VOLUME TWENTY NINE APRIL 2016 NUMBER ONE

The Lobster NEWSLETTER

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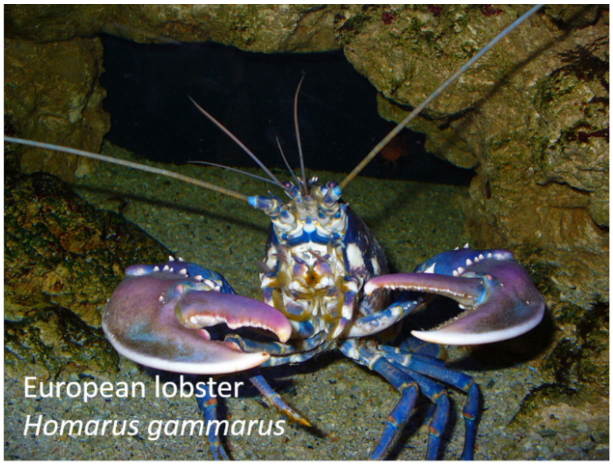

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Lobsters in the Headlines:

Sweden to the EU: Ban imports of live American lobster

From Co-editor, Richard Wahle, Ph.D.

Just as this issue of *The Lobster Newsletter* was being finalized, on March 18th the Associated Press broke with the story "**Sweden asks EU to stop American lobster invasion.**" As one who has followed this story from its beginning over a decade ago, I am aware of the growing concern among many in the EU about the increasing frequency of *Homarus americanus* found in the waters of southern Scandinavia and Ireland. Virtually all the lobsters found to date are likely escapees or accidental releases from European holding facilities in the chain of custody from the US & Canadian fisheries to dining rooms throughout Europe. Risk assessments conducted by Norway, Sweden and the UK identify the American lobster as a potentially invasive species and vector of disease, and a biological threat to the closely related native European lobster, *H. gammarus*. To say the least, the prospect of a ban on EU imports of live American lobster alarms both North American suppliers and European importers because of the massive economic importance of the US $196 million trade. It supplies a huge European appetite for the American lobster that cannot be fulfilled by its European counterpart. This issue of *The Lobster Newsletter* starts off with the Swedish position, followed by an American response, and then a series of short articles on some of the science behind the problem. May good science and level heads prevail as this controversy comes to resolution over the coming weeks and months.

The Swedish Position

The following summary is excerpted from ***Risk Assessment of the American lobster (*****Homarus americanus*****)*** *adopted in December 2015 by the Swedish Agency for Marine and Water Management. It gives the conclusions of an expert panel on the potential risks and impacts of the entry, establishment and spread of American lobster in European waters.*

Entry (Risk: Very Likely; Confidence: Very high): About 13 thousand metric tons of live American lobsters (*Homarus americanus*) are yearly imported mainly by flight transport for human consumptions from Canada and the USA to the European countries. The imports are registered at EU-boarder [*sic*] via products border inspections post (BIP).

Despite national prohibitions to release or hold *H. americanus* in net cages, information campaigns, money reward for live caught animals and governmental controls, 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. The introduction pathways into the sea are escapes from net cages, accidental release and disposal.

Establishment (Risk: Likely; Confidence: Medium): In 2014 a high number (n=26) of *H. americanus* were reported inside the Gullmar Fjord, Sweden. Four of the females that were caught, were ovigerous. One of these females carried hybrid eggs, which has also been reported from Norway in 2010. These findings in the Gullmar fjord might be an indication of *H. americanus* as a permanent resident with possibilities of both hybridisation with the local *H. gammarus*, and establishing a subpopulation in the area. Once the species is established it will be impossible to eradicate.

Spread (Risk: High; Confidence: Medium): Given the human involvement with the movement of *H. americanus* between land-based holding facilities, markets and restaurants based all over the risk assessment area, in addition to their own dispersal, it would seem likely that they would disperse rapidly along the European Atlantic coast. Although, *H. americanus* is more migratory than *H. gammarus*, natural spread is likely to be slow. The natural dispersal capability will however exceed any management attempt to control its spread.

Impacts (ecological, economic, and social) (Risk: Major/Massive; Confidence: Medium)

- *H. americanus* can hybridize with the *H. gammarus*, leading to fertile or sterile offspring. This can also contribute to a reduced recruitment of the *H. gammarus*. In some experiments with hybrids they have fertile or, in others sterile. The hybrids may be able to compete with the *H. gammarus* and hybridization may also eventually result in a gradient of phenotypes between the two species, i.e. cuticle thickness that could have a negative effect on resistance to infections.
- The introduction of *H. americanus* into the area of risk assessment may transfer several contagious diseases that *H. gammarus* is susceptible to, for example, Gaffkemia, a lethal bacterial blood disease.
- *H. americanus* may out-compete native lobster for shelter and food resulting in a reduction in numbers of *H. gammarus* as the lack of resources impacts on recruitment. Disease could enhance the potential of the *H. americanus* to establish due to a certain resistance to the disease. The result would be catastrophic for the native populations.
- *H. americanus* can affect other commercially important species that share a similar habitat, for example the edible crab (*Cancer pagarus* [sic]) and Norway lobster (*Nephrops norvegicus*), but also species in greater depths, as squat lobsters and deep water crabs (50-300m depth).

- *H. americanus* is a potential vector for introduction of other invasive alien species, such as barnacles, polychaetes, nematodes, foraminifera's, copepods etc.
- An establishment of *H. americanus* will, considering the above, give negative effects on recreational fishing, the fishing industry and the export market, especially in coastal communities and may also affect the tourism industry in the northern part of the risk assessment area negatively. The discussion is found in annex 2.
- Once established, *H. americanus* will affect national programmes for increasing populations of *H. gammarus*. If *H. americanus* invade established or future reserves for *H. gammarus* such reserves will be contra productive.

Conclusion of risks: high (confidence: medium): A ban on live import of *H. americanus* to Europe is considered to be required and will protect the risk assessment area from being invaded by this species, as alternative measures are estimated as being not enough risk reducing enough, or economically and technically feasible. The discussion on alternative measures is found in sections 3.04 and 4.05 of this risk assessment. Norway has banned import of live *H. americanus* from the 1st of January 2016.

Additional questions:
Climate: *H. americanus* are plastic, considering a higher variety in habitats, broader range of temperature and salinity compared to *H. gammarus*. *H. americanus* are hence presumed to have potential advantage over *H. gammarus* as an effect of climate change.

Potential impacts of *H. americanus* on ecosystem services (supporting, provisioning, regulating, and cultural) in the risk assessment area are presented in Annex 1.

Potential socio-economic impacts including if live *H. americanus* is introduced and established in the risk assessment area, management costs so far and costs if *H. americanus* is introduced and established and also impacts from a ban on live imports of *H. americanus* are presented in Annex 2.

The full risk assessment is available at:
https://www.havochvatten.se/download/18.1f4499311538d55bb494594b/1458738591968/risk-assesment-american-lobster.pdf

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North America Responds

Letter conveyed by the National Fisheries Institute and the Maine Lobster Dealers' Association to the US Consulate in Belgium. Much of the imports of live American lobster are routed through Brussels, Belgium.

NATIONAL FISHERIES INSTITUTE ®

MLDA
MAINE LOBSTER DEALERS' ASSOCIATION

March 23, 2016

The Honorable Denise Campbell Bauer
Ambassador
Embassy of the United States in the Kingdom of Belgium
Regentlaan 27 Boulevard du Régent
B-1000 Brussels
Belgium

Dear Ambassador Bauer:

On behalf of the American seafood community, we would like to address a shared concern with regard to the petition from the Government of Sweden to add live *Homarus americanus*, to the European Union (EU) Invasive Species List under EU Regulation No 1143/2014. If the petition is implemented, this will be a *de facto* ban and stop this U.S. seafood trade between the United States and Belgium.

The United States and Canada annually ship about $196 million of live lobsters to the EU. This trade is a success story in President Obama's call for American companies to focus on export markets. As you grew up in Massachusetts, lobster is fully integrated to local culture as a diet but more as a symbol of hardworking maritime Americans. We need your help to ensure that this success is not lost.

We are unconvinced that the Government of Sweden has demonstrated legitimate reasons in its December 2015 Risk Assessment to show the invasiveness of North American lobster. For instance, over an 8-year period, 32 North American lobsters have been found in European waters. This is not an "invasion." Additionally, according to Dr. Bob Steneck, a marine ecologist and a University of Maine professor, "Active attempts to relocate [North America] lobsters [to European waters] all failed; reproductions require molting, which is triggered by temperature that in Europe where its range is much lower than that in Maine."

It is important that the European Union uses sound science before making a decision that would significantly affect iconic U.S. seafood trade to the EU. Instead of an EU-wide trade ban, the European Commission should consider less restrictive means to achieve its goals, such as enforcing local laws on introducing non-native species into its waters.

The Honorable José Manuel Barroso, the President of the European Commission, stressed in his visit to the United States in 2014, “Since together Europe and the United States are the backbone of the world economy with nearly half of world GDP, 40 percent of the purchase power and a third of world trade, it is simple good common sense if we start by making trade freer between ourselves.” Reductions in tariffs while constructing non-tariff barriers runs counter to Mr. Barroso’s comments.

We urge you to address our concerns with the Government of Belgium and ensure they clearly understand the impact of this trade barrier on Brussels. Further, we ask that you encourage them to express their national government concerns through the European Union deliberation and process.

We can be reached at jconnelly@nfi.org or +1-703-752-8881.

Sincerely,

John Connelly, President National Fisheries Institute

Annie Tselikis, Executive Director Maine Lobster Dealers’ Association

RESEARCH NEWS

Implications of export of live American lobster (*Homarus americanus*) to Norway; crossbreeding and ecological implications

From: Ann-Lisbeth Agnalt, Ellen S. Grefsrud, Eva Farestveit, and Knut E. Jørstad

The USA and Canada export live American lobster (*Homarus americanus*) to several continents, including the European market. As American lobster do not naturally occur in Europe, introductions of live specimens impose a high risk of interactions with the native European lobster (*H. gammarus*). In 2000, the first American lobsters collected from Norwegian waters were identified using DNA testing. Since then, 145 specimens captured in the wild have been DNA-tested, of which 62 proved to be American: Norway n = 31; Sweden n = 27; Denmark n =1; and, Ireland n = 3 (Figure 1). Six of the females captured in Norway were ovigerous. If the eggs hatched in the wild, this could lead to competition with the European lobster. Although the chances for crossbreeding are considered small, analysis of eggs has routinely been carried out. In 2009, the first evidence of a successful cross-mating was found in Norway and is the first documented case of hybridization between the two species under natural conditions. The hybrids were successfully hatched in 2010 at Institute of Marine Research. Larvae and juvenile development was monitored and characterized. Hybrid juveniles showed a high degree of asymmetry e.g., the abdomen twisted to one side was a common finding. Hybrids also showed a high variation in growth. Records in 2014 showed that females ranged from 31 to 59 mm CL, and males from 35 to 73 mm CL. The largest hybrid males are now sexually mature and fertility tests will be conducted on the males.

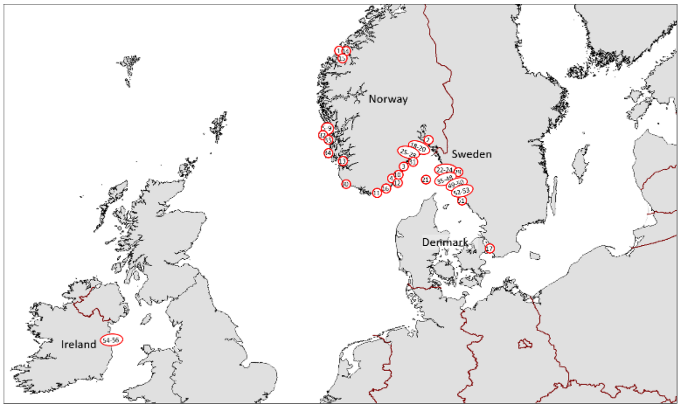

Figure 1. Location of 62 American lobsters caught in European waters as confirmed to date by DNA analysis.

Acknowledgements

Declan Quigley for the lobsters from Ireland, and Vidar Øresland (Swedish Agency for Water Management) for the Swedish samples.

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Are European lobsters under threat from invasive Americans?

From: Charlotte Eve Davies

The term 'non-native species' is synonymous with alien, non-indigenous, foreign and exotic; something that has been introduced into a country or area either deliberately or accidentally. On the 19th August 2015, the Great Britain non-native species secretariat released the updated Great Britain Invasive Non-native Species Strategy, which displayed nearly 2000 established non-native species in Britain.

Most non-native species do not cause problems, indeed, the majority of agricultural species (wheat, barley, sheep etc.) are not native to the UK. However, if a species does become invasive, they can have relatively large negative impacts. These impacts can have serious effects on agriculture, forestry or biodiversity interests. An invasive species can displace native species, limit land use and introduce disease.

So why am I talking about invasive species in a lobster newsletter?! In our oceans, invasive species are becoming more of a concern as unlike terrestrial environments, there are no barriers to prevent marine invasive species.

Last year, some media outlets picked up on American/Canadian lobsters (*Homarus americanus*) being landed in the UK. This is not strictly a new phenomenon; they have been imported live into Europe for several decades, which can result in their escape into the wild. However, last summer the Marine Management Organization released a warning to UK fishermen.

As we all know, Epizootic Shell Disease (ESD) has devastated lobster fisheries on the Eastern coast of America and disease transfer to our native European lobsters (*H. gammarus*) is an increasing fear.

In a collaboration between Swansea University, UK and the New England Aquarium, USA, we investigated this possibility. In order to do this, we simulated injuries (e.g. punctures and abrasion), a known precursor of shell disease, onto both species, and monitored the damaged (and undamaged) areas for up to 12 weeks. We had American and European lobsters side by side in the Boston aquarium, plus a control group of European lobsters in the UK, to see if shell disease would develop without the 'help' of the Americans.

Now there is a lot of talk about the definitive 'cause' of ESD. A leading contender is the gram-positive bacterium *Aquimarina* sp. '*homaria*'. Thought to be the pioneer in lesion initiation (Chistoserdov et al. 2012), alongside other bacteria, temperature exacerbation and water quality.

