SURVEY REPORT

from the

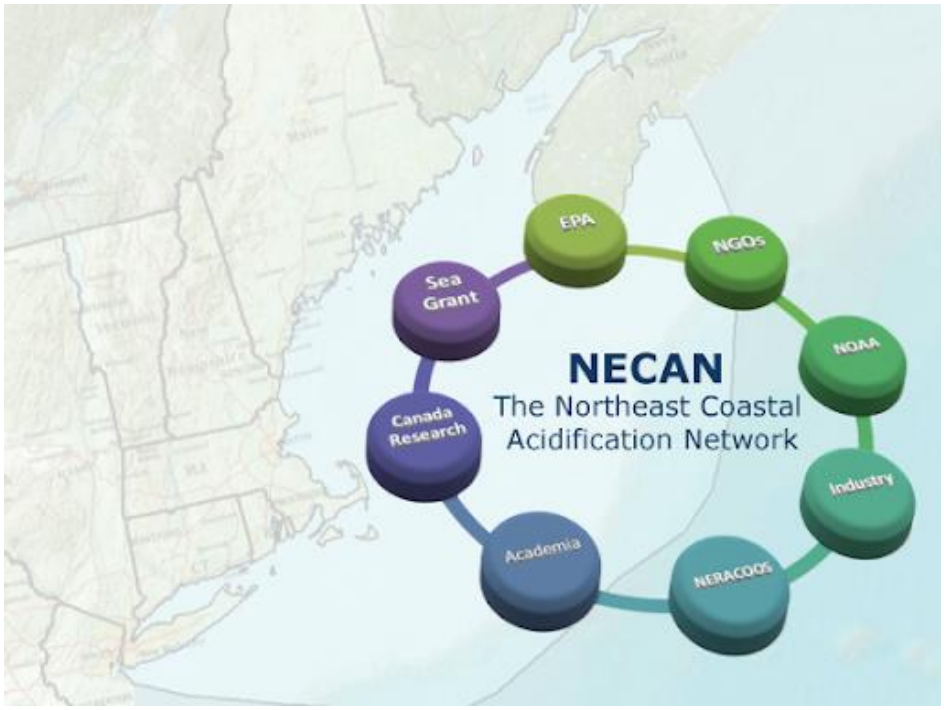
Fall 2018 Industry Survey

by the

INDUSTRY WORKING GROUP

of the

NORTHEAST COASTAL ACIDIFICATION NETWORK (NECAN)



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Executive Summary

In the fall of 2018, the Northeast Coastal Acidification Network (NECAN) Industry Working Group released a survey to industry members, including aquaculturists and wild harvest fishermen, in the US Northeast and Canadian Maritimes to identify their questions and research priorities regarding ocean and coastal acidification (OCA). Responses came from 69 unique respondents and were split into three sections: background questions, questions for hatcheries, and questions for field operators (wild harvest and non-hatchery aquaculturists). Responses were biased towards aquaculturists over wild harvest fishermen. Background questions showed that for OCA monitoring and modelling to be most relevant to industry members, they should represent inshore and nearshore (<1 mile from the coast) regions and include benthic measurements in addition to surface measurements, on a year-round basis. Responding hatcheries were more likely to have suggested they already experienced impacts of OCA on their operations (21.7% of hatcheries vs. 6.5% of field operations). In addition to OCA, hatcheries are concerned about increased nutrient loading and warming waters. Field operations are facing environmental challenges other than OCA that are already having an impact on their operations including harmful algal blooms (HABs), increased storm frequencies and intensities, warming waters, *Vibrio* sp. outbreaks, and nutrient loading. The lack of demonstrated substantial impacts of OCA on aquaculture grow out and wild harvest fisheries makes this environmental issue take a back seat to the issues that are already affecting operations. These groups request data through infographics and fact sheets showing data-driven (not model-driven) direct and indirect impacts of OCA on their harvested species

