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Oyster grower perspectives on green crab (*Carcinus maenas*) interactions: using applied social science to inform research and engagement

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Research that informs the New Hampshire Aquaculture industry, which has grown significantly over the past few years, and helps the overall associated watershed community to keep Great Bay Estuary healthy is vital. Specific study of green crabs, *Carcinus maenas*, and their potential effects on oysters, *Crassostrea virginica*, is important to gain a better understanding of the impact invasive species may have on these ecologically and economically important bivalves. The aim of this study was to document and understand New Hampshire (NH) oyster growers' perspectives on the issue of green crab predation of oysters. Through a survey, this study documented a preliminary understanding of farmer perspectives and research needs regarding the population of green crabs in NH waters. More specifically, this survey provided a social science perspective and information on areas of potential research - abundance, distribution, and diet of green crabs - that could be beneficial to the oyster industry. This study fills knowledge gaps, helps improve future research (including how to better engage with end users), and facilitates creating and implementing solutions that benefit the NH oyster aquaculture industry.

KEYWORDS

oyster growers, green crabs, social science, surveys, aquaculture

1 Introduction

In recent years, there has been a significant increase of incorporating social science into conservation (Moon et al., 2016). Incorporating the social sciences into conservation work can advance research objectives and questions (Moon et al., 2016); promote buy-in from the public and key partners (Endter-Wada et al., 1998); provide for a more robust study and alignment of findings with possible conservation outcomes (Endter-Wada et al., 1998).

Social science has been used to improve wildlife management (Teel and Manfredo, 2010; Bennett et al., 2017a), agriculture landscape management (De Snoo et al., 2013; Bennett et al., 2017a), fisheries management (Heck et al., 2015; Bennett et al., 2017a). Applied social science research improves the relationship among researchers, administrators, and citizens by creating a space of open communication. Management, marketing, education, and decision making (Bennett et al., 2017a, b) are a few of the key improved outcomes that could be gained by including social science into conservation studies. One sector of conservation research that can greatly benefit from applied social science is aquaculture.

Aquaculture has become an important avenue to supply the global demand for seafood (Botta et al., 2020; FAO, 2018; Johnson et al., 2019). Oyster aquaculture production, including the Eastern oyster (*Crassostrea virginica*), has increased significantly over the past decades (Botta et al., 2020), especially in the Northeast USA (Grizzle et al., 2020), and specifically New England. New England oyster aquaculture generates millions of $US in revenue each year (Morse and Pietrack, 2009; Lapointe et al., 2013). New Hampshire (NH) is a rising state in the oyster aquaculture industry, having increased enormously over the past decade. In 2013, only 81,274 oysters were harvested and in 2023 821,257 oysters were harvested (New Hampshire Fish and Game, unpublished data). It is expected for this to continue to increase as avenues for enhancing production and efficiency have been identified (Grizzle and Ward, 2012; Scuderi and Chen, 2019).

Currently in NH, there are more than 32 farmed hectares of oysters (Grizzle et al., 2023) and since 2000, approximately 30 hectares of oyster reef restoration projects have been implemented (Grizzle et al., 2023). In addition to their importance for the seafood economy, ecosystem services provided by both cultivated (Higgins et al., 2011) and wild (Zu Ermgassen et al., 2013) oysters include creation of reef habitat for a variety of organisms (Beck et al., 2011), removal of carbon, nitrogen, and phosphorus from the water column (Higgins et al., 2011), ability to engage in denitrification (Carmichael et al., 2012; Kellogg et al., 2014; Ray et al., 2019), and control of primary production and algal blooms (eutrophication) (Yu and Gan, 2021). Oyster populations along the North American Atlantic coast, and particularly in NH, have been impacted by a combination of factors including overharvesting (Grizzle and Ward, 2016), excess sedimentation (Grizzle and Ward, 2016), and predation (Poirier et al., 2017). The NH oyster farmers are aware of this decline and have provided oysters for stock enhancement on struggling reefs for restoration, where it is key to better understand the impact of these factors, specifically predation. Investigating predation by invasive species, like the green crab *Carcinus maenas*, is important to determine success of those supplementation efforts and to make decisions on appropriate oyster aquaculture practices.

