VOLUME THIRTY FIVE JUNE 2022 VOLUME ONE

# The Lobster NEWSLETTER

## A New Look for *The Lobster Newsletter*! What do you think?

We finally decided to take a leap into the 21st Century and give ***The Lobster Newsletter*** a new format. We're eager to know what you think. This new MailChimp format has some important advantages. Chief among them for our readers is the ability to scroll through the articles in the body of an engaging email format and link directly to articles of interest. MailChimp also provides valuable analytics on viewership. And it still can be archived, as always, on the Newsletter website hosted by Western Australia Fisheries.

Let us know what you think!

Send your comments and questions to the editors,

Rick Wahle richard.wahle@maine.edu, and

Nick Caputi Nick.Caputi@dpird.wa.gov.au

Happy reading!

Rick & Nick

# RESEARCH ARTICLES

## A next-generation climate vulnerability assessment for *Homarus americanus* in Atlantic Canada

*From: Brady K. Quinn, Helen Gurney-Smith, Adam Cook, Courtenay Parlee, Diane Lavoie, Erin Miller, Blair Greenan, Nancy Shackell, Chris Chambers, Katherine Mills, Samantha Siedlecki, and Charles Stock*

Fisheries for American lobster (*Homarus americanus*) are extremely important for the social, cultural, and economic livelihood of coastal communities in the Northeast United States and Atlantic Canada. Increases in ocean temperatures have recently impacted lobster landings (largely positively north of southern New England). The implications of further warming due to a changing climate, and the impacts of other associated factors like ocean acidification, remain unknown but are likely to be detrimental. For instance, lab studies demonstrated a combined contribution of end-of-century warming and acidification to reduced survival and increased stress of lobster larvae and juveniles (e.g., Waller et al., 2016; Noisette et al., 2021). This is also a region that is strongly influenced by climate variability, which poses significant challenges in projecting future conditions on the time scales of years to several decades.

The Canadian Department of Fisheries and Oceans (DFO), under the Fisheries Act, seeks to explicitly incorporate climate change considerations into fisheries management. Tools are needed that quantify the exposure, sensitivity, and adaptive capacity (i.e., risk or vulnerability) of lobsters and fishery-dependent communities to climate-induced changes. Such tools must consider the combined and cumulative climate effects on lobsters across multiple life stages *and* the impacts of climate on lobster fisheries and the sustainability of the communities that rely on lobsters. These are inherently multi-disciplinary efforts.

Our new project (2021-2023) in the DFO Maritimes region aims to develop a “next-generation” tool to assess the vulnerability of lobster fisheries in Canada to climate change. A previous vulnerability assessment by Greenan et al. (2019) focused on adult lobsters and applied a broad-brush assessment for lobster fisheries in Nova Scotia and New Brunswick, Canada (Atlantic coast and Bay of Fundy regions). That study focused on temperature-driven changes rather than cumulative climate impacts.

Further, their assessment used aggregated economic vulnerability indicators at a wider geographic scale, which may underestimate the sensitivity of some key production areas (e.g., southwest New Brunswick). Drawing from expertise within DFO and our international collaborative team, our project will also build a multidisciplinary assessment framework incorporating projected multiple climate change impacts on oceanography and lobster sensitivity alongside precise indicators of social, cultural, and economic dependency on lobster fishing.

The study will initially focus on the Bay of Fundy region and adjacent waters in southwest Nova Scotia to build an assessment tool, which could then be modified and applied elsewhere and for other species. This project will collate and combine the following data and resources:

*Biological sensitivities*: Experimental data on the impacts of multiple climate change drivers (warming waters, ocean acidification, and dietary limitation) on the fecundity, behaviour, development, and embryonic period duration. Transcriptional and inherited (epigenetic) responses of lobster will be used to determine the cumulative climate sensitivities of lobsters across life stages.

*Climate exposure:* New climate projections (e.g., Lavoie et al., 2020, 2021; Siedlecki et al., 2021), derived from historical trends and downscaled physical models will be used to determine lobster climate exposures. These models include ocean acidification, temperature, freshwater influence, and their interactions at different depths relevant to pelagic and benthic lobster life stages.

*Climate-forced lobster distribution models*: Outputs from new species distribution models of lobster biomass under projected future climate conditions will be integrated into the vulnerability model. Changes in larval dispersal under climate projections will also be assessed.

*Fisheries management:* Lobster habitat and fisheries-population models (based on Chen et al., 2005) will be used to determine habitat suitability indices under climate scenarios and linked to fisheries management resiliency, thereby facilitating compatibility for longer term use, including seasonal to multi-annual fisheries projections.

*Social, cultural, and economic indicators*: Existing and new social, cultural, and economic and community-level vulnerability indicators for the fishery regions and communities will be assessed. These will include, for example: sustainable communities, sustainable livelihoods, dependency, profitability, and viability.

The project team includes researchers at DFO and in the United States (NOAA, Gulf of Maine Research Institute, and University of Connecticut), and will complement similar efforts being made by US scientists for the Gulf of Maine (Siedlecki et al., 2021). Indeed, the transborder nature of lobster distribution in this region requires consideration of connectivity of this resource in Canadian and American waters, especially if larval dispersal is affected or if lobster populations shift northward and deeper, as some studies predict (Pinsky et al., 2013).

The new vulnerability model will merge our current understanding of how key climate drivers might affect the availability and sustainability of this important commercial resource and the communities that rely on it. For example, this vulnerability assessment will be used by fisheries managers for short-term and longer term forecasting of the lobster resource to provide a sustainable and healthy marine ecosystem. In addition, the vulnerability tool can be used for adaptation planning for this species and communities reliant on this resource.

The main modelling component of this project is being run by Brady K. Quinn (Brady.Quinn@dfo-mpo.gc.ca), under primary supervision of Dr. Helen Gurney-Smith (Helen.Gurney-Smith@dfo-mpo.gc.ca) and Dr. Adam Cook (Adam.Cook@dfo-mpo.gc.ca), all in the DFO Maritimes Region. Please contact us if you seek more information, are interested in collaborating, or would like updates from the team as this project gets underway!

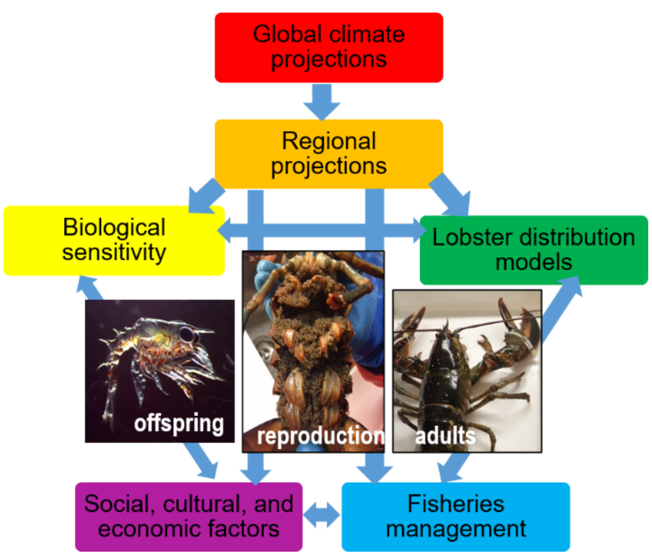


**Figure 1.** Conceptual diagram of the components planned for the American lobster climate vulnerability assessment model. All images courtesy of DFO Maritimes Region.

*This project is funded through a Competitive Science Research Fund grant through the DFO Aquatic Climate Change Adaptation Services Program. For more information (and an upcoming page about our project) please visit:*

[https://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp-psaccma/index-eng.html](https://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp-psaccma/index-eng.html)
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# Raising American lobster embryos individually and isolated from the female brood

*From Sha Bo and Rémy Rochette*

**Introduction**

Among brood-carrying crustaceans, females of most crustaceans carry embryos on the ventral surface of their abdomen prior to their release as planktonic larvae. Although female lobsters are thought to help oxygenate embryos during their incubation period by abdominal flapping and pleopod beating (Ennis 1975), there is no vascular or nervous connection between them and embryos, suggesting it may be possible to raise these embryos physically isolated from a female's brood to study their normal development and hatch. Raising individual embryos instead of ovigerous females would markedly reduce space and husbandry requirements, and hence increase the number of females for which hatch can be simultaneously monitored. Such an advance in methodology would enhance our ability to study American lobster embryo development, and potentially our ability to forecast their hatch in a rapidly changing climate.

**Objective**

The aim of this study was to determine whether American lobster embryos raised individually isolated from one another and from the female's brood develop similarly and hatch at the same time as their siblings still attached to the brood.

**Methods**

We conducted a laboratory experiment in which embryos attached to and detached from the brood of 12 females from the southwest Bay of Fundy were raised in two temperature treatments (constant [ca. 8°C] and ambient [ca. 5-14, mean = 8.2°C]) from late spring until their hatch, and then compared these embryos with respect to their development rate, development status at hatch, and hatch date. Each female was held in a separate plastic container, and individual embryos from each female were kept in wells of a plastic dish (12.5×8.5×2 cm) attached to a plastic panel in the container housing the female (Fig. 1). We used the Perkins eye index (PEI) as an index of the development status of lobster embryos, which is measured as the mean of the greatest width and the greatest length of the embryo's pigmented eye (Fig. 2; Perkins 1972). Hatch date of embryos refers to the appearance of the prezoeal stage, which is a short 24-48 hour "transition stage" between the embryo and the first larval stage (Aiken 1980). Development rate was estimated using Equation 1 below, based on samples obtained at the beginning of May (initial PEI), when ambient temperature had started increasing, and samples obtained at hatch (final PEI, or development status at hatch).

$$development\ rate\ (\mu m/day) = \frac{final\ PEI(\mu m) - initial\ PEI(\mu m)}{time\ interval\ (days)} \qquad [1]$$

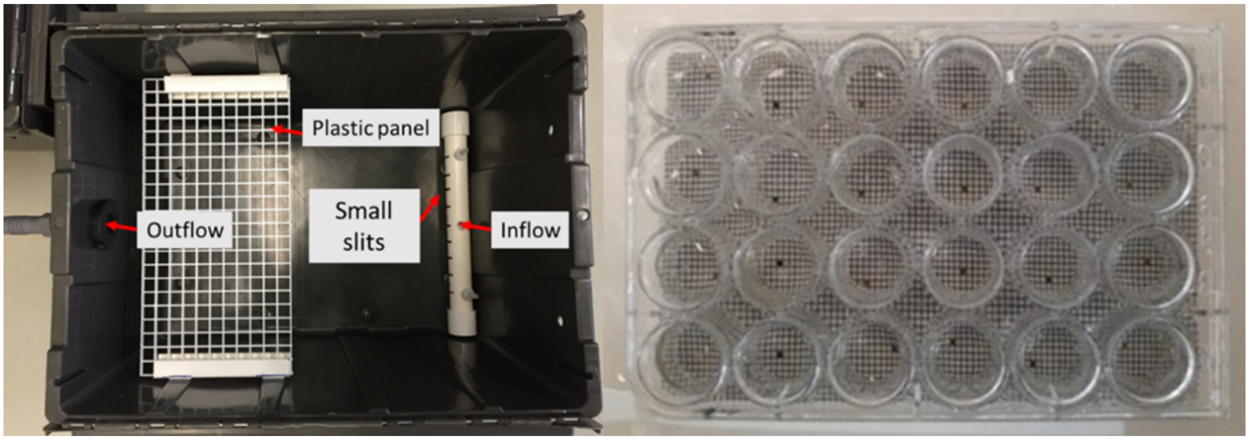


**Figure 1.** ***(Left)*** Plastic container (45 L) in which were held one brooding female lobster and 24 of its embryos that were detached from the brood and placed inside a welled dish attached to a "plastic panel" below water level. The experiment involved 12 such containers, 6 at constant and 6 at ambient temperature (see Methods). Water came from a header tank through the inflow hole and diffused into the container through small slits in the inflow pipe. (***Right)*** Plastic dish (12.5×8.5×2 cm) with 24 wells (2 cm diameter and 2 cm depth) used to house individual embryos. The top and bottom of the plastic dish were replaced with mesh (500 µm) to allow water flow.

