VOLUME THIRTY DECEMBER 2017 NUMBER TWO

The Lobster NEWSLETTER

11th International Conference & Workshop on Lobster Biology and Management Portland, Maine, USA | June 4 – 9, 2017

(photo: RW)

ICWL Celebrates its 40th year!

From: Rick Wahle and Kari Lavalli

For the first time in US Northeast, the University of Maine and Boston University hosted the 11th ICWL in Portland, Maine, June 4-9th, 2017, on the shores of some of the most productive lobster grounds on the planet! We welcomed 257 attendees from 14 countries. The Holiday Inn by the Bay in downtown Portland proved to be the perfect central venue to take advantage of the city's many restaurants and waterfront activities.

This year marked the 40th anniversary since the first ICWL gathered a cozy group of 35 in Perth Australia in 1977. Bruce Phillips (Western Australia Fisheries) and Stan Cobb of (University of Rhode Island) organized that first meeting. It was their vision to assemble scientists, fishery managers and industry members with common interests in the biology and management of lobsters of all stripes. We stand on their shoulders, a legacy of prolific scientific contributions and a virtual army of students who have gone on make significant contributions in their own right. This year's ICWL convened in recognition of the career of Jelle Atema (Boston University) who attended that first ICWL and retires this year after a long, productive and even musical career! Most notably, a distinguishing feature of the 11th ICWL was the large

number of new and young faces, with a huge increase in the number of female researchers. This bodes well for the future of lobster research and this conference.

Introduced by UMaine president, Susan Hunter, US Senator Angus King officially opened the meeting. His remarks underscored the need for the scientists who study these important creatures to disseminate their findings to help guide policy makers in their work. "Tell us how climate change will affect local economies and what we as policy makers need to do about it!" was his plea to energize the research community.

During the week, five plenary speakers led off the major themes: Jelle Atema (Boston University) gave an overview of the arc of his career using the American lobster as a model in research on behavior and neurophysiology. Paulo Prodöhl (Queens College Belfast, Northern Ireland) used his work with the European lobster to illustrate the power of molecular genetics in fishery science. Malin Pinsky (Rutgers University, USA) used large-scale data sets on the distribution and abundance of benthic species, such as lobster, to illustrate the concept of "climate velocity," the rate of poleward range shifts of marine species in a warming ocean, and the consequences for coastal communities. Bob Steneck (University of Maine) warned of "the gilded trap" so clearly manifest in the economies of Maine and Atlantic Canada which rely so heavily on the lobster fishery. Finally, Mark Edwards (New Zealand Rock Lobster Industry Council) spoke to the benefits of industry-science-manager collaboration in ensuring the sustainability of their lobster fisheries. In the sessions that followed, we had 157 oral presentations and 49 posters. At this writing, some 47 manuscripts are in review for the conference proceedings to appear in a special issue of the *Bulletin of Marine Science* in the spring of 2018.

Although the week started on the chilly and gray side, the sun came out as if on command for the mid-week outings. Wednesday afternoon excursions ranged from kayaking in Casco Bay, to an LL Bean shopping spree in Freeport, to a Portland Brew Bus tour, a guided tour of the Ready Seafood Co. plant, and as far afield as a boat tour of UMaine's Darling Marine Center and Damariscotta River oyster farms further down the coast. Then, after Thursday's Industry Day, we capped off the evening by crossing Casco Bay on the ferry for a traditional outdoor Maine lobster bake on Peaks Island with volley ball to boot. The conference closed Friday evening with a farewell reception with savory appetizers and music at the Gulf of Maine Research Institute's waterfront facility in Portland.

Whether spiny or clawed, lobsters are iconic world-wide in no small part because of their commercial importance. While the large clawed lobsters may compirse the most productive lobster fisheries, the spiny and slipper lobster fisheries are by far the most widespread and diverse globally. Some have become poster-children in their parts of the word for changing marine ecosystems. Although we did not formally declare a theme for the 11th ICWL, if we did, we might call it *"Lobsters-at-a-Cross-Roads,"* because in 2017 we find ourselves at a cross-roads of unparalleled uncertainty. To be sure, climate change, overfishing and disease are central, long-standing issues. For the fishing industry, there is also the rising cost of the business of lobstering, and the opportunities and challenge of expanding global trade with Asia. In another corner we even see lobster as an invasive species! And now, at least in the United States, the very future of government support and leadership in scientific research on climate and fisheries is hanging in the balance. The uncertainties are also generational. As the fishing fleet ages, what does the future hold for the next generation? From Down-under to Downeast, it all begs the question, how do we confront the challenges facing the next generation of fishermen, scientists, and policy makers? Our hope is that at this 11th ICWL was a small step in addressing those

challenges. One advantage we should not underestimate: the iconic status of lobster as a powerful tool, a model organism, to study and communicate the prospects and perils of the new world we face.