The green crab, a now naturalized member of many ecosystems along the Atlantic coast of North America, has been known to affect commercial shellfish industries in other regions (Lovell et al., 2007), including oysters (Pickering et al., 2017; Poirier et al., 2017), soft-shell clams (Floyd and Williams, 2004), and blue mussels (Christie et al., 2020). Research has been devoted to developing a green crab fishery (St-Hilaire, 2016), but work remains to be done firmly establish this fishery and improve profits (St-Hilaire, 2016). Given the lack of means to eradicate green crabs, frameworks have been proposed to provide population suppression (Green and Grosholz, 2021). For shellfish growers, avoidance of benthic dweller predation is an option by specifically using floating gear (Getchis, 2014). However, floating gear is not permitted in many areas in the northeast (Grizzle et al., 2020), including Great Bay Estuary (GBE). Fed by seven rivers, GBE is a tidally driven and small estuary (~24 km^2) located on the eastern border of New Hampshire-Maine (Short, 1992). This estuary is part of the Gulf of Maine, and consists of multiple habitat types, and is highly utilized for commercial and recreational activities (Short, 1992). Due to rapid growth of aquaculture in GBE, conducting research that helps identify challenges that NH oyster growers face with green crabs, it is important to investigate means to mitigate these challenges.

The aim of this study was to document NH oyster growers' perspectives on the potential impact of green crabs on their farming operations and businesses, and other ecosystem issues that may affect their farming operations. The NH oyster growers are the people who view oyster biology and ecology daily and their experiences with green crabs constitute crucial information to help understand the potential effects of this now well-established invasive species. Integrating social aspects from the industry helps to identify challenges oyster growers face and what research may be beneficial to mitigate these challenges. One study in the past has shown that involving our NH oyster aquaculture industry in research is important and surveys can be an effective way for researchers to better understand the interests of affected parties and opportunities to inform conservation and resource management (Tosiello, 2019). Engaging in substantive ways with this industry can help farmers tackle the issues they face on a daily basis.

This study involved a survey that was distributed to the owners and operators of oyster growing businesses in NH querying them about their experiences with and opinions of green crabs. The aim was to understand the impacts of green crabs in terms of risks and potential benefits, with the ultimate objective of identifying steps to expand potential benefits and mitigate risks. This study highlights the main findings and themes of the growers' perspectives from the survey, and touches upon further recommended and developed research that arose from the findings, underscoring the benefit of involving end users with research.

2 Materials and methods

An anonymous online survey (via Qualtrics, (not pretested)) was distributed to 20 NH oyster growers in January 2022 (UNH IRB-FY2022-163, see Supplementary Data Sheet 1 for survey questions). The survey was designed based on existing knowledge of green crab ecology in GBE and experience with industry members and was intended to draw out their perceptions of green crabs and other related potential impacts, along with their research interests. The online survey consisted of 13 questions including a mix of open-ended and multiple-choice questions and took approximately 10-15 minutes to complete. The mix of

multiple-choice and open-ended questions was structured to allow for both quantitative and qualitative analysis of data collected through the survey.

Results included both qualitative and quantitative data (data from question 11 were not used in this study as the question was unclear to participants). Responses to each multiple-choice question, three (A-C) options, were analyzed using percentages. Open-ended questions requested two to three sentences about a grower's opinion on a certain matter; for example, "Are there other issues of concern more pressing than green crabs?" Qualitative data from open ended questions were coded to explore themes across respondents (Bradley et al., 2007). The thematic analysis in this case focused on "participant perspective," which identified participants' feelings about a certain experience (in this case, green crabs on their farms) as neutral, positive, or negative (Bradley et al., 2007; Vaismoradi et al., 2016). Further research able to be developed and conducted because of this survey are highlighted to showcase why involving end users is vital in research.

3 Results

Nine oyster growers responded, representing roughly half of the oyster aquaculture businesses operating in NH at the time of the survey. The oyster growers reported their perspectives on research being planned and implemented, such as investigating the abundance, distribution, and diet of green crabs in GBE, New Hampshire. Most of the farms are located in GBE, in the upper part of the Bay, so it was considered important to gain a sense if they felt this type of research would benefit their farms.

