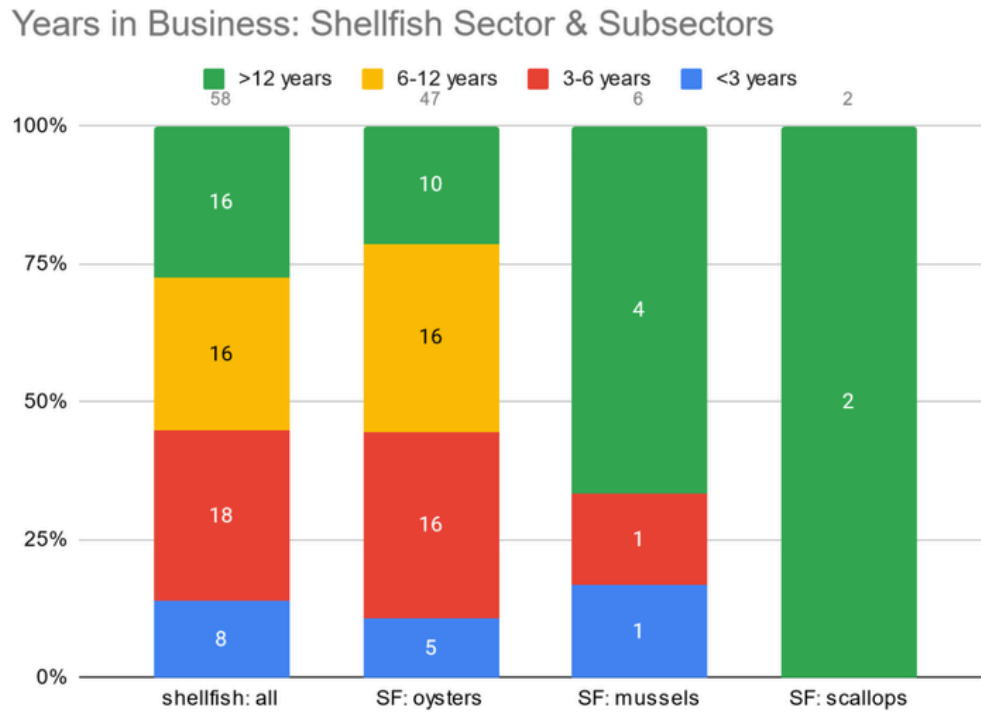
- Whilst the industry demographics shown in this survey have to be approached with caution, it is likely that this change demonstrates a maturation of aquaculture businesses since 2019, and this is reflected in some of the themes identified in Question 7 (What is the single greatest barrier to your success?). Themes associated with maturation of newer farms included accessing workforce, understanding financing and capitalization, and the timeline associated with the leasing process.

FIGURE 4: 2022 Frequency Distribution of Years in Business for Maine Aquaculture Producers by sector (n=75)



Finfish growers represented the sector with the most experience in aquaculture, with 55.5% of respondents having over 12 years of experience, and 66.6% having at least 6 years. Shellfish growers featured a more uniform distribution, but the majority of respondents still represented more mature growers (>6 years).

FIGURE 5: Amount of time that responding *shellfish growers* have been involved in Maine Aquaculture in 2022 (n=58)



The relative uniformity of the shellfish sector reflects the experience distribution of oyster growers, who make up 81% of the shellfish respondents overall. Interestingly, the mussel and sea scallop respondents have high levels of experience in the aquaculture sector.



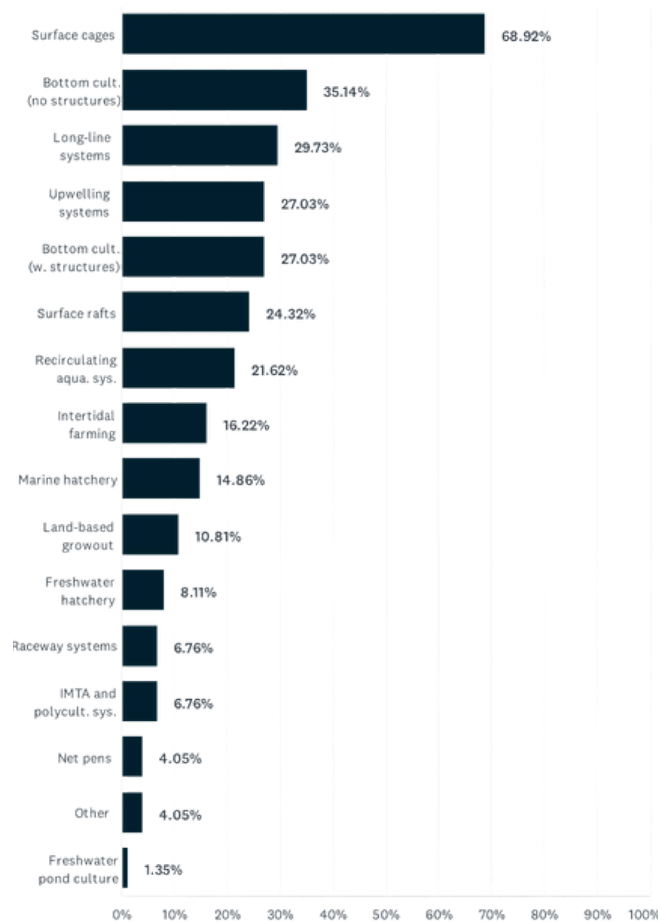
## QUESTION 5: Which of the following culture systems do you work with (check all that apply)?

2022 Survey: Answered: 74 Skipped: 1; N/A: 106

All responding growers (total n=75) were guided to this question but 1 grower chose not to answer (shellfish n=57, finfish n=9, sea vegetable n=5 and recreational growers n=3).

Surface cages are the most commonly used culture system by responding shellfish growers. Sea vegetable growers reported using long-line systems above all other options. For recreational growers, surface rafts were the most common culture system, and for finfish growers, it was Recirculating Aquaculture Systems (RAS). In 2019 and 2022, Recirculating Aquaculture Systems (RAS) were used by all sectors - shellfish, finfish, and sea vegetable growers.

FIGURE 6: Frequency Distribution of Culture Systems used by Producers in 2022



The culture systems used by growers have changed only slightly over time (Table A). The following systems were not reported by survey respondents in 2012:

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

Freshwater pond culture was not reported as a system by survey respondents in 2016.

In 2019 and 2022, all systems were reported, as well as alternative methods listed under "other." Responses also suggest gear experimentation by Maine growers.

Additional culture systems described by respondents that selected other included the following:

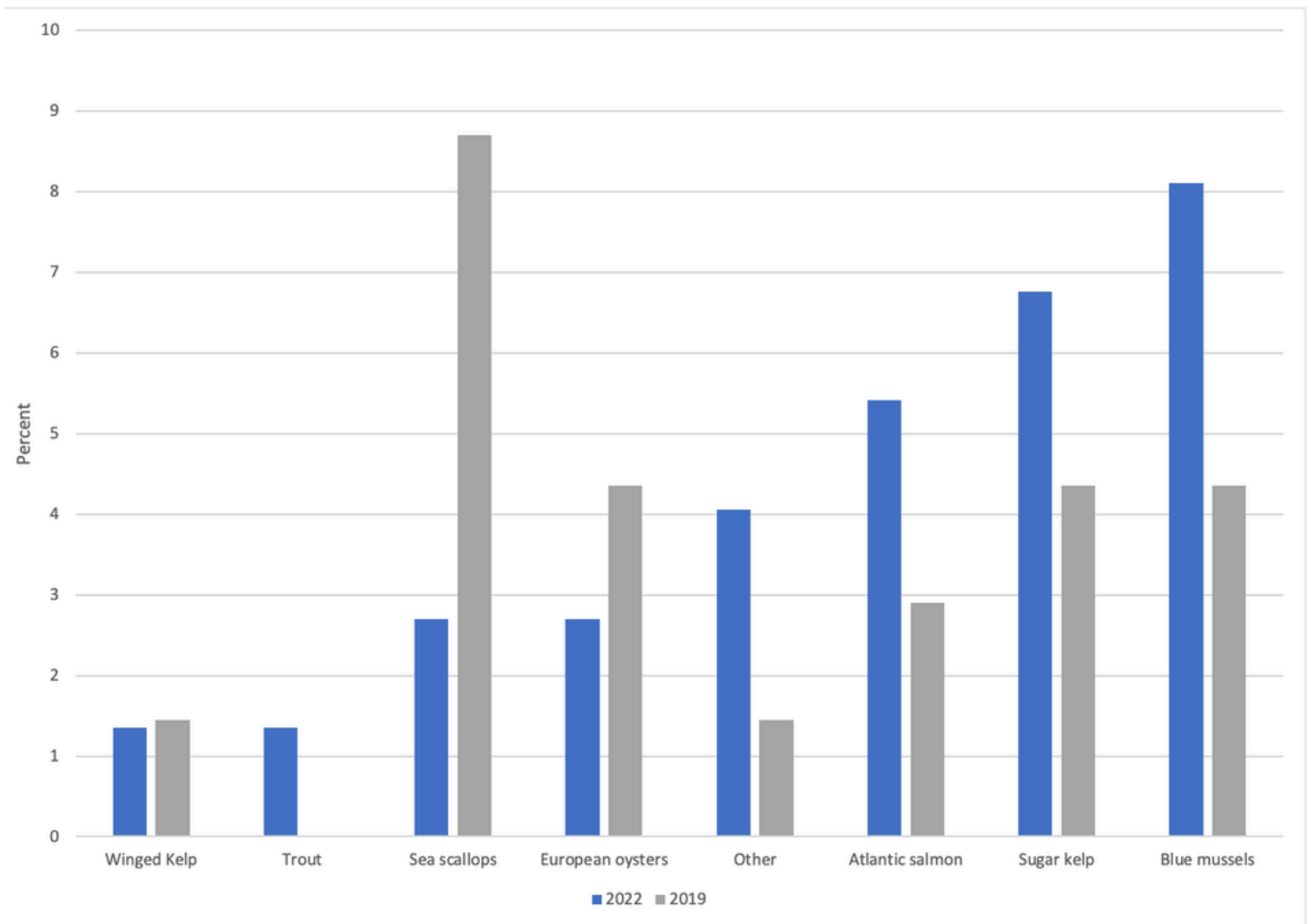
- Lantern nets

## QUESTION 6: Please indicate the primary species you culture (check only one box).

2022 survey: Answered: 74; Skipped: 1; N/A: 106

All growers (total n=75) were guided to this question but 1 grower chose not to answer (shellfish n=57, finfish n=9, sea vegetable n=5 and recreational growers n=3).

FIGURE 7: Principal Species Cultured by Maine Growers in 2022 vs. 2019



Since 2016, the number of respondents who identified as growers has slightly increased from n=61 to n=74, however, the number of unique primary species has largely remained the same, ranging from 12 to 13 different species. The most consistently represented species include Eastern oysters, Atlantic salmon, blue mussels, European oysters, sea scallops, eels, and sugar kelp. Since 2019, microalgae and skinny (sugar) kelp have not been reported. New species in 2022 included tilapia, sea bass, and sea bream. Soft-shelled clams have not occurred since the 2016 report, and Porphyra species have never been reported. Eastern oysters, in particular, have consistently represented the majority of the reported primary species. Since increasing from 46.1% to 66.7% from 2012 to 2016, they have maintained a majority, representing around  $\frac{2}{3}$  of the survey responses.

## QUESTION 7: What is the single greatest barrier to your success?

2022 Survey: Answered: 69; Skipped: 6; N/A: 105

All growers (shellfish, finfish, sea vegetable and recreational growers) were guided to this question and 6 did not answer. This was an open question, and a qualitative, thematic analysis was carried out.

Overarching themes in 2022: Several cross-cutting themes were highlighted by growers from all of Maine's sub-sectors, as barriers to the success of their business in 2022 (Table 1).

Table 1: Barriers to success impacting all Maine aquaculture sub-sectors (shellfish, fin fish and sea vegetable)

Theme	Number of times mentioned
Capital & assets	30
Regulations	19
Market Issues	15
Invasives, parasites, pests, & diseases	11
Environmental threats	4

Grower comments within the “capital and assets” theme most frequently related to issues identifying capital and finance to support the transition from limited purpose aquaculture licenses (LPAs) to leases, particularly for shellfish growers. Affordability of processing equipment, raising capital to reach an economical scale of farm, and identifying initial investment were also identified as barriers to success.

### **"Initial investment was the biggest barrier to the success path"**

Issues identified within the “regulations” theme were also often related to the transition from limited-purpose aquaculture licenses (LPAs) to leases, and the length of time associated with the lease process.

### **"Permitting process requires such a long timeline"**

For the “market issues” theme it was more difficult to analyze the specific barriers encountered by growers, as comments often simply stated “markets”. However, “low market prices” was a frequent comment from oyster growers.