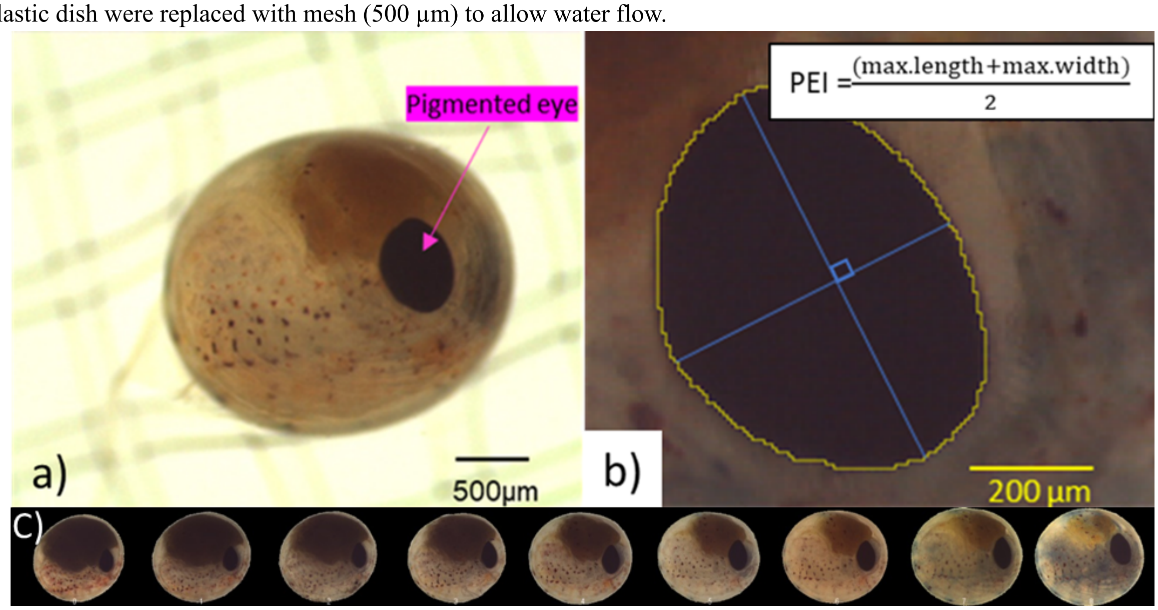


**Figure 2.** ***(a)*** Polar view of a lobster embryo, which shows the maximum area of the pigmented part of its eye (black oval). ***(b)*** Close-up showing the PEI measurement, which is the average of the maximum length and the perpendicular maximum width of the pigmented area of the eye. ***(c)*** Embryo growth over a two-month period, photographed at weekly intervals, showing gradual increasing in eye size (from 415 to 578 mm; this embryo hatch at 602 mm) and concomitant decrease in size of the yolk reserve.

**Results & Discussion**

Of the 288 embryos we raised separated from the brood of 12 females (24 per female), only five did not make it to hatch (>98% hatch rate). The hatch period of embryos detached from and still attached to the females was very similar, ranging from June 20th to July 31st (41 days) for the former and June 19th to July 29th (40 days) for the latter. Furthermore, there was no significant difference between embryos attached and detached from a same female's brood in terms of their mean development rate ($t = -1.89$, $df = 6, p = 0.11$), mean development status at hatch ($t = -0.46$, $df = 6, p = 0.66$), or median hatch date ($t = 2.05$, $df = 11, p = 0.06$), although the correspondence between the two was admittedly not very strong (Fig. 3). The difference in median hatch date did approach statistical significance ($p = 0.06$), but it was relatively small, with detached embryos hatching on average 3 days later than attached embryos. It is unclear whether this small mean difference is due to sampling error associated with a relatively small sample size, or whether it reflects a true difference in hatch data of attached and detached embryos. If the latter, the "delayed" hatch of detached embryos could be due to the light fouling observed on some of the embryos. Brooding lobsters have been described to "groom" or "fan" embryos by beating their pleopods during the incubation period, presumably cleaning the embryos to prevent diseases and enhance gas exchange, which may accelerate development (Baeza et al. 2016). The absence of such grooming may be responsible for the fouling we observed on detached embryos, which could have slowed their development and retarded their hatch. Additional validation work, with a large sample size and enhanced water flow conditions (to reduce fouling), may thus be worthwhile.

These findings open the door to more detailed studies of lobster embryo development, based on the tracking of the same individual embryos over time. It also opens the door to more comprehensive comparative studies of hatch, by simultaneously raising embryos from many locations in different conditions. For example, this approach could be used to simultaneously create temperature-based development functions of lobster embryos from many locations, which in turn would enable the prediction and study of geographic and inter-annual variation in hatch over the species' range. Such information on lobster hatch is particularly relevant to our understanding of larval dispersal, connectivity, and match-mismatch with prey, which are all becoming increasingly important as lobster phenology and ecological interactions are impacted by climate change.

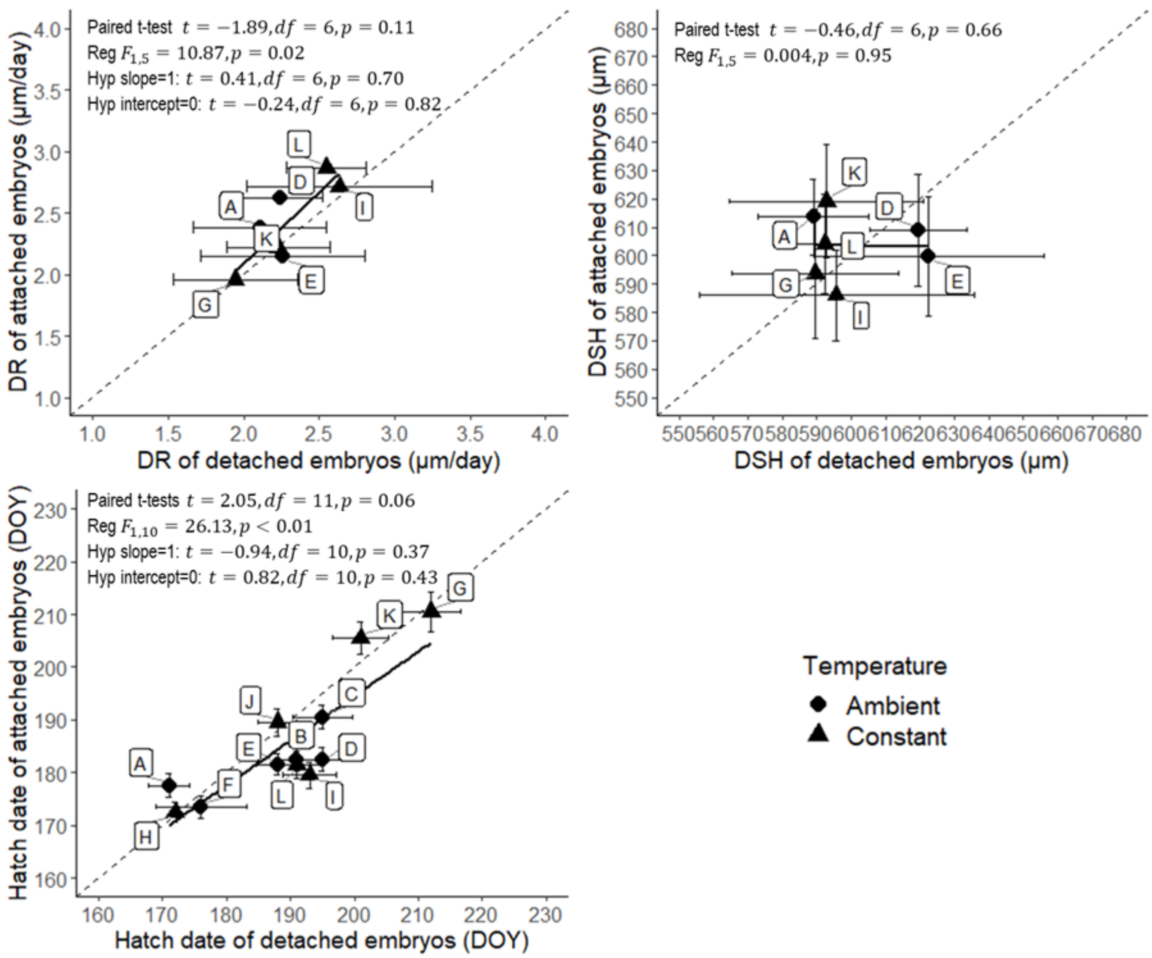


**Figure 3.** Comparison of the ***(a)*** mean (±95% CI) development rate (DR), ***(b)*** mean (±95% CI) development status at hatch (DSH), and ***(c)*** median (±95% CI) hatch date of embryos isolated from a female's brood and embryos attached to the same females' brood; DR of attached embryos is based on mean values from embryos sampled on each of two occasions, hence the absence of error bars around these particular female-level estimates. Females A – F (circles) and G – L (triangles) were housed at ambient (ca. 5-14 °C) and constant (ca. 8°C) temperature, respectively. The stippled line represents the 1:1 line of perfect correspondence between values for detached and attached embryos, and the black solid line represents the line of best fit between these data. Paired t-tests were used to test if there was a significant difference, for each metric, between detached and attached embryos belonging to a same female. Linear regression was used to test the null hypothesis of no relationship between values for detached and attached embryos; where a significant relation was found between detached and attached embryos, we also tested the null hypotheses of slope =1 and intercept =0, to determine if the relationship differed significantly from 1:1.