What we found was very interesting; *A. homaria* was detected at a much higher prevalence among American than European lobsters, but its presence correlated more with exacerbation of existing lesions rather than with lesion initiation. It was also only found at the start of lesion formation in American lobsters.

There were **three** bacterial genera associated with shell lesions:

- *Arenicella* – There are no published reports of *Arenicella* sp. being identified from lobster samples.
- *Eionea* (in European lobsters only) - There are no reports of these bacteria being associated with lobsters but *Eionea* species occurring on crustaceans was reported recently by Hazra et al. (2013) from healthy carapaces of green, spider and Atlantic horseshoe crabs.
- *Maribacter* - Previously associated with lobster shell lesions: Quinn et al. (2012) identified the bacterium *Maribacter polysiphoniae* in spontaneously occurring lesions from captive American lobsters, and Chistoserdov et al. (2012) also reported unique *Maribacter* species in enzootic shell disease lesions.

There were also two putative **beneficial** bacterial species (detected exclusively in healthy cuticle or healing damaged cuticle); an unclassified Flavobacteriaceae and unclassified a-proteobacterium. These were found on healthy cuticle and later disappeared upon lesion formation. Aquarium biofilms were also examined but revealed no candidate pathogens for environmental transmission.

Heterospecific transmission (between the two species) of potentially pathogenic bacteria appeared to be very limited; however, the claws of European lobsters were more likely to develop lesions when reared in the presence of American lobsters.

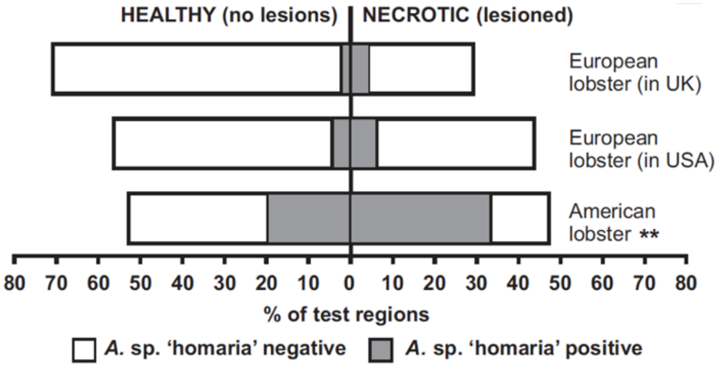


Figure 1. Prevalence of *Aquimarina* sp. '*homaria'* in swabs taken from both lesioned and healthy lobster cuticle samples. *A. homaria* was detected by PCR and a sample was classified as positive if the bacterium was detected at any point during the study. Experimentally damaged and control regions are combined. A much greater proportion of lesions were associated with *A. homaria* among the American lobsters than in either cohort of European lobster (**$P < 0.01$). The bacterium was also more prevalent in healthy cuticle samples taken from American lobsters versus European lobsters. Taken from Whitten et al. (2014).

So now we must ask – why?! Why can't our European lobsters seemingly contract ESD? The answer lies in Scanning Electron Microscopy (SEM). We used SEM as a method to identify differences in the cuticle structure and consequences of the shell disease damage.

The carapace and claws of the American lobsters were shown to be thinner and more vulnerable to abrasion damage than their European counterparts. In addition, the number and distribution of setal pits and pore canal openings also differed between the two species of lobster – there were a lot more in the Americans. We also noted that American lobsters, unlike their European counterparts, had extensive bacterial colonisation on the margins of shell disease lesions

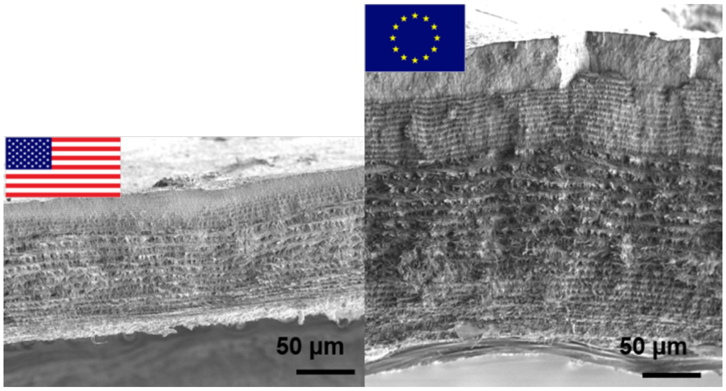
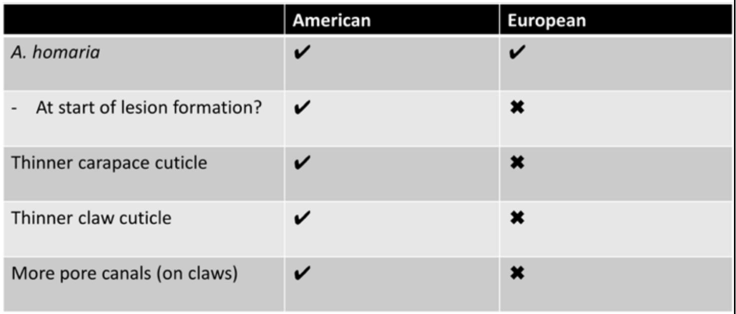


Figure 2. Low power scanning electron micrographs of cross sectional views of the control carapace from (A) an American lobster, *Homarus americanus* and European lobster, *Homarus gammarus*. Adapted from Davies et al. (2014).

Overall, it is concluded that the cuticle of the American lobster is more susceptible to damage and resulting microbial colonization than that of the European lobster. This sounds like it is good news for our European lobsters, but with more and more American lobsters being found in EU waters – even one with ESD; it is definitely something for us to keep an eye on.

To read more about our studies on the importation of live American lobsters into the U.K., see Whitten et al. (2014) and Davies et al. (2014).

Table 1. Summary table showing differences between the American lobster, *Homarus americanus* and European lobster, *Homarus gammarus*.



	American	European
A. homaria	✔	✔
- At start of lesion formation?	✔	✖
Thinner carapace cuticle	✔	✖
Thinner claw cuticle	✔	✖
More pore canals (on claws)	✔	✖

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Exploring the microbial community associated with lobster shell disease in the American lobster (*Homarus americanus)*

From: Andrea Unzueta Martínez, Sarah G. Feinman, Jennifer L. Bowen, and Michael F. Tlusty

American lobsters are a cultural icon and one of the most important commercial fisheries in the Northeast United States. As epizootic shell disease slowly creeps towards the productive fishing grounds in the Gulf of Maine, a great deal of attention has been given to its causes and spread. During the short history of this disease, the study of bacteria has advanced rapidly. Whereas in the past we could only study bacteria grown in culture, we now have the ability to sequence both whole bacterial communities and entire bacterial genomes, thus telling us a great deal more about the bacteria involved in lobster shell disease.

The aim of our study was to characterize the microbial community associated with diseased lobster shells, and to look at the change in community composition on a transect across the exoskeleton beginning at a disease lesion and heading away from it toward healthy shell. We believe that this information might lead us in the direction of identifying potential pathogens responsible for the initiation and progression of shell disease in American lobsters. To describe the microbes on diseased shell, we sampled five juvenile lobsters from the New England Aquarium Lobster Hatchery that exhibited shell disease on their left claw. Using sterilized toothpicks to scrape the shell, we sampled the center of the spot or lesion (0 cm), and at increasing distances from it (0.5 cm, 1 cm, and 1.5 cm) as shown in Figure 1. We tracked the microbial communities at these locations every ten days for a total of four time points.

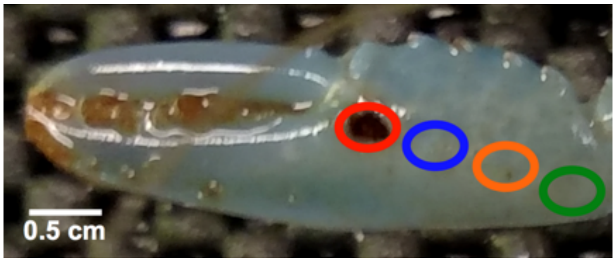

Figure 1. Left claw of a juvenile American lobster exhibiting shell disease. The colors indicate the different locations where samples were collected. Red- center of spot or lesion (0 cm), blue- 0.5 cm, orange- 1.0 cm, and green- 1.5 cm

After the samples were collected, we extracted the DNA from the toothpicks and amplified the 16S rRNA gene sequences (this region of the genome is universally found in all bacteria, so is used to identify bacterial taxa). The amplification process creates many millions of copies of this gene (referred to as amplicons), which were then sequenced using the Ilumina MiSeq platform and analyzed using QIIME (Quantitative Insights Into Microbial Ecology). To identify patterns in the microbial communities, we first grouped the sequences by lobster. Microbial communities did not display lobster specific patterns, so we did not distinguish them in further analyses. When we organized sequences by distances from the diseased area, we found a distance-dependent pattern, with distinct microbial communities at different distances from the center of a spot or lesion. We also organized the sequences by disease stage and found distinct clusters of diseased and non-diseased samples, indicating that different disease stages harbor distinct microbial communities.

We found that the relative abundances of the microbial orders changed with distance away from the center of a spot or lesion. For example, the relative abundance of *Cardiobacteriales* decreased with distance from the center of a disease area (Figure 2a). We also found that the taxonomic richness and diversity of microbial communities increased with distance away from the center of a spot or lesion, towards the healthy shell (Figure 2b). Further identification and characterization of the bacterial taxa that change will give us an insight into what type of microbes are present at different distances and what their function might be.

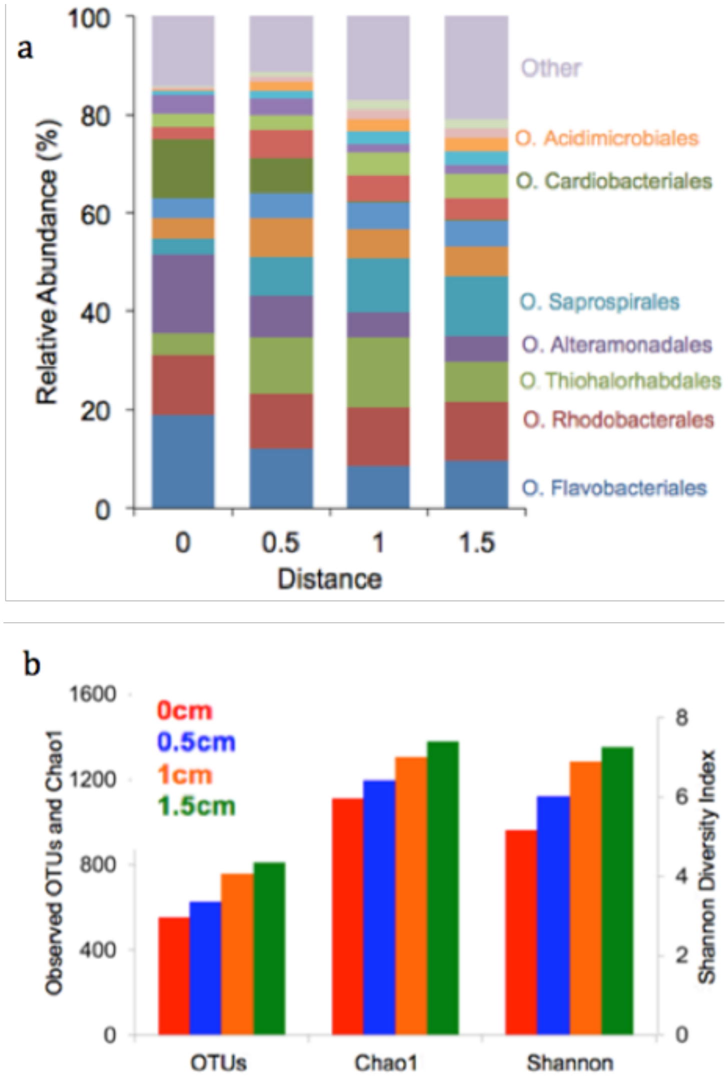

Figure 2. (a) Most abundant microbial orders at the site of disease and (b) Observed Operational Taxonomic Units (OTUs, analogous to species), species richness (Chao 1), and Shannon Diversity index of microbial communities at the center of a spot or lesion and at four increasing distances away from it.

We found slightly different patterns when comparing the relative abundances of microbial orders by disease stage. We found that the relative abundance of *Cardiobacteriales* was high at the spot, the initial stage of the disease, while *Flavobacteriales* were the most abundant in more advanced lesions (Figure 3a). A species within the Order *Flavobacteriales*, *Aquimarina 'homaria'*, has previously been identified as a key member of the microbial community in lesions (Chistoserdov *et al*., 2005) and is also thought to be important in the initial lesion formation (Chistoserdov *et al*., 2012). However our results suggest that there are other more abundant members of the microbial community in initial stages of the disease that may be playing a significant role in the initial erosion of the shell, and that *Aquimarina 'homaria'* may be more important in later stages of the disease. We also demonstrated that initial stages of the disease (spot) have a reduced microbial diversity in comparison to a clean shell and a more advanced lesion (Figure 3b). We speculate that the increased microbial diversity observed in the pitted lesions was due to the newly formed microenvironment. This new microenvironment provides open niches and allows for the colonization of a variety of secondary microbes that are not necessarily causing the disease, such as *Aquimarina 'homaria'*. The reduced diversity and richness observed at the initial stages of the disease might be due to certain microbial members that are dominant during the initial lesion formation.

In conclusion, our study described the microbial communities found on lobster shells at different distances away from a diseased area, and at different disease stages using culture-independent, next-generation sequencing of bacterial DNA sequences. We found that the relative abundances of microbial orders changed with distance away from the diseased area and with different disease stages. We also observed the richness and diversity of microbial communities increasing with distance away from diseased areas and differing between healthy and diseased areas of the shell. This fine scale topographical survey provides a baseline for studies that examine the role of bacterial communities in disease states, the microbial interdependencies required to maintain a healthy lobster shell, and will ultimately help us understand the microbial community ecology of the transition from healthy to diseased shell in American lobsters.