The Holiday Inn by the Bay in downtown Portland proved to be the perfect centrally located venue to take advantage of the city's many restaurants and waterfront activities. Although the week started on the chilly and grey side, the sun came out as if on command for the mid-week outings. Wednesday afternoon excursions ranged from a Portland Brew Bus tour, a guided tour of the Ready Seafood Co. plant, and a boat tour of UMaine's Darling Marine Center and Damariscotta River oyster farms further down the coast. Then, after Thursday's Industry Day, we capped off the evening by crossing Casco Bay on the ferry for a traditional outdoor Maine lobster bake on Peaks Island with volley ball to boot. Jelle Atema even treated us to a lobster claw flute demo. The conference closed Friday evening with a farewell reception at the Gulf of Maine Research Institute's waterfront facility in Portland, sporting both savory appetizers and music.

We now look forward to the 12th ICWL in 2020 to be hosted again in Perth, Australia, this time by Nick Caputi of Western Australia Fisheries, and Matt Taylor of the Western Rock Lobster Council.

In closing, we express deep gratitude to our steering committee and subcommittees for all their hard work. Particular thanks are due to Curt Brown (Ready Seafood Co.) who, with the help of Patrice McCarron (Maine Lobstermen's Association), organized Industry Day and gave the tour of Ready Seafood's waterfront facilities. And a huge thank you to our sponsors, chief among them Maine Department of Marine Resources, Ready Seafood Co., New Zealand Rock Lobster Industry Council, Massachusetts Department of Marine Fisheries, the Northeast Regional Sea Grant Consortium, Boston University, the University of New England, and the University of Maine's Office of Research. And finally, we thank all of our section editors who have been working hard in ushering the submitted papers through the review process for our proceedings.

See you in Perth in 2020!

Many thanks,

Rick Wahle & Kari Lavalli
Co-chairs, 11th ICWL

Sunset over Casco Bay, Maine, from Peaks Island, the site of the 11th ICWL lobster bake. (photo: C. Davies)

11th ICWL SESSION SUMMARIES

ICWL Session: **Behavior, Neurobiology, and Behavioral Ecology**

Chairs: Ehud Spanier, Winsor Watson III, and Kari L. Lavalli

Behavior, Neurobiology, and Behavioral Ecology occupied a full day of talks and opened with a keynote address by **Dr. Jelle Atema** of Boston University's Marine Program. Jelle, who was one of the original attendees at the first ICWL, reminded the audience that, when considering the biology of any animal, it is important to understand its sensory systems and the environment in which those sensory systems must operate. As lobsters are aquatic animals, primarily active during dusk to dawn where vision will play less of a role, understanding how their senses of smell and taste work is critical to understanding their behavior. He presented a historical review of the work on the tuning properties of both "taste" (mouthparts and walking legs) and "smell" (antennules) of the American lobster *Homarus americanus*. He then reviewed work on odor plumes because the way odor disperses in the marine environment is important for understanding how the lobster may or may not detect chemical signals that would lead to changes in their behavior. This is not easy by any means because visualizing odor dispersal in nature is extremely complicated. Thus, experimenters should be cognizant of the environment in which they "test" for behavior, the odor signals that are present in those environments, and the possible dispersal of those odor signals, before trying to explain why a lobster behaved in the manner observed.

Jelle Atema demonstrates the lobster claw flute. (photo: RW).

Following the keynote address, the first session focused on Behavior and Neurobiology. **Chuck Derby** (Georgia State University, USA) contrasted the chemoreceptor proteins making up receptors

in vertebrates and invertebrates, and then described how chemoreception in crustaceans is broken into olfaction and distributed chemoreception, each of which is mediated by specific sensory sensilla, and each of these sensilla are tuned differently. Both olfactory and distributed chemoreception sensilla detect amino acids, amines, nucleotides and other chemicals in food; however, only olfactory sensilla are tuned to signals important for conspecific signaling (mating, alarm cues, aggregation, aggression, etc.). This difference appears to be the result of antennules (the olfactory organ) having many more ionotropic glutamate receptors (IRs) than the walking legs. **Robert Major** (University of Aukland, New Zealand) presented laboratory work on how New Zealand scampi, *Metanephrops challengeri,* respond to different bait odors and odor regimes (laminar vs turbulent flow). Conclusions from these studies suggest that scampi are highly efficient at locating odor sources in turbulent flow, that they prefer oily fish, and that amino acid profiles are more important for search behavior than concentrations. **Erica Ross** (University of Florida, Gainesville, USA) examined the effects of extreme environmental events that alter salinity levels, temperature, and/or pH on "typical" Caribbean spiny lobster *Panulirus argus* aggregation behavior. In experiments contrasting normal seawater conditions with high salinity, high pH, or high temperature, spiny lobsters decreased their sheltering behavior with healthy conspecifics, did not significantly avoid lobsters infected with PaV-1, and did not avoid competitors. She proposed that the altered behavior may be due to changes in the chemoreception abilities of lobsters exposed to extreme environmental conditions.