Summary of Key Findings and Recommendations

- The majority of responding hatchery operators, wild harvesters, or aquaculturists suggest no direct impacts, or no evidence of direct impacts, of OCA on operations
- Hatchery operators are more likely than field operators to have experienced OCA impacts
- Field operators felt that increased storms, HABs, poor water quality (for a variety of reasons), and warming waters were the biggest immediate environmental challenges to their operations, outweighing the challenges of OCA
- Certain industries still rely significantly on wild spat for shellfish production, while some are more hatchery based
- The majority of respondents were harvesting from nearshore waters so efforts should be made to prioritize funding for monitoring and modelling in these environments
- The majority of respondents are harvesting from the bottom, more benthic monitoring instrumentation and biogeochemical models that include a depth component would aid in understanding how OCA impacts these operations
- The high percentage of respondents harvesting in each season indicates a need for year-round monitoring and modeling
- Respondents indicated decent understanding of CO_2 and freshwater drivers of OCA but less so for the influence of temperature or other factors
- Future educational support should focus on simple fact sheets or hand outs and summarize the understanding of direct impacts to species being harvested

Background and Objectives

The Northeast Coastal Acidification Network (NECAN), founded in 2013, represents a network of scientists, federal and state resource managers, and marine industry partners dedicated to coordinating and guiding regional observing, research, and modeling endeavors focused on ocean and coastal acidification (OCA). The geographic region that NECAN covers ranges from Long Island to the Scotian Shelf, including coastal waters of New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia (Fig. 1). The overarching goal of NECAN is to better identify critical vulnerability to ocean and coastal acidification, particularly with respect to regionally important and economically significant marine resources.