The specific issues raised within the “Invasives, parasites, pests, & diseases” theme varied between sub-sectors. Within the fin fish sector comments most frequently referred to sea lice.

### **"Lack of treatment options for sea lice"**

Within the shellfish and seaweed sub-sectors, comments within this theme referred to biofouling, with only one reference to shellfish disease as a barrier to success.

### **"Biofouling, barnacles & mussels..."**

Environmental threats was a new theme in the 2022 report that had not been raised in previous years. In particular, these comments referred to changing water quality and environmental conditions.

Themes identified in question 7 can also be compared to the grower priorities ranked on a Likert scale in question 13. Policy & regulations (Likert score of 2.03), management of environmental change (2.05), management of invasives/predators/biofouling (2.25), access to capital (2.52), and economic research (2.76) were all rated as moderately important by growers and validates these key barriers to success as high priorities for the sector.

"Workforce & training" (19 mentions) and "Human dimensions" (16 mentions) were also themes that were raised frequently, but not by every sub-sector. The first was represented by shellfish and recreational growers, while the second was emphasized by shellfish and finfish growers.

Issues such as finding reliable labor, and inefficiencies in farm husbandry that inevitably lead to the need to hire more staff, were raised within the "workforce & training" theme

### **"Inherent inefficiencies that lead to hiring more folks"**

Human dimensions often referred to community relations (riparian landowners, and other working waterfront users) highlighting a need for the development of community relations programming and communication strategies. There were occasional references to conflict and anti-aquaculture lobbying, and one reference to "machismo" as barriers to success.

### **"Changing peoples mind about good/safe aquaculture process"**

Additional themes raised as barriers to success were:

- Resource equity (mentioned 4 times)
- Farm management strategies (mentioned 4 times)
- R&D (mentioned once)
- COVID-19 (mentioned once)



# Overarching Themes Over Time

Access to capital and regulations have been identified as key barriers to success since 2016. Crop loss & shellfish health were not identified as key themes in 2022, despite being noted in 2019 and 2016. Market issues and environmental threats represent some of the themes unique to this year's report.



## Shellfish growers

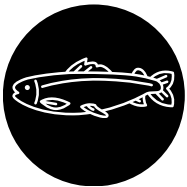
identified a greater number of barriers to their success due to the higher number of respondents. In addition to the overarching themes discussed above, some species-specific barriers were mentioned. These included references within the oyster sector relating to grower learning curve being a barrier to success.

### "My own mistakes"

For the mussel sector, "reliable seed collection" and within the sea scallop sector, access to affordable equipment were mentioned as barriers to success.

Finally, one reference was made to the difficulty of accessing key infrastructure as a small business.

**"Small farm infrastructure: often find it difficult to acquire cold storage and trucking resources while trying to grow"**



## Finfish growers

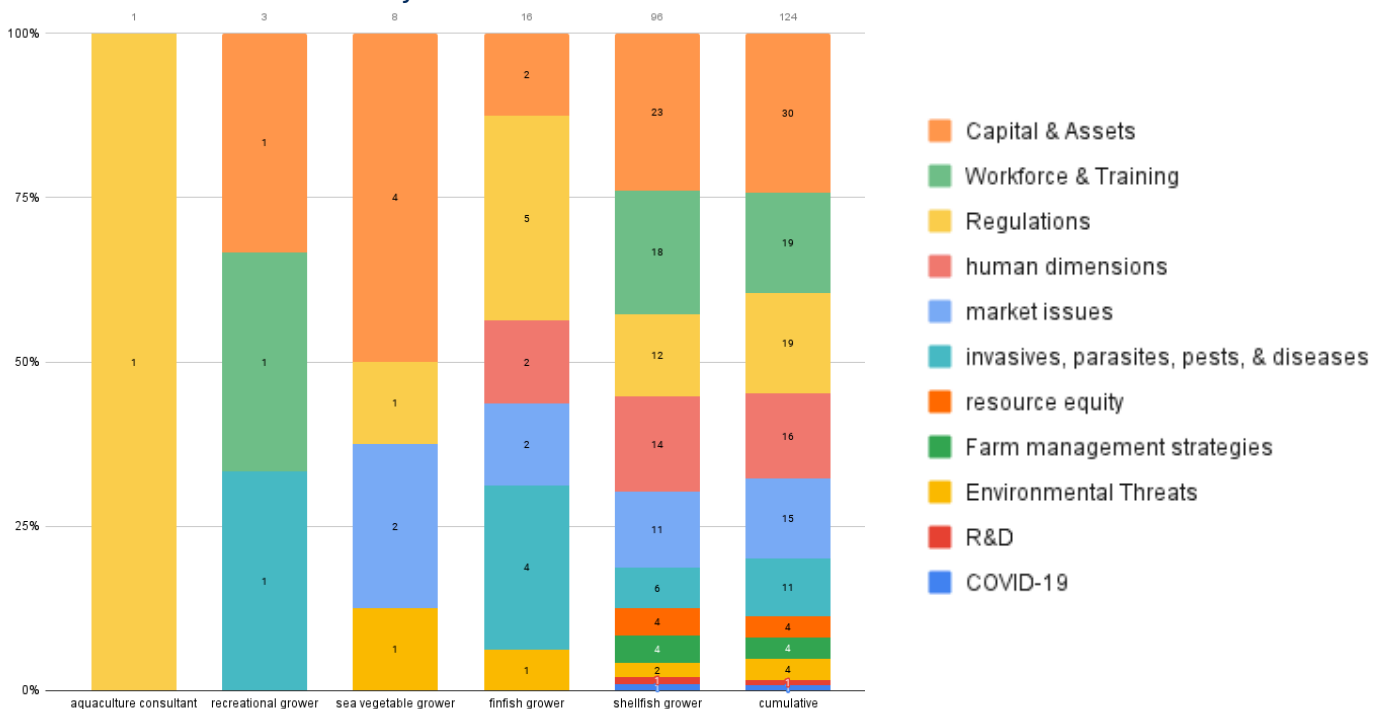
emphasized sea lice as a significant barrier to success, and specifically the lack of treatment options available. Human dimensions issues were also raised as key barriers, including community relations, and anti-aquaculture lobbying.



## Sea vegetables growers

raised the time required for the lease process as a key barrier to the success of this sub-sector. Other significant barriers included raising capital to expand lease sites, purchase processing equipment, and for accessing other key infrastructure.

FIGURE 8: Barriers to success by subsector



## QUESTION 8: What do you see as the greatest opportunity to succeed in your venture?

2022 Survey: Answered: 57; Skipped: 18

All growers (shellfish, finfish, sea vegetable and recreational growers) were guided to this question. This was an open question, and a qualitative, thematic analysis was carried out. Several cross-cutting themes were identified as opportunities by growers in the 2022 survey.

Table 2: Opportunities for success impacting all Maine aquaculture sub-sectors (shellfish, fin fish and sea vegetable)

Theme	Number of times mentioned
Marketing	30
Capital & assets	20
Workforce & training	14
Solutions from R&D	5

Marketing, including product diversification, have been consistently defined as opportunities (and challenges) since 2012.

### "Promotion of local, sustainable farm raised seafood"

Other market-related opportunities for success mentioned in 2022 include farmers working together in partnerships to support marketing of their products, the success of the farmer-buyer partnership model, strong market demand, and price stability.

### "Partnering with fellow help growers to support marketing of our crop"

Access to capital and infrastructure was frequently raised as key to the success of a business. Similarly, access to a trained workforce was emphasized as important.

The importance of applied research programs in supporting the sector were evident in the "Solutions from R&D" theme. Growers acknowledged the opportunities for success resulting from existing or potential advances in:

mussel hatchery seed production,

mechanical systems for control of environmental conditions in RAS systems

Automation technologies for oyster husbandry

- mussel hatchery seed production,
- mechanical systems for control of environmental conditions in RAS systems
- Automation technologies for oyster husbandry

Additional themes raised that were not raised by all sub-sectors include :

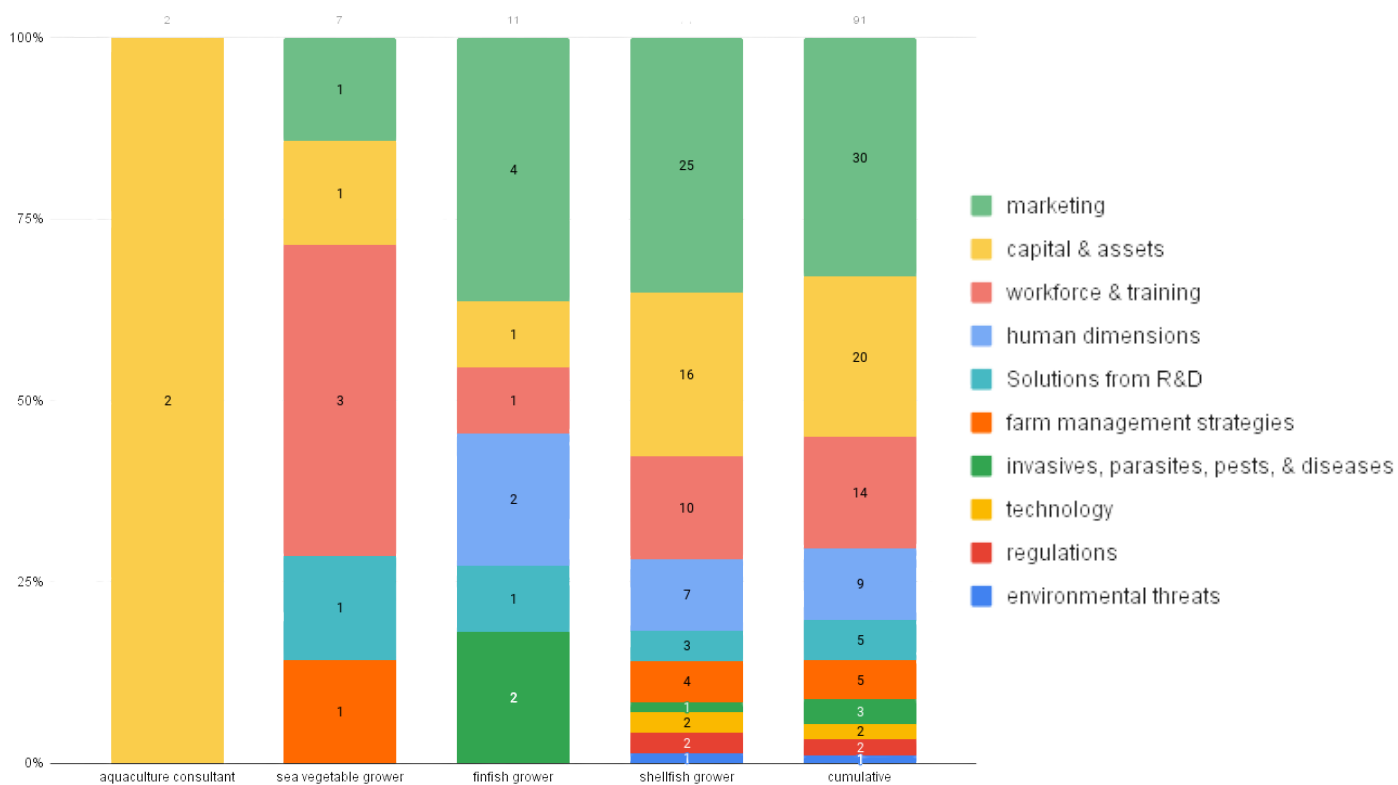
- Human dimensions (mentioned 9 times)
- Farm management strategies (5 mentions)
- Management of invasives, pests, parasites, & diseases (3 mentions)
- Technology (mentioned twice)
- Regulation topics (mentioned twice)
- Management of environmental threats (mentioned once)

Human dimensions was a recurrent theme from 2019. This theme was raised in the context of either farmers experiencing a supportive community, or understanding the importance of community relations as an opportunity for success. The emphasis of this theme has led to several recommendations being made in this report, such as community relations and developing communication strategies, and understanding riparian landowner concerns.

**"Avoid too many screw-ups and hope Mother Nature don't kick our asses"**

**"Education of the public about our industry and employing the local workforce" "Education of the public"**

FIGURE 9: Greatest opportunity by subsector



## QUESTION 9: Please indicate all the species you are currently involved with (check all that apply).

2022 Survey; Answered: 155; Skipped: 25; N/A: 0 All survey respondents were guided to this question

By jointly analyzing responses to questions 6 and 9, including responses filtered for growers or non-growers, it was possible to identify primary commercial species, secondary commercial species, and non-commercial species (Table C).