Following the focus on chemoreceptive abilities of lobsters, the session shifted to an understanding of movement patterns of lobsters. A number of talks focused on the use of ultrasonic telemetry to track the movements of lobsters. **David Diaz** (Instituto Español de Oceanografia,, Spain) presented acoustic tagging data on the elusive Mediterranean slipper lobster, *Scyllarides latus*. His goal was to try to tease apart why these lobsters disappear from monitoring studies in winter months. The data obtained indicated that rather than moving into deeper waters during winter months, slipper lobsters remained in their home range, but moved deeper into cave shelters, perhaps in an effort to exploit the higher temperatures within these caves. They then reduced activity patterns to a torpor-like state. He suggested that incorporating caves into management areas and protected areas is important for conserving the species. **Steve Jury** (Saint Joseph's College, USA) argued that accelerometers, if properly calibrated via laboratory studies on individual species, could be used to simultaneously capture both the timing of activity (percent of time active during day and night periods) and intensity of activity (distance travelled). He then demonstrated with the American lobster how one could use accelerometers and video data to calibrate accelerometer data and then used this calibration to determine activity patterns and distance moved of lobsters in the field. Data recovered with this technique corresponded well with other published methods. Acoustic tags with passive telemetry receivers set out in a variety of grids (tracking and emigration) were used by **Rodney Bertelsen** (Florida Fish and Wildlife Conservation Commission, USA) to investigate the movement patterns and sheltering preferences of various life-stages of Caribbean spiny lobsters. Juveniles

tended to have short-distance movements around their dens, with only a few individuals changing their locations and denning areas. In contrast, while adults had clear activity and movement patterns, as well as homing ability back to dens inhabited the previous day, they also changed shelters frequently and therefore had much more random movements, which contrasted with sub-adults that seemed to be more unidirectional in their movement patterns. Finally, berried females conducted multi-day reproductive movements to deeper waters to release eggs and then returned to their dens. **Ehud Spanier** (University of Haifa, Israel) closed the session presenting the first known stranding data on slipper lobsters, *Scyllarides latus*, and suggested that such strandings are

Ehud Spanier dismantles his dinner.(photo: RW)

rare as they require a severe storm event that occurs during the onshore movement of slipper lobsters when their ability to cling to inshore, complex habit is reduced.

The Behavioral Ecology session continued the focus on lobster movements, then shifted to substrate choices and predation risks. **Eric Bjorkstedt** (NOAA Southwest Fisheries Science Center, USA) opened the session by examining how an individual based model of *Homarus americanus* movement, tied to bathymetry and bottom temperature, could be used to infer the movements of two ovigerous female lobsters that had previously been fitted with archival tags for ~ 10 months during egg brooding. The model generated thousands of potential paths that were ranked by how well a particular path followed the tagged lobster's daily depth and temperature exposure and therefore, under the proper circumstances, could be useful in inferring movements of marine organisms without having to track each individual. **Patricia Hanley** (University of New Brunswick, Canada) used this individual based model, combined with archival depth/temperature tags placed on two ovigerous Americanlobsters, to predict the rules that influence lobster movements. The model closely followed the actual movement data and demonstrated that female lobsters move to deeper waters when shallow waters begin to cool during brooding, most likely to increase growing degree days. **Josh Carloni** (New Hampshire Department of Fish and Game and University of New Hampshire, USA) presented data showing that American lobsters, like spiny lobsters, appear to move to new locations right before their eggs hatch. In the case of American lobsters, they move to deeper water, where the prevailing currents are also a bit stronger, presumably so their larvae are released in an area that facilitates dispersal and survival. **Martial**

Laurans (IFEMER, France) used traditional tag/recapture methods to demonstrate that once *Homarus gammarus* reach sexual maturity, they are capable of some very long migrations along the coast of France. Interestingly, like many American lobsters that have been tracked in waters off New England, USA, most of them move in the same direction as the dominant prevailing currents (west in France, south in NE). **Jason Goldstein** (Wells National Estuarine Research Reserve, USA) used traditional mark-recapture methods as well as temperature and depth data loggers placed on animals in the field and activity loggers placed on laboratory specimens in running wheels to demonstrate that slipper lobsters, *Scyllarides latus*, increase their expression of daily activity patterns and movements in response to increases in thermal gradients. These movements may result in lobsters leaving inshore regions for more stable, cooler temperatures in deeper waters during the hot summer months.