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## A Sea of Concerns Troubles New England Lobster Fishery

From Melissa Waterman, *Maine Lobstermen's Association*

On May 1, new federal regulations came into force in the U.S. Northeast lobster fishery. The regulations are part of a 10-year plan to protect the endangered North Atlantic right whale population as required by the federal Endangered Species Act and Marine Mammal Protection Act.

The regulations come at a time when the lobster fishery remains robust. Maine lobstermen landed close to 109 million pounds (nearly 50 thousand metric tons) in 2021, a sharp uptick from the depressed landings of 2020 when the pandemic first appeared. Last year was the tenth year during the past eleven years when the state's landings topped 100 million pounds. The 2021 value of $730.6 million was by far the greatest ever, reflecting the growth of domestic and international demand as restaurants and other venues reopened during the year.

Yet signs of change in the lobster population have become more apparent. Surveys conducted over the last five years by the Maine Department of Marine Resources (DMR) suggest that the lobster harvest may not be as strong in future years.

**Status of Maine fishery**

Each year DMR conducts scientific surveys related to all life stages of the lobster. In 2021 each survey indicated a decline (Maine DMR 2021). The surveys provide multiple streams of data from different areas and depths along the coast. Agreement in trends among the surveys suggest a decline in lobster abundance.

Maine's Lobster Settlement Index tracks young-of-the-year lobsters. Since 2013, this survey has shown low levels of settlement along the Maine coast. The sampling takes place during October and November each year at 40 sites along the Maine coast. By contrast, sites to the north of Maine, such as Prince Edward Island and Newfoundland, saw an increase in settlement.

DMR's Ventless Trap Survey tracks juvenile lobsters less than the state's minimum size of 3.25 inches (83 mm) carapace length. This survey has shown decline in some areas, especially in eastern Maine, beginning in 2018. The Ventless Trap Survey takes place from June through August, with two data collection days per month, in collaboration with Maine lobstermen. Lobstermen set baited ventless triples in three randomly selected sites; they return after three days to haul the traps and, with a trained sea sampler, record all the lobsters and crabs in each trap.

Maine's biannual Inshore Trawl Surveys track all sizes of lobster hauled along with other species. The Fall Trawl Survey showed a decline in sublegal-size lobsters in all areas, with higher declines in eastern portions of the coast. The Spring Trawl Survey data began showing a decline in 2019 among all sizes of lobster in all areas with a sharp decline in 2021. The spring and fall Inshore Trawl Surveys take place along the New Hampshire and Maine coast and have been conducted since 2000.

DMR conducts sea sampling each year aboard commercial lobster vessels. The 2021 sea sampling data confirm the downward trend in sublegal lobsters throughout the coast. Three sampling trips take place in each of Maine's seven lobster zones from May through November. Sea samplers observe a commercial lobstering trip to record biological information such as lobster carapace length, sex, cull status, V-notch condition, egg development stage, molt status and extent of shell disease of all lobsters caught in traps. Samplers also record final catch weight and price as well as gear characteristics and bait type.

**Possible changes to the interstate Lobster Fishery Management Plan**

The 2020 American Lobster Benchmark Stock Assessment, conducted by the interstate Atlantic States Marine Fisheries Commission (ASMFC), found record high abundance and recruitment in the Gulf of Maine and Georges Bank lobster stock (GOM/GBK). However, the ASMFC declared in 2021 its management goal to keep the lobster stock at its highest biological productivity levels by taking proactive measures to increase spawning stock biomass in response to a population decline. ASMFC is considering a range of changes to the lobster fishery management plan, such as increasing the minimum size, decreasing maximum size, and standardizing management measures across federal areas in response to the decline in lobster abundance over the last five years.

**Right whale protection measures**

In May 2021, the National Marine Fisheries Service (NMFS) released a Biological Opinion on the impact of the federal lobster fishery on the recovery of North Atlantic right whales. NMFS determined that the lobster fishery does not jeopardize the right whale population provided it complies with a 10-year plan to reduce risk by 98% by 2030.

The plan will be implemented in three phases. The Northeast lobster fishery complied with the first phase in May 2022 through a 60% risk reduction, which removes rope from the water through large seasonal closures and requiring more traps per buoy line, weakening remaining buoy lines to allow whales to break free, and unique gear-marking requirements to differentiate gear fished by state, and in federal versus state waters (*Table 1- Page 13*).

NMFS announced earlier this year that it planned to move the lobster fishery through the second phase of the whale conservation plan earlier than originally planned, aiming to achieve a 90% risk reduction as soon as possible. Additional risk reduction measures will be considered before 2030.

The Maine Lobstermen's Association (MLA) sued NMFS in September 2021, arguing that the Biological Opinion is unlawful because it relies on arbitrary assumptions, fails to rely on the best scientific information or account for the positive impact of conservation measures already adopted by the Maine lobster fishery. The MLA claims that NMFS relied on worst case scenarios to inflate the risk assigned to the lobster fishery.

"NMFS's mandate ignores the reality that the Maine lobster fishery already has an extremely low incidence of interactions with right whales due, in part, to a suite of mitigation measures that have been implemented for many years. Reducing its already low impact by another 98% is not possible without driving most of Maine's harvesters out of business permanently," stated the MLA in its original filing. NMFS disregards "critically important new scientific information about right whale migration patterns [that] shows that the Maine lobster fishery will continue to pose very little risk to North Atlantic right whales.

**Table 1.** New Whale Rules from Maine DMR Science Update 2022

<table>
<tr><th></th><th colspan="3">New Whale Rules (effective May 1, 2022)</th><th colspan="2">Whale Rules Still in Place</th></tr>
<tr><th></th><th>Trawling Up</th><th>Weak Points</th><th>Gear Marking</th><th>Universal Gear Requirements</th><th>Sinking Groundlines and Other Measures</th></tr>
<tr><td>State waters Exempt</td><td>No changes</td><td rowspan="2">1 weak insert ½ way down the buoy line<br>*Exempt waters only May use 5/16" rope with knots per DMR regulations in addition to NMFS approved weak inserts</td><td rowspan="2"><u>3 purple marks</u><br>36" purple mark w/in 2F buoy<br>12" purple mark at middle and bottom<br>*Exempt waters <100 feet only 2 marks required at top and bottom only</td><td rowspan="5">No buoy line floating at the surface<br>No wet storage of gear. Gear must be hauled at least every 30 days<br>Maintain knot-free buoy lines is encouraged</td><td><u>Choose one</u>: 1) sinking rope for buoy line or 2) sinking rope for groundline or 3) 600 pound breakaway at buoy</td></tr>
<tr><td>State waters Sliver</td><td>See chart by zone<br>Island exemption remains in place</td><td rowspan="4">Groundlines must be comprised of all sinking rope<br>600 pound breakaway below buoy is now OPTIONAL<br>Pocket waters are considered state waters for all whale regulations</td></tr>
<tr><td>Federal 3 to 6 miles</td><td>See chart by zone</td><td rowspan="2"><u>Zones A west, B, C & D</u><br>2 weak inserts (1/4 and ½ way down buoy line)<br><u>Zones A east, F & G</u><br>1 weak insert 1/3 down the buoy line</td><td rowspan="3"><u>4 purple & 4 green marks</u><br>36" purple mark w/in 2F buoy<br>12" purple mark at top, middle and bottom<br>12" green mark within 6" of each purple mark</td></tr>
<tr><td>Federal 6 to 12 miles</td><td>See chart by zone</td></tr>
<tr><td>Federal 12+ miles</td><td>25's/2 EL</td><td>1 weak insert 1/3 down the buoy line</td></tr>
</table>

**Reference:**

Maine Department of Marine Resources (DMR) 2021. 2021 Lobster Monitoring Update. https://www.maine.gov/dmr/science-research/species/lobster/research/documents/2021monitoring.pdf Accessed May 6, 2022

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## Updates from the Sea Grant American Lobster Initiative

*From: Amalia Harrington*

In 2019, the National Oceanic and Atmospheric Administration's (NOAA) National Sea Grant College Program established the **Sea Grant American Lobster Initiative (ALI)**. The ALI's overarching goal is to increase the American lobster industry's resilience to the biological, economic, and social impacts of ecosystem change in the Gulf of Maine, Georges Bank, and southern New England. The ALI is accomplishing this goal through scientific research supported through the American Lobster Research Program, as well as a Northeast Regional Lobster Extension Program. The research program is addressing critical knowledge gaps about American lobster and its iconic fishery in a dynamic and changing environment, and the extension program is supporting the region by enhancing and complementing the research efforts. Together, these programs are working to develop and share new knowledge and understanding with industry stakeholders and resource managers from Maine to New York.

The research program has supported **22 projects** spanning three research cohorts since 2019. The investigators on these projects include scientists, industry partners, and resource managers from more than 40 institutions across the Northeastern US and beyond. The program's research priorities have shifted across the three cohorts to include biological and ecological topics (e.g., understanding life history parameters, spatial distribution and migration patterns, ecosystem shifts, and species interactions); socioeconomic lessons to be learned from southern New England and applied to the Gulf of Maine and Georges Bank; and socioecological investigations to inform future management decisions (e.g., research exploring bait alternatives to herring and their implications for the lobster fishery). Although the COVID-19 pandemic caused some delays in the research program, projects in the 2019 and 2020 cohorts have been making great progress. Many teams shared their work during the "**American lobster in a changing Gulf**" session of the 2021 Annual Science Meeting of the Regional Association for Research on the Gulf of Maine, and several graduate students have provided research updates through **blog posts** and **radio show interviews**. The ALI looks forward to sharing the findings of the ongoing projects in the research program, and encourages readers to follow along on social media via **#SeaGrantLobster**. The most recent research cohort began in fall 2021 and includes six new projects:

- **An ecosystem-based approach to American lobster habitat and trophic dynamics: Integrated modeling to evaluate climate-related impacts** Damian Brady (University of Maine)

- **Answering an industry question, "Who's eating juvenile lobsters?": An evaluation of lobster predation in the Gulf of Maine using stomach content analysis** Rebecca Peters (Maine Department of Marine Resources)
- **'Connecting the dots': Environmental drivers of egg production and stability in ovigerous American lobsters in the Gulf of Maine** Jason Goldstein (Wells National Estuarine Research Reserve)
- **Evaluating impacts of changing life history parameters on the American lobster stock dynamics under different management regulations in a warming Northeastern US** Yong Chen (Stony Brook University)
- **Investigating the ecological impacts of range-expanding species to the American lobster fishery using collaborative surveys, fisher observations, and predator-prey experiments** Jonathan Grabowski (Northeastern University)
- **The influence of season and temperature on the distribution and abundance of juvenile lobsters assessed via traditional ventless and novel early benthic phase traps** Joshua Carloni (New Hampshire Fish and Game)

The **regional extension program** includes individuals from the seven Northeast Sea Grant Programs – Maine, New Hampshire, Massachusetts Institute of Technology (MIT), Woods Hole, Rhode Island, Connecticut, and New York – with Maine serving a coordinating role. The extension program has been active in leading state-specific projects while contributing to building capacity for lobster research, outreach, and engagement across the region since its inception. In collaboration with MIT and Woods Hole Sea Grant Programs, Maine Sea Grant developed an **interactive StoryMap** that explores how climate change is expected to impact the lobster population and highlights how the ALI fits into that research landscape. In partnership with Maine's Department of Marine Resources and the University of Maine's Lobster Institute, Maine Sea Grant led the effort to develop the "**Collaborative Chats**" webinar series that highlights successful research partnerships in the lobster industry, including projects funded through the ALI. Members of the extension network also adjusted their efforts to address emerging needs of stakeholders during the pandemic. New Hampshire and Rhode Island Sea Grant extension associates are documenting direct sales benefits and challenges of lobstermen in their states through survey-based data collection. They also developed a **Rhode Island Seafood Finder**, modeled after the **New Hampshire Seafood Finder** to link consumers with dockside sales from fishermen. Extension associates from Connecticut, New York, and MIT Sea Grant Programs have continued to advance their work gathering oral histories documenting perspectives from stakeholders with first-hand experience of past events that led to the decline in American lobster population in southern New England. Interviews are still underway, but staff plan to add this project to the NOAA Voices Oral History Archives.