Thirteen different species were identified as “primary crop” species by survey respondents. Thirty-two species were identified as “secondary crop” species, up from 12 species since 2019. Between the two categories, 32 unique species were identified.

# Shellfish Sector Priorities

## QUESTION 10: How would you rate the importance of research in each of these shellfish sector areas:

2022 Survey; Answered: 147; Skipped: 33; N/A: 0

Survey respondents were asked to rate a list of research topics using a 5 point Likert-scale (1= urgently important to 5 = 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 by shellfish species (oysters, scallops, mussels), and newer vs. more experienced growers.

Table 3: Top 3 R&D Priorities for the Shellfish Sector as rated by all shellfish growers (n=53)

Importance	Topic	Weighted Avg.
Moderately important	Shellfish disease	2.18
Moderately important	Crop protection	2.33
Moderately important	Biofouling	2.45

*\*Lower numbers indicate higher priorities*

Shellfish diseases ranked as the most important research priority, similar to the 2020 report. Crop protection, biofouling, and vibrio detection/resistance followed (table 3). All research topics were rated as “moderately important,” but within the category, probiotics was ranked last (figure 21).

At 83% of responding shellfish growers, Eastern oyster farmers are driving the importance of the shellfish diseases, vibrio detection/resistance research priorities, and crop protection (Table 4). Responding scallop (Table 5) and mussel (Table 6) growers identified alternative research priorities. For example, vibrio detection/resistance ranked 2nd among eastern oyster growers but did not rank in the top 3 for the overall shellfish sector. Similarly, biofouling ranked third overall but was not included in the top 3 for eastern oyster growers.

Table 4: Top 3 R&D Priorities for the Shellfish Sector as rated by all Eastern oyster growers (n=43)

Importance	Topic	Weighted Avg.
Urgently important	Shellfish disease	1.90
Moderately important	Vibrio Detection/Resistance	2.25
Moderately important	Crop Protection	2.38

*\*Lower numbers indicate higher priorities*

Table 5: Top 3 R&D Priorities for the Shellfish Sector as rated by all scallop growers (n=2)

Importance	Topic	Weighted Avg.
Urgently important	Crop Protection	1.00
Urgently important	Harvesting Technology Seed Collection Technology Direct Sales from Farms	2.00
Moderately important	Selective Breeding Nursery Technology Biofouling Control Shellfish Diseases Value-added products	3.00

*\*Lower numbers indicate higher priorities*

Scallop growers identified crop protection as the most important research priority by a significant margin. Other topics that ranked urgently important were harvesting technology, seed collection technology, and direct sales from farms. (Table 5).

Research priorities classified as not important included site selection for grow out, comparing the efficiency of grow out strategies, reducing grow-out period, and vibrio detection/resistance. All other listed research areas were rated as moderately important (Figure 9).

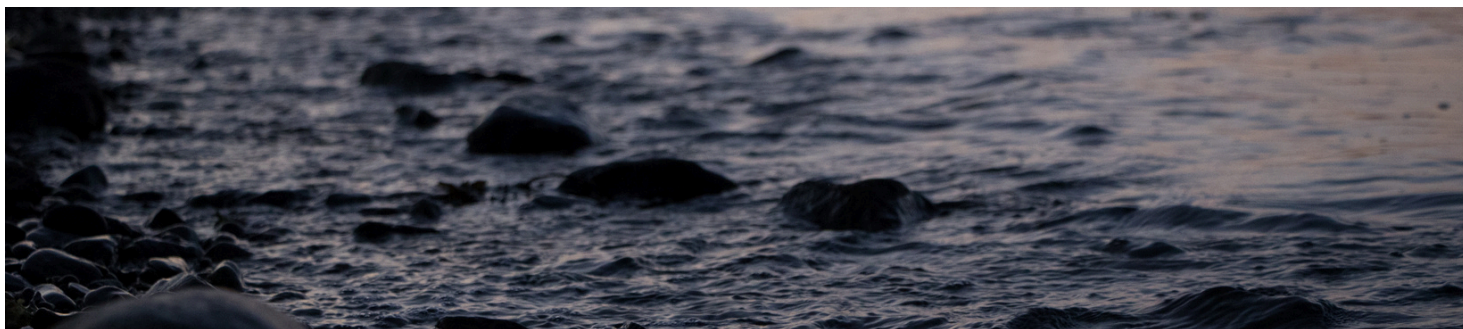


Table 6: Top 3 R&D Priorities for the Shellfish Sector as rated by all mussel growers (n=6)

Importance	Topic	Weighted Avg.
Urgently important	Biofouling Control	1.5
Moderately important	Value-added Products	1.8
Moderately important	Selective Breeding	2.25

*\*Lower numbers indicate higher priorities*

Mussel farmers identified biofouling control as the most important research priority for their businesses, along with the development of new value-added products. Third on the list was selective breeding, which was rated as *moderately important*. (Table 6).

All other listed research areas were ranked as *moderately important* (Figure 9).

### Newer vs. More Experienced Growers:

Research priorities were parsed for newer and more experienced growers. Overall, newer growers ranked biofouling control, comparing efficiency of grow-out strategies, and site selection for grow-out as their top three priorities, all of which were rated urgently important. More experienced growers reported three different topics, with shellfish diseases as the only urgently important topic, followed by selective breeding and vibrio detection/resistance in the moderately important category.

For oyster growers, notable similarities among the top three priorities for newer growers include comparing efficiency of grow out strategies and biofouling. While the former retains its urgently important rating, the latter is slightly reduced to moderately important. With more experienced growers, both shellfish diseases and vibrio detection/resistance retained a top three rating. For newer eastern oyster growers crop protection (urgently important) was an additional priority, for and their more experienced counterparts it was nursery technology (moderately important).

Scallop grower respondents all self-identified as more experienced growers, resulting in no newer grower data to consider for comparison. The inverse was the case in our 2019 report. For mussel growers, given the small sample size (n=6) and to retain confidentiality, we did not carry out an analysis of newer vs more experienced growers.



Table 7: Newer vs More Experienced Responding Growers

	All shellfish growers	Oyster growers	Scallop growers	Mussel growers
Newer Growers <i>&lt;6 years in the sector</i>	45% of all shellfish growers have been in the sector for less than 6 years	45% of all oyster growers have been in the sector for less than 6 years	None	33% of mussel growers have been in the sector for less than 6 years
More Experienced Growers <i>&gt;6 years in the sector</i>	55% of all shellfish growers have been in the sector for more than 6 years	55% of all oyster growers have been in the sector for more than 6 years	100% of scallop growers have been in the sector for more than 6 years	67% of mussel growers have been in the sector for more than 6 years

Table 8: Top 3 R&D Priorities for the Shellfish Sector - Newer vs experienced

Combined	Newer Growers <i>&lt;6 years in the sector</i>	More Experienced Growers <i>&gt;6 years in the sector</i>
Shellfish Diseases <i>Urgently important</i>	Biofouling Control <i>Urgently important</i>	Shellfish Diseases <i>Urgently important</i>
Crop Protection <i>Moderately important</i>	Comparing Efficiency of Grow Out Strategies <i>Urgently important</i>	Selective Breeding <i>Moderately important</i>
Biofouling <i>Moderately important</i>	Site Selection for Grow Out <i>Urgently important</i>	Vibrio detection/resistance <i>Moderately important</i>

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

Combined	Newer Growers <6 years in the sector	More Experienced Growers >6 years in the sector
Shellfish Diseases <i>Urgently important</i>	Comparing efficiency of grow out strategies <i>Urgently important</i>	Shellfish Diseases <i>Urgently important</i>
Vibrio Detection/Resistance <i>Moderately important</i>	Crop Protection <i>Urgently important</i>	Vibrio Detection/Resistance <i>Moderately important</i>
Crop Protection <i>Moderately important</i>	Biofouling control <i>Urgently important</i>	Nursery technology <i>Moderately important</i>

FIGURE 14: Shellfish Sector R&D Priorities in 2022 (newer shellfish growers)(n=19)

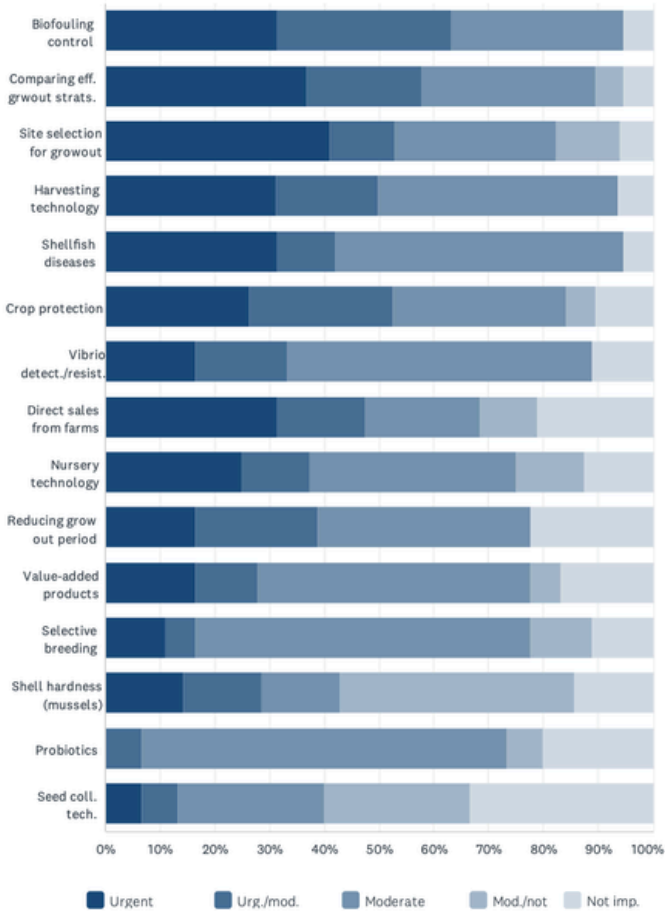
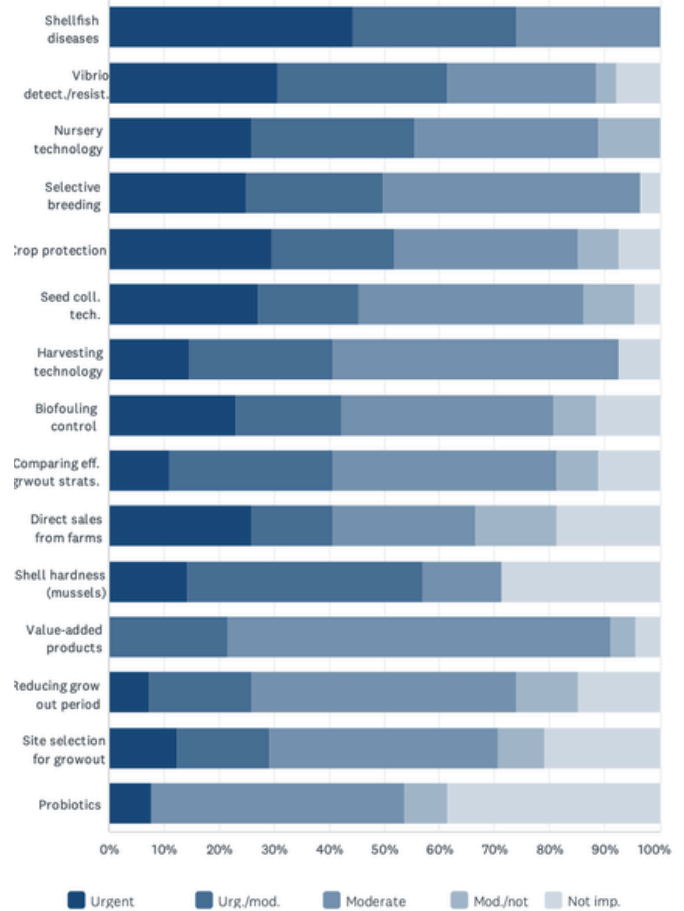


FIGURE 15: Shellfish Sector R&D Priorities in 2022 (more experienced shellfish growers)(n=30)



# Finfish Sector Priorities

## QUESTION 11: How would you rate the importance of research in each of these finfish sector areas:

2022 Survey; Answered: 141; Skipped: 39; N/A: 0

Survey respondents were asked to rate a list of sector research areas using a 5 point Likert-scale (1=urgently important to 5=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 priorities of newer vs. more experienced growers