The survey commenced by asking whether research on the distribution, abundance, and diet of green crabs at reef and farm sites in Great Bay Estuary would be beneficial. In response to that multiple-choice question, 100% of the NH oyster growers who participated in the survey saw some benefit of the research to their farm. Specifically, 22% of those who participated saw a huge benefit (Figure 1) and 78% judged there being some benefit to this type of research. Participants were then asked whether they found green crabs beneficial to their farms. A few respondents mentioned they do not see them as a benefit, and one respondent mentioned they were unsure and would like to know more; for example, whether crabs consume oyster drills. Further questions became more specific with regard to various aspects of this research that would be helpful to their industry.

When asked whether farmers believed that trapping near farms would help with occurrence and/or reduction of green crabs, 100% saw some benefit. Specifically, 12.5% saw it as a huge benefit and 87.5% saw some benefit to this. An open-ended question was then asked whether farmers personally would consider trapping near their farms and supplying crabs to the bait market. Three out of the nine participants said yes; however, most participants indicated this would only be undertaken if economically worthwhile, and one indicated trapping was not likely. It appeared that trapping near farms for mitigation of green crabs is likely more of a value to the industry than a valued product in an of itself.

The trapping response led to the confirmation and further development of a separate project, being analyzed, and written

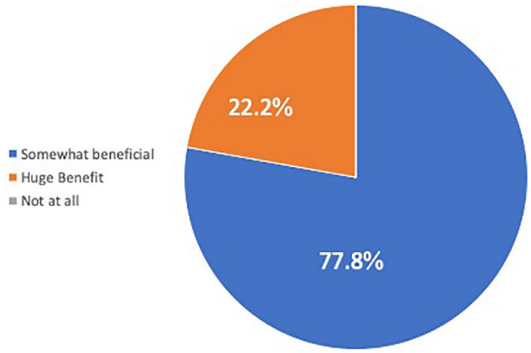

FIGURE 1
Survey respondent perspectives on the potential benefit of conducting green crab research.

as a separate manuscript, investigating the abundance and distribution of green crabs throughout GBE, where most of the NH oyster farms reside, by trapping at wild reefs, oyster restoration areas, and oyster farms (Meyer et al., 2023; Meyer et al., in review). That subsequent project provided population estimates at both oyster farm areas and natural/restoration oyster areas in GBE and metadata on size and sex of green crabs in those area (Meyer et al., 2023; Meyer et al., in review). The trapping question from this survey is an illustration of how perspectives and experiences of oyster growers relating to green crabs was used to enhance research approaches.

When asked further about their observations of how green crabs interact with oysters on their farms, the respondents indicated that they noticed green crabs are present on the farm, directly and in surrounding areas, and that crabs were found commonly throughout the operating season (April through December), even year-round in some responses. One respondent stated that crabs were observed in higher numbers in the warmer months and highest in the late summer. Another respondent who operates from just May-November, stated they found crabs in their trays but were not sure if they were trying to consume oysters or hunting for other prey that may also be in the trays. When asked further if they noticed any oyster damage or mortalities due to green crabs, some growers were concerned that green crabs are a threat to oyster seed and juvenile oysters. A portion of respondents stated that they were not sure if mortality was directly attributable to green crabs.

This study helped shed light on how much effort it takes for oyster growers to deal with the number of green crabs in and near their farms. From this survey, it became apparent that time was being spent removing the crabs from growing containers. Of the respondents, 44% thought green crabs were a nuisance on their farm and 22% thought green crabs were a "huge nuisance" to their farm. Interestingly, 33% thought there may be bigger issues at hand; for example, oyster drills (*Urosalpinx cinerea*) or tunicates (*Tunicata*) (Figure 2).