The extension program is also informed by a Regional Steering Committee that consists of industry and management representatives from across the Northeast. This Committee provides input and advice on the direction for the extension program, but also provides input on emerging industry, management, and research needs across the region. Since the ALI was established, two major areas of concern have arisen: the intersection of lobstering and offshore wind energy development, and recent regulatory changes modifying the Atlantic Large Whale Take Reduction Plan (ALWTRP). In response to these emerging issues, members of the extension program have become engaged in state and regional conversations focused on offshore wind energy and the North Atlantic right whale. In partnership with the Rhode Island Sea Grant Legal Program, Maine Sea Grant developed **technical reports** and engaging webpages to **explore the litigation** surrounding the North Atlantic right whale. In April, a fourth funding opportunity through the research program was **announced**. The program seeks applications from research teams and encourages research partnerships between state agencies, academia, and/or industry stakeholders that address development and operationalization of gear technologies that help industry comply with the requirements set forth in the final 2021 rule to modify the ALWTRP; and socioeconomic research to understand the social, economic, and technological opportunities and/or barriers associated with bringing gear technology to commercial scale in the lobster fishery. Applications are due May 24, and more information can be found on **grants.gov**.

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List of links:

1. Sea Grant American Lobster Initiative (ALI): https://seagrant.umaine.edu/extension/american-lobster-initiative/
2. 22 projects: https://seagrant.umaine.edu/extension/american-lobster-initiative/research-projects/
3. American lobster in a changing Gulf: https://www.rargom.org/video-day-3/
4. Blog posts: https://seagrant.umaine.edu/category/blog-entry/
5. Radio show interviews: https://seagrant.umaine.edu/2020/11/20/coastal-conversations-lobster-research-in-a-changing-environment/

6. Regional extension program: https://seagrant.umaine.edu/extension/american-lobster-initiative/extension-projects/
7. Interactive StoryMap: https://arcg.is/1mGn49
8. Collaborative Chats: https://seagrant.umaine.edu/extension/american-lobster-initiative/collaborative-chats-2020/
9. Rhode Island Seafood Finder: https://storymaps.arcgis.com/stories/e37880fdc24a4c7eb05b727ae228fe97
10. New Hampshire Seafood Finder: https://storymaps.arcgis.com/stories/448001c265f049e186baf63f9918a8b1
11. Technical reports: https://docs.rwu.edu/cgi/viewcontent.cgi?article=1005&context=law_ma_sp
12. Explore the litigation: https://seagrant.gso.uri.edu/wp-content/uploads/2021/07/Understanding-the-North-Atlantic-Right-Whale-Litigation-FINAL.pdf
13. Announced: https://seagrant.noaa.gov/funding
14. Grants.gov: https://www.grants.gov/web/grants/view-opportunity.html?oppId=338870

## Assessing the feasibility of on-demand gear in New England lobster fisheries

*From: Noah Oppenheim*

*Lobster Newsletter* readers who are tracking policy are doubtless well aware of the discourse around on-demand fishing gear, popularly known as 'ropeless' gear. Nowhere in the world is this conversation more active, or divisive, than in New England, USA, where the critically endangered North Atlantic right whale swims off our coasts alongside, and at times amongst, the extraordinarily profitable American lobster fisheries.

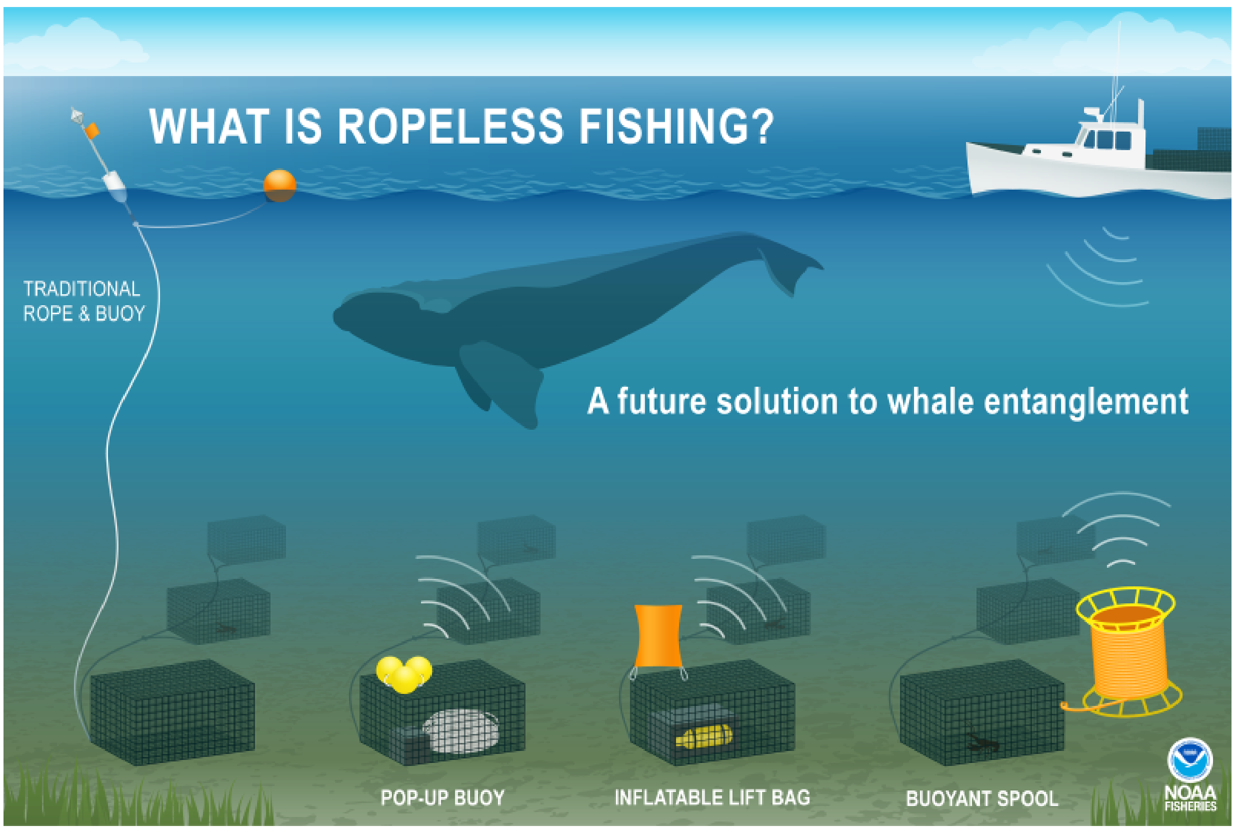


**Figure 1.** Types of on-demand or ropeless lobster or crab trap configurations.

On-demand fishing gear is used in fixed-gear fisheries by replacing traditional static vertical buoy lines (called 'persistent' lines in the US regulatory space; Fig. 1), which can result in entanglements with marine mammals including North Atlantic right whales, with new gear retrieval and virtual marking methods. Most on-demand fishing gear systems consist of submerged buoyancy devices that are activated using time-release mechanisms or acoustic signals transmitted from the surface. To some, on-demand gear is a panacea representing the glide path to right whale recovery; to others it is synonymous with economic peril and an existential threat to a way of life.

In late 2020, with funding provided by the National Fish and Wildlife Foundation, the Massachusetts Division of Marine Fisheries hired me to conduct a feasibility study of the issues, challenges, and opportunities of on-demand gear in New England lobster fisheries. While a great deal of work on the subject to date has focused on how on-demand fishing gear might be used to reduce risk to endangered marine life, this report was the first of its kind designed to evaluate how implementation of the gear would impact lobster fisheries and ocean governance across all issues from all perspectives.

The first step was to generate source material, which consists of the knowledge and experience of experts in the field including fishermen and their advocates, gear developers, conservation organization staff, fishery managers, law enforcement officials, and fishery scientists. Despite the media I conducted around 65 two-to-three-hour interviews with these experts and hosted a two-day workshop last fall. Using this rich and candid source material, I wrote a report that synthesizes perspectives across diverse sectors and analyzes the operational, technological, legal & regulatory, and socioeconomic challenges and opportunities of on-demand fishing gear in a comprehensive way. The report presents these issues fully, in many cases through the words of the experts themselves. It concludes with a set of recommendations for further study and policy development work. You can find the report at www.bit.ly/ropeless-report.

This project takes a significant step in outlining the next phases of on-demand gear research and testing, benchmarked against the operational characteristics that have made lobster fisheries some of the most profitable and culturally vibrant in the US. Resolving these issues across diverse interests requires equal investment in understanding their utility, technology, legal & regulatory, and socioeconomic implications. Through diligent and collaborative evaluation of on-demand gear, the numerous unanswered questions about feasibility, compatibility, and impacts of this emerging technology can ultimately be addressed.

The report includes the following recommendations for focused research and policy development:

I. Utility

- Continue to broaden and diversify collaborative approaches to on-demand gear engineering, development, and testing.
- Fully evaluate on-demand gear performance against benchmarks set by the fishery today.
- Develop and demonstrate procedures for the safe operation of on-demand gear under normal fishing conditions.
- Demonstrate procedures for safe single-hand operation of on-demand gear under normal fishing conditions.
- Evaluate on-demand gear rough weather performance and the potential for loss reduction.
- Determine how densely on-demand fishing gear can be efficiently and effectively operated.
- Develop and demonstrate effective techniques for lost on-demand gear recovery.

II. Technology

- Develop an open-source, interoperable underwater acoustic communication standard that minimizes impacts to marine biota.
- Establish universal open-source, interoperable gear marking and location standards across on-demand gear platforms.
- Develop universal open-source, interoperabile standards for the integrated display of on-demand gear deployment information.
- Demonstrate the performance and effectiveness of hull-mounted transducers
- Establish standards for gear detection distance.
- Demonstrate the performance and effectiveness of electronic methods to avoid gear conflict.
- Explore opportunities for collection of oceanographic data using on-demand gear.
- Develop standards and procedures for on-demand gear telecommunication and data fields.