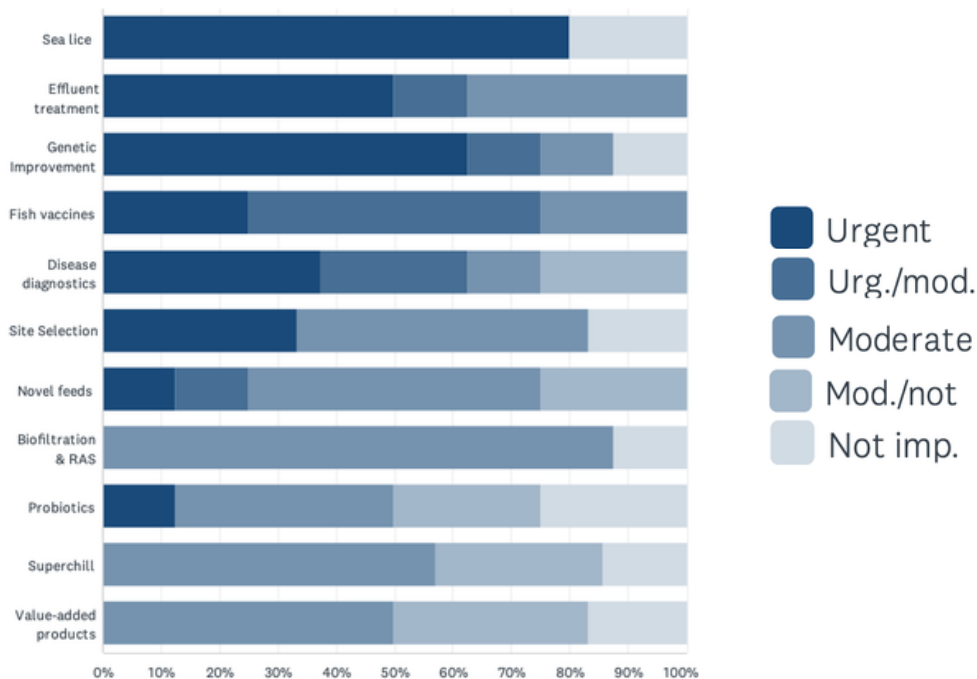
Table 10: Top 3 R&D Priorities for the Finfish Sector (n=6)

Importance	Topic	Weighted Avg.
Moderately important	Sea Lice	1.80
Moderately important	Effluent Treatment Genetic Improvement	1.88
Moderately important	Fish Vaccines	2.00

\*Lower numbers indicate higher priorities

Sea lice, effluent treatment, genetic improvement, and fish vaccines were all identified by responding finfish growers as urgently important research priorities. All the other listed areas were scored as moderately important research priorities. Value-added products were rated as of lowest importance.

FIGURE 16: Shellfish Sector R&D Priorities in 2022 (newer shellfish growers)(n=19)



# Sea Vegetable Sector Priorities

## QUESTION 12: How would you rate the importance of research in each of these sea vegetable areas:

2022 Survey; Answered: 137; Skipped: 43; N/A: 0

Survey respondents were asked to rate a list of sector research areas using a 5 point Likert-scale (1=urgently important to 5=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 businesses in Maine, it is not appropriate to parse results for species-specific priorities nor the priorities of newer vs. more experienced growers.

Table 10: Top 3 R&D Priorities for the Sea Vegetable Sector (n=4)

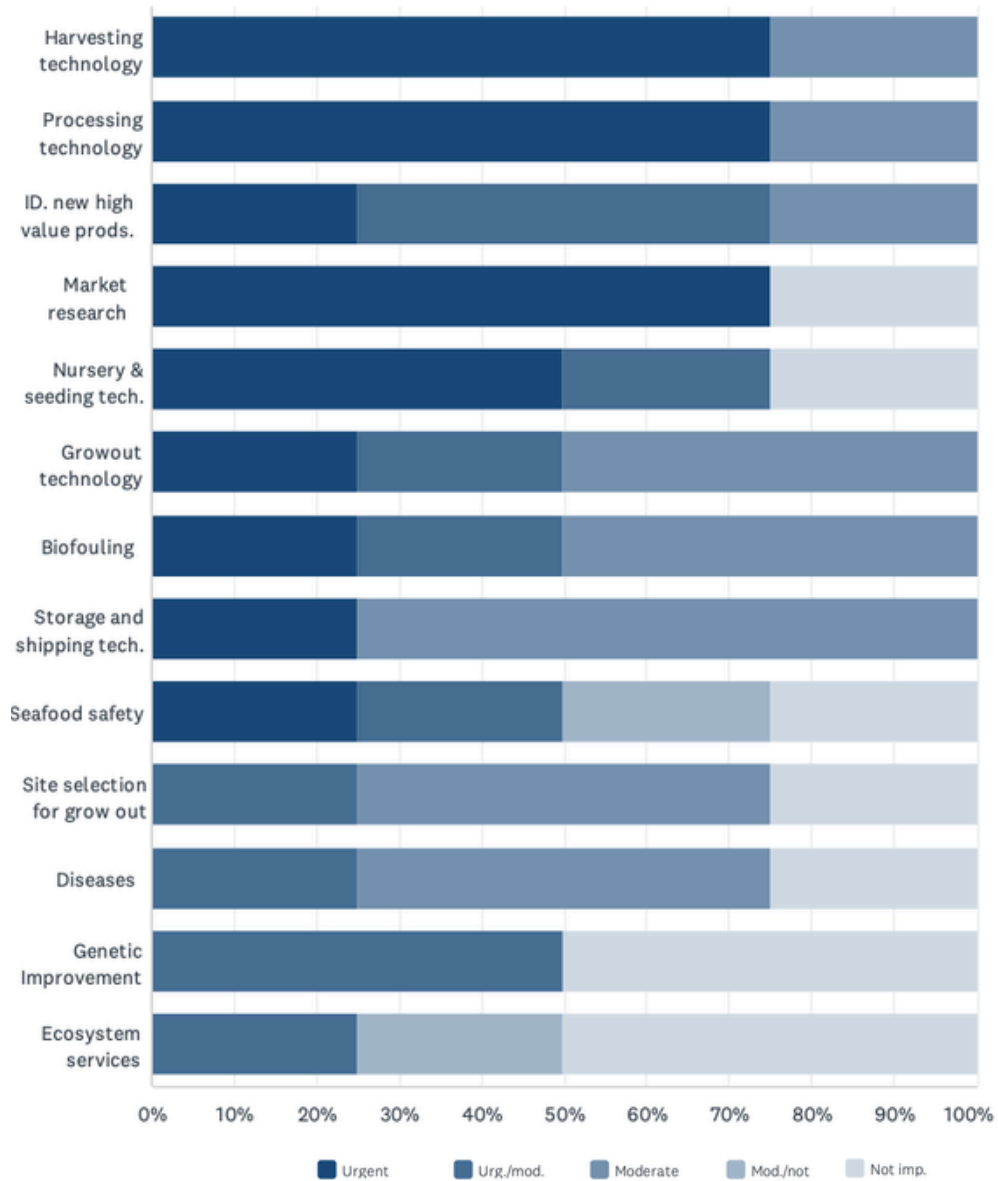
Importance	Topic	Weighted Avg.
Urgently important	Harvesting technology Processing technology	1.50
Urgently important	Identifying New High Value-added Products Market Research	2.00
Moderately important	Nursery & seeding technology Growout technology Biofouling	2.25

*\*Lower numbers indicate higher priorities*

Harvesting technology and processing technology were the most important research priorities identified by sea vegetable growers. Identifying New High Value-added Products, and Market Research were also identified as urgently important priorities (Table 10). Ecosystem services was ranked last and was the only topic area rated as not important. All the other listed areas were scored as moderately important research priorities.



FIGURE 17: Shellfish Sector R&D Priorities in 2022 (newer shellfish growers)(n=19)



# General Aquaculture Priorities

## QUESTION 13: How would you rate the importance of R&D in each of these areas:

2022 Survey; Answered: 139; Skipped: 41; N/A: 0

Survey respondents were asked to rate a list of sector research areas using a 5 point Likert-scale (1=urgently important to 5=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 businesses in Maine, it is not appropriate to parse results for species-specific priorities nor the priorities of newer vs. more experienced growers.

Table 11: Top 3 General Aquaculture R&D Priorities (responding growers)(n=61)

Importance	Topic	Weighted Avg.
Urgently important	Access to working waterfront	1.66
Urgently important	Social acceptability	1.93
Moderately important	Policy and regulations	2.03

*\*Lower numbers indicate higher priorities*

Access to working waterfront and social acceptability of aquaculture were rated as urgently important R&D topic areas. All the other listed areas were scored as moderately important research priorities.

When filtering by sub-sector (Shellfish vs Finfish vs Sea Vegetable growers) some differences in priorities become apparent (Table 12).

- Shellfish growers identified 5 urgent priorities
- Finfish growers identified 4 urgent priorities
- Sea vegetable growers identified 5 urgent priorities.



Table 12: Urgently Important Priorities General Aquaculture - Shellfish vs Finfish vs Sea Vegetable

Shellfish (n=46)	Finfish (n=8)	Sea Vegetable (n=4)
Access to working waterfront (weighted average 1.43)	Social acceptability (weighted average 1.50)	Waste utilization and effluent reduction (weighted average 1.0)
Management of impacts of environmental change (weighted average 1.83)	Waste utilization and effluent reduction (weighted average 1.63)	Social acceptability (weighted average 1.33)
Management of invasive species, predators & biofouling Policy and regulations Water quality monitoring and accessing water quality information (weighted average 1.93)	Information materials for the general public (weighted average 1.75)	Access to working waterfront (weighted average 1.5)
	Training and professional development (weighted average 1.88)	Market & branding research (weighted average 1.75)
		Information materials for the general public (weighted average 2.0)



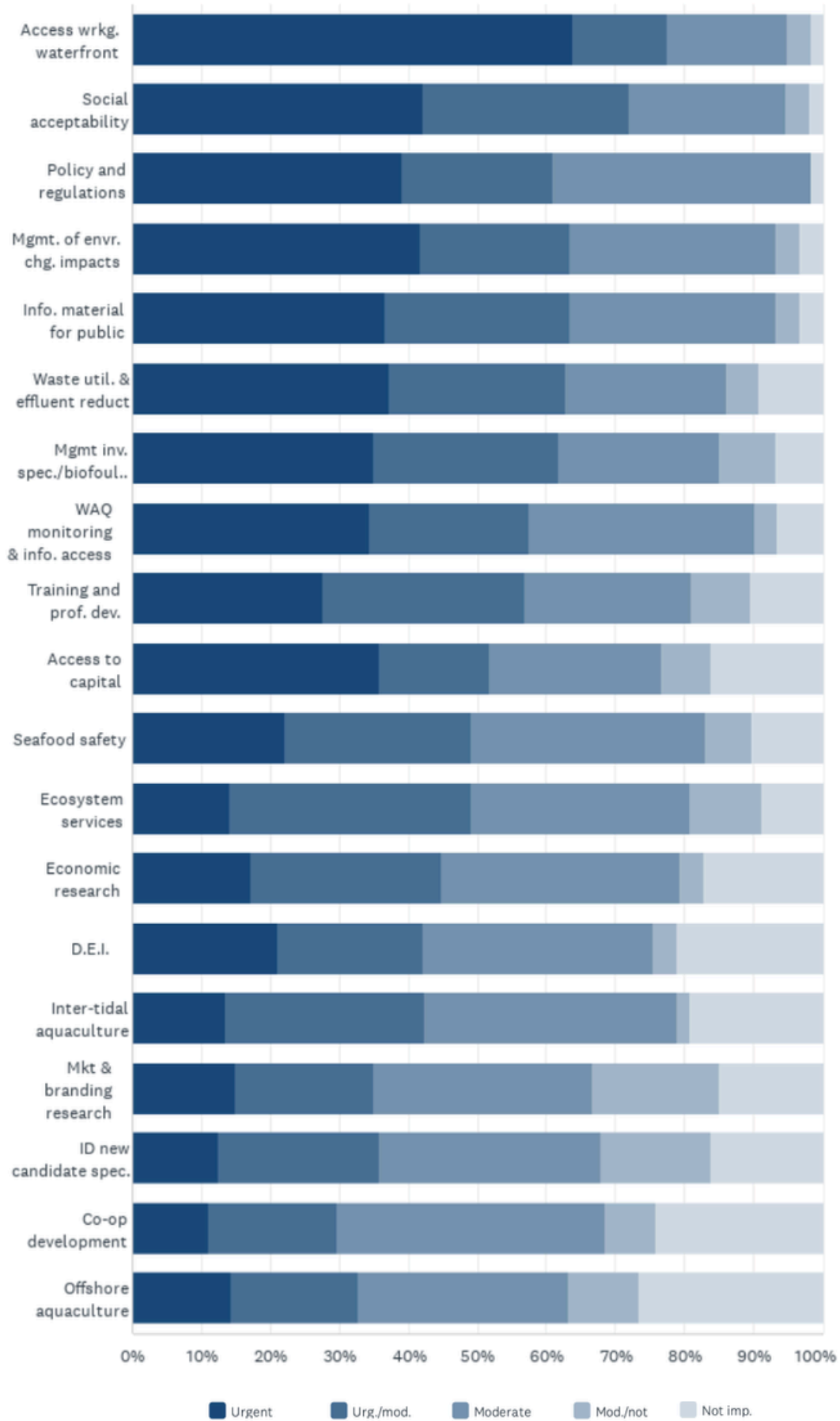
Table 13: Urgently Important Priorities General Aquaculture -Scallop vs Mussel vs Oyster

Scallop (n=2)	Mussel (n=6)	Oyster (n=37)
Social acceptability Identification of new candidate species Policy and regulations Access to working waterfront Seafood Safety (weighted average 1.0)	Access to working waterfront (weighted average 1.33)	Access to working waterfront (weighted average 1.49)
Waste utilization and effluent reduction Management of invasive species, predators & biofouling Water quality monitoring and accessing water quality information Ecosystem services Coop development (weighted average 2.0)	Management of invasive species, predators & biofouling (weighted average 1.5)	Management of impacts of environmental change (weighted average 1.73)
	Policy and regulations (weighted average 1.83)	Water quality monitoring and accessing water quality information (weighted average 1.81)
	Social acceptability Management of impacts of environmental change (weighted average 2.0)	Management of invasive species, predators & biofouling (weighted average 2.0)

When differentiating between shellfish sub-sectors (scallop vs mussel vs oyster growers), there are some differences in priorities, but for all three groups of farmers improving access to working waterfront is a high priority (Table 12).