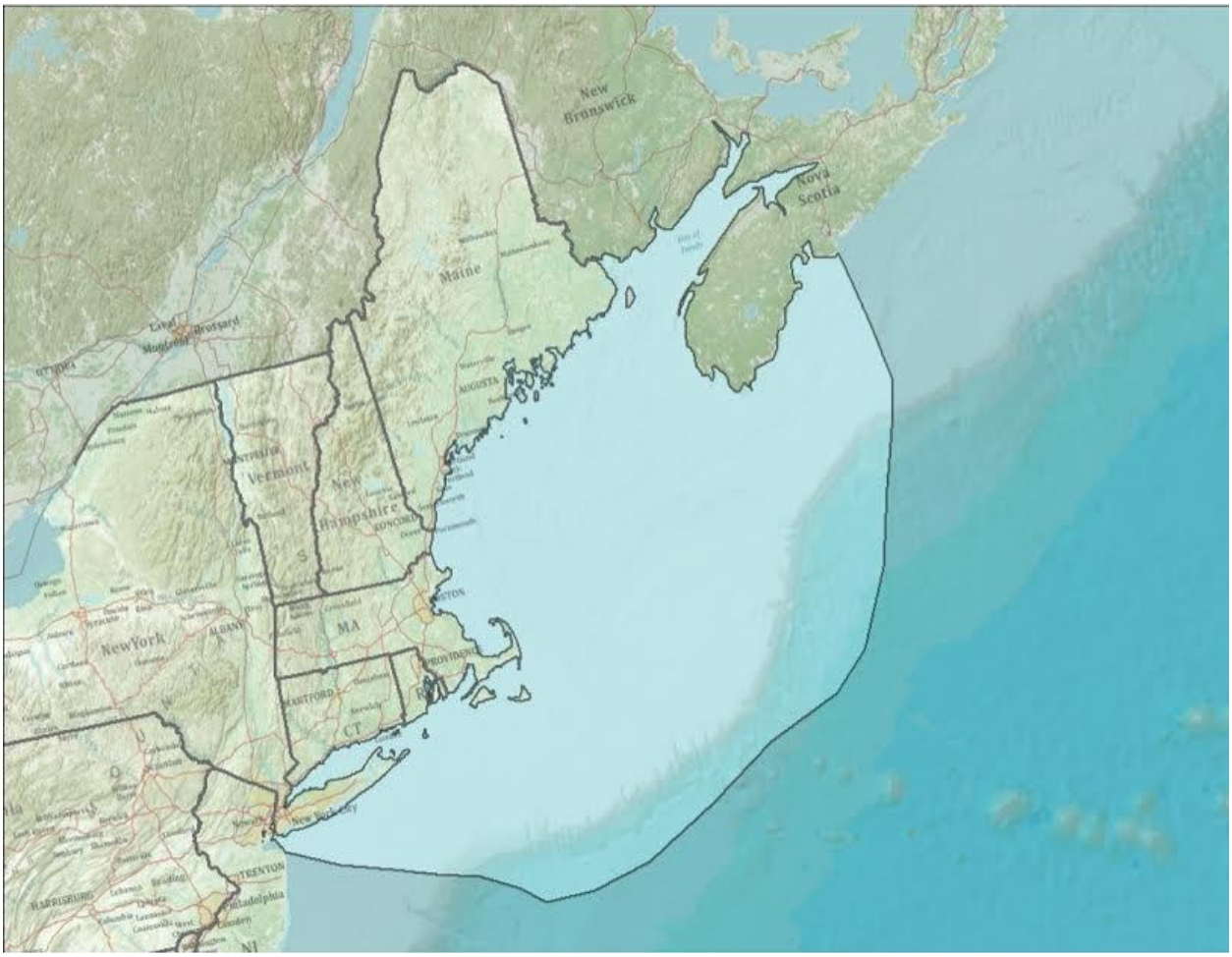

Figure 1. The geographic extent of the NECAN region, ranging from just south of Long Island, northward include the entire Gulf of Maine and the southern portion of the Scotian Shelf.

NECAN is organized into a Steering Committee and four working groups: Education and Outreach, Science, Policy and Management, and Industry. For the purposes of NECAN, 'industry' is defined as any operation that harvests cultured or wild marine organisms.

The success of NECAN in engaging a wide range of stakeholders through an email newsletter, workshops, webinars, and publications has been used as a model for forming other regional Coastal Acidification Networks (CANs) that now cover every coastal US region. As a whole, the

CAN networks help to connect scientists, non-profit institutions, academics and industry stakeholders.

The Industry Working Group (IWG) was formed in 2015 and rejuvenated in 2017. Members of the IWG represent the geographic region from Long Island Sound to Nova Scotia and New Brunswick. The group is comprised of extension agents, shellfish farmers (hatchery and growout), and resource managers. In 2018, the IWG organized and hosted a series of six webinars presented by experts within the fishing and aquaculture industries as well as research institutions on the impacts of ocean and coastal acidification within these sectors. All webinars are archived on the NECAN website.

Additionally, the IWG issued an Industry Survey in the late fall of 2018. The impetus for this survey was to gather information about the questions and concerns of marine industry members in the US Northeast and Canadian Maritimes, regarding impacts of ocean and coastal acidification (OCA) on their livelihoods. Following the definition set for NECAN, for this survey, 'industry' refers to any operation that harvests cultured or wild marine organisms. The survey was also intended to gauge where OCA concerns fall in the list of environmental or other concerns faced by industry members. The ultimate goal of the work was to communicate the findings with federal and stated resource managers and funding agencies to inform them of industry research priorities regarding OCA.

Survey Objectives

1. Determine what experiences Northeast/Canadian Maritime industry members have had with regard to OCA.
2. Identify other environmental changes that industry members have experienced or are concerned about.
3. Determine what questions industry members have regarding OCA, and how to convey information to industry members effectively
4. Communicate the survey results with federal and state resource managers and funding agencies to inform them of industry priorities

Methodology

The questions on the survey were developed by the NECAN IWG, along with input from the NECAN Steering Committee, which includes scientists, representatives of federal agencies, federal and state resource managers, and industry partners.

The survey was prepared on Survey Monkey and was distributed by members of the IWG to through email listservs to aquaculture and wild harvest associations in the US Northeast and Canadian Maritimes. Admittedly, due to the membership of the IWG, the listserv recipients of the survey were weighted towards shellfish aquaculture over finfish aquaculture or wild harvest fisheries. This bias is apparent in the compiled responses of the survey.

The survey was split into three sections: Part 1: Background Questions, Part 2: Questions for Hatchery Operations, and Part 3: Questions for Field Operations. Background questions were intended to determine how respondents fit into the industry and where/how they harvest or culture marine organisms. Hatchery operations and field operations were differentiated because A) different life stages of organisms face different risks and B) because these types of operations offer different opportunities for control of conditions. Hatchery operations were defined as land-based raising of larval fish, invertebrates, or seaweed. Field operations were defined as aquaculture nursery upwellers or growout in ambient water conditions and any type of wild

harvest. If a respondent indicated they were only engaged in hatchery operations, the survey directed them only to the background and hatchery questions. If they indicated they were only engaged in field operations, the survey directed them only to the background and field operations questions. If they indicated they were engaged in both hatchery and field operations, the survey directed them to all three sections of questions.