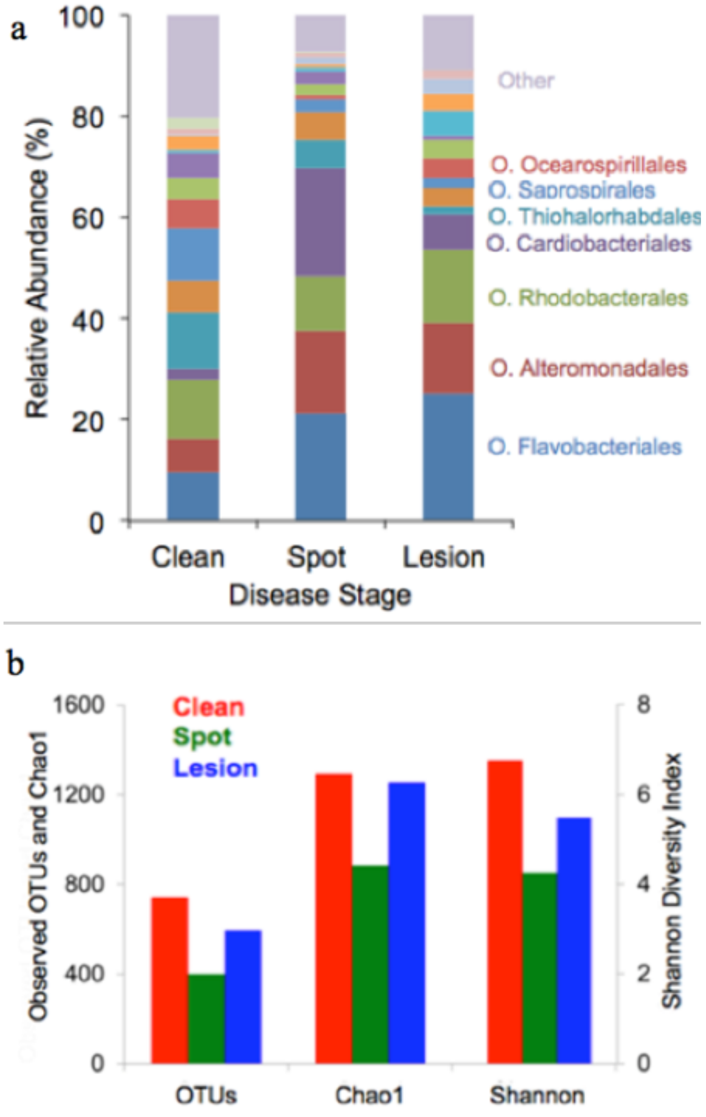

Figure 3. (a) Most abundant microbial orders and (b) Observed Operational Taxonomic Units (OTUs, analogous to species), species richness (Chao 1), and Shannon Diversity index of microbial communities for three different disease stages.

Acknowledgements

This project was undertaken by Andrea with support from the US National Science

Foundation – Research Experience of Undergraduates (REU) Program.

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Competitive lobsters fighting it out in UK's first marine park

From: Charlotte Eve Davies
Reprinted with permission from The Conversation

It has long been news that overfishing persists in many of the world's oceans. Fish and invertebrate stocks have been over-exploited for our ever-hungry, growing human population, leaving some species in dangerous decline.

The establishment of marine protected areas (MPAs) across the globe has been hailed as the silver bullet for conservation, with reports of increased catch, and spillover of recovered populations into adjacent fisheries, helping to replenish overfished stocks. But there may be unintended consequences if these areas are left unchecked. As populations of certain species are restored, disease can increase too.

Lundy Island, off the coast of Devon, was the UK's first MPA. It was established as a marine nature reserve in 1986, incorporated a no take zone in 2003 and was designated a marine conservation zone in 2010 (Figure 1, 2).

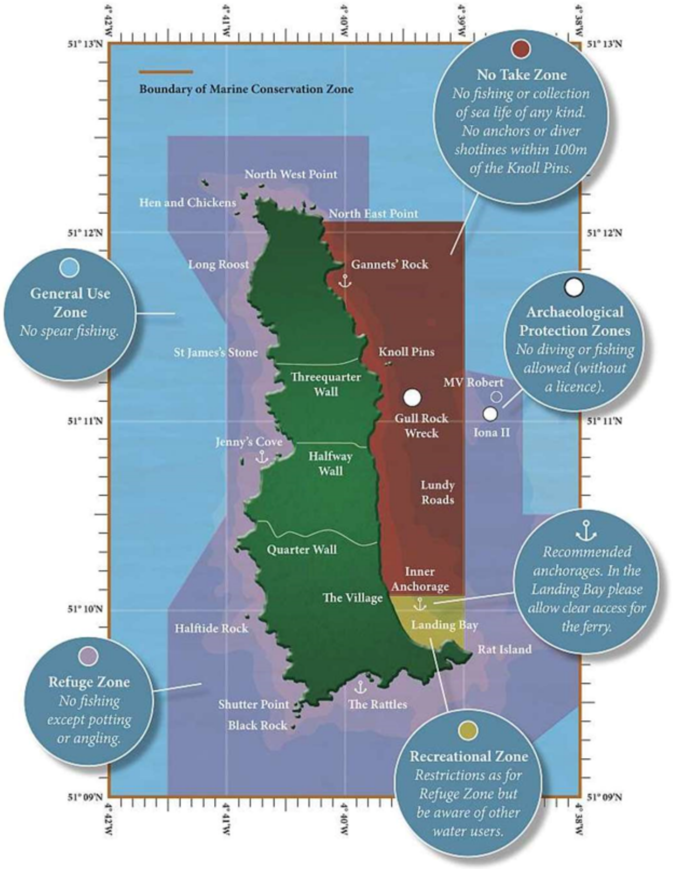

Figure 1. The Lundy Island Marine Conservation Zone. Lundy Field Society.

Figure 2. Lundy Island: where more lobsters may mean more disease. Michael Maggs, CC BY-SA.

Four years of monitoring from 2003 to 2007 saw a marked increase in commonly fished species, such as lobster (Figure 3), inside the no take zone when compared to fished areas. But in 2010, a study of Lundy called for a cost-benefits review of marine reserves, after it was found that shell disease in European lobsters may be increasing inside the protected area, supposedly caused by the high density of certain species (Figure 4).

Figure 3. Catch my disease. H. Zell, CC BY-SA.

Figure 4. Lobster from Lundy Island with shell diseased claws. Charlotte Eve Davies.

We returned to Lundy the following year to monitor the populations of European lobster (Figure 5). When we compared a fished area to the eight-year-old, unfished, no take zone, we found more abundant, and larger lobsters inside the no take zone. This phenomenon is a well-known upshot of establishing MPAs and one of the reasons they are celebrated. Local fishermen agreed that since the no take zone was implemented, there has been an increase in catch around the area.

But in the same survey, we found that there was a higher probability of lobsters being injured inside the Lundy no take zone. Injury is thought to be induced by the European lobsters' aggressive and solitary nature, so naturally in areas of high density such as the no take zone we expected to find a lot. Injury is known to be a precursor to disease. The shell of a lobster is its first line of defence and once breached, this may give rise to entry of pathogens.

Figure 5. Training fishermen in surveying techniques at Lundy Island. Charlotte Eve Davies.

This is crucial to understand because other studies have shown that pathogens in marine ecosystems are on the rise, a phenomenon which may be exacerbated by climate change. In the past, disease in American lobsters is thought to have contributed to the collapse of a lobster fishery in southern Massachusetts. It is important to monitor disease and understand the effects on populations elsewhere in the world, especially those species which are commercially exploited.

Our study is interesting in that it introduces the idea that un-fished populations in marine parks may eventually reach a threshold at which conditions become unhealthy. This may even introduce the possibility of controlled fishing in long-standing no take zones. This may be a controversial move but studies have shown high abundance in marine reserves may render animals vulnerable to disease particularly because infections can no longer be "fished out". A total ban on fishing is certainly positive in allowing recovery of populations back to unexploited densities, but they may have a finite time span of success.

There is no doubt that fishery closures and marine protected areas do help contribute to the conservation of species, but the important message here is that we must monitor them closely. In November 2013, the UK designated 27 new MPA sites. Monitoring species richness, abundance and disease in these areas will be crucial to avoid any unwanted byproducts such as disease increase.

This research was funded by SEAFISH to Swansea University and the ERDF INTERREG IVA, Ireland–Wales programme grant—SUSFISH (Project No. 042).

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<h1>Competitive lobsters are fighting it out in UK's first marine park</h1> Charlotte Eve Davies, University of Swansea

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Is there potential for European lobster culture?

From: Carly Daniels, Ph.D. and Charlie Ellis, Ph.D.

1. STATE OF THE FISHERY

The European lobster (*Homarus gammarus*) is an ecologically important species of the Northeastern Atlantic which supports trap fisheries that are critical to the economic prosperity of coastal communities. However, populations across its range are pressured by rising exploitation, from which fisheries management has failed to prevent stock collapses in the recent past, and now struggles to stimulate recovery (Kleiven et al., 2012). While the species has long been transported as a live export commodity, chiefly from the UK and Ireland to France and the Iberian Peninsula, emerging markets, particularly those in East Asia (Uglow, 2010), threaten to create additional demand for the species which far exceeds current capture yields. A number of management measures have been employed in the hope of generating improved recruitment to restore depleted stocks and sustain or enhance harvests in regions which remain productive. One of these, the hatchery-rearing of offspring from the clutches of wild-mated females, has also triggered attempts to meet rising market demand for *H. gammarus* via aquaculture (e.g. Drengstig & Bergheim, 2013). The exploitation of novel aquaculture species, such as the European lobster, could be key to relieving pressure on natural stocks and meeting the ever increasing global demand for protein by diversification of markets.

2. AQUACULTURE POTENTIAL

There are three major sectors of global aquaculture: product enhancement, resource enhancement, and full grow-out (Butler et al., 2013; Radhakrishnan, 2015). Product enhancement, the captive on-growth of wild-captured stock to improve marketability (Radhakrishnan, 2015), is limited in *H. gammarus* as it protected by fishery MLS and unsuited to communal rearing techniques (Wahle et al., 2013; Ellis et al., 2015), although some industry stakeholders store lobsters over periods of weeks or months to take advantage of seasonal variation in market price. The majority of aquaculture-based initiatives using *H. gammarus* have focused on the potential of resource enhancement (Wahle et al., 2013); the improvement of wild-capture fishery harvests via the release of hatchery-reared juveniles (‘hatchery stocking’, including both restocking and stock enhancement – Bell et al., 2005). The technique should be well suited to *H. gammarus*, a high-value, fecund species with a recent history of stock collapse and early life-stages, which are presumed to be considerable recruitment bottlenecks in nature (Bannister & Addison, 1998), and monitored trials have demonstrated a proof-of-principle of hatchery stocking. Considerable numbers of released lobsters have been recovered, having survived, grown, and mated successfully in the wild across multiple locations and ecotypes, although evidence of direct economic viability of the approach is yet to be seen (Ellis et al., 2015). Strategies of full grow-out, the captive culture of wild or hatchery stock to marketable sizes, have also been tested in recent years (e.g. Drengstig & Bergheim, 2013), and technological progress has raised the possibility that commercial aquaculture of *H. gammarus* may soon be realized.

Rearing for full grow-out is complicated by the slow growth rate and particularly the willingness of lobsters to cannibalise in the confines of captivity (Cooper & Uzmann, 1980). These challenges mean that aquaria-based grow-out has also yet to realise economic viability despite encouraging progress in recent years (Kristiansen et al., 2004; Drengstig & Bergheim, 2013), but potential also exists in the on-growth of hatchery-reared juveniles in containers moored at sea (Knudsen and Tveite, 1999; Beal et al., 2002; Beal, 2009; Perez-Benavente et al., 2010; Browne et al., 2011; Beal, 2012; Beal and Protopopescu, 2012; Daniels et al., 2015), which avoid many of the rearing costs associated with aquaria-based operations.

3. THE FUTURE

The National Lobster Hatchery (NLH) in Padstow, UK, a conservation, education and research charity set up as a stock enhancement program to help support local sustainability of *H. gammarus* has spent 6 years investigating the potential for on growing at sea in container systems, following initial success with clawed lobsters (Knudsen and Tveite, 1999; Beal et al., 2002; Beal, 2009; Perez-Benavente et al., 2010; Browne et al., 2011; Beal, 2012; Beal and Protopopescu, 2012; Daniels et al., 2015). More recently the NLH has engaged a diverse consortium of expert partners to help develop the equipment and techniques to evaluate the potential for rearing cultured lobster juveniles in custom made baskets to pioneer this sea-ranching aquaculture approach (Figure 1). The Innovate UK/BBSRC funded project, ‘Lobster Grower 2’ follows up on an early stage investigation of container design, lab testing and development, and features consortium partners the University of Exeter, Westcountry Mussels of Fowey, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and Falmouth University. The consortium aims to field test these bespoke containers, the first ever purpose-built to support semi-intensive lobster culture in a semi-wild environment. As well as raising the possibility of initiating aquaculture applications, rearing at sea appears to promote traits that are likely to have a positive impact on juvenile settlement success and their adaption to the natural environment. Container rearing of European lobsters appears to offer significant potential as a step to acclimate cultured individuals prior to wild release to increase the recruitment benefits of hatchery stocking, as well as to produce early-benthic phase juveniles (which we remain unable to locate in the wild – Linnane et al., 2001; Mercer et al., 2001) for purposes of ecological and behavioural research.

Figure 1. Custom made, stacking, lobster rearing containers for sea ranching and a juvenile *Homarus gammarus*.

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Small but mighty and surprisingly complex: evaluating behavior in larval American lobster (*Homarus americanus*)

From: Ryan RE Stanley & Paul VR Snelgrove

Most early studies modelled dispersal of early life stages of marine fish and invertebrates (eggs and larvae) as a primarily passive process (e.g. Hjort 1914, Petrie & Drinkwater 1978, Lough et al. 2006), however, increasing evidence suggests that active larval movement, even over small distances (mm-cm • s^{-1}), can significantly alter larval transport outcomes (Metaxas 2001, Corell et al. 2012, Lloyd et al. 2012), particularly when comparing larvae that occupy a single depth layer to those that move actively between depth layers. For example, larval dispersal simulations of Caribbean spiny lobster (*Panulirus argus*) showed that inclusion of vertical migration as larvae developed, significantly reduced dispersal distances (Butler et al. 2011). Similarly, dispersal simulations of larval Norwegian lobster (*Nephrops norvegicus*) released near the western Irish seasonal gyre that considered vertical movement significantly decreased local retention (Phelps et al. 2015). Clearly, oversimplification of larval behaviour can influence the accuracy of dispersal simulations. Careful consideration of biological information, including swimming speeds and vertical movement, increases in importance as physical oceanographic models improve in spatial resolution and can potentially improve accuracy at smaller scales (Treml et al. 2015).