III. Legal/Regulatory

- Establish standards and protocols for on-demand gear testing and reporting, and implement equitable testing programs across jurisdictions.
- Establish a clear regulatory pipeline/process for on-demand gear, including the assignment of regulatory responsibilities across state and federal jurisdictions.

- Develop law enforcement agency standards and procedures for inspecting on-demand gear and enforcing relevant laws and regulations.
- Facilitate coordination on regulatory and management across jurisdictions, and between fishing industry groups for the establishment of cooperative agreements
- Develop standards and responsibilities for on-demand gear database. management and address confidentiality issues.
- Investigate legal and regulatory processes that would require fishing vessel operators to use systems to detect on-demand gear.

IV. Socioeconomics

- Broaden collaborative on-demand gear development and testing efforts with fishing industry members and organizations.
- Coordinate across agencies and jurisdictions to require the use of open-source standards and interoperable platforms/systems to prevent monopolies, reduce costs, and disincentivize fishing fleet consolidation.
- Develop gear acquisition pipelines for the retail market.
- Demonstrate the scalability and integrability of on-demand gear, including use and acquisition, across sizes/locations/harvester demographics.
- Initiate and complete comprehensive socioeconomic studies and cost-benefit analyses of on-demand gear.
- Identify funding to support the acquisition of on-demand gear.
- Establish and fiscally support on-demand gear training and education programs.
- Begin mental health and wellness benchmarking in the lobster fishery and develop and implement new health and wellness programs.

After scores of interviews and days of discussion, one common theme has emerged: on-demand fishing gear requires significant thoughtful experimental testing and policy discussion if we are to determine where, how, and by whom it can be used in New England lobster fisheries and its impact to coastal communities and the marine environment. It will take years to make these determinations, but it must be done if an equitable policy for the use of on-demand gear is to be devised.

The hard work begins…

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# Larval thermal tolerance shifts ontogenetically in the American lobster *Homarus americanus*

*From: Eric Annis, Doug Rasher, Markus Frederich, Jes Waller, Aubrey Jane*

Despite numerous studies over the past 100+ years, substantial gaps remain in our understanding of the thermal tolerance in the earliest life stages of the American lobster, *Homarus americanus* (Quinn 2017). The abundance of adults is settlement driven (Steneck & Wilson 2001) and settlement appears to be regulated in part by temperature sensitivity of the larvae (Annis et al. 2013, Steneck & Wahle 2013). The goal of our research is to establish the physiological thermal tolerance of lobster larvae and link it to settlement patterns in the field. We report our preliminary results on the physiological thermal tolerance of the four planktonic larval/postlarval stages, and the first benthic stage. Apparent ontogenetic shifts occur in critical temperatures ($T_c$) and correspond broadly to the environments inhabited by each developmental stage.

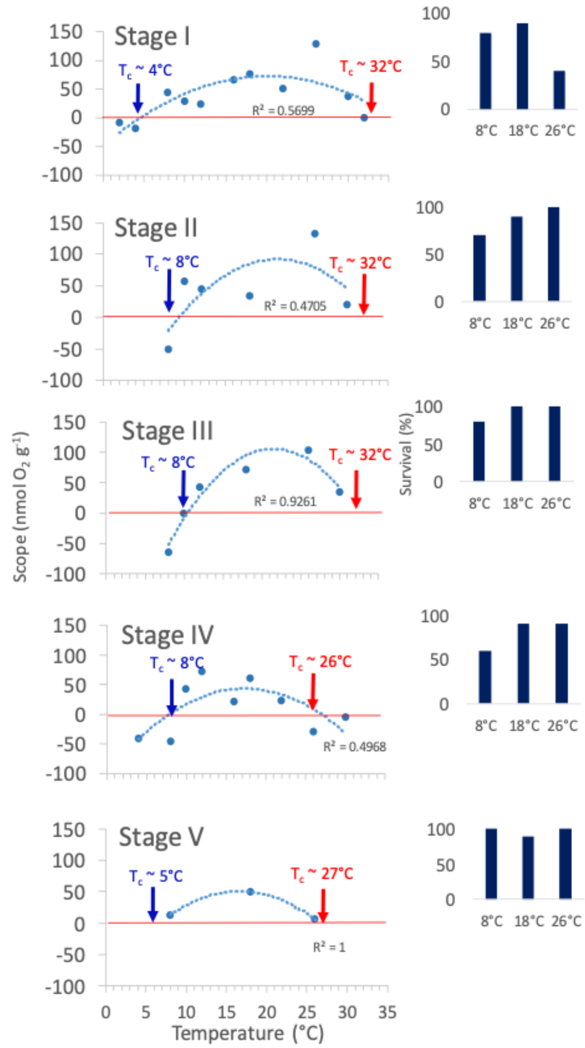


**Figure 1.** Scope for activity (left-side panels) in stage I-V lobster raised in lab in 18°C water and subjected to acute temperature treatments at 2-32°C (n = 4-5 at each temperature). Survivorship (right-side panels) in chronic temperature treatments.

We used *scope for activity* as a metabolic indicator of thermal stress to define $T_c$. Scope for activity was calculated as the difference between active and resting rates of $O_2$ consumption, which were measured in a closed chamber microrespirometry system (sensu Waller et al. 2017). We define critical temperatures ($T_c$ ) as the approximate temperature at which scope for activity was reduced to zero. Respirometry trials were acute treatments lasting only 30 minutes, and utilized larvae that were lab-reared at 18°C. We also conducted chronic exposure trials in which larvae reared at 18°C were transferred to treatment temperatures of 8, 18 and 26°C at each developmental stage and held until they molted or died.

Ontogenetic shifts in thermal tolerance based on respirometry occurred at stages II, IV and V (Figure 1). The approximate lower and upper $T_c$ were: 4-32°C for stage I, 8-32°C for stages II and III, 8-26°C for stage IV (= postlarvae), and < 8°C to > 26°C for stage V. Chronic temperature stress resulted in reduced survivorship of stage I larvae in response to heat stress, but not cold stress (8°C, Figure 1). Stages II-IV experienced reduced survivorship in response to cold stress but not heat stress. Stage V lobsters had 100% survival at both heat and cold stress temperatures.

The shifts in thermal tolerance we observed in our laboratory experiments align well with changing environmental conditions reported for each stage in the field. Vertical distribution, and therefore temperature exposure, varies ontogenetically. Newly hatched stage I larvae showed high cold tolerance and lower heat tolerance, which makes sense because in the wild this stage over-winters on the bottom as developing embryos, and has a deeper depth distribution after hatch than later stages (Harding et al. 1987). Stages II and III, which displayed a lower tolerance to cold stress, have a vertical distribution closer to the ocean surface (Harding et al. 1987), and stage IV are concentrated in nature in the warm upper meter of the water column (Annis 2005). Stage V lobsters, which would have recently settled on the benthos and experienced cool temperatures on the sea floor, displayed a greater cold tolerance.

Our research will improve our understanding of shifts in available suitable habitat for larval settlement as a consequence of climate change. Thermal tolerance parameters may be incorporated into models projecting larval viability and species range shifts to sustainably manage this fishery and adequately plan for its future in a warming ocean.

*This ongoing project is funded by The National Science Foundation Biological Oceanography Program.*

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## Latest advances in American lobster health and monitoring

*From Cassandra Leeman and Ben Gutzler*

While Maine's lobster fishery reached a record value of 725 million USD in 2021, roughly 2.1 million pounds of lobster were unable to be sold due to post-harvest mortality (referred to as "shrinkage" in the industry). Here, we report on two new methods of monitoring stress in *Homarus americanus*: first, a rapid non-invasive physical assessment that can predict the likelihood of mortality; and second, a heart rate and activity datalogger. These advances will hopefully prove useful in minimizing shrinkage throughout the supply chain and enable industry partners to maximize the value of their product.

Existing methods to assess American lobster health are unable to effectively predict mortality seen in the lobster supply chain. Rather than assessing the commonly used physiological indicators of stress with costly and time-consuming hemolymph chemistry, the ***Reflex Action Mortality Predictor (RAMP)*** method uses the failure of specific behavioral reflexes as a direct indication of a lobster experiencing extreme stress. This RAMP method has been successfully applied to many other crustacean species such as the Dungeness crab, blue crab, and tanner crab. Researchers at the University of Maine's Lobster Institute have recently developed the first-ever RAMP model for the American lobster after sampling almost 1000 lobsters in the summer of 2021. This RAMP model is a reliable indicator of lobster vitality after experiencing the stress of the supply chain and can confidently predict the likelihood of mortality for any lobster evaluated. Of the suite of reflexes, injuries, and physical characteristics measured, four reflexes (walking leg motion and three other mouth part motions), five injuries (damage to a claw, carapace, uropods, antenna, and missing claw(s)), and carapace length were significant predictors of mortality. Likelihood of mortality increases with increased number of injuries, failing reflexes, and body size - with larger lobsters being most at risk (Fig. 1).

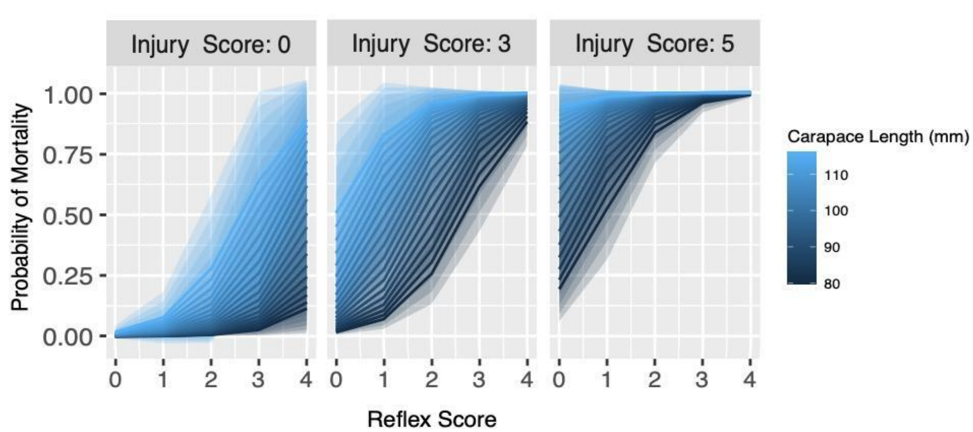


**Figure 1.** RAMP-estimated likelihood of mortality of American lobster, *H. americanus,* as a function of the absence of 0-4 behavioral reflexes (x-axis), presence of 0, 3, or 5 injuries (left, center, & right panels), and carapace length (colored lines, with shading indicating confidence intervals).