The survey remained open from October 18, 2018 - November 30, 2018. Responses were compiled and respondents who reported they were from regions other than the US Northeast/Canadian Maritimes were excluded from the analysis, as this survey was intended to focus on the region under NECAN's purview.

Results

Responses were collected from 69 unique survey respondents in the US Northeast/Canadian Maritimes. Results reported here are limited to these respondents and percentages of respondents refer to the percent of respondents who answered the given question. Sections are titled and figures are captioned with the question posed to respondents.

Part 1: Background Questions

What species do you harvest or culture?

The species most frequently cultured or harvested by respondents was by far the Eastern oyster (*Crassostrea virginica*), with 84% of respondents landing this species. Bivalves represented the top four species harvested by respondents with hard clams (*Mercenaria mercenaria*, 31.9% of respondents); bay scallops (*Argopecten irradians*, 24.6% of respondents), and sea scallops (*Placopecten magellanicus*, 15.9% of respondents) following the Eastern oyster majority (Fig. 2)

Are you engaged in aquaculture or wild harvest?

This bias towards shellfish likely resulted from the fact that the membership of the NECAN IWG at the time of the survey was largely those involved in shellfish aquaculture (Appendix A), and therefore the survey's distribution was biased towards aquaculture associations over wild harvest fisheries associations. The bias towards shellfish further reflects nearshore fisheries and aquaculture in this region, of which permits are dominated by shellfish. Among respondents, 63.8% were only involved in aquaculture, 2.9% were only involved in wild harvest, and 33.3% were involved in both aquaculture and wild harvest. Of the 33.3% involved in both aquaculture and wild harvest, 82.6% cultured or harvested more than one species, so it is probable that their split between culturing and harvesting may have been based on different species.

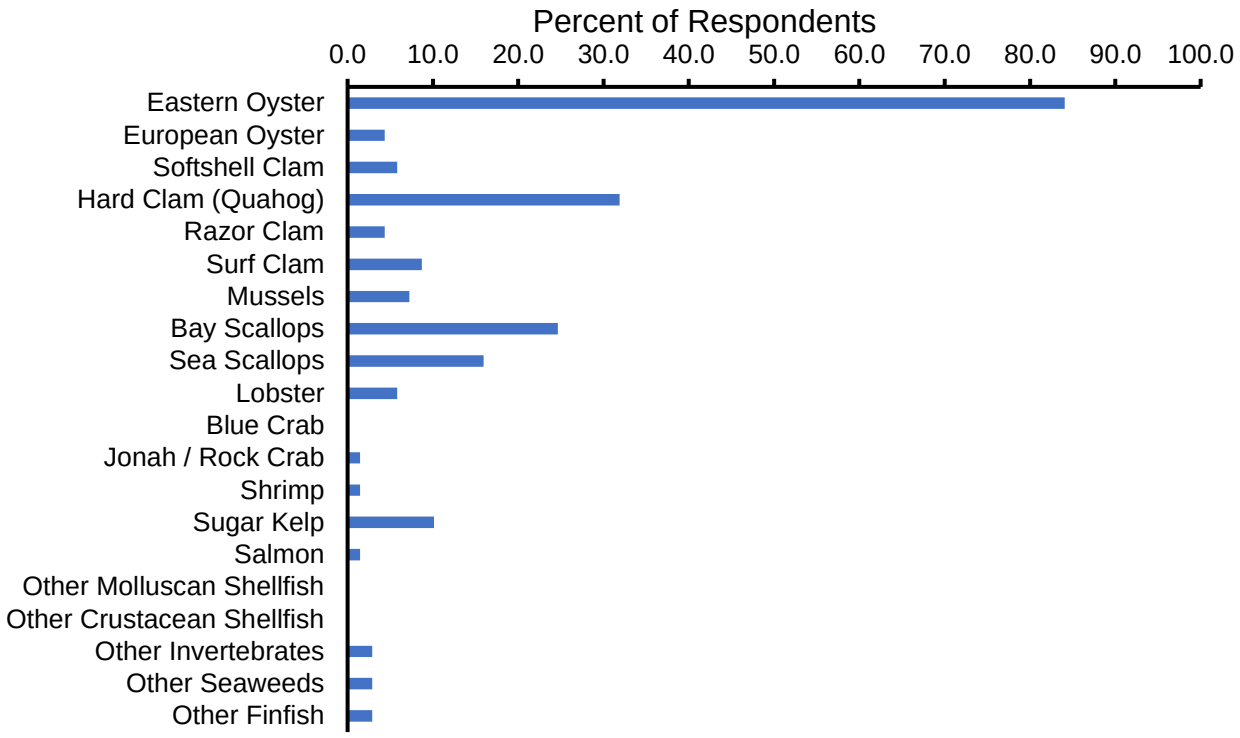

Figure 2. What species do you harvest or culture? Percent of respondents harvesting or culturing different marine organisms.