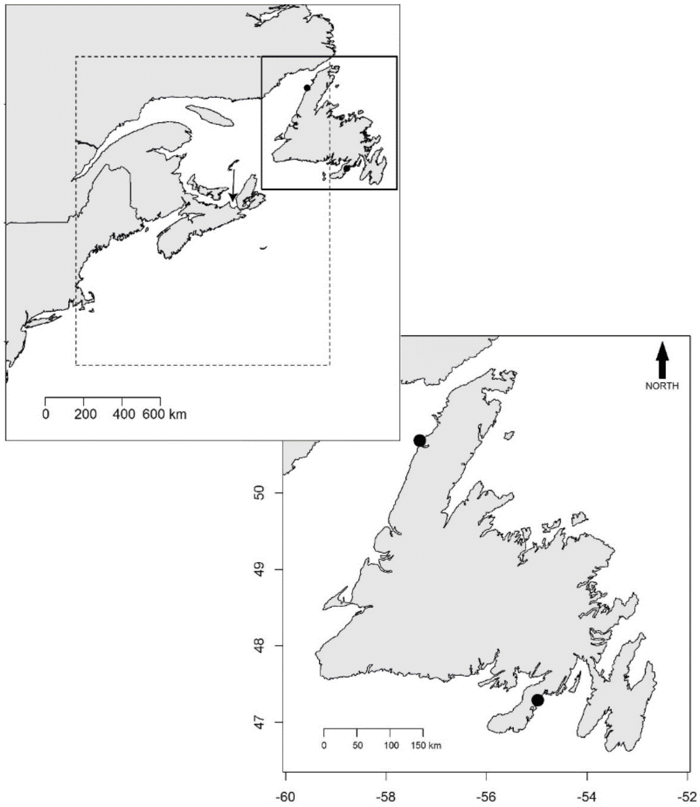

Figure 1. Map detailing locations of ovigerous female collections (black circles). Inset shows the island of Newfoundland with respect to the American lobster range spanning eastern Canada and the northeastern United States. Port au Choix represents the cold-origin and Red Harbour the warm-origin. Dashed box in the upper panel corresponds to the biophysical model domain, and the arrow points to St. George's Bay where dispersal simulations originated.

Several studies have used biophysical modelling of American lobster (*Homarus americanus*) to explore a variety of ecological processes including spatial recruitment dynamics (Xue et al. 2008, Incze et al. 2010) and larval exchange among geographic management units (Chasse & Miller 2010), to name a few. However, to date no study has tested the potential influence of early pelagic larval behaviour and behavioural variability on dispersal, despite evidence that early larvae are capable swimmers (Ennis 1986) and postlarval swimming influences dispersal (Cobb et al. 1989, Katz et al. 1994). Inadequate information on swimming abilities, coupled with a general assumption of weak swimming capacity relative to horizontal velocities of ocean currents has likely contributed to limited inclusion of pelagic larval behaviour in biophysical models.The objectives of our study were to measure the swimming ability of the pelagic larval American lobster stages, quantify potential sources of variability, and simulate how behavioural variability could influence dispersal patterns.

We designed a series of experiments to measure the behaviour of larval American lobster. Specifically, we investigated how behaviour varies among ontogenetic developmental stages and natal origins. We collected egg-bearing female lobsters from two coastal locations in Newfoundland, Canada (Figure 1) characterized by an ~ 7 °C difference in summer sea surface temperature, and reared larvae in lab under common conditions. Larval swimming was videotaped under three different lighting (~1200, 600, and 30 (± 20) lx) and temperature (20, 15, and 10 (±1.25) °C) treatments, reflecting the range of conditions larvae likely experience daily (light) and across their range (temperature). Using plexiglass columns, we compared light response (phototaxis) of stage I larvae (Hadley 1905) as a function of temperature and vertical movement in response to lighting condition (Figure 2). Finally, we integrated laboratory observations into a 3-dimensional hydrographic model (see Chasse & Miller 2010 for more details) to test the sensitivity of dispersal simulations to vertical movement (Figure 1).

Swim speed, characterized as average of a given path observed in the horizontal arena, varied as a function of larval stage, lighting condition, and the interaction between stage and both temperature and light. Overall, ontogeny influenced swim speed most, with stage IV larvae swimming significantly faster 4.2 (±1.2) cm·s^{-1}, than preceding stages, 1.9 (±1.5), 0.9 (±1.3), and 0.7 (±1.1) cm·s^{-1}, 54, 78, and 84% faster, for stages I-III, respectively. Swimming ability of intermediate stages (II and III) were significantly less responsive to temperature and light than stages I and IV. Similarly, under each lighting treatment we found that intermediate stages occupied significantly deeper water column positions compared to stage I larvae, which actively responded to light and stage IV which did not move vertically in the upper water column.

Surprisingly, our results run counter to past studies on American (Ennis 1986) and European lobster (Schmalenbach & Buchholz 2010), which reported increases in swimming ability with developmental stage. We attribute this difference to how studies measured swimming capacity. These previous studies evaluated behaviour in a flume and usually relative to an averaged flow rate within a complex three-dimensional flow environment. Our study is the first to measure swimming velocity directly, tracking individual larvae at a relatively fine spatial and temporal resolution (~0.5 mm resolution filmed at 30 fps) with no assumptions regarding flow experienced by larvae during observation and in nature. Variation in swimming activity during larval development mirror our estimates of swimming capacity, suggesting that intermediate stages were less likely, and potentially less able, to occupy different positions in the water column irrespective of temperature and-or lighting condition.

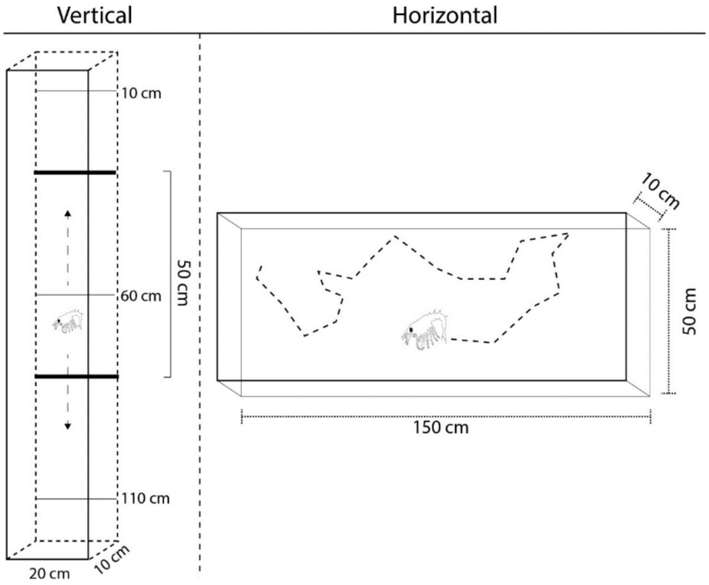

Figure 2. Schematic of vertical and horizontal observational arenas. Dark horizontal lines represent the start and end point of 50 cm swimming window in which vertical swim speed was measured. The vertical chamber was also used for distributional tests where larval count was recorded for each of twelve 10 cm segments. Dashed line and larvae illustrate movement paths for each larva.

We observed significant variation in larval behaviour related to biogeography of larval source. Warm-origin larvae swam significantly faster in the vertical plane than cold-origin larvae at intermediate (15 °C) and warm treatments (20 °C) (>30%, faster). Cold-origin larvae swam faster (<10%) in the coldest treatment (10 °C) but did not differ significantly from warm-origin lobsters. Swimming measured in the horizontal plane mirrored these results. Cold-origin larvae swam significantly faster in the cold treatment than warm-origin larvae (>40%), while the inverse was true in the warm water treatments (~25%). Swim speeds at the intermediate temperature treatment did not differ significantly in the horizontal plane. Overall, swimming varied most in cold-origin larvae over different temperatures. However, the inverse was true when relating larval swimming ability to maternal size (carapace length of mothers), where swimming ability was greater in larvae from larger mothers for warm-origin larvae only (~0.02 $cm \cdot s^{-1}$ per mm carapace length).

Our work provides the first evidence of biogeographic variation in swimming behaviour of larval lobster. We highlight differences in swimming performance based on temperatures representative of the natal site. In both vertical and horizontal swimming trials, larvae performed better in temperatures typical of their natal habitat, suggesting analogies to cogradient variation (Marcil et al. 2006). This variation in swimming traits was surprising given the relatively close proximity of the ports of origin (<800 km) and that past genetic analysis considered the population a single genetic grouping (Kenchington et al. 2009). Recent genetic surveys of American lobster using Restriction Site Associated DNA sequencing (RAD-seq) suggests potentially more genetic structure in Atlantic Canada (Benestan et al. 2015), than previously reported (Kenchington et al. 2009). Our results on differences in swimming capacity support these new findings. Given that the larval dispersal stage likely contributes more to connectivity in American lobster than other life history stages, the behavioural capacity of larval lobster could contribute significantly to the dispersal-recruitment process (Pezzack et al. 1992, Incze et al. 2010) and thus any realized genetic structure.

To explore how behaviour might influence dispersal we incorporated our lab-based behavioural estimates into a behavioural sub-model nested within a biophysical model of the Northwest Atlantic previously published by Chasse and Miller (2010) (Figure 1). This simulation demonstrated that active vertical movement measurably influenced three important dispersal parameters: duration, extent, and direction. Indeed, addition of our laboratory observations into the simulation extended the duration of dispersal by up to two weeks. Even in a system characterized by highly variable circulation (sensu Daigle et al. 2014), we found that addition of behaviour significantly increased dispersal potential up to 200 km relative to models run with passive dispersal, depending on release location.

Despite their small size, larval lobsters exhibit a diversity of swimming behaviour and response to stimuli. Collectively this work provides an updated and comprehensive assessment of the movement ecology of pelagic larval American lobsters and its potential to influence dispersal and connectivity. Importantly these experiments and simulations provide baseline information needed to test assumptions of behaviour (i.e., sources of variability) and a means to incorporate behaviour in biophysical dispersal models of larval lobster. Inclusion of behaviour will be particularly important in evaluating dispersal-recruitment processes at small scales as well as defining the influence of variable mortality, noting the relationship between behaviour, larval duration, and mortality.

Stay tuned in 2016 for manuscripts detailing our observations of larval behaviour and biophysical simulation of dispersal!

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Are immature female lobsters capable of normal mating behavior?

From: W. Watson, T. Pugh, E. Morrissey, and J. Goldstein

In 2013 Pugh et al. investigated the mating success of >1600 female lobsters in the field by determining if they had sperm in their seminal receptacles. Overall, >75% of the lobsters sampled had successfully mated. One of the most surprising findings, however, was that more small females mated than would be expected, given estimates of the percent of females that should be mature in a given size class. More females might be maturing at a smaller size due to ocean warming, which is consistent with the known relationship between water temperature and size at maturity in female American lobsters (Aiken et al. 1980, Little & Watson 2003, 2005). Or, some females might have been capable of normal mating behavior, even though their eggs were not developed enough to be used (i.e. they were not physiologically mature). Recently, we decided to test the second hypothesis by: (1) determining if some females with sperm in their spermatophores were, in fact, not physiologically immature and; (2) pairing immature pre-molt females with males to see if they would exhibit ‘normal’ (consensual) mating behavior.

In the 2013 study Pugh et al. tested for the presence of sperm in the females’ receptacles, but they did not dissect animals to examine their ovaries and thus determine, definitively, if they were mature and ready to successfully reproduce. In this study, we tested both for sperm, and determined the ovary stage, of 209 females captured off the coast of New Hampshire, USA. Lobsters with ovaries that were at developmental stages 1-3 (based on their color and the size of individual ova; Figure 1), and which had the appropriate AB:CL ratios and/or cement gland stages, were considered to be immature (Aiken and Waddy 1982). We found that 27.8% of the females with immature ovaries had sperm (spermatophores) in their seminal receptacles, which supported the hypothesis that some females in their natural habitat mate while still immature.

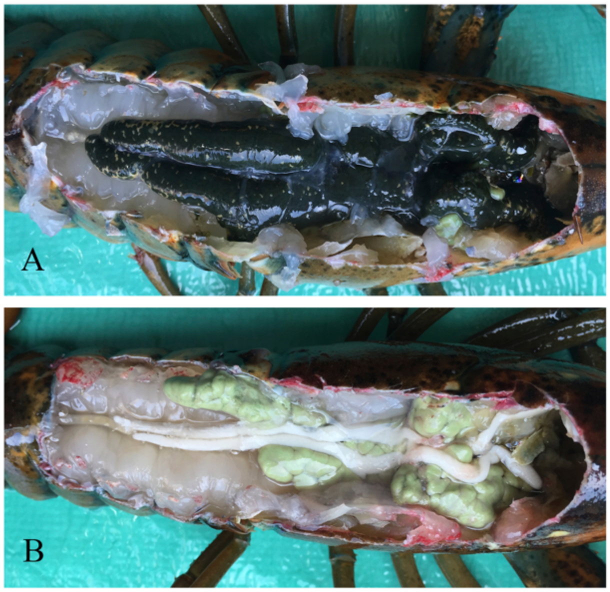

Figure 1. Dorsal view of a partially dissected female lobster. A) An example of mature ovaries, containing large, dark green, oocytes. B) An example of immature ovaries that contain smaller, white, oocytes and occupy a much smaller volume than mature ovaries.