This method is not only of academic interest; it is a practical tool that will be easy for the industry to apply. Dealers already conduct less formalized assessments during the grading process, but the RAMP method provides a quantitative estimate of the probability of mortality for each lobster. Once an assessor is trained, a RAMP assessment should take no more than 20 seconds per lobster to complete. This method could be applied at any stage of the supply chain to gauge lobster health to help identify stressful points in the supply chain or at lobster dealers to better inform which lobsters should be shipped live or processed at the facility.

On the technology development side, the ***Crustacean Heart and Activity Tracker***, or ***C-HAT*** (Fig. 2) is a datalogger designed to monitor the heart rates and motion of lobsters. Relatively simple and inexpensive to construct, it has proven to be of utility in both ecological studies of lobster behavior, as well as in understanding stress points throughout the supply chain from trap to market. Higher heart rates are detected when lobsters are active or stressed, and brief pauses of the heartbeat are a characteristic startle response to novel stimuli. Additional sensors can be added for other applications, such as measurements of feeding activity, ambient light, or temperature. A major advantage of this approach is that measurements of lobster physiology can be conducted on animals that are able to move freely, rather than being constrained by trailing wires to recording devices. For example, by coupling C-HATs with acoustic tracking pingers, we have been able to measure the heart rates and feeding bouts of lobsters walking freely in the wild.

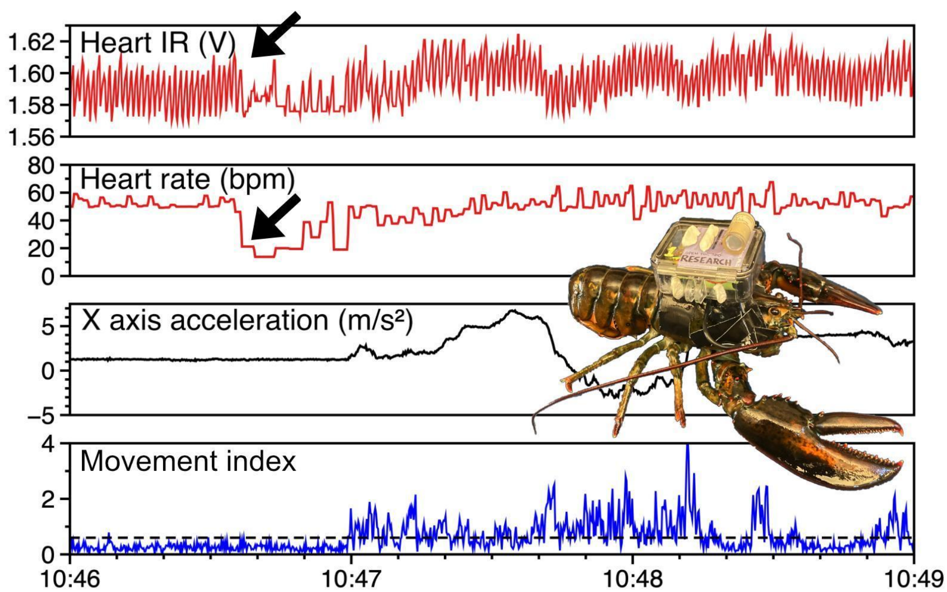


**Figure 2.** Example C-HAT output showing a lobster responding to a stimulus with a cardiac startle response (arrows), followed by movement away from the source of the startle.

Currently, the C-HAT design has sufficient battery life for about three days of continuous logging, depending on the parameters being monitored. While the whole package is large enough that it can only be deployed on adult lobsters, the design uses off-the-shelf components rather than custom circuit boards to keep costs low (the total cost is less than 100 USD for each logger) and ensure it can be built and modified by any interested researcher with a basic knowledge of circuitry and programming.

Continued improvements to the methods used to monitor lobster health in both the wild and throughout the supply chain serve to both allow new questions to be asked about behavior and physiology, as well as ensure sustainability and profitability for harvesters. We hope to continue working to demonstrate the effectiveness of both the RAMP and C-HAT protocols, and working with our industry partners to integrate the two to provide a more complete picture of the physiological consequences of various methods of harvesting and holding live lobster.

For C-HAT details, see:

Gutzler BC, Watson III WH. 2022. Measurements of American lobster heart rate and movements in the wild using a low-cost open source datalogger. Marine Biology 169:52.
DOI: 10.1007/s00227-022-04046-7
https://github.com/gutzler/C-HAT

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## Lobster shell meal as a soil amendment for disease suppression in potatoes

*From: Katherine Ashley and Jianjun Hao*

It turns out that lobsters and potatoes may go together in more than just a culinary sense! Maine's cold coastal waters encourage shellfish production, including crustaceans, such as crabs and the American lobster. Lobsters are well known to be the mainstay of Maine's coastal economy, and now, their shells could play a role supporting the state's most valuable crop – potatoes! In 2019, 51,500 acres of potatoes totaling a yield of 1,673,800,000 pounds were grown in Maine (USDA 2021). As with other agricultural products, the potato industry is challenged by the ever-present issue of soilborne diseases.

A greenhouse pilot study initiated this year at the University of Maine will extend into field trials in 2023 to evaluate lobster shells as a tool for reducing potato diseases. The thought is that lobster shells ground into a fine powder, referred to as lobster shell meal (LSM; Fig. 1), could decrease the impact of soilborne diseases and consequently increase yields of potatoes. Soilborne diseases are commonly managed with various strategies, including using tolerant or resistant varieties, chemical treatments, such as soil fumigation, and cultural practices. An example of cultural practices is the addition of organic soil amendments which can stimulate disease-suppressive beneficial microbial communities in addition to improving soil quality and nutrient availability to plants (Larkin 2015).

**Figure 1.** Lobster shells post-processing (left), and lobster shell meal (LSM) before mixing into soil (right).

Early indications from our greenhouse studies suggest LSM amendment could have a positive effect on potato growth (Fig. 2). Depending on the source, soil amendments have different functions and effects on soilborne pathogens and potato growth and nutrition. Therefore, it is critical to understand how an amendment works before using

**Figure 2.** Potato plants with differing levels lobster shell meal (LSM) amendment; in this case without disease added. The left-hand row was not amended with LSM, the middle row was amended with a lower rate, and the right-hand row was amended with a higher rate. These plants were planted approximately one month before photographing.

it. For example, an amendment such as LSM contains a high concentration of chitin, the second most common polysaccharide on earth, after cellulose; it isn't surprising therefore that many organisms have adapted to degrade chitin and utilize it as a nutrient source (Ramirez et al. 2020). Chitin-rich soil amendments can promote native communities of beneficial soil microbes, such as actinomycetes, which can degrade chitin. Once the populations of these microbes have been built through the decomposition of the shells, they are present in large numbers to suppress other chitin-containing pests, such as nematodes and fungi (Ramirez et al. 2020).

There are several ways these beneficial microorganisms can suppress plant pathogens, such as directly degrading and feeding on the pathogens' cells or other structures containing chitin as a major structural component or by producing antimicrobial substances (Ramirez et al. 2020). The increase of beneficial microbial communities through the introduction of organic matter could also be described as an improvement of soil health. Soil health is a critical factor of sustainability and longevity of agricultural lands. In order for farmers to continue practicing agriculture for generations to come, sustainable practices contributing to soil health and subsequent plant health are of utmost importance (Larkin 2015). Agricultural practices which rely on the existing ecology of microbes in the soil to assist in disease suppression, as opposed to solely chemical application methods, encourage this longevity and reduce the impact on the environment resulting from chemical application.

A second aspect of this study is the innovative utilization of lobster byproducts post-processing to remove them from the waste stream. According to the Maine Department of Marine Resources, approximately 96.6 million pounds of lobsters were harvested in 2020 in the state of Maine, a portion of which were sold fresh, and another portion were processed to be distributed both nationally and internationally. Of the lobsters processed and sold by the state of Maine, a local processor estimated that shell byproducts could constitute approximately 25% of the weight. While a portion of lobster shell waste is composted, the majority is sent to landfills (Skonberg and Bolton 2012). This can become an economic challenge for processors, as disposing of lobster shell waste can be costly. For example, it can cost a facility processing 15,000 pounds of lobster per day, upwards of $4000 per month in disposal fees (Skonberg and Bolton 2012).

Overall, this study will address two problems by both advancing sustainable agriculture and longevity through soil health and by reducing the post-processed waste stream of lobster shells. Maine is uniquely positioned as a state with a wealth of agricultural production amidst the highly valuable lobster industry. The use of lobster processing waste as a soil amendment could help build collaboration between these two vital industries in the state of Maine. While lobster shells are already used on a few farms as a fertilizer, the potential benefit of disease suppression and impacts to the native soil microbial community will be further investigated in this study. Who would have thought that lobsters and potatoes could pair so nicely before they even hit the plate?

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## A “mob attack” by Caribbean spiny lobsters on a moray eel in the laboratory

*From: Patricia Briones-Fourzán, Fernando Negrete-Soto, Cecilia Barradas-Ortiz, and Enrique Lozano-Álvarez*

Caribbean spiny lobsters (*Panulirus argus*) are gregarious and tend to share shelters. This social behavior is mediated by conspecific chemical communication and is related to the communal defensive behavior exhibited by these lobsters, whereby cohabiting individuals use their long, stout spiny antennae to fend off approaching predators. Yet, Lozano-Álvarez (1996) observed that groups of *P. argus* kept in sea cages for over six weeks increasingly displayed more diurnal activity and became more aggressive, to the point that recently molted conspecifics were cannibalized. He ascribed this behavior to a lack of appropriate shelter for lobsters combined with the absence of predation risk.

We routinely collect *P. argus* lobsters from the Puerto Morelos coral reef system (Mexico) and hold them in tanks with an open seawater flow to use them in different types of experiments. In one of these tanks, 3 m in diameter with a water level of 50 cm, a group of 10 lobsters (size range: 75–95 mm CL), too large to use in certain experiments, was held for about 4 months. The lobsters had been provided with a large ‘casita,’ a flat-roofed artificial shelter 1 $m^2$ in surface area and 15 cm in height, and were regularly fed with frozen (thawed) mussels and crabs. No lobsters were cannibalized during this period, even though some molted and grew, a particularly vulnerable time in the life of a lobster.

Casitas have been the subject of several investigations by our research group. In a long-term controlled field experiment, we showed that casitas increased lobster biomass by providing them with communal shelters and promoting survival (Briones-Fourzán et al. 2007). A concern was that casitas might increase mortality of small lobsters by attracting potential predators. Moray eels are generalist predators and are certainly capable of consuming lobsters (Weiss et al. 2006), yet both purplemouth (*Gymnothorax vicinus*) and spotted morays (*G. moringa*) are commonly observed sharing shelters, including casitas, with *P. argus* in Caribbean reef lagoons and back-reef areas, with no evidence of either predation or intimidation of lobsters by morays (Lozano-Álvarez et al. 2010).