Are you involved in hatchery operations (onshore fish, invertebrate, or seaweed hatchery) or field operations (wild harvester or aquaculture field nursery or growout lease)?
Does your harvesting depend on hatchery-produced young or wild-spawned young?
Hatchery operators may face different OCA threats than those involved in field operations and may also have different opportunities to mitigate OCA. For example, because hatcheries can control water chemistry by buffering or by selecting the timing of pumping in water (Barton et al. 2015), industries dependent on hatchery-produced young may be less vulnerable to effects of OCA than those dependent on wild-spawned young. 34.8% of respondents were involved in hatchery operations and 93.9% were involved in field operations. The overlap indicates that a significant number of hatchery operators also have nurseries or growout operations. However, if someone is only involved in field operations (either wild harvest or aquaculture), the larval stage of the species they harvest may still come from either hatchery-produced or wild-spawned young. For example, nearly all Eastern oyster farmers in the Northeast US purchase oyster seed from hatcheries, while some oyster farmers in the Canadian Maritimes rely on wild-set oyster seed. The entire aquaculture industries for blue mussels and sea scallops are dependent on wild-set spat, yet some wild harvest of quahogs, oysters, bay scallops and softshell clams is supplemented by hatchery-reared seed. As such, 53.6% of respondents were dependent on hatchery-produced young, 14.5% of respondents were dependent on wild-spawned young, and 31.9% of respondents were dependent on both hatchery-produced and wild-spawned young. Of the 31.9% of respondents whose harvest is dependent on both hatchery-produced and wild-spawned young, 81.8% were harvesting multiple species, indicating the difference in production of young may be based on different species.

Where do you harvest?

The vast majority of respondents (79.7%) harvest from inshore waters including estuaries, bays and inlets. 36.2% harvest from nearshore waters, defined as less than one mile from the coast. Only 7.2% of respondents harvest from offshore waters, defined as further than one mile from the coast. Multiple respondents harvest from multiple regions, as evidenced by the sum of these percentages being greater than 100%. Industry members will be most helped by current and projected information regarding water conditions close to their harvesting area. The prevalence of harvesters in inshore and nearshore waters is an important point which can help funding agencies determine where to direct resources for monitoring and modelling.

Do you harvest from the bottom or the water column?
Water chemistry can vary by depth, with benthic waters experiencing higher pCO_2 conditions from increased respiration (Wallace et al. 2014). As such, it is helpful to understand where in the water column organisms are being grown or harvested. 60.9% of respondents harvest from the seafloor, 36.2% harvest from the mid-water column, and 33.3% harvest from the surface. This breakdown is not necessarily based on the species being harvested. For example, when blue mussels are wild-harvested, they are taken from benthic mussel beds, but when they are cultured, they are typically grown on ropes in the mid-water to surface water. Eastern oysters can be cultured on the bottom or in floating surface cages. However, with the majority of respondents harvesting from the bottom, it is clear that more benthic monitoring instrumentation and biogeochemical models that include a depth component would aid in understanding how OCA impacts these operations.

In which seasons do you harvest?
Water chemistry can vary seasonally, with lower temperatures leading to lower saturation states in the winter and changes in photosynthesis and respiration causing strong diurnal variability during the summer (Gledhill et al. 2015, Wallace et al. 2014). 58% of respondents harvest year-round, and only 7.2% of respondents harvest in only one season. Fall was the most common harvesting season, with 92.4% or respondents harvesting, followed by summer and spring with 87% and 85.5% of respondents harvesting, respectively. 69.6% of respondents harvest in the winter. The high percentage of respondents harvesting in each season indicates a need for year-round monitoring and modeling.