While adult American lobsters are capable of moving long distances to their preferred habitats, juvenile lobsters do not have this luxury and, despite preferences for settling in cobble, it is relatively sparse in some areas compared to sand and mud. **Kristin Dinning** (University of New Brunswick, Canada) presented data suggesting that even though the density of juvenile lobsters is generally lower on sand/mud bottom, these habitats should not be ignored in estimating populations of juvenile lobsters because those substrates are often the dominant habitat in some areas. Hence, when determining benthic recruitment, large densities of YOY on sparse cobble habitat may be equivalent to small densities of YOY on extensive mud/sand flats. Furthermore, density of juveniles on mud/sand increased at night and also was higher in the summer than in the fall, reflecting both diel and seasonal behavioral changes.

The final session focused on predation and social behavior. **Graham Sherwood** (Gulf of Maine Research Institute, USA) presented two mesocosm studies examining how lobsters alter shelter use when predators are present. One of these studies was in a large lobster pound where Atlantic cod *Gadus morhua* were introduced; here the cod influenced the amount of time sheltering, as well as the percent of time spent foraging. In a smaller mesocosm study, both cod and sea raven *Hemitripterus americanus* increased the amount of time spent sheltering, but striped bass *Morone saxatilis* did not have an effect on lobster behavior. This suggests that responses to predators might be more dependent on the predator's feeding modality rather than by its mere presence. **Marissa McMahon** (Northeastern University, USA) examined how range expansion in predators may have profound effects on lobsters, given that exposure history may be required for appropriate behavioral responses in the presence of predators. She exposed three sets of lobsters (Massachusetts, mid-coast Maine, downeast Maine) to black sea bass (*Centropristis striata*); two of these sets of lobsters had prior experience with the predatory fish while one has not had much opportunity to interact with them. Both Massachusett and mid-coast Maine lobsters significantly increased shelter usage, decreased foraging trips, and decreased prey handling time in response to the presence of black sea bass, but downeast Maine lobsters did not. This study suggests that as predators begin moving due to warming waters, lack of familiarity with such predators may significantly impact lobster populations. **Andrew Allyn** (Gulf of Maine

Research Institute, USA) expanded on shifting predator distributions by modeling expected predator shifts for predators ranging from traditional groundfish to mid-Atlantic elasmobranchs. Such shifts could have important implications for how natural mortality is calculated in stock assessment models. **Kaitlyn Lowder** (University of California – San Diego, USA) added an additional wrinkle by presenting a study on various regions of the exoskeleton (dorsal carapace, rostral horn, antenna base) of the California spiny lobster *P. interruptus* that provided baseline data on microstructure, composition, and hardness. She then subjected lobsters to low pH conditions that were either stable, or fluctuated greatly, or had low amounts of fluctuation. Her preliminary data suggested that conditions of fluctuating but low pH would result in a weakening of these regions of the carapace and thus would affect the lobster's ability to withstand attacks from predators.

The final two talks concerned the Caribbean spiny lobster. **Michael Childress** (Clemson University, USA) presented data showing that conspecific attraction has declined in Florida Bay. Laboratory studies suggested that this was not due to changes in aggression levels, frequency of den sharing, or substrate type. Field studies suggested that substrate composition was more important than shelter or conspecific density and that den fidelity played a strong role rather than a preference for sheltering with conspecifics. Thus, while conspecific attraction might be declining, other factors, especially den fidelity, may cause lobsters to aggregate at typical frequencies seen over the past several decades. **Enrique Lozano-Álvarez** (Universidad Nacional Autónoma de México, Mexico) presented data looking at the nutritional consequences of coral reef degradation on two species of spiny lobster: one an obligate reef dweller, *P. gutatus*, and the other a habitat generalist, *P. argus*. In comparisons between two reefs, one degraded and one architecturally complex, lobster blood refractive indices, hepatosomatic indices, and weight/CL ratio did not differ for the reef obligate, but stable isotope values ($\delta^{13}C$ and $\delta^{15}N$) did. The obligate reef dweller incorporated more high value foods in the degraded reef than in the complex reef, likely to compensate for the degradation. In contrast, for the habitat generalist species, none of the variables differed between the reefs, which is likely a result of greater foraging distances.