Additional themes that became evident from the qualitative analysis of open-ended text responses included views of the respondents on other pressing matters besides green crabs. When asked if it would be beneficial if green crabs consumed tunicates, 77.78% said it would be somewhat beneficial, 11.11% said it would

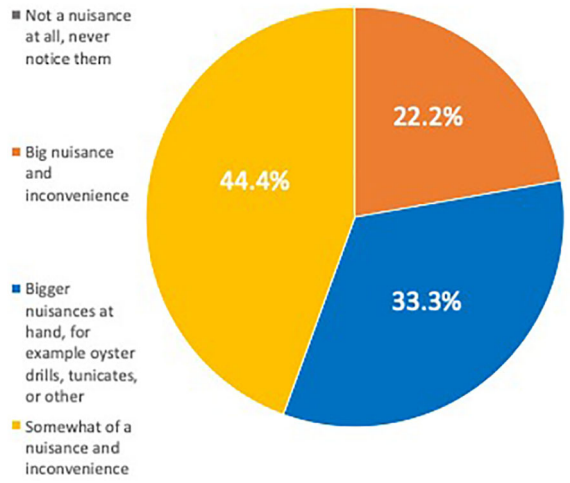

FIGURE 2
Perceived nuisance level of green crabs on oyster farms.

be a "huge benefit," and only 11.11% thought it would be of no benefit. When asked what they thought was a bigger issue to them - green crabs, tunicates, oyster drills, or something else - two participants stated tunicates were the biggest issue, two stated drills were the biggest issue, and three stated green crabs were the biggest and/or most consistent issue. There were a few participants that had a mixed response, for example one participant stated crabs in general were, and another stated "Mud blister worm, Boring Sponge, drills, in that order". When asked more directly about more pressing issues of concern than green crabs, one participant stated no, whereas a few others mentioned mud blister, worms, or drills.

The responses to the last set of questions led to further development of studies on green crab diets and of interactions between aquacultured oysters and green crabs. Preliminary results of the gut contents of green crabs indicate that they have a scavenger diet and preliminary results of crab-oyster interactions on farms indicate that although large adult green crabs can consume small oysters, crabs neither consumed nor damaged a significant number of oysters. These studies are being analyzed and written as separate manuscripts.

In general, NH oyster growers believe green crabs have the potential to be a detriment to their farms. These perspectives informed biological and ecological research by taking into account the knowledge and concerns of oyster farmers. The results of the survey were communicated to the NH oyster growers and preliminary research data of each resulting project have been discussed with farmers at meetings (~1-2 hours over the course of several meetings), in casual conversations, and assembled into a report of the main research highlights and emailed specifically to the growers.

4 Discussion

Integrating social aspects from the NH oyster aquaculture industry can provide data to improve research projects, management programs, and inform the overall GBE watershed community. In the face of climate change, access to sustainable aquacultured foods will be challenging (Barange et al., 2018; Birthisel et al., 2020). Aquaculture of organisms that don't require exogenous feeds and fertilizers (e.g., algae or filter feeding bivalves) is a large and rapidly developing sector of sustainable seafood. Conducting research that is multi-disciplinary will help mobilize change and fill knowledge gaps to make food more sustainable and accessible while also building bridges across the food production and research communities. It is also of high importance to conduct research to mitigate issues that come with the territory of aquatic invasive species, such as green crabs. Aquatic invasive species have cost the global economy an estimated $345 billion ($US), most were from aquatic invertebrates, and management actions will be needed to help reduce these costs (Cuthbert et al., 2021). The current survey helps provide data to management teams relevant to green crabs in GBE.

Surveying industry participants, such as oyster growers, enables the integration of social and life sciences and can inform interactions between regulators and growers. This study highlights that using Institutional Review Board (IRB) approved surveys to identify what type of research is important to end users is of high interest and can assist in evolution of more impactful regulations. For example, this survey identifies a potential impediment to oyster aquaculture that relates to best management and predation avoidance (i.e., restrictions on floating gear). This study shows the importance of codifying farmer input using surveys as they provide quantitative and qualitative data that could be missed if having only casual conversations.

It is important to note that not all NH oyster growers participated in the survey. Their untapped experiences and opinions may have differed from those who responded. One NH oyster farm business is located in Hampton Harbor, a nearby estuary. Because this survey was anonymous, it is not known whether all answers were from GBE or what answers were relevant to Hampton Seabrook Estuary. The specific locations of farms (kilometers up into a tributary, at the mouth of a river, or in the Bay proper) may yield site-specific themes of ecological importance, but location data intentionally were not included to maintain anonymity.