Do you have a good understanding of the following drivers of coastal acidification?
We attempted to determine the background knowledge of respondents regarding coastal acidification by asking their understanding of various drivers of coastal acidification (Fig. 3). The majority of respondents understood the influence of atmospheric CO_2 and freshwater inputs/intensifying precipitation events, but fewer understood impacts of respiratory CO_2 from algal blooms and the temperature impacts on oxygen diffusion (Fig. 3).

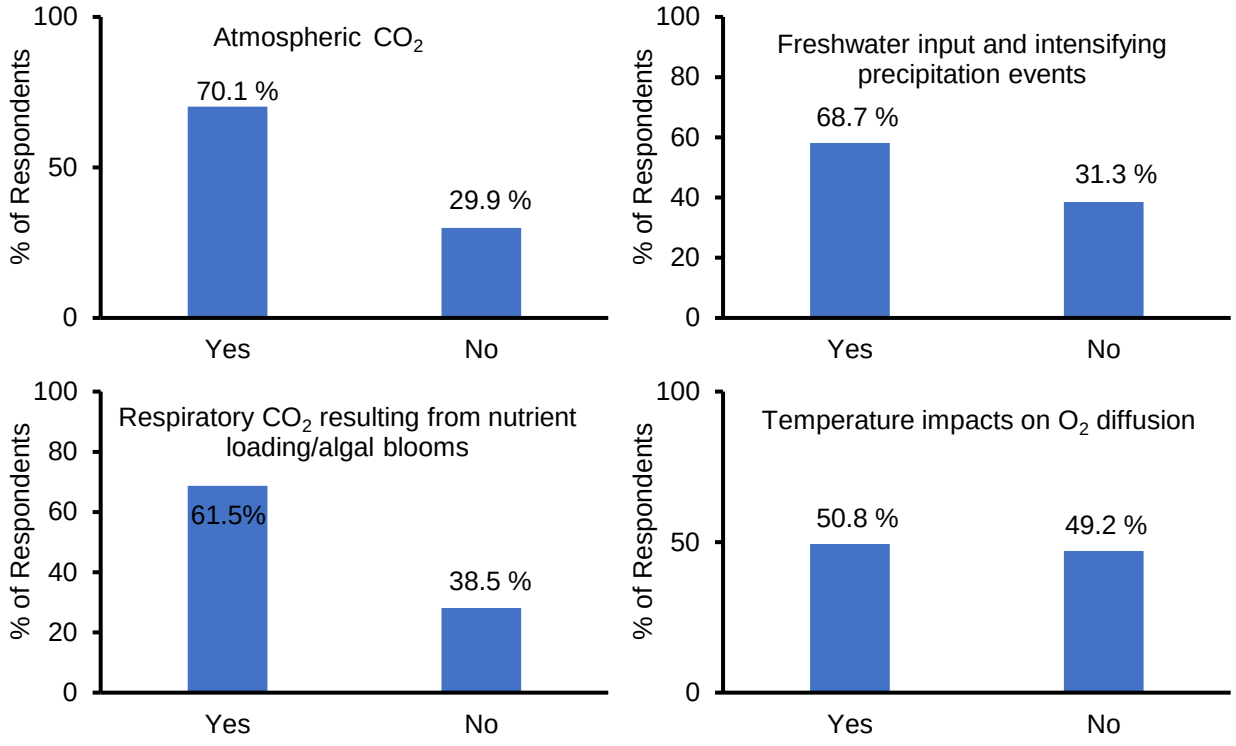

Figure 3. Do you have a good understanding of the following drivers of coastal acidification? Percent of respondents who do or do not have a good understanding of the various drivers of coastal acidification.

What information would be useful for gaining a better understanding of these drivers?
The majority of open-ended responses indicated that simple fact sheets with infographics would be most helpful, but one respondent requested access to research literature. Furthermore, multiple respondents pointed out that actual data would be more useful than model results.

'Pictures of the cycles and drivers and how everything effects everything (like a rainfall cycle diagram).'

'Info graphic or one page hand out could be available on a website.'

'Simple outreach handouts.'

'A fact sheet similar to those produced by NRAC projects.'

'Compiling multitude of research into one, convenient place.'

'Access to research literature produced.'

'Actual measurements versus model results.'

'Actual data at individual sites.'

'in situ experimental trials.'

'Documented growth/survival impacts at all life stages for all commercially important shellfish species, regarding differential aragonite/pH levels.'

'Detailed information about the relationship between runoff and carbonate chemistry.'