Experimental lobsters. (Photo: RW)

What are the next questions? While many of the presentations investigated why and when lobsters move, this is an area that deserves more attention. We need to know more about the environmental cues that lobsters can detect and how they respond to them. We have a fairly good understanding of this for temperature, but this knowledge is only based on studies with mature lobsters and not juveniles or reproductive females. Moreover, we know little about the ability to sense changes in water depth or magnetic fields, both of which could clearly play an important role in movements. We also need to have a better of understanding of how lobsters respond to predators – those with

which they are familiar and those that they have never seen before – so that we can better predict the impacts that range expansion of predators will have on lobster populations. Finally, understanding how habitat degradation might affect different lobster species is important as it may have consequences for lobster foraging behavior that could also affect movement patterns and dispersal patterns.

What do policy makers need to know? First, despite all we know about various lobster species, we still have a difficult time assessing their abundance, in part, because they are so mobile. If we can't track changes in the population, we cannot adequately manage lobster fisheries. And, in some cases, we may make unsupported assumptions about how we should monitor abundance, as illustrated by Dinning and Rochette with the American lobster. Studies such as theirs need to be integrated into existing monitoring programs. Moreover, population trends will be strongly influenced by behavioral responses to climate change, as illustrated by Ross and Behringer with the Caribbean spiny lobster suggesting that alterations in pH and salinity may have impacts for the proper functioning of chemoreceptors that are so important in lobster behavior. From another perspective, McMahan and Grabowski suggested that naïve lobsters may not identify or properly respond to novel predators extending their range as the oceans warm. Therefore, policy makers need to understand that climate change could lead to dramatic alterations in the distribution and behavior of lobsters which, in turn, could have serious socioeconomic repercussions. Finally, the best way for policy makers to make sure that our fisheries remain sustainable is to provide the support necessary to do the science required to inform the people who manage the fisheries. Importantly, this includes training the future scientists who will need to carry on this work.

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ICWL Session: Diseases & Parasites

Session chairs: Grant Stentiford, Donald Behringer and Charlotte Eve Davies

This year, the diseases and parasites session had 22 presentations in total (17 talks and 5 posters). Although we had a nice diversity of presentations representing pathogens and lobsters from around the world, it was not surprising, considering the location of this 11th ICWL, that Epizootic Shell Disease (ESD) dominated.

We kicked off the week with **Joseph Kunkel** of the University of New England, USA, who introduced us to new analyses for carapace structure, synthesis and development throughout the moult cycle, demonstrating how fundamental studies will continue to play a key role in deciphering ESD in the American lobster *Homarus americanus*. **Britnee Barris** from Virginia Institute of Marine Science (VIMS), USA, continued the theme of ESD

progression with a temperature based study and **Melissa Hoffman** of the University of Rhode Island, USA, explored the novel possibility of the use of probiotics to manage carapace lesions in aquarium animals. The session continued towards microbiome-based analyses of ESD, with both **Michael Tlusty** of the New England Aquarium (now of UMass Boston), USA, and **Jeff Shields** from VIMS both using high-throughput sequencing approaches to look at the progression of the syndrome. The concept of the pathobiome seems fitting for the application to the ESD phenomenon - here, a consortium of microbes, possibly including both prokaryotes and eukaryotes exploit the altered immune status, environment condition, or both to create the lesions observed. The jury is still out on the 'causative agent' being *Aquimarina* "*homaria*".

Nice bibs! Don Behringer, Grant Stentiford, and Carlie Daniels. (photo: C. Davies)

Other microbiome work presented by **Michelle Pond** from Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK, on European lobster *Homarus gammarus*, highlighted the need to consider microbiomes from the 'inside' and not just the outside, and a novel microsporidian (and possible virus) in this species. This work was supported by **Corey Holt**, also of CEFAS, who discussed new tactics for the study of syndromes based on the metagenomics of gut microbes, which could provide critical insight into etiology.

Fraser Clark of Mount Allison University, Canada, continued the theme of high-throughput sequencing, this time applying it to the testing of potential biomarkers which could aid in post-capture holding success of *H. americanus*, and in exploring its immune response to a variety of pathogens, from the scuticociliate *Anophryoides haemophila* to the causative agent of gaffkemia *Aerococcus viridans* var. *homari*. **Samantha O'Gorman**, University of Maine, USA, also touched on gaffkemia and the effects of its *absence* in Maine.