FIGURE 17: Shellfish Sector R&D Priorities in 2022 (newer shellfish growers)(n=19)



# Processing & Product Development Priorities

**QUESTION 14:** How would you rate the importance of research in each of these areas:

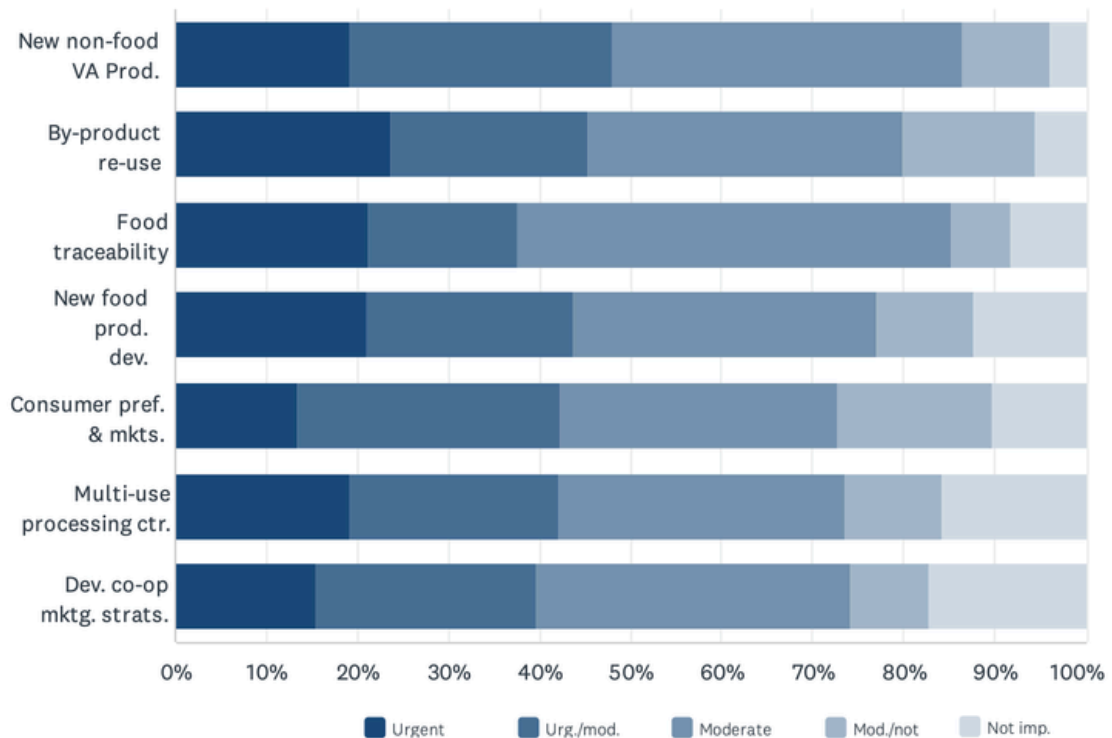
2022 Survey; Answered: 138; Skipped: 42; N/A: 0

Table 14: Top 3 Processing & Product Development R&D Priorities (responding growers)(n=62)

Importance	Topic	Weighted Avg.
Moderately important	New non-food value-added products	2.50
Moderately important	Byproduct reuse	2.56
Moderately important	Food traceability	2.64

*\*Lower numbers indicate higher priorities*

FIGURE 18: Processing & Product Development R&D Priorities\* (responding growers)(n=62)



While table 14 highlights the top 3 priorities, all the listed areas scored as moderately important research priorities (Figure 18). Food traceability was also one of the top three priorities in 2019.

When filtering by sub-sector (Shellfish vs Finfish vs Sea Vegetable growers) differences in priorities become more apparent (Table 15). Finfish and sea vegetable growers are the only grower affiliations to identify any urgently important priorities: byproduct reuse and non-food value added products, respectively. (Table 15).

Table 15: Urgently Important Priorities Processing & Product Development - Shellfish vs Finfish vs Sea Vegetable

Shellfish (n=47)	Finfish (n=8)	Sea Vegetable (n=4)
None. All priorities were rated as moderately important	Byproduct reuse (weighted average 1.75)	New non-food value added products for pharma, biotech etc industries (weighted average 1.75)

When considered together, shellfish growers did not identify any urgently important priorities. However, when parsed by shellfish species, sea scallop growers identified the development of value-added products as an urgently important priority.

Table 16: Urgently Important Priorities Processing & Product Development - Scallop vs Mussel vs Oyster

Scallop (n=2)	Mussel (n=6)	Oyster (n=40)
New non-food value-added products (weighted average 1.0)	None. All priorities were rated as moderately important or not important	None. All priorities were rated as moderately important



# Farm Operations Technology

**QUESTION 15.** How would you rate the importance of research in each of these areas:

2022 Survey; Answered: 136; Skipped: 44; N/A: 0

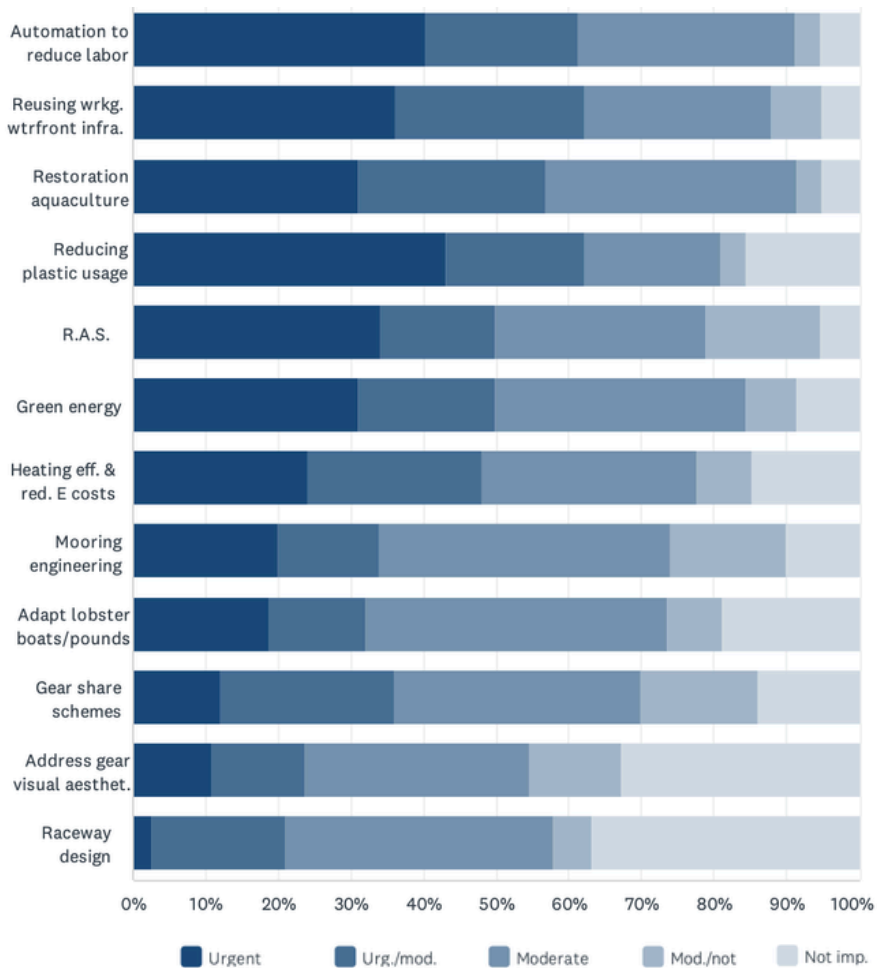
Table 17: Top 3 Farm Operations Technology R&D Priorities (responding growers)(n=61)

Importance	Topic	Weighted Avg.
Moderately important	Automation to reduce labor	2.12
Moderately important	Re-using working waterfront infrastructure for aquaculture	2.19
Moderately important	Restoration aquaculture	2.26

*\*Lower numbers indicate higher priorities*

Although the above were the Top 3 priorities (Table 17), all listed areas scored as moderately important research priorities (Figure 18).

FIGURE 18: Farm Operations Technology R&D Priorities\* (responding growers)(n=61)



When comparing newer growers (n=26) vs more experienced growers (n=35), reducing plastic usage was ranked in the top 3 by newer growers. More experienced growers ranked recirculating aquaculture systems in the top 3.

When filtering by sub-sector (Shellfish vs Finfish vs Sea Vegetable growers) some differences in priorities become apparent (Table 18).

- Shellfish growers rated all topic areas as moderately important.
- Finfish growers rated 4 topic areas as not important:
  - Adapting lobster boats for aquaculture, & Using lobster pounds for aquaculture (weighted average 4.20)
  - Addressing visual aesthetics of gear (weighted average 4.33).
  - Raceway design (weighted average 4.67),
  - Gear share schemes (weighted average 4.75)

Sea vegetable growers rated automation to reduce labor as urgently important (weighted average 1.82), whereas shellfish growers (weighted average 2.09) and finfish growers (weighted average 2.50) rated this as moderately important

Table 18: Urgently Important Priorities Farm Operations Technology - Shellfish vs Finfish vs Sea Vegetable

Shellfish (n=47)	Finfish (n=8)	Sea Vegetable (n=4)
None. All priorities were rated as moderately important	None. All priorities were rated as moderately important or not important	Automation to reduce labor (weighted average 1.33)

When drilling down into shellfish species (scallop vs mussel vs oyster growers) more differences in priorities become apparent (Table 16).

Oyster growers only identified one farm operations topic area as an urgently important research priority: reusing working waterfront infrastructure (weighted average 1.95). All other farm operations topic areas were rated as moderately important by oyster growers.

Mussel growers identified automation to reduce labor (weighted average 1.8) and restoration aquaculture (weighted average 2.0) as urgently important (Table 16). All other topic areas were moderately important.

Scallop growers rated reusing working waterfront infrastructure for aquaculture as urgently important (Table 16), while reducing working waterfront infrastructure (weighted average 3.0) was rated as moderately important. All other farm operations topic areas were rated as not important or not applicable by scallop growers.

Since 2019, the number one priority for each shellfish species has remained consistent in rank and level of urgency.