The use of a survey investigating the NH oyster growers' perspectives of green crabs provided baseline data on what next steps need to be taken. This study showcases how the survey and integration of social science led to and developed other important research that can support oyster growers. Those additional studies highlighted in this report and based on themes extracted from the oyster growers' perspectives on green crabs in general are in data analysis phase and will be published separately. Of most immediate interest for farming, and consequently restoration, are the survey findings confirming the potential importance of other predators. The survey helped to initiate a two-year investigation of green crab abundance and distribution in GBE, specifically at oyster farms areas and restoration/natural oyster reef areas, where most of the NH oyster farms occur. The survey also prompted an analysis of crab gut contents to determine the diet of green crabs that will inform both oyster cultivation techniques and oyster restoration plans in the region.

Incorporating social science methods and approaches was beneficial to the study of green crab effects on oysters in NH because it allowed and further developed research that directly

addressed the concerns of oyster growers and provided a guide to relevant study designs. Subsequent data analyses from studies that spun off the survey will be shared with all the NH oyster growers through scheduled meetings, emails, and written reports. Further engagement with industries such as the NH oyster aquaculture sector will promote development of responsible and strategic efforts to mitigate issues affecting seafood businesses and overall best management practices to help these businesses contribute to sustainable seafood.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary Material. The data may be obtained upon request to the corresponding author.

Ethics statement

The study was conducted according to the guidelines and approved by the UNH IRB and UNH Research Integrity Services. Project ID for this is UNH IRB-FY2022-163. Contact person is Melissa McGee. The studies were conducted in accordance with the local legislation and institutional requirements. All participants were emailed a consent form to read over before participating in the study. The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

KM: Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – original draft, Writing – review & editing. LW: Conceptualization, Writing – review & editing. KW: Writing – review & editing. BB: Funding acquisition, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

Author KM works with NH oyster growers outside of her graduate degree, but because all responses were anonymous, this does not influence the results of the survey. Author KW outside of her role at the University of New Hampshire, is also an oyster farmer.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/faquc.2024.1436340/full#supplementary-material

References

Barange, M., Bahri, T., Beveridge, M. C., Cochrane, K. L., Funge-Smith, S., and Poulain, F. (2018). *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options. FAO Fisheries and Aquaculture Technical Paper No. 627* (Rome: FAO).

Beck, M. W., Brumbaugh, R. D., Airoldi, L., Carranza, A., Coen, L. D., Crawford, C., et al. (2011). Oyster reefs at risk and recommendations for conservation, restoration, and management. *BioSci* 61, 107–116. doi: 10.1525/bio.2011.61.2.5

Bennett, N. J., Roth, R., Klain, S. C., Chan, K., Christie, P., Clark, D. A., et al. (2017a). Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biol. Conserv.* 205, 93–108. doi: 10.1016/j.biocon.2016.10.006

Bennett, N. J., Roth, R., Klain, S. C., Chan, K. M., Clark, D. A., Cullman, G., et al. (2017b). Mainstreaming the social sciences in conservation. *Conserv. Biol.* 31, 56–66. doi: 10.1111/cobi.2017.31.issue-1

Birthisel, S. K., Eastman, B. A., Soucy, A. R., Paul, M., Clements, R. S., White, A., et al. (2020). Convergence, continuity, and community: a framework for enabling emerging leaders to build climate solutions in agriculture, forestry, and aquaculture. *Clim. Change.* 162, 2181–2195. doi: 10.1007/s10584-020-02844-w

Botta, R., Asche, F., Borsum, J. S., and Camp, E. V. (2020). A review of global oyster aquaculture production and consumption. *Mar. Policy* 117, 103952. doi: 10.1016/j.marpol.2020.103952

Bradley, E. H., Curry, L. A., and Devers, K. J. (2007). Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Heal. Serv. Res.* 42, 1758–1772. doi: 10.1111/j.1475-6773.2006.00684.x

Carmichael, R. H., Walton, W., and Clark, H. (2012). Bivalve-enhanced nitrogen removal from coastal estuaries. *Canad. Jour. Fish. Aqua. Sci.* 69, 1131–1149. doi: 10.1139/f2012-057