It is clear that high quality phylogenetic analyses (based on full pathogen genomes) are improving our ability to understand disease interactions with the host with development of sensitive and specific diagnostics that can be applied to field/lab studies, with the full description of PaV1 from the Caribbean spiny lobster *Panulirus argus* presented by **Abigail Clark** of the University of Florida, USA. Abigail also discussed the viability of the virus in seawater, and the theme of PaV1 was continued by **Charlotte Davies** from the National University of Mexico, Puerto Morelos, who talked of untangling the effects of size and habitat on disease prevalence.

Emerging diseases were also reported – including idiopathic blindness in *H. americanus*, with presentations from **Mitch Hatzipetro** from the University of Rhode Island, and **Addison Ochs** of VIMS talking about rapid diagnostics and the distribution

of this little-known disease. **Hamish Small**, also of VIMS used transmission electron microscopy and molecular analysis to identify a microsporidian parasite of the Caribbean spiny lobster and **Andrew Jeffs** talked tail-fan necrosis in the southern rock lobster, *Jasus edwardsii.*

It was noted that the utilization of long term datasets (e.g., linking climate change, disease, etc.) are critical for providing definitive statements on emergence/spread of conditions such as ESD. **Maya Groner** of VIMS used 35 years of mark recapture data to show what is possible, but unfortunately funding for monitoring is difficult to secure resulting in a paucity of well-conducted, long term studies focused on health. Better integration of fishery and health monitoring could be a way around this. Future focus on good diagnostics/pathology/case descriptions will continue to be at the centre of rapid response and common language when discussing and reporting disease. This also seems to be important in consistent discrimination of syndromes like the emergent ESD from other 'black spot' and necrosis observations in crustaceans.

In conclusion, it seems that the American lobster fishery in the US may be a 'perfect storm' for disease emergence, with high density, a warming sea, and lack of predators. Considering the risks to valuable crustacean fisheries around the globe, there should be more focus on training the next generation of pathologists able to recognize and report diseases. For policy makers, it is important that marine diseases are taken into account in legislation. Climate change and warming oceans could have a huge effect on the abundance and distribution in marine diseases, as is already being documented. In the US steps are already being taken with the recent introduction of the Marine Disease Emergency Act of 2015, but only time will tell if other countries follow suit.

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ICWL Session: Population Genetics & Connectivity

Chair: Laura Benestan

Keynote speaker, **Paulo Prodöhl** (Queens University Belfast, Northern Ireland), set the stage for the theme of population genetics and connectivity. He presented results of his groundbreaking use of genetic tagging by microsatellite DNA profiling to evaluate the stock enhancement benefits of protecting reproductive female *Homarus gammarus* through V-notching. In a partnership with a local fisherman's cooperative that started in 2003, Prohdol's team genetically tagged more than 26,000 berried lobsters. By comparing the maternal genetic profile with that of the offspring, they inferred the paternal contribution by subtraction. This approach allowed them to quantify the

direct contribution of the released V-notched females to the population.

The subsequent session comprised seven oral presentations by a group of worldwide researchers (Europe, Oceania, and North America). The session started broadly, with a talk by **Benestan *et al.*** (Laval University, Canada) introducing the use of powerful genomic tools to reveal patterns of gene flow (*i.e.*, genetic connectivity) and local adaptation in marine species, with the aim of resolving fisheries-specific questions. Indeed, their work demonstrated how the use of next generation sequencing tools, with thousands of single nucleotide polymorphisms (SNPs) genotyped, could detect fine-scale genetic structure that was not previously described using few genetic markers, in American lobster (*Homarus americanus*) populations along the Atlantic coast of North America. This work led to the identification of 11 genetic units within two larger regions that may represent demographically isolated populations, and help delineate appropriate fishery management units. Using more than 10,000 SNPs allowed the origin of an individual from an unknown region to be powerfully determined, which suggest that these markers may provide a future new traceability tool for detecting fishing fraud such as the genetic tests developed for the Atlantic cod though the work of the geneticist **Einar Nielsen** (Denmark). This study also elucidates that adaptive genetic variation in this species is linked to minimum sea surface temperature, which suggests that climate change may have a strong influence on it in the future. During the talk, new conceptual and technological approaches were presented, with an emphasis on the necessity of combining evolutionary biology and marine ecology tools to pave the way for the widespread integration of genomics into fishery management programs.