Table 16: Table 19: Urgently Important Priorities Farm Operations Technology - Scallop vs Mussel vs Oyster

Scallop (n=2)	Mussel (n=6)	Oyster (n=40)
Re-using working waterfront infrastructure for aquaculture (weighted average 2.0)	Automation to reduce labor (weighted average 1.8)	Re-using working waterfront infrastructure for aquaculture (weighted average 1.95)
	Restoration aquaculture (weighted average 2.0)	

# Education & Training:

## Question 16. How would you prioritize target audiences for outreach and education?

2022 Survey; Answered: 136; Skipped: 44; N/A: 0

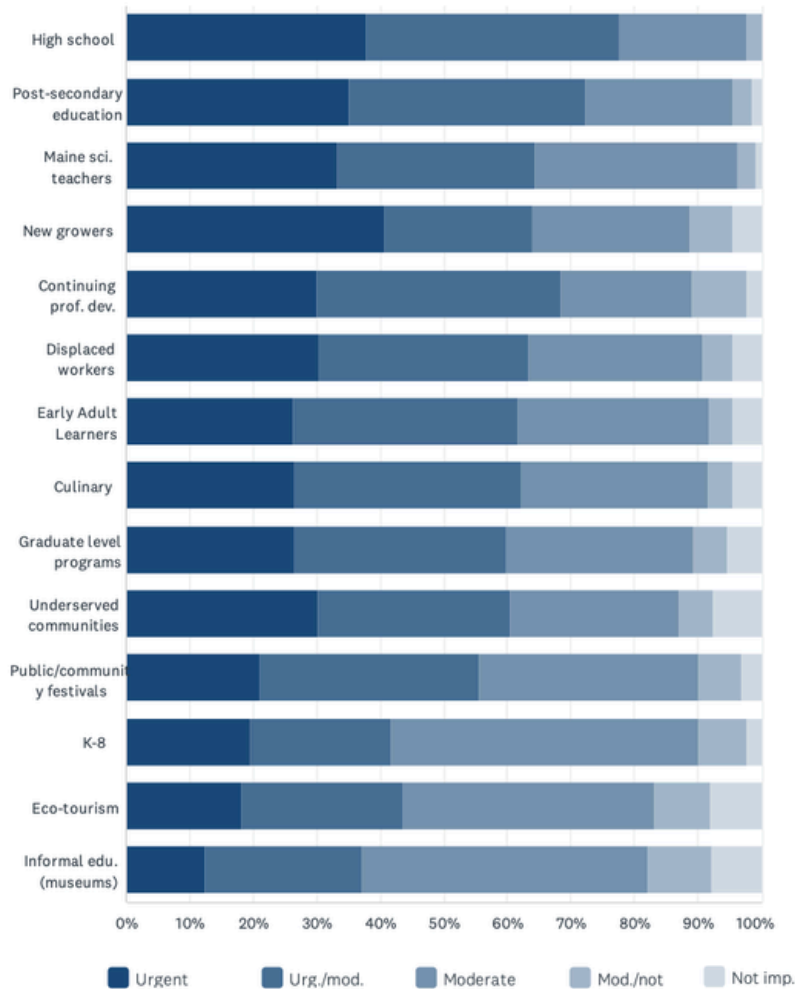
Table 17: Top 3 Farm Operations Technology R&D Priorities (responding growers)(n=61)

Importance	Topic	Weighted Avg.
Urgently Important	High schoolers	1.87
Urgently Important	High schoolers	1.99
Moderately important	Maine science teachers	2.07

\*All respondents were guided to this question.

High schoolers were highlighted as the top priority target audience by the entire population of respondents. Previously reported trends did not reflect the priorities represented by growers. However, this year growers also identified high school, marine science teachers, and postsecondary education as their top three target audiences.

FIGURE 19: Education Priorities: Target Audiences (as scored by all respondents)(n=136)



## Question 17. How would you prioritize curricula and training needs?

2022 Survey; Answered: 135; Skipped: 45; N/A: 0

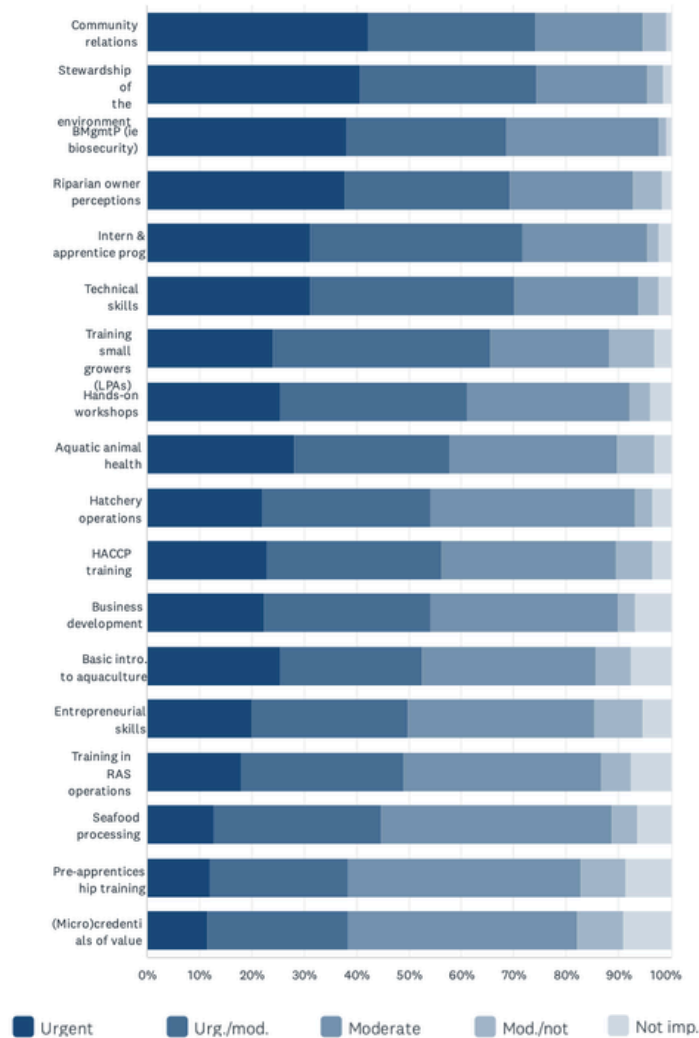
Table 18: Top 3 Farm Operations Technology R&D Priorities (responding growers)(n=61)

Importance	Topic	Weighted Avg.
Urgently Important	Community relations	1.89
Urgently Important	Stewardship of the environment	1.91
Urgently Important	Better management practices such as biosecurity	1.96

*\*All respondents were guided to this question.*

Overall, community relations, stewardship of the environment, and better management practices were identified as urgently important (weighted averages of 1.89, 1.91, and 1.96, respectively) training needs. Growers (n=60) identified the same three priorities. Since 2019, addressing riparian owner concerns has been reduced to moderately important, but otherwise, in 2022, the same topics retain their urgent status.

FIGURE 20: Education Priorities: Curricula (as scored by all respondents)(n=135)



## Question 18. Other education and outreach needs. Do we need programs to address the following?

2022 Survey; Answered: 135; Skipped: 45; N/A: 0

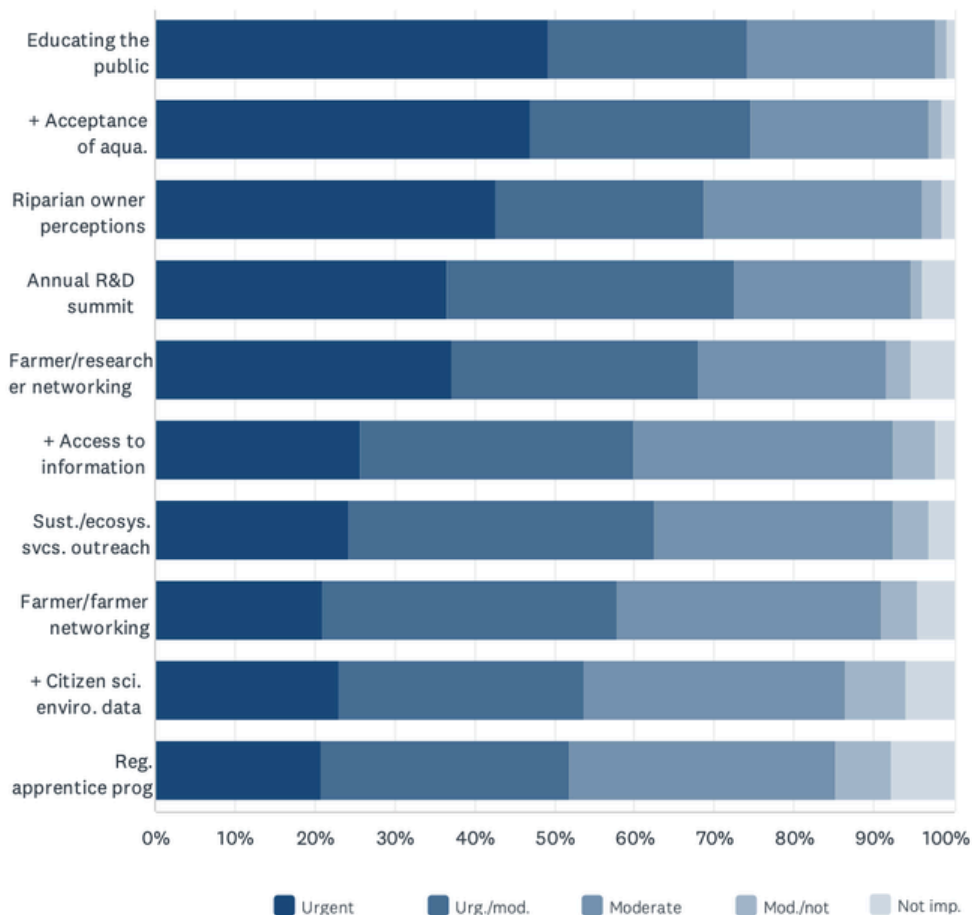
Table 19: Top 3 Programs: Education Priorities (n=135)

Importance	Topic	Weighted Avg.
Urgently Important	Educating the public	1.80
Urgently Important	Increasing acceptance of aquaculture	1.83
Urgently Important	Addressing riparian owner concerns	1.94

*\*All respondents were guided to this question.*

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 parsing out just growers, these education program priorities did not change. Since 2019, the top 3 topics have remained the same and retained the same status of urgently important.

FIGURE 21: Education Priorities: Programs (as scored by all respondents)(n=135)



## Question 19. Which time of year would be best for you to attend training sessions?

2022 Survey; Answered: 135; Skipped: 45; N/A: 0

Winter was identified by 67% of respondents as the best time of year to attend training sessions. When selecting just growers, the preference for winter training sessions rose to 73% of the respondents.



# Community Identified Research Needs

## Question 20. 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?

2022 Survey: Answered: 106; Skipped: 74; N/A: 0

All respondents were guided to this question; 106 answered and 74 skipped the question. This was an open question, and a qualitative, thematic analysis was carried out. Overall the dominating themes raised by growers as research and development topics for seed grants are shown in Table 20. Several topics were raised by multiple sub sectors. Some topics were raised by only one sub-sector.

Table 20: Overarching themes raised by growers for 2022:

Theme	Topic	Number of instances
Capital & assets	22	Shellfish, Seaweed, fin fish
Gear & innovation	12	Shellfish, sea vegetable
Workforce & training	9	Shellfish, finfish
Human dimensions	8	Shellfish, finfish
Regulations	4	Shellfish, consultant
Growing techniques	3	Shellfish, finfish, sea vegetable
R&D	3	Shellfish, sea vegetable
Water quality management	3	Shellfish, finfish
Sustainability	3	Shellfish, finfish
Environmental threats	2	Shellfish, finfish

Additional seed grant research themes included

- Invasives, parasites, pests, & diseases (9 instances)
- Seed (5 instances)
- Product development (2 instances)
- Climate change solutions (2 instances)



## **Shellfish growers (n=41) the most frequent seed grant themes identified by shellfish growers are:**

- Capital & assets (20 instances)
- Gear & technology innovation (11 instances)
- Invasives, parasites, pests, and diseases (9 instances)
- Workforce & training (7 instances)
- Shellfish seed (5 instances)

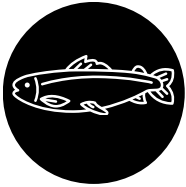
For the first time since 2012, some respondents answered this question in the context of the seed grants being available for business development rather for research and development projects. For this reason, responses were dominated by the theme capital & assets. Responses within this theme suggested that shellfish growers would use \$25,000 business seed grants to upgrade gear and other assets.

Research and development themes included suggestions for research on green technologies, reduced plastics, research on biofouling and invasive species species management, hatchery seed development, and workforce programs for women and minorities.

**"Electric motors to replace current gasoline motors"**

**"Less plastic in grow-out gear and shipping!"**

**"Developing training program for minorities, members of the immigrant community, and/or young women"**



## **Finfish growers (n=8) suggested 7 topics for seed grants:**

- Human dimensions (7 instances)
- Water quality management (2 instances)
- Workforce & training (2 instances)
- Capital & assets (1 instance)
- Environmental threats (1 instance)
- Growing techniques (1 instance)
- Sustainability (1 instance)

Finfish grower representation of human dimensions served as the greatest factor in the topic breaking the overall grower top 5 priorities for seed grants. Relationships with stakeholders and interest groups are an immutable aspect for grower operations; public perception, relations, education, & outreach can be a strength, not a challenge, if industry resources can be effectively allocated.

**"Community outreach (RAS education/good PR, eel citizen science, general RAS community talks)"**



## **Sea vegetables growers (n=3) suggested 4 topics for seed grants:**

- Capital & assets (1 instance)
- Gear & tech innovation (1 instance)
- Growing techniques (1 instance)
- R&D (1 instance)

Two of the four topics presented by sea vegetable growers aligned with the general consensus among all grower affiliations, those topics being capital & assets as well as gear and technological innovation. Relative to the status-quo, the notable representation of growing techniques and R&D seed grant foci makes the sea vegetable grower priorities stand out from the whole.