Christie, H., Kraufvelin, P., Kraufvelin, L., Niemi, N., and Rinde, E. (2020). Disappearing blue mussels–can mesopredators be blamed? *Fron. Mar. Sci.* 7, 550. doi: 10.3389/fmars.2020.00550

Cuthbert, R. N., Pattison, Z., Taylor, N. G., Verbrugge, L., Diagne, C., Ahmed, D. A., et al. (2021). Global economic costs of aquatic invasive alien species. *Sci. Tot. Environ.* 775, 145238. doi: 10.1016/j.scitotenv.2021.145238

De Snoo, G. R., Herzon, I., Staats, H., Burton, R. J., Schindler, S., and van Dijk, J. (2013). Toward effective nature conservation on farmland: making farmers matter. *Conserv. Let.* 6, 66–72. doi: 10.1111/j.1755-263X.2012.00296.x

Endter-Wada, J., Blahna, D., Krannich, R., and Brunson, M. (1998). A framework for understanding social science contributions to ecosystem management. *Ecol. App.* 8, 891–904. doi: 10.1890/1051-0761(1998)008[0891:AFFUSS]2.0.CO;2

FAO (2018). *The State of World Fisheries and Aquaculture 2018 - Meeting the Sustainable Development Goals* (Rome: FAO), 227. Available at: http://www.fao.org/3/i9540en/i9540en.pdf.

Floyd, T., and Williams, J. (2004). Impact of green crab (*Carcinus maenas* L.) predation on a population of soft-shell clams (*Mya arenaria* L.) in the southern Gulf of St. *Lawrence Jour. Shellf. Res.* 23, 457–463. Available online at: https://link.gale.com/apps/doc/A123080672/AONE?u=anon~d48331e4&sid=googleScholar&xid=703b2837

Getchis, T. L. (2014). *Northeastern U.S. Aquaculture Management Guide: A Manual for the Identification and Management of Aquaculture Production Hazards. NRACAMG-2014* (New Jersey: Northeastern Regional Aquaculture Center).

Green, S. J., and Grosholz, E. D. (2021). Functional eradication as a framework for invasive species control. *Front. Eco. Envir.* 19, 98–107. doi: 10.1002/fee.v19.2

Grizzle, R., and Ward, K. (2012). Diversifying shellfish aquaculture in coastal New Hampshire. *Final Report.* (Portsmouth, NH: New Hampshire Department of Environmental Services).

Grizzle, R., Ward, K., Burdick, D., Payne, A., and Berlinsky, D. (2020). Eastern oyster *Crassostrea virginica* growth and mortality in New Hampshire (USA) using off bottom farm gear. *North Amer. Jour. Aqua.* 82, 132–142. doi: 10.1002/naaq.10135

Grizzle, R. E., and Ward, K. M. (2016). *Assessment of recent eastern oyster (*Crassostrea virginica*) reef restoration projects in the Great Bay Estuary, New Hampshire: Planning for the future* (Durham, NH: PREP Rep. & Pub), 353. Available at: https://scholars.unh.edu/prep/353.

Grizzle, R. E., Ward, K., and Atwood, R. (2023). *Oyster Restoration* (Durham, NH: PREP State of Our Estuaries 2023).

Heck, N., Stedman, R. C., and Gaden, M. (2015). The integration of social science information into Great Lakes fishery management: Opportunities and challenges. *Fish. Res.* 167, 30–37. doi: 10.1016/j.fishres.2015.01.008

Higgins, C. B., Stephenson, K., and Brown, B. L. (2011). Nutrient bioassimilation capacity of aquacultured oysters: quantification of an ecosystem service. *Jour. Environ. Qual.* 40, 271–277. doi: 10.2134/jeq2010.0203

Johnson, T. R., Beard, K., Brady, D. C., Byron, C. J., Cleaver, C., Duffy, K., et al. (2019). A social-ecological system framework for marine aquaculture research. *Sustain* 11, 2522. doi: 10.3390/su11092522

Kellogg, M. L., Smyth, A. R., Luckenbach, M. W., Carmichael, R. H., Brown, B. L., Cornwell, J. C., et al. (2014). Use of oysters to mitigate eutrophication in coastal waters. *Estuar. Coast. Shelf Sci.* 151, 156–168. doi: 10.1016/j.ecss.2014.09.025

Lapointe, G., Fisheries, M., and Ocean, N. R. (2013). *NROC White Paper: Overview of the aquaculture sector in New England* (New York, NY, USA: Northeast Regional Council).