From left, Paulo Prodohl, Ann-Lisbeth Agnalt, Ellen Grefsrud, and Suzanne Eriksson chat at breakfast. (photo: RW)

The second oral presentation by **Rougemont *et al.*** (Laval University, Canada) aimed to compare the population genomic inferences obtained using four different genomic protocols: Restriction-site associated DNA (RAD-seq), Restriction-site associated DNA combined with a capture method (Rapture), a Genotyping-By-Sequencing method (GBS), and a pool sequencing strategy (Pool-seq). These protocols may differ in their power to resolve the weak population structure common in the vast majority of marine species. They may also differ in the cost of sequencing, which is highly correlated to the number of individuals used. Thus, protocols such as RAD-seq and GBS are costlier than a Pool-seq approach since individual sequencing is not required for the latter. On the other hand, preserving individual-level information may be critical for inferring accurate population genetic structure in non-model marine species, where genetic differentiation tends to be weak. This study evaluated this risk by presenting the advantages and ability of each method to give accurate population genetic inferences

in four American lobster populations in eastern Canada.

Two large-scale studies investigated the genetic structure and connectivity pattern of the European lobster (*H. gammarus*) in the third and fourth oral presentations. The presentation by **Jenkins *et al.*** (University of Exeter, United Kingdom) used RAD-seq technologies on 55 individuals from across Europe to test whether SNPs can help delineate fine-scale population structure. Multivariate analyses on RAD-seq datasets revealed a fine-scale genetic structure, with three genetic units identified as the Atlantic, Skagerrak, and Mediterranean locations. Then, the top 95 SNPs showing the highest genetic differentiation among these three genetic units were selected to create a panel of SNPs that captures any population structure detected. This panel was then used to explore the assignment success of individuals back to their location of origin and also give managers the opportunity to assess genetic structure of thousands of samples across Europe and over time. In the fourth oral presentation by **Dahle *et al.*** (Institute of Marine Research, Norway), 12 polymorphic microsatellite loci were used to monitor the population structure of Norwegian lobster populations and assess the stability of their genetic structure over time. Genotyping more than 2000 individuals along the Norwegian coast revealed a high and significant genetic differentiation between southern and northern locations. This differentiation is in agreement with biological data showing large differences in size distribution and size at maturity.

Genomic population studies of the eastern rock lobster (*Sagmariasus verreauxi*) by **Woodings *et al.*** (La Trobe University, Australia) aim to enhance our understanding of the connectivity among New Zealand, Australia, and Tasmania. Indeed, the fishery for this species is currently managed with two management units corresponding to New Zealand and Australia, whereas connectivity between these areas is not well understood. Previous work suggested genetic homogeneity that may results from the long planktonic phase of *S. verrauxi* (*i.e.*, 8-12 months), but this needs to be reassessed with new genomic tools. Using double-digest restriction-site associated DNA (ddRAD), **Woodings *et al.*** identified 667 SNPs genotyped in 90 lobsters that were putatively neutral and 29 putatively under selection. They found genetic homogeneity among the three locations and comparable genetic diversity using neutral markers, whereas outlier SNPs highlighted selective genetic differentiation among the three regions. Their results underline the use of using outlier SNPs to improve the delineation of relevant conservation units for this fishery.

Following the work of **Benestan *et al.***, the fifth oral presentation by **Dorant *et al.*** (Laval University, Canada) presented a future population genomic study on American lobster populations, which will genotype more than 4,000 individuals in 80 locations. This large sampling design encompassing locations to be sampled in different years will shed light on the temporal and spatial stability of the genomic structure of this species along its entire range. In addition, the study aims to assess the correspondence between the genetic structure observed and the current management units. Therefore, 82% of Canada's Lobster Fishing Areas (LFA) will be sampled in order to provide fisheries management recommendations for this species at a large scale. Since thousands

of individuals will be analyzed, a new RADseq protocol has been developed to target 10,000 SNPs in each individual and then minimize sequencing cost.

Session chairs give their summaries in plenary. (photo RW)

Using genomic tools for fishery management without having sex information may lead to false interpretation of population structure and thus potentially erroneous management recommendations. While genetic differentiation is expected to occur among subpopulations from ecologically divergent locations, regardless of sex, the analyses by **Benestan *et al.*** of inshore *versus* offshore *H. americanus* populations along the United States coast showed a significant difference in genetic structure estimates between female and male lobsters. This significant genetic structure only resulted from a few sex-linked markers, which belong to known genes involved in molecular pathway linked to sex determination. This presentation fittingly closed the session by showing how the use of genomic tools, which are very promising, as shown by the first presentation, need to be analyzed with caution.