**"On-farm processing and cold chain"**

FIGURE 22: Grower seed grant priorities

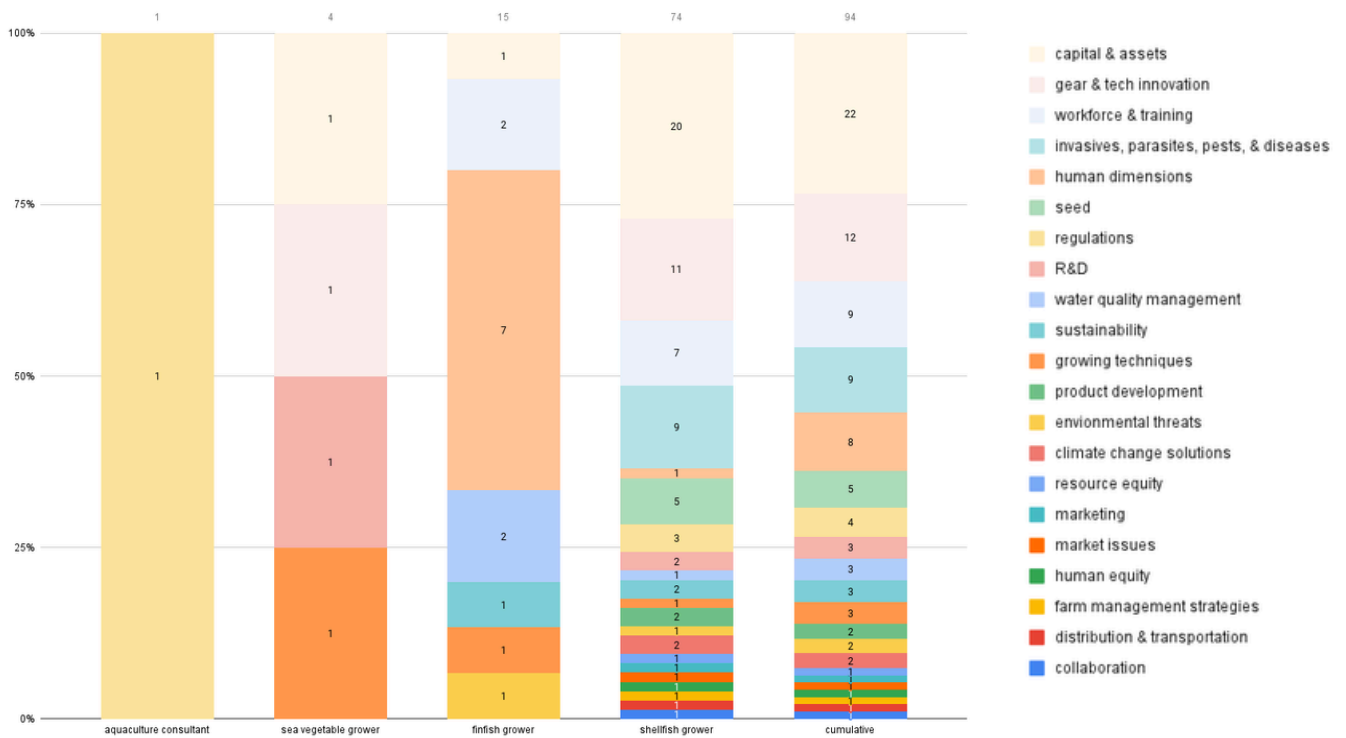
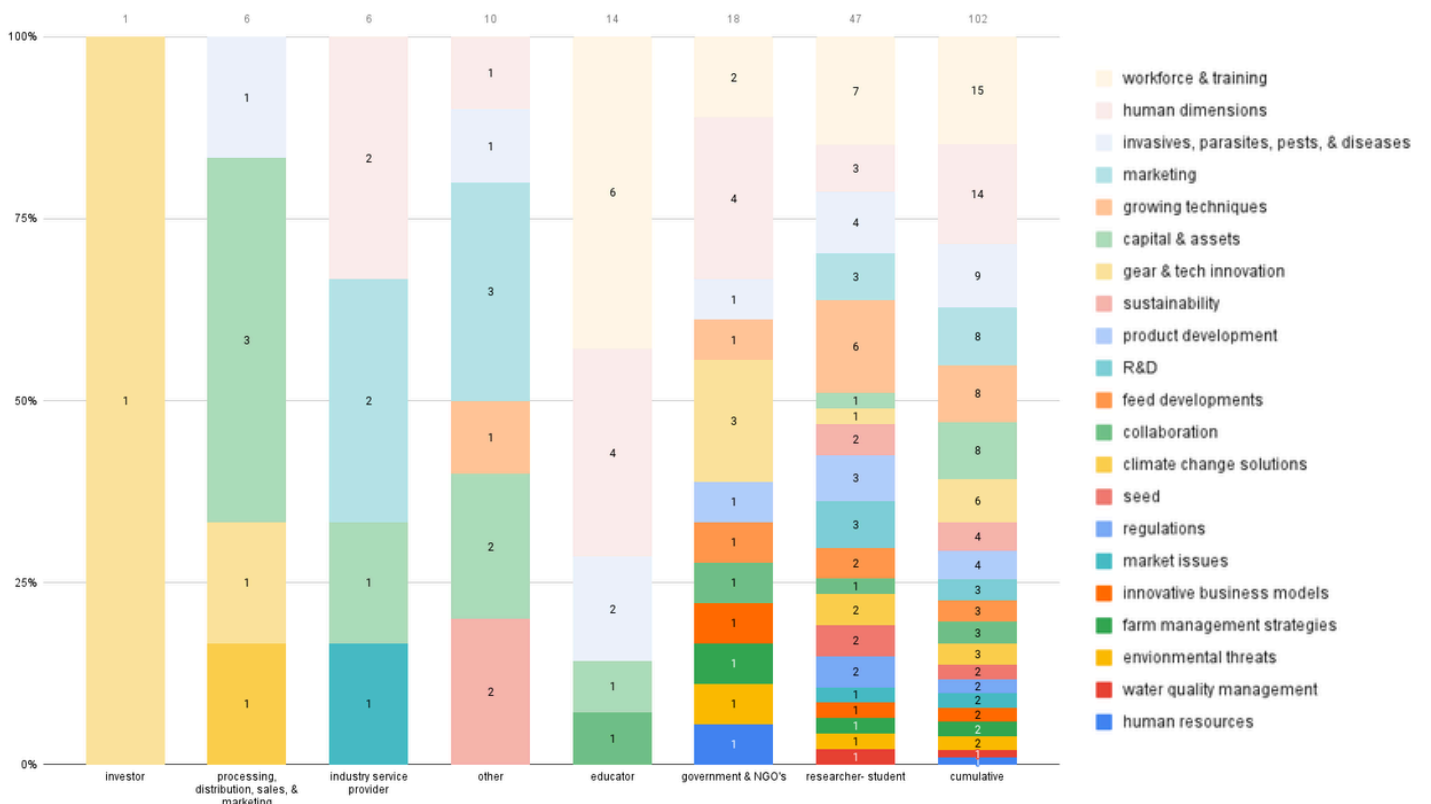


FIGURE 23: Non-grower seed grant priorities



## Question 21. If you could direct a \$1,000,000 research initiative, what would be its focus?

2022 Survey: Answered: 108; Skipped: 72; N/A: 0

All respondents were guided to this question; 108 answered and 72 skipped the question. This was an open question, and a qualitative, thematic analysis was carried out. Overall the dominating themes raised by growers as research and development topics for seed grants are shown in Table 21.

Table 21: Overarching themes across grower affiliations for 2022

Theme	Topic	Number of instances
Invasives, parasites, pests, and diseases	23	Shellfish, finfish
Capital & assets	9	Shellfish, consultant
Sustainability	6	Shellfish, consultant
Product innovation	6	Shellfish, sea vegetable
Human dimensions	5	Shellfish, finfish, sea vegetable
Regulations	4	Shellfish, consultant
Marketing	3	Shellfish, sea vegetable

Additional research initiative themes included:

- Hatchery research (10 instances)
- Innovation (7 instances)
- Farm management strategies (6 instances)
- Climate change solutions (5 instances)
- Environmental threats (5 instances)
- Growing techniques (5 instances)
- Collaboration (4 instances)
- Regulations (4 instances)
- Harvest management strategies (3 instances)
- Human resources (3 instances)
- Marketing (3 instances)
- Workforce & training (3 instances)

Some additional, meaningful research and development themes were identified only once:

- Data collection
- Distribution & transportation
- Feed development
- Human equity
- Market issues
- Probiotics
- Technology



### **Shellfish growers (n=41)**

suggested research topics on invasives, parasites, pests, and diseases (mentioned 14 times), and hatchery research (10 mentions), and made some specific innovation suggestions (7 mentions). Topics include research into biofouling and invasive species management, climate change resilience strategies, developing predictive tools for environmental change, development of new food and non-food value-added products, the role of probiotics in hatcheries, and cost effective wintering technology and techniques.

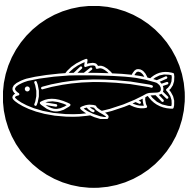
Innovations sought by the shellfish sub-sector include grow-out gear innovations, RAS for shellfish hatcheries, and “creat[ing] the John Deere for corn equivalent for aquaculture”.

Sector development themes include market development and investments in the Department of Marine Resources.

**"Energy efficient, zero discharge RAS Systems"**

**"Exploring resilience strategies in a changing climate for the industry"**

**"Another hatchery for oyster seed in Maine seems important, ... Research into HABs and disease is obviously important. Sea squirts are the bane of my existence, so figuring out how to deal with those and terrible barnacle sets would be good."**



### **Finfish growers (n=7) suggested research and development within 4 themes:**

- Invasives, parasites, pests, & diseases (9 instances)
- Feed development (1 instance)
- Human dimensions (1 instance)
- Probiotics (1 instance)

Specifically, within the theme “Invasives, parasites, pests, & diseases”, fin fish growers are looking for research and development support to identify treatments for sea lice that can be approved for use in Maine.

Other research topics suggested by fin fish growers include “culture of alternative protein sources for fish feeds” and research to understand the role of probiotics in hatcheries.

**"An in-depth assessment of freshwater and saltwater pathogens, paying close attention to approaching bio security threats"**



### **Sea vegetables growers (n=4) suggested research and development within 4 themes:**

- Human dimensions (2 instances)
- Product diversification (2 instances)
- Distribution & transportation (1 instance)
- Marketing (1 instance)

Research topics suggested by sea vegetable growers include developing new value-added products, and understanding the impact of consumer education on market development. Innovations sought by the sub-sector include developing: solar technologies, low-sound emitting equipment, and developing alternatives to plastic gear. Sub-sector development strategies sought by sea vegetable growers focus on two areas: reducing the timeframe for processing lease applications, and consumer education.