Next we used a digital time-lapse video system in the laboratory to record the behavior of pre-molt immature females placed in tanks with mature males to determine if mating was consensual. The mating behavior of American lobsters has been previously described in considerable detail and typically involves mature females that are about to molt approaching a male that has established a mating den, the exchange of chemical signals (pheromones), cohabitation, molting, mating, and then cohabitation for some additional time while the female’s soft, postmolt shell, hardens (see Atema 1986 for review). Previous studies have demonstrated that in order for this sequence of behaviors to take place normally, the exchange of chemical signals is very important, and probably necessary (Atema 1986, Atema & Cowan 1986, Atema & Steinbach, 2007). In this study 11 of 14 immature females exhibited normal mating behavior and successfully mated. We examined these animals after they had mated to confirm that they were, in fact, immature and that they had, in fact, mated. Three of the females did not cohabitate with the males and when they molted they were eaten by the male. Pre-molt male lobsters placed in a tank with another male as controls were also eaten after they molted. Thus, it appears as if some of the presumably immature females were capable of producing the appropriate signals (likely pheromones, see Atema & Steinbach 2007 for review) to reduce the aggressive behavior of the males.

Other authors have also reported finding immature females carrying spermatophores in their seminal receptacles (Templeman 1936, Krouse 1973, Waddy & Aiken 1990). However, to our knowledge, this is the first study to show that female lobsters with immature ovaries, both in the field and the laboratory, were capable of successfully mating. Atema et al. (1979) noted that some small adult females exhibited incomplete formation of the typical pair bond and suggested that these size classes represented a transitional stage from adolescents to adults. Both our sperm data and behavioral observations appear to support this hypothesis and demonstrate that some females are capable of completely normal mating behavior even though they are unlikely to be capable of utilizing the sperm they receive; because they will molt and lose the spermatophore before their ovaries become mature.

Even though mating will not lead to successful reproduction, there are several possible reasons why immature female lobsters might mate. First, it may be in their best interest to "trick" the male, so that he will protect her during the post-molt period when she is most vulnerable to predation. The use of dishonest signals has previously been demonstrated in a number of other species, although not quite in this same manner (Steger et al. 1983, Funk & Tallamy 2000, Wilson et al. 2007, Lailvaux et al. 2009, Whiting et al. 2009, Barry 2015). Second, this type of behavior might allow lobsters to "practice" mating. This appears to take place in some spiders, and while male spiders do not pass sperm to the female, this type of 'practice' sex seems to increase reproductive success for those individuals who do it (Pruitt & Riechert 2011). Although American lobsters are capable of living >20 years and they can produce and fertilize many eggs each year, continued fishing pressure means that many female lobsters may only have one mating opportunity. Thus, it might be adaptive both for females to reach sexual maturity at a smaller size and to "practice" so they will be more successful when they do have the opportunity. These traits, in turn, may be maintained in the population by a proportion of females both because of the advantages stated above and because there are no apparent disadvantages to this behavior.

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New slipper lobster added to the Andaman & Nicobar Islands, India

From: Anuraj and DamRoy

Scyllarid lobsters contribute about 8% of total global lobster production. Their size ranges from small to large lobsters (total length between 2 and 40 cm) and their body is more distinctly flattened than other groups of lobsters. These lobsters usually prefer to inhabit sandy or muddy bottom. *Thenus* is the only genus in seven scyllarid genera that is economically significant. The lobsters reported from the Andaman and Nicobar Islands include species belonging to Nephropidae (*Nephropsis stewarti*), Palinuridae (*Panulirus polyphagus*, *P. ornatus*, *P. homarus*, *P. homarus*, *P. versicolor*, *P. longipes*, *Puerulus sewelli*, *Linuparus somniosus*, *L. andamanensis*) and Scyllaridae (*Thenus orientalis*). Scyllarid lobster, *Thenus orientalis* has been reported from a depth of 45 metre during a survey conducted in these Islands in 1978.

Now, another species of shovel nosed lobster, *Thenus unimaculatus* has been recorded during a recent survey conducted at Junglighat landing centre, South Andaman from the landings of multiday trawlers operated in Andaman and Nicobar Islands (Figure 1). These shovel nosed lobsters are caught by the trawlers operating in the east coast of the Islands at a depth between 20-60 metres. Investigations were carried out on the newly recorded species for around six months based on the integrated taxonomic approach combining morphometry with mitochondrial COI gene sequencing for confirmation of the species.

Taxonomic characters and morphometric ratios as described in the revision of the genus *Thenus* (Burton & Davie, 2007; Figure 1) were followed in our study to differentiate from other shovel nosed lobsters. DNA isolation (Sambrook & Russell 2001) and amplification (Folmer *et al.* 1994) was done using standard methods. The species were identified based on the purple blotches on the inner face of one or more pereiopods spines on merus of the third maxilliped, dentition on ischium of the third maxilliped and setae on the propodus of second pereiopod. Further the morphometric ratios used to differentiate the species showed 96% concurrence with the values of Burton and Davie (2007). DNA barcoding using the COI gene also confirmed the species identity, and on comparison with NCBI GenBank submissions, showed more similarity to submissions from the Andaman Sea. Morphological identification together with mitochondrial gene sequencing carried out during the study period confirmed the occurrence of *Thenus unimaculatus* and a further addition to lobster fishery of the Islands.

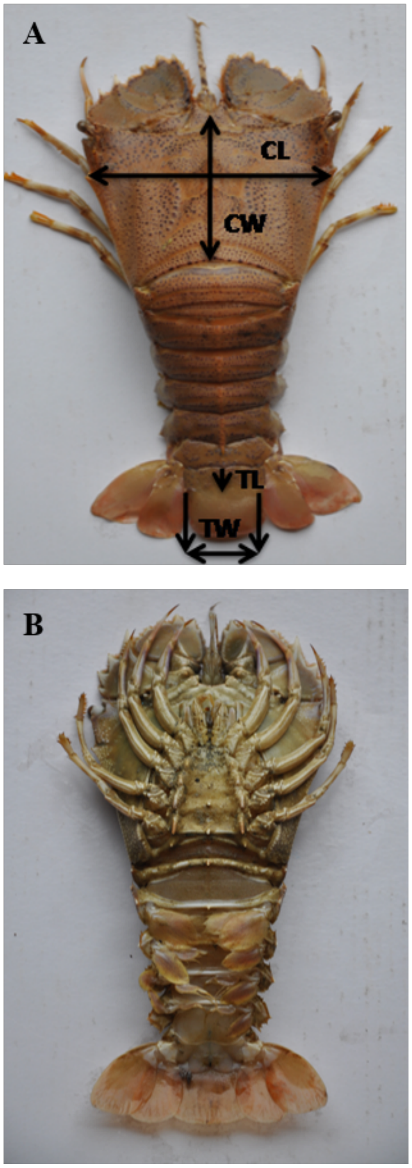

Figure 1. Morphometric ratios used to identify species (A) and a ventral view of *Thenus unimaculatus* (B).

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Resistance to starvation of first-stage juveniles of *Panulirus argus*

From: Alí Espinosa-Magaña and Patricia Briones-Fourzán

The Caribbean spiny lobster, *Panulirus argus*, is one of the most important fishing resources in the western-central Atlantic and accounts for over 50% of the world catch of spiny lobsters (Phillips et al. 2013). However, total catches of *P. argus* have suffered a substantial decline since the late 1990s (Ehrhardt & Fitchett 2010). Because of its relatively fast growth rates (compared to temperate-water lobsters) and year-round availability of wild seed, aquaculture of *P. argus* appears as a viable alternative to increase production (Cruz et al. 2006; Jeffs & Davis 2003). Thus, understanding the nutritional requirements of early juveniles is needed to minimize mortality and develop a cost effective feeding program. However, to our knowledge, the resistance to starvation of early benthic juveniles of *P. argus* has not been studied to date.

Spiny lobsters have a non-feeding postlarva (puerulus) that actively swims back to coastal areas to settle in benthic habitats after a protracted oceanic larval phase. The pueruli of *P. argus* settle in shallow vegetated habitats and molt into the first juvenile stage (hereafter JI) 7-10 d after settlement (Calinsky & Lyons 1983). However, in the laboratory, the total duration of the puerulus stage of *P. argus* was 11–26 d depending on the temperature (Goldstein et al. 2008). Feeding is not resumed until after the molt to JI, but this may depend on local food availability and predation risk (Lozano-Álvarez 1996; Weiss et al. 2008). If JIs cannot restore sufficient energy reserves quickly enough, they may die. Therefore, we aimed to experimentally determine how resistant to starvation were JIs of *P. argus* after their long non-feeding but energetically demanding postlarval stage.

There are two measures of resistance to starvation: the "point-of-no-return" (PNR) and the "point-of-reserve-saturation" (PRS). The PNR is the time of initial food deprivation that will cause irreversible damage, i.e. not allowing for recovery even after later re-feeding, whereas the PRS is the minimum time of initial feeding after which a later food-independent development to the next stage is possible (Anger & Dawirs 1981). We conducted experiments with JIs of *P. argus* to determine their PNR by exposing individuals to different initial starvation periods followed by continuous feeding, and their PRS by initially feeding individuals for different periods before food was permanently withheld. In both cases, the initial periods were 3, 6, 9, 12, 15 and 18 d, plus continuously fed and continuously starved controls (Figure 1). Both indices were estimated during a warm and a cold season (i.e., 4 experiments in total).

In each experiment, we used 160 pueruli divided into 8 groups of 20 individuals each. The influence of the initial starvation periods (PNR experiments) or the initial feeding periods (PRS experiments) was measured as percent mortality and the length (in d) of the intermolt period (into second-stage juveniles, hereafter JII). Starvation tolerance was quantified as the median point-of-no-return (PNR_{50}) and point-of-reserve-saturation (PRS_{50}), which were obtained by adjusting a sigmoid dose-response curve to the values of % mortality per increasing days of initial starvation or feeding, respectively.

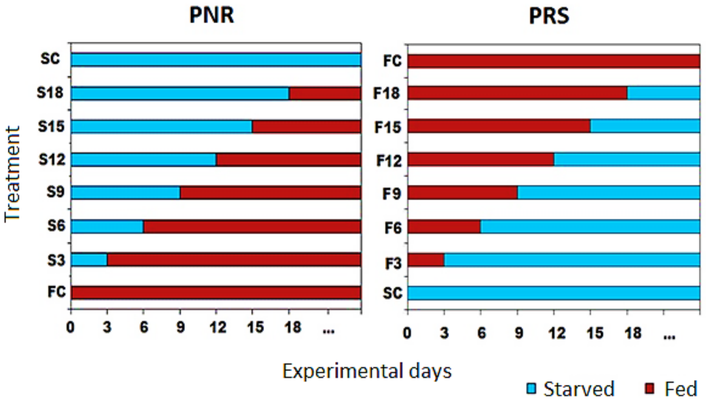

Figure 1. Experimental design of point-of-no-return (PNR; initial starvation, followed by feeding) and point-of-reserve-saturation (PRS; initial feeding, followed by starvation) experiments. FC: continuously fed control; SC: continuously starved control; S3–S18: no. of days starved, followed by continuous feeding; F3–F18: no. of days fed, followed by continuous starvation. Initial number of pueruli per treatment, FC and SC groups, n = 20 per treatment.

In both PNR and PRS experiments, the mean intermolt period was significantly longer during the cold season relative to the warm season, and overall, mortality of JIs increased with period of initial starvation (PNR) and decreased with increasing period of initial feeding (PSR). We found a significantly higher PNR_{50} in the warm season (12.1 ± 1.2 d, mean ± 95% CI) compared to the cold season (9.5 ± 2.1 d) (Figure 2a). However, PRS_{50} values showed no significant difference (cold season: 13.1 ± 0.7 d; warm season: 12.1 ± 1.1 d) (Figure 2b). In PRS experiments, high mortality rates in individuals subjected to short periods of initial feeding (<9 d) prior to starvation, overall shorter intermolt periods (compared to PNR), and similarity in PRS_{50} values between seasons, suggest that resumption of feeding is more important near the molt to JII than immediately after molting to JI; i.e., near the PRS or "D_0 threshold" (Anger 1987), which is a critical point for most crustaceans that occurs during the transition between the intermolt and premolt stages (C/D_0 transition in Drach's molt classification system)

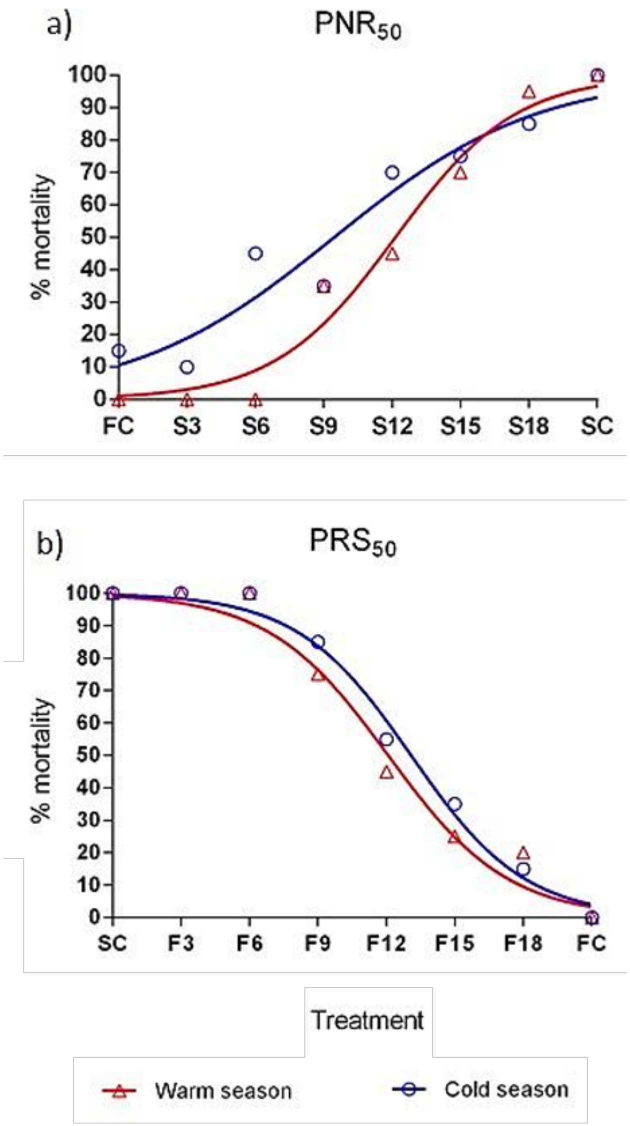

Figure 2. Sigmoidal dose-response curves fitted to the mortality percentages of first stage juveniles of *Panulirus argus* (a) submitted to different periods of starvation before being fed to determine the point-of-no-return in a warm season (June-October 2012) and a cold season (January-April 2013), and (b) submitted to different periods of feeding before being starved to determine the point-of-reserve-saturation in a cold season (January-April 2014) and a warm season (July-November 2014).