Following the Caribbean invasion of the Indo-Pacific red lionfish (*Pterois volitans*), another concern was that casitas might provide habitat for this invasive species in shelter-poor reef lagoons and shallow bays. However, the presence of lionfish in casitas on our experimental field sites has been rather low, whereas the co-occurrence of morays and spiny lobsters continues to be high (our unpublished data). This led us to hypothesize that casita-dwelling morays might be chasing away, or preying on, the lionfish. Predation on lionfish by morays has been reported in their native (Bos et al. 2017) and non-native ranges (Muñoz 2017). To conduct preliminary observations on the behavior of cohabiting individuals of the three taxa, we first introduced two relatively small lionfish, about 20 cm in total length, into the same tank holding the group of lobsters. The lionfish readily took shelter beneath the casita (the only shelter available in the tank), but after several days they were usually observed drifting in the water column or in a vertical position on the walls of the tank, far from the lobsters, which would occasionally attempt to climb the wall to reach them.

Two weeks after introducing the lionfish, we further introduced one purplemouth moray, which appeared sufficiently large (78 cm in total length) to be able to consume the lionfish. The moray was introduced at 13:00 h and swam around the tank for a few minutes before hiding beneath the casita, where the lobsters were sheltered. However, at about 18:00 h, when the lobsters were about to be fed, the entire group of lobsters was observed aggressively attacking the moray, which was moribund. The largest lobster was biting the moray's head while another lobster was biting its tail, and both lobsters were holding it down with its pereopods. Two other lobsters were also biting and holding down the moray's elongated body, constraining its movements. The attacking lobsters were simultaneously performing these activities and walking (backward, forward, or sideways), while the rest of the lobsters followed in what appeared to be a frenzy. Although we extracted the moray from the tank, it did not survive the attack.

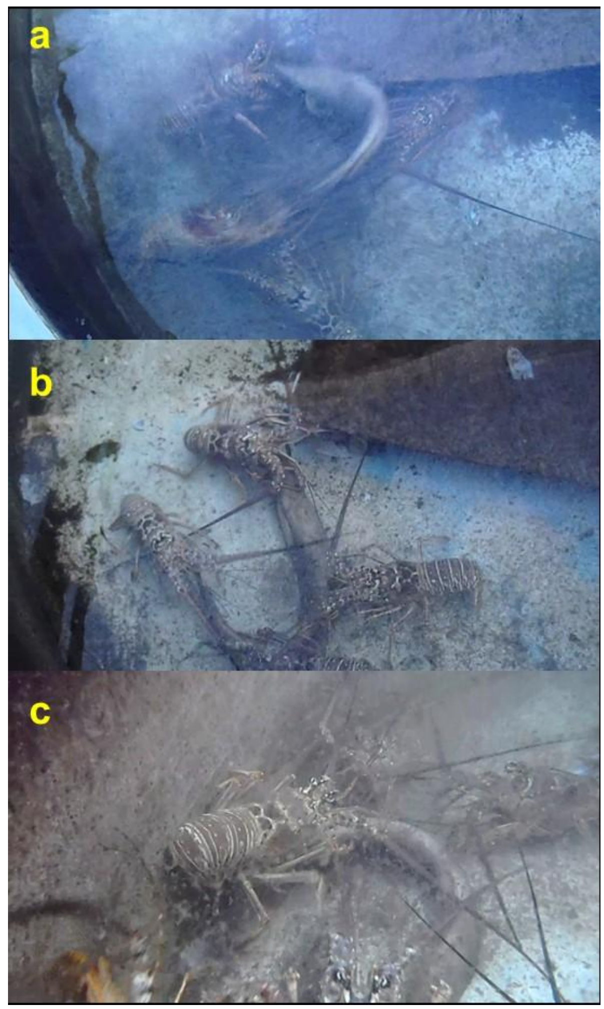


**Figure 1.** a) Lobsters biting the head and tail of the moray, b) two other lobsters pinning it down along the body, c) all lobsters following in a frenzy.

What brought about this uncommon behavior? Perhaps the moray gave some signs of weakness or stress and the lobsters capitalized on the opportunity to feed on it.

Fish is generally not considered a good feed for lobsters (Lellis 1992) and these lobsters were not starved, but spiny lobsters are opportunistic feeders. However, spiny lobsters are not known as pack predators and to the best of our knowledge this type of behavior has never been recorded in natural conditions. Another possibility could be the priority effect (Almany 2003), whereby the established residents (the lobsters) were defending the communal shelter they had occupied for the previous 4 months from a total stranger. This behavior could also explain why the lionfish would rather remain in the open than take shelter in the casita. In the case of the moray, the level of aggression possibly became so intense that it turned into a predation event.

Interspecific interactions may be conditional, potentially shifting from negative, to neutral, to positive, and vice versa, depending on the environmental context (Hay et al. 2004). Moray eels have been variously reported as predators, mutualists (Berry 1971), and competitors (for shelter) of lobsters (Lozano-Álvarez et al. 2010). However, to our knowledge, this is the first report of captive spiny lobsters communally attacking and preying on a live moray eel. The conditions were certainly far from natural, but it shows how the interactions of spiny lobsters with moray eels can change from prey to mutualists, to competitors, or to predators, depending on the ecological context.

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## Possible explanations why there are (almost) no reports on non-indigenous lobsters

*From: Ehud Spanier*

Crustaceans, especially the Decapoda, are among the most successful taxa to demonstrate migration between biogeographic provinces (Galil *et al.,* 2011). Yet, why are there only very few reports of alien lobsters, despite the large natural geographic and ecological dispersal potential and the economic importance of many species?

In the recent centuries, and especially during the present era of globalization (extreme increases in global marine trade), man-made activities in the sea have enhanced the introduction of Non - Indigenous Species (NIS) into new areas outside their historic range. Shipping, via ballast water, is considered the most important marine invasion pathway, however other anthropogenic factors, such as canals, transport of marine species in aquaculture, research projects and aquarium trade, fishing activities and global warming also have important roles in invasion processes (e.g., Minchin *et al.,* 2009). As far as we know, there is no report of an invaded slipper lobster. The Mediterranean is strongly impacted by migration of organisms through the Suez Canal ("Lessepsian migration" of Indo-Pacific species) but is also affected by other human associated activities such as shipping (Katsanevakis *et al.,* 2014), given that two-thirds of global marine traffic occurs in the region (Ulman *et al.,* 2017). Non-indigenous crustaceans are the second-most abundant group in the Mediterranean, with 91 species belonging to the order Decapoda (Galil *et al.,* 2015). Nevertheless there are only 2 reports of Lessepsian NIS palinurids in the Mediterranean, both in the vicinity of the Port Haifa, Israel. These are a single *Panulirus ornatus* (Galil *et al.,* 1989) (Figure 1) and one exuvia of the colorful *P. longipes longipes* (Spanier and Friedmann, 2019) (Figure 2). A finding of a single painted spiny lobster *P. versicolor* in Georgia, USA (Page, 2013), is another rare example of a non-indigenous spiny lobster. A request for information on NIS lobsters published in the *Lobster Newsletter* [32(1)] in 2019 has revealed no results.

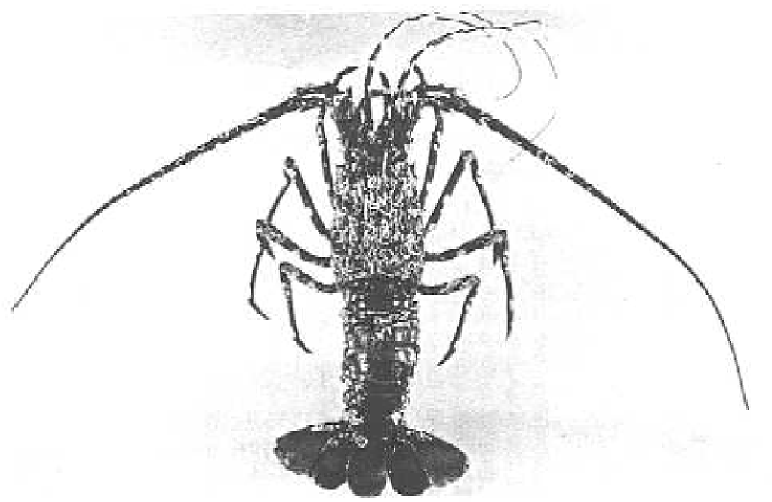


**Figure 1.** An ornate Indo-pacific spiny lobsters, *Panulirus ornatus*, collected in 1988 in the Port of Haifa, Israel

**Figure 2.** An exuvia of an Indo-pacific long-legged spiny lobster, *Panulirus longipes longipes*, collected in 2018 in the vicinity of the Port of Haifa, Israel.

However there is one exception for the scarcity of records of NIS of lobsters, and this is the American clawed lobster, *Homarus americanus*. This species, which is native to the northwest Atlantic coast, can be found now in northern Europe. Recently there have been two confirmed records of *H. americanus*, in the Mediterranean region: one individual from Croatian waters of the Adriatic (Pavičić *et al.*, 2020), and another from the Greek water of the Aegean Sea (Kampouris *et al.*, 2021). The origin of these specimens is unknown, but their presence is likely due to live seafood importation to markets in these countries.

Adult marine organisms may pass actively through man-made canals, by swimming or walking, and eggs, larvae, and juveniles may drift passively in currents in these artificial waterways. Yet unfavorable environmental conditions may limit the success of biotic migration through these pathways. Propagules, juveniles and adults may be carried in ballast water of ships over natural barriers of salinity, temperature and other abiotic and biotic obstacles. Modern ships are larger and faster and hence carry larger volumes of ballast water (and organisms), making travel time shorter, and increasing the probability of the NIS to survive in the unfavorable conditions (e.g., dark, stagnant water, low oxygen content) of the ballast tanks during the trip. In addition to shipping traffic, other vectors of introduction are vessels of the energy, fishing and mariculture industries, as well as floating debris to which potential NIS adhere. Such equipment and debris may be transferred or drift to other geographic regions with the potential live NIS attached to them. Deliberate and accidental transfer of NIS can be done also by scientists and the aquarium trade. Live import of marine organisms as food for humans may be another vector of introduction if some of these live animals are released or escape to the sea in the countries of destination, either legally and illegally. Some of the NIS have managed to overcome competition, predations and pathogens in the new habitats and were able to establish permanent successful reproductive populations. However, successful NIS are typically characterized by ecological and physiological plasticity, and often by an r-selected breeding strategy (early maturity, short generation time, high fecundity, rapid growth rates) (reviewed in Geburzi and McCarthy, 2018).