**"Processing, new products and consumer education"**

FIGURE 24: Research initiative grower responses

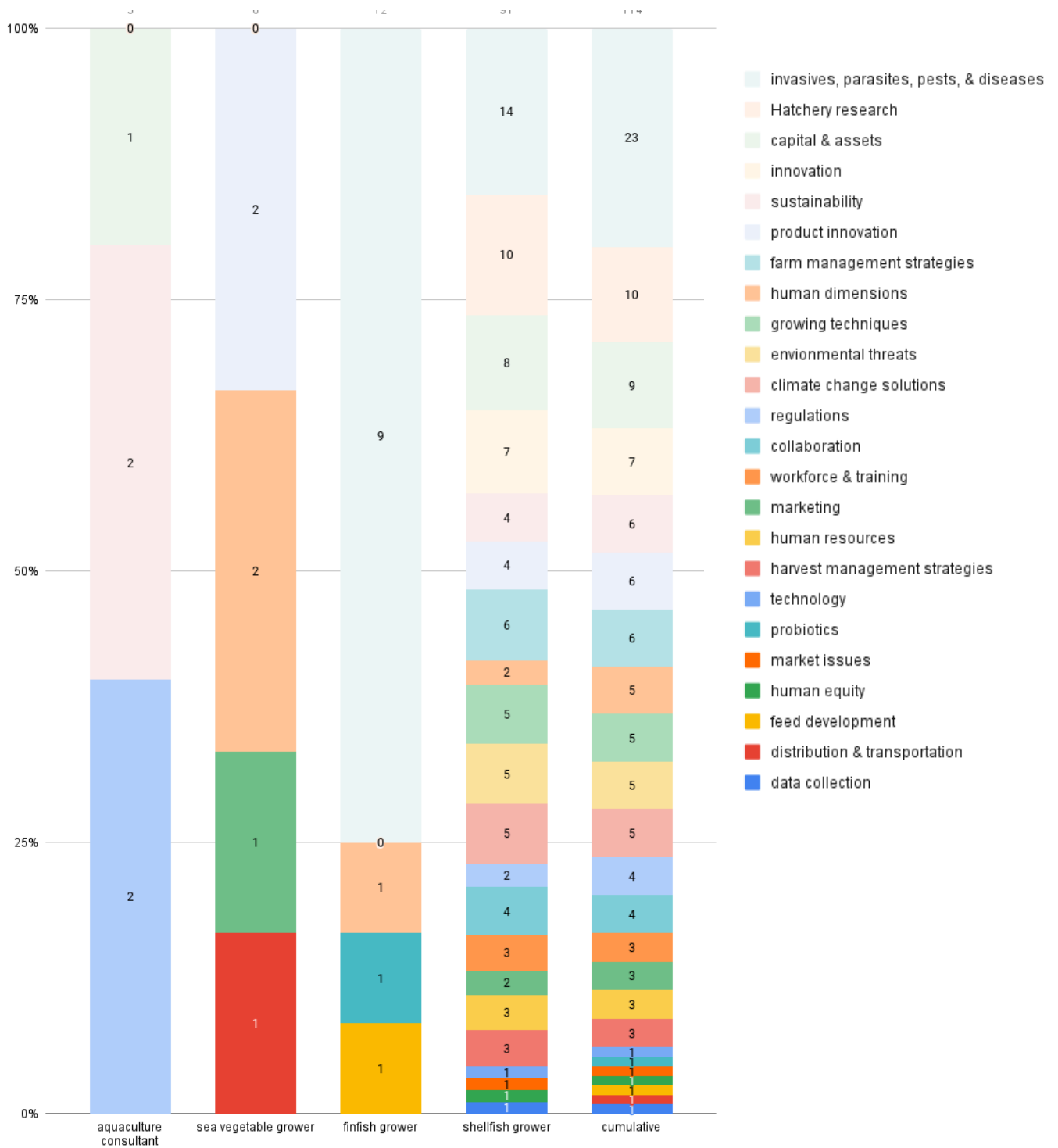
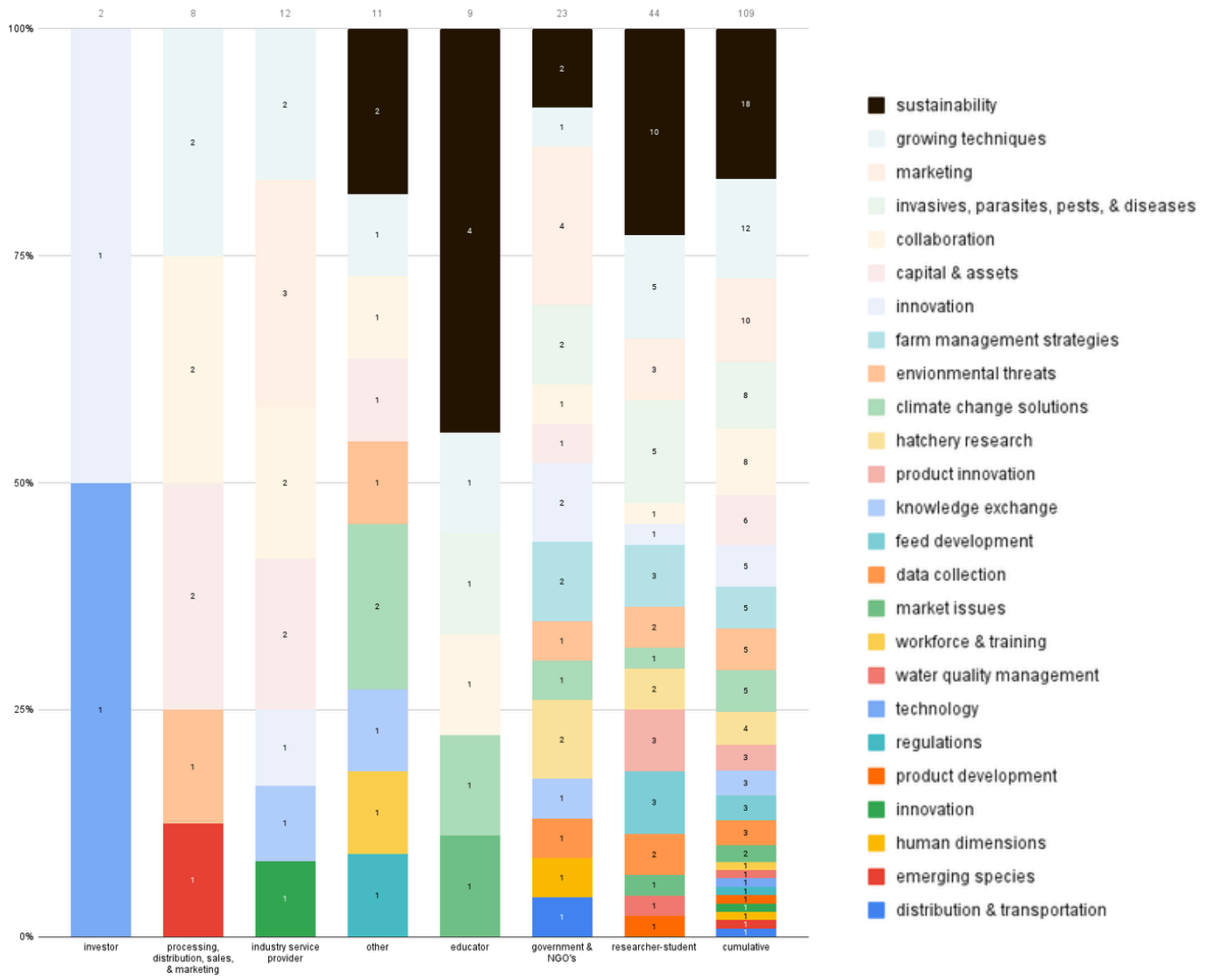


FIGURE 25: Research initiative grower responses





# Conclusions and Recommendations

## **Parsing sectors:**

Examining priorities by sector with emphasis on analyzing open questions is crucial in identifying specific research needs while also ensuring urgent needs for emerging sectors are not overlooked.

## **Newer vs More Experienced Growers:**

Research and development needs differ between newer and more experienced growers. However, differences are less apparent than in 2019 as the percentage of growers involved in the sector for less than 3 years has decreased.

## **Parsing research priorities for sectors:**

In future surveys, it would be helpful to follow-up the survey with interviews or focus groups to clarify the research needs of different sub-sectors. For example, in this 2022 survey, climate resilience/adaptation was a prominent theme with many sectors pointing out green technology as a priority. For different sub-sectors this could mean a variety of things such as electric motors for shellfish farmers, solar technology for sea vegetable farmers, or alternative feed sources for finfish farmers.

## **The difference between research and development:**

There are differences between research and development that are not easily ascertained by responses to a survey, and require interpretation. This survey has identified topics and strategies for research as well as for specific sector development initiatives that could promote economic growth. For example, many of the themes identified in this survey relate to issues associated with maturation of newer farms. These issues include accessing workforce, understanding financing and capitalization, and the timeline associated with transitioning from

LPAs to leases. Addressing these issues do not require research; they require state-wide sector development initiatives. Other sector development topics that were identified by this survey include:

- Initiatives to leverage the Maine brand to promote local, sustainable, farm-raised seafood
- Understanding riparian landowner concerns,
- Better strategies for community engagement and education, and
- Development of evidence-based public information materials for use and dissemination by the aquaculture community.

## **Research on farm management strategies:**

Many of the researchable topics identified by growers require farm-level research to identify and/or develop economically and environmentally sustainable farm management strategies. Some examples include:

- Biofouling and invasive species management strategies research, including understanding the economic and environmental pro's and con's
- Farm management strategies to improve labor efficiencies

## **Quality economic and market data:**

The last Maine Aquaculture Economic Impact Report was completed in 20145. Maine's aquaculture has changed significantly since then, and there is an urgent need to gather quality data to understand the latest direct economic impacts, the effects of a global pandemic, the federal regulatory environment, statewide multiplier effects and accurate labor statistics. Understanding these elements are imperative to appropriately focus resources to maximize the sustainability of the sector, and there needs to be a commitment to regularly update these data.

## **Innovations**

Innovations are needed across multiple research disciplines. These include but are not limited to innovations in: communication strategies; water quality for effluent treatment; value-added product development; green technology, and building climate resilience.

*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. **Responding to stakeholders' research, education, and training needs using academic-industry partnerships is key for resolving aquaculture bottlenecks and challenges. Maine is well positioned to continue the sustainable development of this sector. Interdisciplinary knowledge exchange and cross-collaboration are essential parts of the economic growth and output of the sector if we are to create resilient, rural, and coastal economies. These biennial surveys and resulting summits are invaluable tool for strengthening these connections.***



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# APPENDIX

## Question 5. Which of the following culture systems do you work with (check all that apply)?

2022 Survey: Answered: 74 Skipped: 1; N/A: 106

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

Culture System	2012	2016	2019	2022
Net Pens	X	X	X	X
Surface Cages	X	X	X	X
Surface Rafts	X	X	X	X
Upwelling Systems	X	x	X	X
Longline Systems	X	X	X	X
Bottom Culture (no structures)	X	X	X	X
Bottom Culture (with structures)	X	X	X	X
Freshwater Ponds	X		X	X
Freshwater Hatchery	X	X	X	X
Marine Hatchery	X	x	X	X
Raceway Systems	X	X	X	X
Intertidal Systems		X	X	X
Land Based Grow-out Systems	X	X	X	X
Recirculating Aquaculture Systems		X	X	X
Integrated Multi-trophic Systems		X	X	X

**Question 5. Which of the following culture systems do you work with (check all that apply)?**

2022 Survey: Answered: 74 Skipped: 1; N/A: 106

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

Principal Species	2012	2016	2019	2022
Atlantic salmon	X	X	X	X
Atlantic cod	X			
Atlantic halibut	X			
Eels		X	X	X
Trout			X	X
Baitfish				
Aquaponics Species			X	
Ornamental Species	X			
Eastern oysters	X	X	X	X
European oysters	X	x	X	X
Blue mussels	X	X	X	X
Hard clams	X			
Soft-shelled clams		X		
Razor clams				
Surf clams				
Arctic surf clams				

Table B: CONT'D

Principal Species	2012	2016	2019	2022
Sea scallops		X	X	X
Bay scallops				
Green sea urchins	X			
Marine worms				
Sugar kelp	X (kelp species not presented as separate species in the 2012 survey)	X (sea vegetables not presented as separate species in the 2016 survey)	X	X
Skinny (sugar) kelp			X	
Winged kelp			X	X
Horsetail kelp				
Dulse			X	
Irish moss			X	
Porphyra Species			X	
Other		Seriola spp, microalgae	microalgae	Tilapia, sea bass, sea bream; Seriola spp

**Question 9. Please indicate all the species you are currently involved with (check all that apply).**

2022 Survey; Answered: 155; Skipped: 25; N/A: 0 All survey respondents were guided to this question. By jointly analyzing responses to questions 6 and 9, including responses filtered for growers or non-growers, it was possible to identify primary commercial species, secondary commercial species, and non-commercial species (Table X).

Table C: Aquacultured Species in Maine, 2022(as represented by survey respondents)

Principal Species	Primary Commercial Species	Secondary Commercial Species	Non-commercial
Atlantic salmon	X		X
Atlantic cod			X
Atlantic halibut			X
Eels	X		
Trout	X	X	X
Baitfish			X
Ornamental Species			X
Eastern oysters	X	X	X
European oysters	X	x	X
Blue mussels	X	X	X
Hard clams		X	X
Soft-shelled clams		X	X
Razor clams		X	X
Surf clams		X	X
Arctic surf clams		X	X

Table C: CONT'D

Principal Species	Primary Commercial Species	Secondary Commercial Species	Non-commercial
Sea scallops	X	X	X
Green sea urchins			
Marine worms			X
Sugar kelp	X	X	X
Skinny (sugar) kelp		X	X
Winged kelp	X	X	X
Horsetail kelp			X
Dulse		X	X
Irish moss			X
Porphyra Species			X
Other	Tilapia, Sea Bass, Sea Bream, Seriola spp	Seriola spp, Lumpfish, Sablefish, Shrimp, Lobster, Tilapia, Giant Kelp, Ulva, Lake Trout, Lake Whitefish, Charr, Morone, Green Crab	Seriola spp; Lumpfish; Sablefish, Shrimp, lobster; tilapia; giant kelp; Morone