Part 2: Hatchery Operation Questions

Of the 69 respondents to the survey, 23 (33.3%) indicated they operate land-based finfish, invertebrate, or seaweed hatcheries. Only these respondents had access to the questions about hatchery operations.

Do you feel that your operations have already been impacted by ocean and coastal acidification?
21.7% of hatchery operators felt that their operations have been impacted by OCA, 26.1% felt that their operations have not been impacted by OCA, and 39.1% were unsure. 13.0% of hatchery operators did not answer the question. When asked to elaborate, the two responses were 'Poor larval performance that has now been corrected' and 'I see pH dips down to 6.8 now'.

Do you monitor the pH of your intake water or the water in your tanks?
Do you take any corrective action to improve the water pH (i.e. buffering)?
Hatcheries are essentially industrial scale laboratories, therefore, 60.9% of hatchery operators are monitoring the pH of the intake or tank water. 21.7% are not monitoring the pH and 17.4% didn't answer. This indicates that more hatchery operators are monitoring the pH than feel that OCA has affected their operations, and also shows that they have some amount of data record to support their conclusions. While just over 60% of hatchery operators monitor pH, only 17.4% take corrective action, such as buffering. 56.5% do not take corrective action and 26.1% did not answer the question. Interestingly, those buffering are not necessarily the same respondents who feel that OCA is impacting their operations. One respondent who did not feel that OCA was impacting their operation was buffering the water nonetheless, and one respondent who felt that OCA was impacting their operations was not taking corrective action. When asked to elaborate, all those who answered indicated that their corrective action was to buffer, with a range of buffers including KOH, soda ash, and calcium supplementation.

Have you noticed changes to your operation that may be caused by unknown environmental changes?
More hatchery operators have noticed operational changes caused by unknown environmental changes than by OCA: 43.5% responded yes to this question, 34.8% responded no, and 21.7% didn't answer. Elaborations included:

'Yes, but this is how the hatchery has been since…2004. There are periods when the water is excellent, then suddenly degrades in spite of regular filter changes. Suspect residential yard care products, but still not sure.'

'Die-offs at Day 6. Currently trying to diagnose.'

'Loss of larvae.'

'Had an interval a few years ago that was characterized by poor larval production.'

'Recent difficulties in larval production in mid August. Suspect toxic algae or higher bacterial loading.'

'We occasionally have unexplained issues in both our hatchery and growout.'

'Localized die-offs from multiple hatchery sites when no perceivable change has occurred in the observable measurements.'

'Unexplained mortalities are common.'

What do you feel are the biggest environmental changes to your operation?
This open-ended question had varied responses, although multiple responses referenced warming waters and increased nutrient loading. Responses included:

'Production is becoming less stable and the need to control and monitor water within the shellfish hatchery has changed a lot over the past 20 years.'

'Toxic algal blooms. Warmer temperatures.'

'Biofouling increase and water temp increase.'

'Nitrate load in water, warmer summer waters, proliferation of invasive and domestic nuisance species.'

'Residential shoreline development that changes the natural flow of freshwater into the estuary and contaminates that water with excess nitrogen and other chemicals.'

'Drier summers, wet springs and higher water temperatures overall.'

'Hypoxia/ Salinity changes'

'Storm events'

'Understanding unexplained mortality causes so we can rectify.'

Part 3: Field Operation Questions
Of the 69 respondents to the survey, 62 (89.9%) indicated they operate in the field (wild harvester or aquaculture field nursery or growout lease). Only these respondents had access to the questions about field operations.

Have you noticed any changes to your operations or product that may be caused by ocean acidification?
Far fewer field operators than hatchery operators have noticed changes to their operations or product that may be caused by ocean acidification. Only 6.5% of field operator respondents felt their operations have been affected by OCA (compared to 21.7% of hatchery operators). 45.2% of respondents felt that their operations have not been affected by OCA, 41.9% were unsure, and 6.5% did not answer the question. This supports experimental evidence that larval life stages may be more susceptible to OCA than adult life stages (Gledhill et al. 2015).

What, if any, environmental changes have you observed in your growing or harvesting region, and in what time frame? (e.g. sea level rise, more frequent and intense storms, harmful algal blooms, vibrio outbreaks or concerns, etc.)