Limbourn et al. (2008) estimated the PNR_{50} of JIs of *P. cygnus*, a subtropical species, in 22 days, which is about twice what we estimated for the tropical *P. argus*. Regardless, the resistance to starvation of JIs of these lobsters is remarkable, considering the energetic demand imposed on the non-feeding pueruli during their transit from oceanic waters to the coast (e.g. Fitzgibbon et al. 2014).

Acknowledgements

We would like to thank Enrique Lozano-Álvarez, Fernando Negrete-Soto and Cecilia Barradas-Ortiz for their support.

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Recent Advances in Lobster Management

Study Case: Continental Shelf off the State of Ceará, Brazil

From: João V. M. Santana[1] and Raúl Cruz[2]

The current models of extraction and management of Brazilian spiny lobster resources were examined and we looked into the problems caused by different types of associated externalities. The Brazilian continental shelf is not divided into fishing zones, making it impossible to prevent the concentration of fishing vessels and effort. The lobster production and wholesale marketing chain is complex: vessels of varying size and different legal or illegal methods and fishing gear are used, none of which are selective, and a significant part of the production is sold to middlemen who retain a large percentage of the profits. In general, fishermen disregard existing regulations on resource use and access. This is equivalent to a regime of non-property (open access) in which individuals can directly take possession of resources. Unrestricted access leads to overexploitation of common property, making rational allocation of resources impossible and generating negative externalities.

Fishing grounds in the continental shelf off the State of Ceará

Ceará State (Figure 1) is the most important lobster producer along the Brazilian coast. Since this region accounts for 40% of total Brazilian catches, the strong fluctuations observed in yields are probably due to the capture of undersized lobsters (>50%), leading to growth overfishing in shallow waters (Cruz et al., 2013).

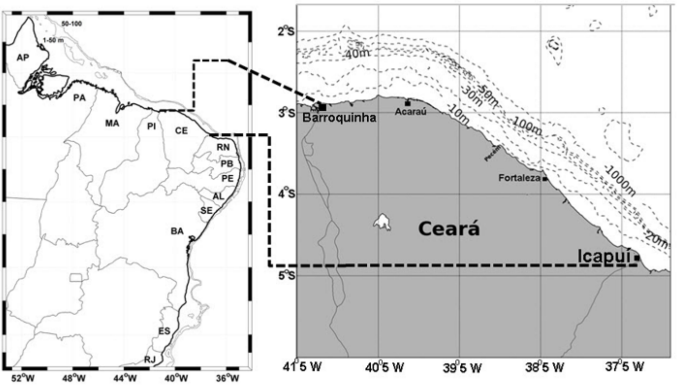

Figure 1. Left: Area on the Brazilian continental shelf (depth: 1-100 m) exploited by the spiny lobster (*Panulirus argus* and *Panulirus laevicauda*) fishing fleet. The lobster catch is along the 12 states. Right: Spiny lobster fishing grounds off the state of Ceará, from Barroquinha (03°01'08''S; 41°08'10''W) to Icapuí (04°42'47''S; 37°21'19''W), with indication of depth in meters. Fortaleza is the state capital. Acaraú is a port of lobster landings

The records of *P. argus* catches in Ceará date from 1983 (1299 t). Annual catch increased to nearly 2200 t by 1985, but plummeted to 1161 t in 1986. A record high was set five years later, in 1991 (2670 t). A decreasing average trend was observed between 1992 and 2007 (739 t), followed by an increasing trend from 2008 to 2010 (1721 t). Between 2009 and 2011, production was rather stable. Revenues from Brazilian lobster exports have grown steadily over the last decade, from USD 40.1 million in 2000 to USD 50 million in 2011 (Figure 2)

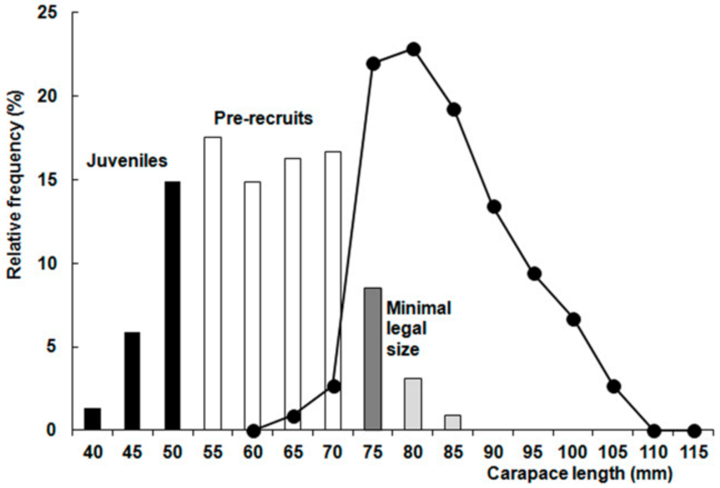

Figure 2. Trends of landings of red spiny lobsters (*Panulirus argus* Latreille, 1804) on the continental shelf off Ceará and lobster export revenues (in million USD).

Previous studies on lobster fishing have established that three basic fishing methods are used along the coast of Ceará: baited traps (BT), scuba diving in artificial shelters (AS), and bottom nets (BN).

The use of liftable wooden-frame lobster traps (BT) with one or two entrances is legal. However, because the traps are not selective, undersized lobsters are often caught (depending on location) along with highly diversified by-catch, with a tendency to increase by-catch with depth (Ivo et al., 1996). In addition, Cruz et al. (2013) suggested productivity may be compromised if the lobster traps become saturated with by-catch—a question that remains to be investigated. The lobster harvested (N= 2083) from AS at a depth of 3-10 m, out of which 22% were caught as juveniles (16-50 mm CL), 65% pre-recruits (50-73 mm CL), and only 13% mature lobster. However, it is evident in BT at a depth of 30-50 m the total harvest (N= 1500) composition are basically mature lobster (96%). The size distribution at depth is shown in Figure 3. On the other hand, in this region we do not have information about the BN. According to our findings above, fishermen are using BN in deeper waters (50-100 m) farther north, in Amapá (AP) and Pará (PA) region (Figure 1), where they cannot use traps. However, fishermen generally admit only to using traps, due to the current ban on the two other methods.

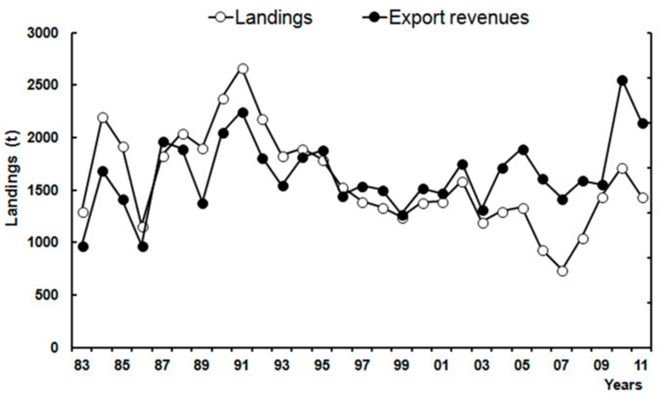

Figure 3. Size composition of spiny lobster (*Panulirus argus*) for the year 2014 (January-December) in artificial shelters and at traps fishing grounds. Column: shallow waters (3-10 m). Line with point black: deep waters (30-50 m).

Lobster resources and property regimes

According to Bromley (1991), fishing resources may be subject to different property regimens: state property, private property, common property and non-property (open access). In Brazil, fishing resources are state property, with a managing agency in charge of enforcement and inspection, but fishermen commonly disregard the rules of proper use and access. Enforcement has been shown to be woefully inadequate to ensure compliance with existing regulations in the region (Cavalcante et al., 2011). In practical terms, it is equivalent to a regime of non-property (open access), in which individuals can directly take possession of resources. According to Arnason (1999) and Seijo et al. (1997), open access and unrestricted use lead to overexploitation of common property resources, make it impossible to allocate such resources rationally, and thereby generating negative externalities.

In the absence of lobster fishing regulations (other than the closed season), fishermen compete with one another to land the greatest possible volume, catching undersized lobsters and employing seemingly productive but illegal fishing methods such as BN (Moura, 1963) and AS (Cruz et al., 2011). The vast extension of Brazilian lobster fishing grounds and the lack of effective management, control and law enforcement render lobster fisheries disorderly and unsustainable. The number of fishermen, boat, and type of boat required by fishing zone for a rational management of the lobster resource has not been determined. In view of the well-documented inefficiency of the current management approach and the ambiguous nature of the property regime, a new management plan and zoning system must be developed urgently which takes into account the Brazilian socioeconomic reality and the biology and ecology of wild lobsters and their interplay with oceanic processes.

Externalities and management regimes

The fishing methods and gear described above are associated with several types of externalities. An example of technological and dynamic externalities, as suggested by Seijo et al. (1997) and Wachsman (2003), respectively, is seen in the capture of lobsters using BN and BT which impact the structure of both target populations and by-catch, potentially compromising the productivity of fellow fishermen by changing the relative abundance of targeted species other than lobster (e.g. fish). Likewise, increasing the fishing effort, or using a method which requires less effort (e.g. AS), is likely to deplete resources shared with other fishermen. Thus, Clark (1980) observed that fishermen engage in overfishing because they are unconcerned about the social consequences of their behavior and about other fishermen's ability to exploit the resource.

According to the studies of Cruz et al. (2014), Cruz et al. (2015), and Santana et al. (2015), we identified the following sequential externalities (Figure 4).

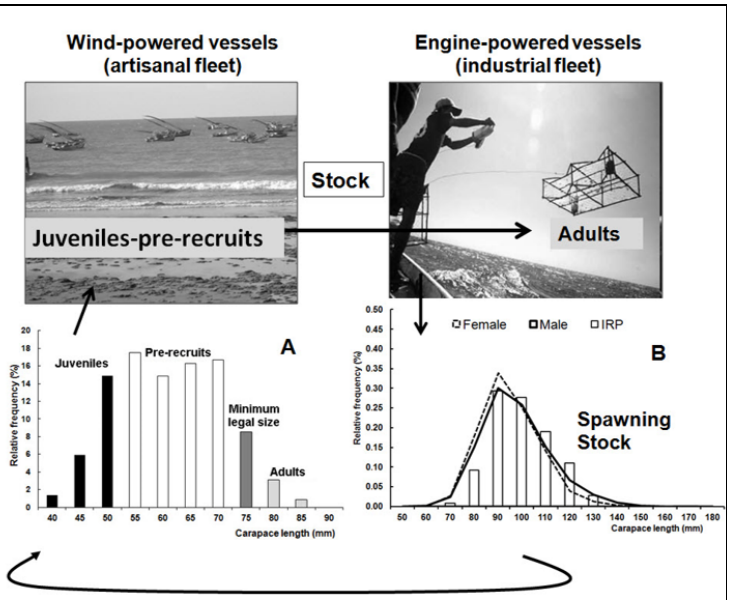

Figure 4. Summary of the dynamics of lobster fisheries on the Brazilian continental shelf. A. Size composition of juveniles and pre-recruits on the coast of Acaraú (modified from Cruz et al., 2015); B. Relative size structure of female/male spiny lobsters caught on the continental shelf off Northern Brazil. IRP = index of reproductive potential (white bar) for the period 2001-2003 (modified from Cruz et al., 2014). Curved arrow below the figures represents the relationship between spawning stock and recruitment (juveniles).

By exploiting lobsters outside the recommended size range, the artisanal fleet and the industrial fleet affect the size structure of the lobster stock, thereby generating sequential negative externalities for one another. On the left side of Fig. 4 the artisanal fishing fleet exploits primarily juveniles and pre-recruits in shallow waters (3-10 m); on the right side the industrial fishing fleet exploits primarily adult lobsters in deeper waters. The relative size structure of spiny lobsters exploited by each fleet along with the relationship between spawning stock and recruitment is represented in Figure 4A and B.

AS act as ecological traps generating impacts for which the expression "biomass agglomeration externalities" may be suggested. AS are often deployed clandestinely on fishing grounds in shallow waters (3-10 m) causing an increase and redistribution of the exploitable lobster biomass due to the large proportion of undersized lobsters captured: between 60% (Nascimento, 2006) and

88% (Cruz et al., 2015) (Figure 5). Polovina (1991) concluded that if artificial shelters aggregate juveniles, thereby making them more accessible to capture, the exploitable biomass may increase as the size of the individuals at entry to the fishery decreases (growth overfishing). Cruz & Borda (2013) provided evidence that the increasing use of AS concentrates lobster biomass in a small area and increases catch rates at low-cost effort. However, with rational management practices and effective law enforcement, shelters could also be used to generate biomass agglomeration externalities favorable to lobster populations and fisheries.

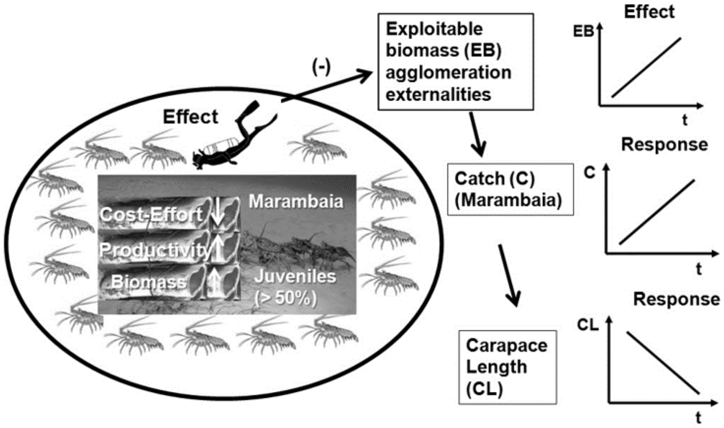

Figure 5. Summary of the impact of artificial shelters, called marambaias (Cruz et al., 2011), on spiny lobster (*Panulirus argus* and *Panulirus laevicauda*) fisheries on the Brazilian continental shelf. The cost-effort decreases (reduction of the fishing grounds) and increases in the stock productivity (kg/km²) and biomass (Cruz and Borda, 2013).