Lovell, S., Besedin, E., and Grosholz, E. (2007). "Modeling economic impacts of the European green crab," in Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007, Vol. 2339. 1–40.

Meyer, K., Brown, B., Bradt, G., Ward, K., Brown, L., Matso, K., et al. (2023). *Green Crabs – Special Feature (SOOE Extended)* (Durham, NH: PREP State of Our Estuaries 2023, Extended Version).

Moon, K., Brewer, T. D., Januchowski-Hartley, S. R., Adams, V. M., and Blackman, D. A. (2016). A guideline to improve qualitative social science publishing in ecology and conservation journals. *Ecol. Soc.* 21 (3), 17. doi: 10.5751/ES-08663-210317

Morse, D., and Pietrack, M. (2009). *Aquaculture Situation and Outlook Report 2009: Maine* (Orono, ME: Maine Sea Grant Pub), 107. Available at: https://digitalcommons.library.umaine.edu/seagrant_pub/107.

Pickering, T. R., Poirier, L. A., Barrett, T. J., McKenna, S., Davidson, J., and Quijón, P. A. (2017). Non-indigenous predators threaten ecosystem engineers: interactive effects of green crab and oyster size on American oyster mortality. *Mar. Enviro. Res.* 127, 24–31. doi: 10.1016/j.marenvres.2017.03.002

Poirier, L. A., Symington, L. A., Davidson, J., St-Hilaire, S., and Quijón, P. A. (2017). Exploring the decline of oyster beds in Atlantic Canada shorelines: potential effects of crab predation on American oysters (*Crassostrea virginica*). *Helg. Mar. Res.* 71, 1–14. doi: 10.1186/s10152-017-0493-z

Ray, N. E., Henning, M. C., and Fulweiler, R. W. (2019). Nitrogen and phosphorus cycling in the digestive system and shell biofilm of the eastern oyster *Crassostrea virginica*. *Mar. Eco. Prog. Ser.* 621, 95–105. doi: 10.3354/meps13007

Scuderi, B., and Chen, X. (2019). Production efficiency in New England's oyster aquaculture industry. *Aqua. Econ. Man.* 23, 45–64. doi: 10.1080/13657305.2018.1449272

Short, F. T. (1992). *The ecology of the Great Bay Estuary, New Hampshire and Maine: An Estuarine Profile and Bibliography* (Durham, NH: PREP Rep. & Pub), 376. Available at: https://scholars.unh.edu/prep/376.

St-Hilaire, S. (2016). Assessing the potential for a soft-shell green crab industry in PEI (Doctoral dissertation). Charlottetown, P.E.I.: University of Prince Edward Island.

Teel, T. L., and Manfredo, M. J. (2010). Understanding the diversity of public interests in wildlife conservation. *Conser. Bio.* 24, 128–139. doi: 10.1111/j.1523-1739.2009.01374.x

Tosiello, L. (2019). Food safety for New Hampshire oysters: A multidisciplinary perspective. (*Master's theses and capstones)*. Durham, NH: University of New Hampshire, 1313. Available at: https://scholars.unh.edu/thesis/1313.

Vaismoradi, M., Jones, J., Turunen, H., and Snelgrove, S. (2016). Theme development in qualitative content analysis and thematic analysis. *J. Nurs. Educ. Pract.* 6, 100–110. doi: 10.5430/jnep.v6n5p100

Yu, L., and Gan, J. (2021). Mitigation of eutrophication and hypoxia through oyster aquaculture: an ecosystem model evaluation off the Pearl River Estuary. *Environ. Sci. Tech.* 55, 5506–5514. doi: 10.1021/acs.est.0c06616

Zu Ermgassen, P. S., Spalding, M. D., Grizzle, R. E., and Brumbaugh, R. D. (2013). Quantifying the loss of a marine ecosystem service: filtration by the eastern oyster in US estuaries. *Estuar. Coast.* 36, 36–43. doi: 10.1007/s12237-012-9559-y