This question was posed to identify what environmental changes have been observed by aquaculturists and fishermen. Responses covered a broad range of environmental changes, but the most commonly referenced changes included harmful algal blooms (HABs), more intense storms, warming waters, and *Vibrio* sp. outbreaks. A representative sample of open responses are listed below.

‘Increased harmful algal blooms.’

‘HABs’

‘Harmful algae blooms happening every year, and earlier onset every year since 2012.’

‘Algal blooms, warming waters, more invasive species.‘

‘Harmful algal blooms, more frequent storms.’

‘More rain, brown algae blooms.’

‘Toxic algal blooms, *Vibrio*.’

‘Harmful algal blooms, *Vibrio* outbreaks last 15 years.’

‘Frequent storms, HAB's, changing sediments on bottom-more anaerobic.’

‘*Vibrio* outbreaks.’

‘Increase in rain events over 3 years.’

‘More intense storms. Warmer summers.’

‘More storms, constant freakin' wind and more HAB's since 2000.’

‘Much stronger storms and much hotter summers.’

What do you feel are the biggest environmental challenges to your operation?
Field operators felt that increased storms, HABs, poor water quality, and warming waters were the biggest environmental challenges to their operations, but others listed social and regulator issues as the biggest (non-environmental) challenges.

‘Storm energy in field growout, potential increases in CO_2 that would affect nursery and growout.’

‘Increasing storm frequency and intensity.’

‘Low O_2, high rainfall leading to more frequent and longer closures, expanding HAB distribution.’

‘Algae blooms – storms.’

‘HAB's, pH fluctuation.’

‘Ocean acidification, general water quality from increased human population in vicinity.’

'Contamination from any and everything that runs off or is dumped into the bay (rain run-off, high septic tank levels due to excessive rain…and of course the ocean acidification issue.'

'Warmer peak temperatures. Acidification, decreased recruitment.'

'We see rising temperatures as a threat; and, to some degree, as a benefit (ie faster growth). Given a choice, we would forego the benefit for the survival of two species: *C. virginica* and us.'

'People.'

'They are social and regulatory not environment.'

What information about ocean and coastal acidification impacts would be most useful to you with regard to business management and planning and preventing economic loss?
Most responses to this question revealed that industry members are interested in factual data regarding direct (and some indirect) impacts of OCA on their harvested species, as opposed to theoretical/potential problems. Demonstrated effects requested included:

'Demonstration that OA is a concern for growout operations. To date, I see no evidence of it being a problem.'

'Growth rates, disease, and invasive species.'

'What we can do about it.'

'Impact on hatcheries and wild sets.'

'Bring me facts, not worries about potential problems.'

'Changes in growth rates and shell strength, impacts on weather, impacts on disease and invasive species.'

'Growth, shell thickness, HABs, invasive species.'

'Impacts on productivity and water quality.'

'1. Biological thresholds on juvenile and market oysters, from field-based studies
2. Timing of when those thresholds will be reached in different growing areas'

'Reduced shell strength. Changes to the phytoplankton community, species composition.'

'Eutrophication, HAB's, disease, anaerobic and acidic bottom sediments.'

Summary of Key Findings and Recommendations

- The majority of responding hatchery operators, wild harvesters, or aquaculturists suggest no direct impacts, or no evidence of direct impacts, of OCA on operations
- Hatchery operators are more likely than field operators to have experienced OCA impacts

- Field operators felt that increased storms, HABs, poor water quality (for a variety of reasons), and warming waters were the biggest immediate environmental challenges to their operations, outweighing the challenges of OCA
- Certain industries still rely significantly on wild spat for shellfish production, while some are more hatchery based
- The majority of respondents were harvesting from nearshore waters so efforts should be made to prioritize funding for monitoring and modelling in these environments
- The majority of respondents are harvesting from the bottom, more benthic monitoring instrumentation and biogeochemical models that include a depth component would aid in understanding how OCA impacts these operations
- The high percentage of respondents harvesting in each season indicates a need for year-round monitoring and modeling
- Respondents indicated decent understanding of CO_2 and freshwater drivers of OCA but less so for the influence of temperature or other factors
- Future educational support should focus on simple fact sheets or hand outs and summarize the understanding of direct impacts to species being harvested

References

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Appendices

A) NECAN Industry Working Group Membership (at time of survey)

Appendix A.
NECAN Industry Working Group Membership (at time of survey)

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