Deployed in shallow waters, the shelters are mostly colonized by juveniles and pre-recruits. Over time, the use of shelters generates exploitable biomass agglomeration externalities (effect) reflected at two levels of response: increasing catches and decreasing carapace length. Further, the AS generated environmental externalities, involve some perturbation of the benthic ecosystem (negative externality) because when they are deployed in the sea floor they affect the biota under the refuge (Cruz et al., 1986) and generate unmeasured negative externalities. However, they can generate a positive environmental impact on fisheries resources (positive externality) by increasing the growth rates, accessibility to the refuge (Cruz & Borda, 2013) and reduce predator pressure (Eggleston, 1991) on mainly exploited population, but also protected lobster population.

Management options and recommendations

To avoid this negative impact (sequential externality) on lobster resources, fishermen should reduce effort by abstaining from taking lobsters under the legal minimum size of 75 mm (CL). This would allow the average lobster size and weight to increase enough to obtain an annual harvest of approximately 4 200 t in Brazil (Cruz et al., 2013) and 1700 t approximately in Ceará state. Likewise, abstaining from capturing berried females and older lobsters (>135 mm CL) in deeper waters (50-100 m) would significantly increase the reproductive potential of the species (Cruz et al., 2014) and perhaps also increase the overall quality of the eggs in the population (MacDiarmid & Sainte-Marie 2006). Eventually, the risk of low recruitment and a fishery collapse would be averted. The strategy would generate a positive sequential externality in a competitive scenario. Cruz et al. (2013) suggested focusing management efforts on control measures and enforcement in order to increase lobster stocks.

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***In situ* monitoring of by-catch interactions in commercial rock lobster (*Jasus edwardsii*) fishing traps in South Australia**

From: Christina Asanopoulos, Adrian Linnane, Charlie Huveneers and Matthew Hoare

The South Australian rock lobster fishery (SARLF), a trap fishery predominantly harvesting the southern rock lobster (*Jasus* edwardsii), is South Australia's highest valued wild fishery with an estimated gross value production of AU$108.8 million in the 2013/14 financial year (EconSearch 2015). Previous assessments of the SARLF have shown that by-catch is dominated by finfish species (>90%) namely the blue throat wrasse (*Notolabrus tetricus*), horseshoe leatherjackets (*Meuschenia hippocrepis*), ocean leatherjackets (*Nelusetta agraudi*), and bearded rock cod (*Pseudophycis barbata*) (Brock et al. 2007).

Escape gaps were introduced into the Northern Zone rock lobster fishery (NZRLF) in 2002 as a management tool to reduce juvenile lobster mortality and finfish by-catch rates (Sloan and Crosthwaite 2007). Linnane et al. (2011) conducted a preliminary study on the effectiveness of escape gaps at reducing landed by-catch and found that the catch rate of key finfish species and undersized lobsters were significantly reduced by >50%. However, while the level of by-catch reduction has been estimated, the mechanisms underpinning how fish utilise escape gaps are still poorly understood.

The development and advances in baited remote underwater video systems (BRUVS) now allows for *in situ* observations to be recorded and sampling to be undertaken at depths not accessible to divers. In addition, BRUVS eliminate underwater dive survey biases such as avoidance or attraction. This study used GoPro™ technology to assess finfish species interactions with *in-situ* commercial rock lobster traps over three fishing seasons from 2010/11 to 2012/13 in the NZRLF and focussed on how primary by-catch species interact with escape gaps during the fishing process (Figure 1).

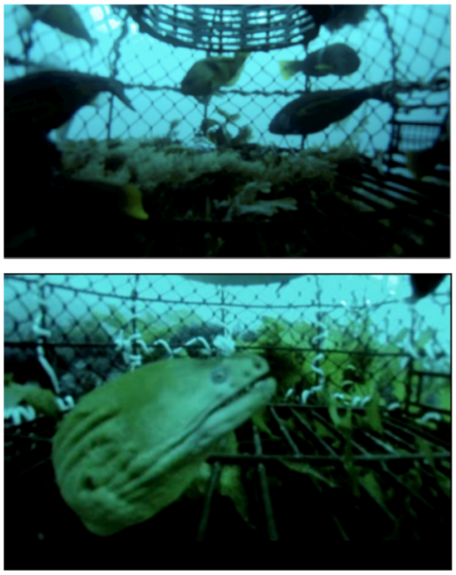

Figure 1. *In-situ* Go-Pro™ camera footage of species interactions with commercial rock lobster traps from the South Australian Northern Zone rock lobster fishery.

Twenty-two different species were observed entering commercial rock lobster traps, 20 of which were temperate reef finfish. Among those, various leatherjackets (*Meuschenia galii, M. scaber, and M. flavolineata*), perches (*Caesioperca lepidoptera, Hypolectrodes nigroruber, Othos dentex*), moray eel (*Gymnothorax prasinus*), and zebra fish (*Girella zebra*) had not been previously recorded during fisheries-dependent by-catch sampling (Brock et al. 2007).

The benefits of escape gaps were found to be dependent on the finfish families. Video observations showed that Monacanthidae species (*Meuschenia hippocrepis*, *M. freycineti*, *M. scaber*, *M.galii* and *M. flavolineata*) in particular, utilised escape gaps significantly more than any other method of trap exit (Figure 2).

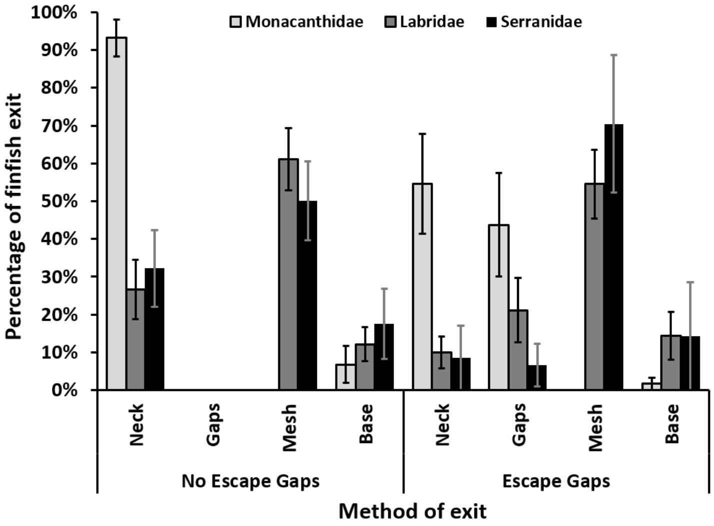

Figure 2. Method of exit in commercial rock lobster traps by major finfish families. Error bars represent standard error.

In the absence of an escape gap, the Monacanthidae also utilised the neck to exit. In contrast, the Serranidae and Labridae (*Caesioperca razor*, *C. lepidoptera* and *Notolabrus tetricus*) significantly used the base and mesh of the traps as both entry and exit methods. It is hypothesised that the different entry and exit strategies are related to body shape. The Monacanthidae species observed interacting with traps were mostly medium-sized fish (31–70 cm, depending on species) with deep rhomboidal and highly compressed bodies that are categorised as oblong to circular depending on species (Gomon et al. 2008). This body shape is not conducive to exiting through the base or mesh and requires a clear opening in the form of an escape gap or neck. Conversely, the morphology of Serranidae (26 cm) and Labridae (20–25 cm), is typically elongated and compressed (Edgar 2008), allowing them to use multiple means of exit and entry. Overall, this demonstrates that escape gaps provide a critical mode of exit for specific fish species that cannot utilise the base or mesh of commercial traps.

A number of additional interesting observations were made during the study, including differences in feeding activity times while inside traps in relation to various baiting methods (Figure 3). The three most commonly used baiting methods are (i) plastic bait baskets that involve small cylindrical holders that are secured to the side of the trap and highly restrict access to bait; (ii) wire bait baskets whereby bait is encased within 50 mm-wide mesh and access is less restricted; and (iii) uncontained toggled bait. Firstly, feeding activity was significantly lower in traps with escape gaps regardless of the baiting method. However, traps with plastic bait baskets also had low feeding activity even without escape gaps.

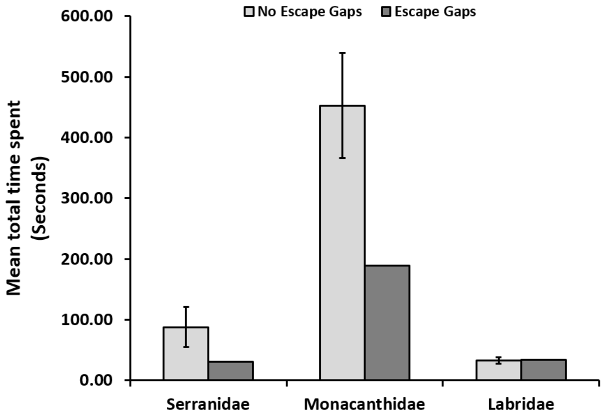

Figure 3. Mean number of finfish approaches and feeding activity per bait basket type in commercial rock lobster traps. Error bars represent standard error.

This decrease in feeding activity found within traps with escape gaps is most likely influenced by the reduction in residence time (Figure 4). In the absence of escape gaps, the Monacanthidae spend significantly more time in traps, reflecting the previous result that this group highly relies on escape gaps as a method of exit. Clearly, these results indicate that the use of bait baskets that restrict access to bait could prolong bait life with the likely benefit of increased catch rates of target species. Overall, this study confirms that escape gaps are an effective management tool for the SARLF in decreasing the by-catch of non-target species. It also highlights that emerging video technology, such as user-friendly GoPro™ cameras, can provide *in situ* high quality, robust data when sampling marine populations.

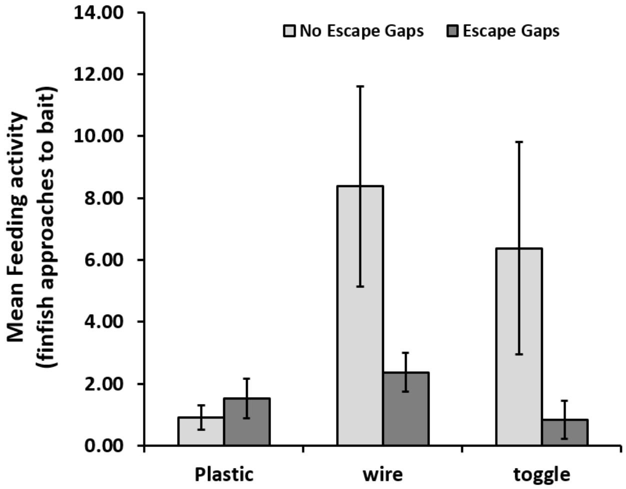

Figure 4. Mean time spent (seconds) per most common finfish families in commercial rock lobster traps. Error bars represent standard error.

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high quality, robust data when sampling marine populations.

Acknowledgements
The authors would like to thank the South Australian Northern Zone Rock Lobster Fisherman's Association for logistics support and allowing video deployments during commercial fishing operations.

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Handled with care: minimal impacts of appendage damage in the Tasmanian southern rock lobster fishery

From: Timothy Emery, Klaas Hartmann, Bridget Green and Caleb Gardner

The majority of undersize lobsters are returned to the sea undamaged by commercial fishers in the southern areas of the Tasmanian Southern Rock Lobster (TSRL) fishery. Where damage such as loss of legs did occur, the overall effect on growth and production was minor. These were the main results from research undertaken at the Institute for Marine and Antarctic Studies (IMAS), which examined the productivity and revenue loss to the TSRL fishery caused by handling damage to both undersize male and female lobsters from southern areas of the state below 42 degrees south.

Growth in crustaceans, such as lobsters occurs across a series of moults. Therefore, damage to appendages such as legs and/or antennae during fishing operations can reduce the growth rate of moulting lobsters because they expend energy resources regrowing appendages at the expense of increasing in size. This can result in lobsters remaining undersize for longer periods of time, reducing the exploitable biomass available for fishers and diminishing the total fishery revenue.

This study used 25 years of data from the IMAS tag-recapture database to estimate the effect of handling damage on the growth rate of undersize male and female lobsters. We limited our analysis to southern areas of the State below 42 degrees south, due to the large number of undersize lobsters handled and released in these areas, with corresponding concerns about the effects of damage. In fact, most of the undersize lobsters returned to the sea in the TSRL fishery came from southern (63%) rather than northern (37%) areas of the State. The large number of undersize lobsters in the southern areas of the State is due to high recruitment and slower growth, with many not even reaching the legal minimum size limit (105 mm for females and 110 mm for males). We estimated that the average annual number of undersize lobsters discarded per potlift in all southern areas of the TSRL fishery between the 2001 and 2010 fishing seasons was 5.77 ± 0.10 lobsters, with an estimated 4.22 ± 0.4 million lobsters discarded annually.

The majority of lobsters returned to the sea by fishers however, are undamaged (Figure 1). Only 6% and 8% of undersize male and female lobsters respectively, had forms of new damage and 14% in both sexes had forms of old damage. The proportion with new damage was size-dependent. Smaller lobsters were more likely to have new damage compared to lobsters closer to the minimum legal size, which were more likely to have old damage.

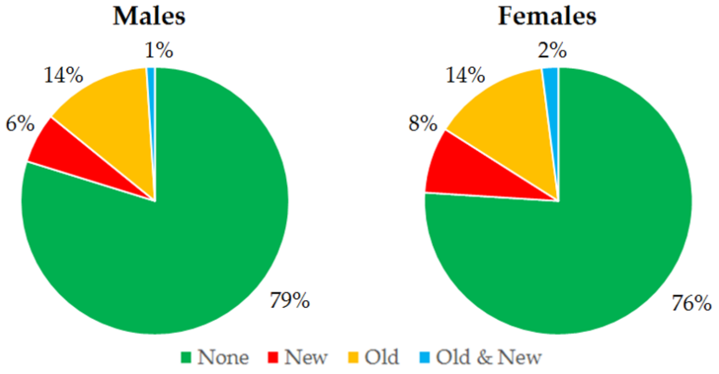

Figure 1. Proportion of undersize male and female lobsters in each damage category in the southern stock assessment areas of the Tasmanian Southern Rock Lobster Fishery.