An example of such a successful decapod invader is the blue crab, *Callinectes sapidus*, a native to the Atlantic coasts of the Americas and globally one of the most highly invasive marine species (e.g., Kampouris *et al.,* 2019). The species is ecologically flexible, inhabiting a very wide variety of habitats and depth ranges and is tolerant to diverse environmental conditions (e.g., Mizerek *et al.,* 2011). It is considered an 'r-selected' species, displaying early age-at-maturation, fast growth and short lifespan. All lobster species, on the other hand, have a complex life cycle with sensitive planktonic larvae, stages that can span in duration 4-8 weeks in clawed lobsters, 26-44 weeks in spiny lobsters (Wahle and Fogarty 2006) and 2-9 months in slipper lobsters (Sekiguchi *et al.,* 2007), compared to the blue crab *C. sapidus* where the total duration to the megalopa stage is 27 days (Zmora *et al.,* 2005). Thus it is unlikely that the sensitive early life stages of lobsters are transferred in ballast water. Also, most juvenile and adult lobsters are considered specialists with regard to their preferred habitats and/or food, which reduce their likelihood to be established in a new region, even if they have succeeded in getting there. The unusual reports of colorful specimens of NIS lobsters, such as *P. versicolor* and *P. longipes longipes* may be associated with the aquarium hobbyists/trade. Yet since they were each reported from a close proximity to a commercial port (as well as the single record of *P. ornatus* in the Mediterranean), the possibility of ballast water serving as the introductory mechanism should also be considered.

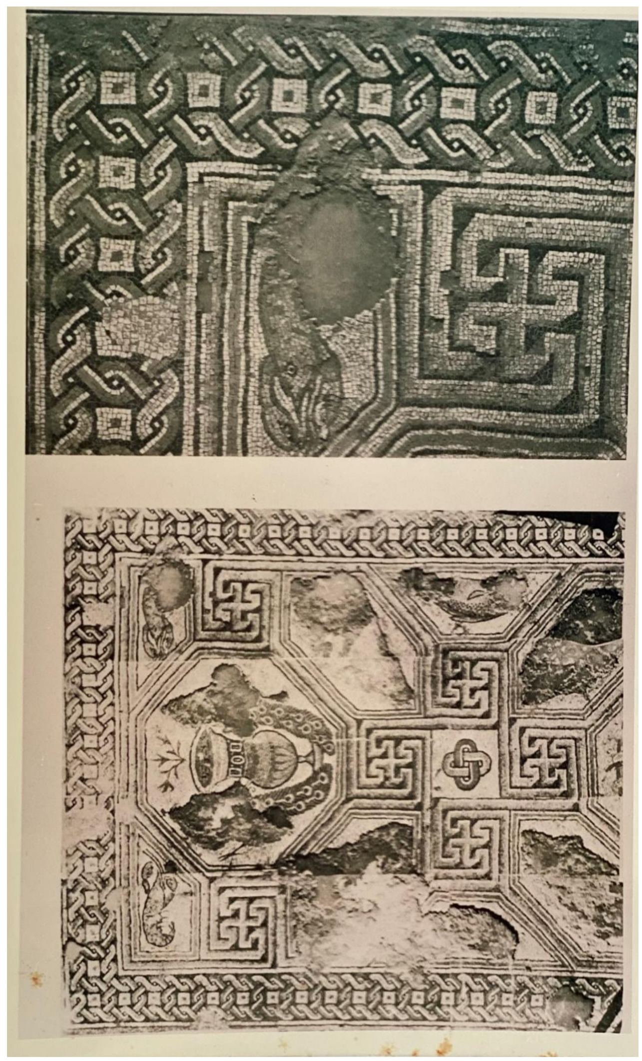
*Homarus americanus* is a species with high commercial value and it is imported worldwide, usually live. In the U.S.A. alone, the landings for 2019 were reported to be more than half a billion Euros (NOAA 2020). About 13 thousand metric tons of live adult American lobsters, are yearly imported, mainly by flight transport, for human consumption, from North America to the European countries. Despite prohibitions to release or hold *H. americanus* in net cages, there have been recorded findings of live *H. americanus* in Sweden, as well as in a number of other European countries including Denmark, Ireland, Norway and Great Britain (e.g., van der Meeren *et al.,* 2010, Stebbing *et al.,* 2012, Øresland *et al.,* 2017). It has established populations in the waters of northern Europe, and can hybridize with the indigenous European lobster, *H. gammarus*, leading to fertile or sterile offspring (Jørstad *et al.,* 2007). The hybrids might be fast growing and viable and thus potentially increase the competition for food, habitat and mates. The relative success of the American lobster in northern Europe may be due to similarity of the North European habitats and environmental conditions to the American ones, and its rather short life cycle (Wahle and Fogarty, 2006). Furthermore, *H. americanus* can prey on the European species (van der Meeren *et al.,* 2010, Øresland *et al.,* 2017), are more aggressive, more tolerant of varying physical conditions, and more flexible in habitat use (Stebbing *et al.,* 2012; Jørstad *et al.,* 2007). Several individuals of the American lobster escaped in Japan (Doi *et al.,* 2011). Deliberate introduction of *H. gammarus* in New Zealand early in the 20$^{th}$ century was unsuccessful (Dodgshun *et al.,* 2007).

The water of the Levant is probably too warm for Mediterranean clawed lobsters such as *H. gammarus,* and the Norway lobster, *Nephropes norvegicus,* that inhabit the water of Central and Western Mediterranean (Holthuis, 1991). However, it is interesting to note that a mosaic from a Byzantine church from circa 6$^{th}$ century CE from Bet Guvrin, southern Israel, includes two figures of clawed lobsters that seem to be *H. gammarus* (Fig. 3). This is peculiar because Israel is outside the present geographic range of this or any other clawed lobster species (Holthuis, 1991). It was suggested that either the artist who created the mosaic was from the western part of the Byzantine Empire where *H. gammarus* was (and still is) common, or that the artist used a models book that originated from the western region, a practice that was common in ancient Mediterranean cultures

(Almog-Shtayer *et al.,* 1989). Another hypothesis, postulated by these authors, is that during the Little Ice Age (e.g., Bar-Oz *et al.,* 2019) *H. gammarus* may have extended into the, then, colder southeastern Mediterranean.

Thus, despite the present, relative scarcity of NIS among lobsters, continuous climate change, this time warming of temperate and colder seas, may enhance range extensions of warm water lobsters. Such hypothetical species invasion may change the food web, posing serious threats to local biodiversity and affecting ecosystem services, regional fisheries, economy and societies.

**Figure 3.** Clawed lobsters in mosaic from a Byzantine church from circa 6th century CE from Bet Guvrin, southern Israel.



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## A new US-Canada Climate and Fisheries Futures Collaborative

*From: Richard Wahle and Rémy Rochette*

A new informal partnership called the US-Canada Climate and Fisheries Futures Collaborative (CFFC) has emerged in the northeast United States and Atlantic Canada out of a growing awareness of the need to enhance collaboration to understand and adapt to a rapidly changing climate in our shared geographic setting. The Northwest Atlantic is one of the most rapidly changing marine ecosystems on the planet. These changes pose both threats and opportunities to our traditional fisheries and the communities that depend on them. We see value in building a cross-border collaborative involving key stakeholders to evaluate climate change impacts on our shared fisheries resources. Our focus is on the American lobster (*Homarus americanus*) fishery, which is the most valuable single fishery in both countries, and a well-studied model system.


In the last months of 2021, parallel collaborative initiatives got under way on both sides of the border. The Lobster Institute secured a University of Maine seed grant to hold two cross-border workshops jointly facilitated by Maine Sea Grant and the Lobster Institute to develop and strengthen partnerships with other institutions and individuals in the region, and to promote collaborations that would elevate future external proposals to a highly competitive level. At the same time in Canada the University of New Brunswick initiated an effort to seek new support to re-energize the very successful Lobster Node of the Canadian Fisheries Research Network it led from 2010 to 2015.

The shared aim is to better understand and adapt to rapid climate change and its effect on the socio-ecological system of New England and Atlantic Canada's coastal communities, the economies of which are highly dependent on their iconic lobster fisheries. Both groups embrace a trans-disciplinary "convergence research" approach that not only crosses academic disciplines but also brings together industry and government stakeholders from project inception. This philosophy and approach was already at the heart of the Lobster Node more than a decade ago.

The short term charge of the CFFC over the last half-year has been to develop proposals to funding agencies on both sides of the border. On the US side, an immediate outcome of the two cross-border workshops was a UMaine-led proposal to the National Science Foundation's Navigating the New Arctic Program submitted in February 2022. Originally planned as in-person workshops, the continuing pandemic forced us into a remote Zoom format, but the silver lining was greater inclusiveness and low cost. Including partners from seven academic institutions, six industry organizations and five government agencies in the US and Canada, this still-pending proposal is grounded in growing evidence that rapid warming in the Arctic has important implications for the Northwest Atlantic ecosystems and its fisheries. On the Canadian side, investigators have submitted two Letters of Interest to Canadian federal funding opportunities, the New Frontiers Research Fund and the NSERC Discovery Horizons program. These proposals, which built on the strong relationships established during the Lobster Node, included partners from 10 academic institutions in Canada and the US, 11 industry organizations, five First Nations groups, and government scientists from all four regions of the Department of Fisheries and Oceans.

The longer-term aim of the CFFC is to build a long-standing US-Canadian partnership that can leverage funding to support cross-border teams and synergies to better understand and evaluate scenarios for the sustainable use of our shared marine resources.

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# ANNOUNCEMENTS

# Postponement (Again!) of ICWL 2020

**12th International Conference and Workshop on Lobster Biology and Management (ICWL)**

**Fremantle, Western Australia**


The Organising Committee of the 12th ICWL have reviewed the likelihood of the ICWL going ahead in October 2022. We have consulted our International Advisory Committee and undertaken a brief survey of the Lobster Newsletter members to get advice from likely attendees on the travel situation in their country and anticipated ability to attend the conference this year.

While the status of the spread on Omicron variant of Covid is improving in some countries and the regulations are easing, we don't believe it is possible to successfully host the lobster (and crab) workshop this year given the current timeframe. There was also some feedback that the conflict in Europe would affect the likelihood of people being able to attend. Therefore, the **Organising Committee has again reluctantly decided to postpone workshop to 22-27 October 2023**. We are quietly confident that this timeframe will enable the conference to go ahead and give attendees sufficient time to get travel funds to attend the conference in person. **Please check the website https://icwl2020.com.au/ for future updates on registration of interest and timing for abstracts.**

We have considered hosting a web-based conference. While these can be successful when participants are from a similar time zone, we believe this poses great difficulties for the participants from the diverse range of time zones we hope to attract . Also, one of the main benefits of the workshop is the face-to-face meetings and the contacts that you make and discussions you have outside of the formal sessions.

The Department of Primary Industry and Regional Development, the Western Rock Lobster Council and the Australian Fisheries Research and Development Corporation are still strongly committed to hosting scientists, managers and industry participants in **Fremantle, Western Australia in October 2023**. Don't hesitate to contact us or the conference organisers, Arinex, if you have any questions. Please stay safe and start making plans for attending the ICWL as we are looking forward to seeing you in 2023.

Your co-hosts of the Workshop,

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The Lobster Newsletter is published electronically once or twice yearly.

Contact Nick Caputi (southern hemisphere) or Rick Wahle (northern hemisphere) about article submissions and inquiries or corrections to the Lobster Newsletter mailing list.

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