Among undersize male lobsters, damage to antennae or legs was estimated to reduce annual growth by 7% (0 – 16% 95% CI). The annual growth of undersize male lobsters was reduced by 40% (24 – 57% 95% CI) when there was damage to both antennae and legs (Figure 2). This suggested that handling damage can lead to significant reductions in the annual growth rate of lobsters, highlighting the importance of good handling practices. We were unable to distinguish any impact of handling damage on the growth of undersize female lobsters, due to small growth increments caused by the cold water temperatures and the onset of sexual maturity.

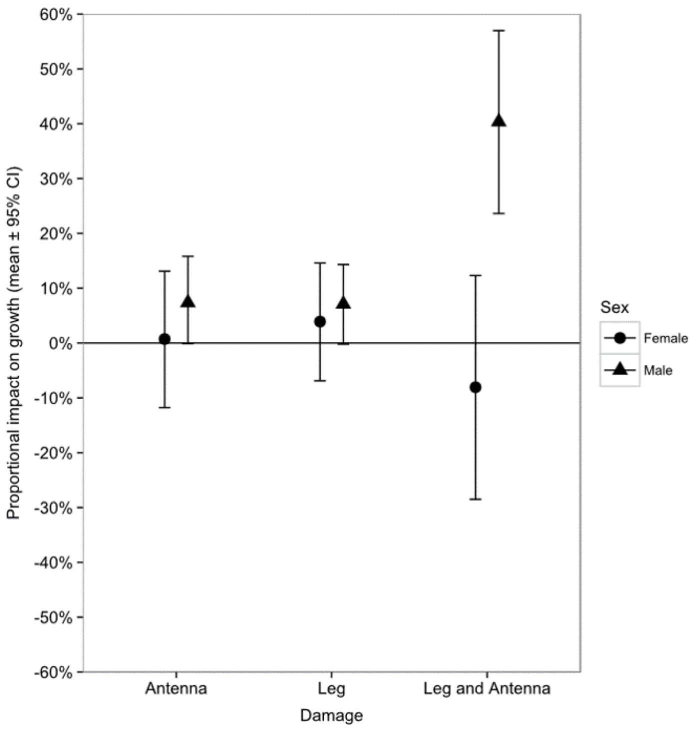

Figure 2. Proportional impact of different forms of new damage on the annual growth increment of undersize male lobsters from southern stock assessment areas of the Tasmanian southern rock lobster fishery.

To determine the impact of handling damage on overall fishery productivity we calculated the proportion of undersize male lobsters in each 5 mm size class that were discarded with particular types of damage and estimated the proportional reduction in growth in terms of lost kilograms. Due to the small proportions of undersize lobsters with forms of new damage, the estimated overall annual lost growth (i.e. productivity) to the fishery between 2001 and 2010 was 1.6 tonnes (1.4 to 1.9 tonnes, 95% CI) for undersize male lobsters. The equivalent loss to fishery revenue using an average of the processor price of rock lobster was AUD $72,905 ($62,023 to $83,788, 95% CI) after taking into account inflation standardised to 2010.

The total of 1.6 tonnes represented only around 0.1% of the total allowable commercial catch in 2010 and highlighted the overall benign nature of potting and efficient processing of undersize lobsters by fishers in reducing excessive amounts of handling damage in the TSRL fishery. Returning lobsters to the sea after each pot is hauled can prevent further damage to lobsters caused by other lobsters waiting sorting in pots or other sources of stress that can lead to loss of appendages. Southern Rock Lobsters are also quite resilient to damage compared to many other lobster species where limb loss is of greater concern.

As this study only examined the effects of handling damage from the Tasmanian commercial pot fishery, further research on the inshore hand-collection recreational fishery would be prudent. Research has shown that hand-collection methods increase the scale and extent of damage to lobsters relative to potting, which may be more pronounced among inshore areas, particularly among faster-growing undersize males.

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CONFERENCE UPDATES

The American Lobster in a Changing Ecosystem II: A US-Canada Science Symposium 2015

From: Andrea Battison

The PEI Fishermen’s Association welcomed scientists representing academia, government, resource managers, industry and fishermen to “The American Lobster in a Changing Ecosystem II: A US-Canada Science Symposium” to participate in scientific sessions on current research on the American and European lobster in Charlottetown, November 3rd– 6th, 2015. The inaugural Symposium was held in Portland, Maine, in November 2012.

The 2015 symposium welcomed 135 attendees from Canada (Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland), the USA (Maine, Massachusetts, New Hampshire, and New York), as well as from Norway, and the United Kingdom. They gathered to hear over 55 presentations and participate in moderated discussion groups focused on four themes examining the lobster and its environment in sessions spanning a progression of increasing scales: The Individual Lobster, Population Dynamics, Ecosystems & Food Webs, and The Business of Lobstering.

The invited plenary speakers, leaders in their respective field, provided excellent presentations to begin each session. These were: Paul Snelgrove of Memorial University, Rémy Rochette of University of New Brunswick, Susan Waddy Scientist Emeritus with Fisheries and Oceans Canada, Robert Fraser of Gardner Pinfold Consultants Inc., Patrice McCarron of Maine Lobstermen's Association, Craig Avery of PEI Fishermen's Association, and Stewart Lamont of Tangier Lobster Company Ltd.

The program saw presentations on lobster biology, physiology, invasive species, lobster health and disease, predictions on the effects of climate change and ocean acidification on lobster, and management strategies. The new theme of the 'Business of Lobstering' began with an overview of the industry (Canadian and American) from economic, harvester, and live shipper perspectives. This was followed by presentations on ghost gear retrieval, holding conditions, and the potential implications of the USA Marine Mammals Protection Act to the industry. The session wrapped up with an open panel discussion.

The symposium brought together representatives from government, industry, and the research sectors. Continuing discussions, interactions, and collaborative efforts should lead to a greater understanding and an enhanced value of this shared natural resource.

The complete scientific program, including abstracts, is available in PDF format online. https://www.regonline.com/builder/site/default.aspx?EventID=1670790. A special issue of the journal *Fisheries Research*, highlighting the symposium is anticipated to be published on or before November 2016.

For more information, contact Melanie Giffin at the PEI Fishermen's Association at commpeifa@eastlink.ca.

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ANNOUNCEMENTS

Hold the date!

Hosted by

1865 THE UNIVERSITY OF MAINE

Co-chairs
Richard Wahle, Ph.D.
University of Maine
&
Kari Lavalli, Ph.D
Boston University

Contact: 11thicwl@gmail.com

Stay tuned for more.

A Call to All Lobster Pathophiles!

(and other curious lobster scientists)

Donald Behringer PhD and Grant Stentiford PhD

It has often been noted that lobsters have comparatively few pathogens (Shields 2011), and although this may be true relative to other crustaceans, it may also partially result from a lack of comprehensive pathogen screening. Lobsters around the globe support valuable fisheries but other than a few notable cases (e.g., Epizootic Shell Disease in *Homarus americanus*, *Hematodinium* sp. in *Nephrops norvegicus*, PaV1 in *Panulirus argus*), the extent to which pathogens may be impacting their populations is largely unknown. This is particularly true for juvenile lobsters, which tend to suffer from a greater number of pathogens and a higher prevalence of infection, but are also often spatially segregated from adults, not present in fishery landings, or are otherwise cryptic (Behringer 2011). To begin filling this knowledge gap, we are collaborating with colleagues from around the globe to complete comprehensive pathogen screenings on their respective species. To date, we have samples (or committed collaborators) for *Panulirus argus* and *Panulirus guttatus* from Florida (D. Behringer), *Palinurus elphas* from the United Kingdom (G. Stentiford/K. Bateman) and Spain (D. Diaz), *Jasus edwardsii* from New Zealand (A. Jeffs), and *Panulirus penicillatus* from Ecuador (M. Brandt).

Dr. David Diaz dissects a specimen of *Palinurus elephas* (above). Juvenile *Palinurs elephas* from Spain (below).

If this project sounds interesting to you, we look forward to collaborating with you! We will supply you with a document describing how to collect, fix, and preserve the various tissues we need, and the data sheets to record information. If necessary, we can also ship you labeled sample tubes, tissue cassettes, and gloves. Due to shipping limitations you will need to provide the Davidson's seawater fixative for histology, 70% ethanol to store fixed histological tissues, gluteraldehyde to fix tissues for electron microscopy, and 95% ethanol to preserve tissues for molecular assays. We can work with you to acquire the necessary export/import permits for shipping the collected samples. To increase the odds that we capture any low prevalence pathogens, we hope to acquire 60-70 juveniles from each location, but more is always better. The pathogen screening results from all lobsters will be shared with collaborators, and collaborators will be included on all publications that include their species.

For questions or to initiate collaboration, please contact:

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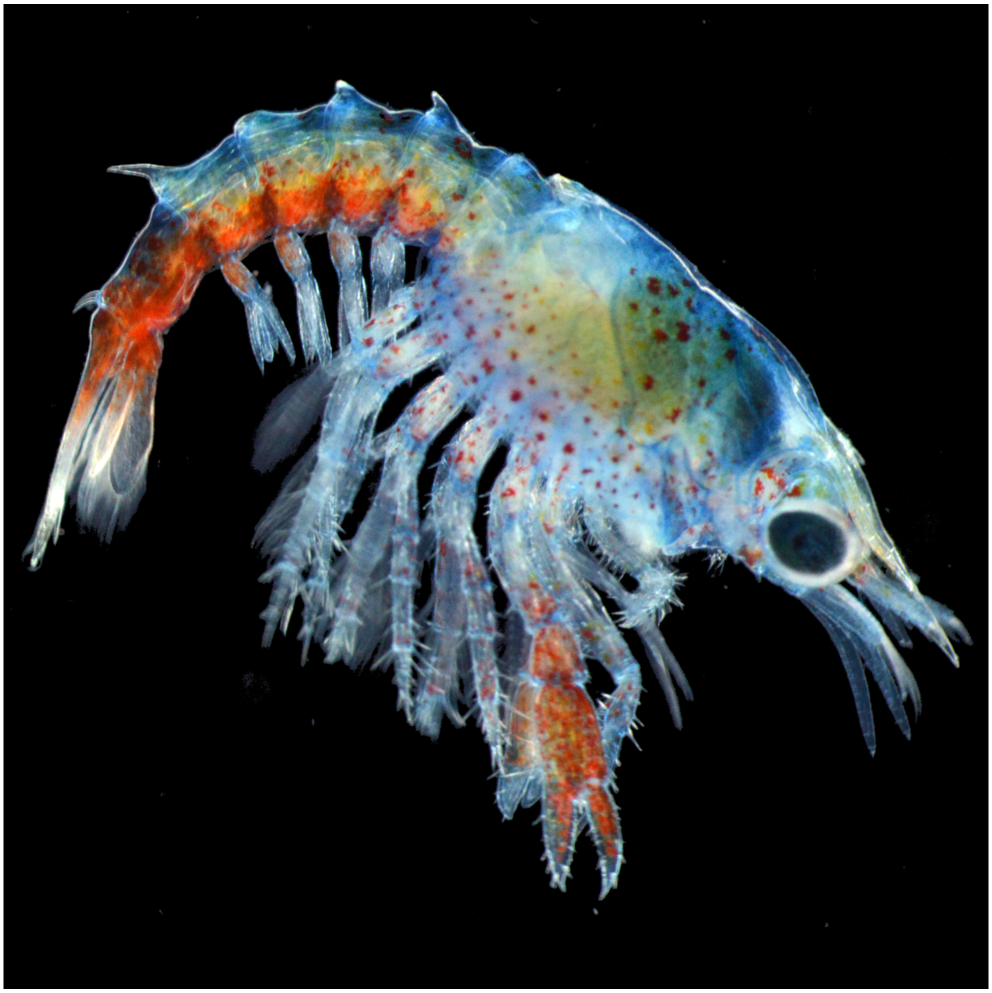
Shields JD (2011) Diseases of spiny lobsters: A review. Journal of Invertebrate Pathology 106:79-91.

And the winner is…



This image of a 3-week-old *Homarus americanus* larva was taken by University of Maine graduate student Jesica Waller. Jesica's research focuses on how American lobster larvae will respond to end-century ocean acidification and warming. The photograph was one of thousands Jesica took during her experiments to document larval development and won the "People's Choice Award" in the photography category of the 2016 Vizzies. The Vizzies is a contest held by the US National Science Foundation and *Popular Science* magazine to recognize beautiful visualizations of science across every form of media. Check it out at https://www.nsf.gov/news/special_reports/scivis/winners_2016.jsp

Vale Alan Pearce

8 November 1940 – 30 March 2016

The marine science community in Western Australia (WA) has lost a much-valued colleague in Alan Pearce who recently passed away. Alan made a highly valuable contribution to the understanding of the oceanographic environment in Western Australia and its effect on fisheries, particularly the western rock lobster (Caputi et al. 1996). His 1988 paper with Bruce Phillips identified the Leeuwin Current as the main cause of the annual variation in the puerulus settlement of the western rock lobster (Pearce and Phillips 1988). More importantly, from an oceanographic perspective, the paper was also the first that identified the link between the El Niño/Southern Oscillation (ENSO) in the Pacific and the strength of the Leeuwin Current off the west coast of Australia in the Indian Ocean.

Alan migrated to Australia from South Africa and worked as oceanographer with CSIRO, initially in Cronulla (near Sydney) and then at the Marmion Laboratory in Perth. After his 'retirement' from CSIRO, Alan joined the WA Department of Fisheries and made a valuable contribution in assessing the cause of the downturn in puerulus settlement in the late 2000s (de Lestang et al. 2014), identifying the lower west coast of Australia as a hotspot of warming temperatures (Pearce and Feng 2007) and describing the severe marine heat wave affecting WA during the summer of 2010/11 (Pearce and Feng 2013). During this period Alan also completed his PhD.

Alan will be greatly missed by the marine science community in Western Australia as he was generous with his time in explaining the oceanographic climate and he collaborated with many scientists over many years. On a personal note, I co-authored about 20 publications with Alan over 30 years and will miss his collaboration. Our condolences to his wife, Valerie, and children, Catherine and Steven and grandchildren.

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The
Lobster
NEWSLETTER

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The Lobster Newsletter is published electronically once or twice yearly.

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