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ICWL Session: Reproductive Biology

Chair: Ann-Lisbeth Agnalt

A total of seven oral and three poster presentations were given, covering five species and several scientific questions. **Gaya Gnanalingam** (Old Dominion University, USA) addressed the importance of conserving large female Caribbean spiny lobster (*Panulirus argus*) as a management measure to benefit from the disproportionately large reproductive contribution of these individuals. Laboratory studies showed that offspring from larger females had better larval survival and growth than those from smaller adult females. **Martial Laurans** (IFREMER, France) presented data showing that up to 90% of legal size European lobster (*Homarus gammarus*) females off the Atlantic coast of France produce eggs every year.

The rising incidence of American lobster (*H. americanus*) found on the wrong side of the Atlantic, including ovigerous females with hybrid clutches, has accelerated the need to assess the implications for the European

lobster and its fishery. **Susanne Eriksson** (University of Gothenburg, Sweden) addressed the question what happens if hybrid larvae of American lobster females hatching in Scandinavian waters. Common-garden experiments with hybrid larvae in competition with European lobster larvae showed similar survival and growth rates. DNA-analysis were made to verify species identity. Upper and lower limits for salinity and temperature tolerance were also investigated and similar thresholds were found for hybrid, American and European larvae. **Ann-Lisbeth Agnalt** (IMR Norway) presented the results of studies of the survival, growth and maturation of a hybrid juvenile offspring from an ovigerous American lobster female captured off Norway in 2009. In conclusion, all studies made so far show that offspring from ovigerous American females survive, grow and mature in Scandinavian waters, and thus do impose a real threat to European lobster.

In the American lobster, management regulations protecting females have raised concerns of sperm limitation because of the selective harvesting of reproductively competent males. Findings of ovigerous females with reduced clutch sizes could indicate reproductive deficiencies. Three presentations were given on this issue (two oral and one poster). **Tracy Pugh** (Massachusetts Division of Marine Fisheries, USA) presented a method to quantify sperm content in mated females, a first step towards quantifying male reproductive contribution. Laboratory mating experiments revealed incomplete fillings of the seminal receptacle of some of the females. **Benjamin Gutzler** (University of New Hampshire, USA) presented in his poster several methods for quantifying sperm per ejaculate, including amount of DNA. All methods were convincing and should be further elaborated. **Feng Tang** (University of New Brunswick, Canada) focused on females and oocyte limitation. Comparing field data with experimental studies, looking at total potential fecundity compared with actual larval production, lead her to the conclusion that there is nothing wrong with the females. **Julien Gaudette** (Fisheries and Oceans Canada) presented a new methodology developed in fish to estimate ovarian fecundity measuring average oocyte diameter and ovary wet weight. A high correlation was found, thus showing the potential for this method. **Tammy Bo** (University of New Brunswick, Canada) refined the Perkins Eye Index – an indicator of lobster embryonic development - to predict time of hatching at different temperatures.

New Zealand scampi (*Metanephrops challengeri*) is a deep-water species harvested around New Zealand. Little is known of its general biology. **Alaric McCarthy** (Cawthorn Institute, New Zealand) compiled 30 years of data to estimate regional differences in size at maturity based on allometric changes in abdominal width in females and claw morphology in males.

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ICWL Session: Recruitment Processes, Population Dynamics & Connectivity

Chairs: Brady K. Quinn and Mark Butler

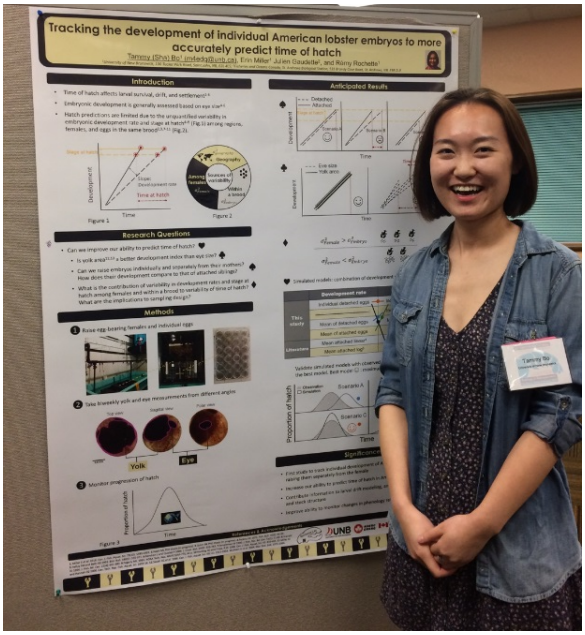
Presentations in the 11th ICWL's sessions on Recruitment Processes (7 talks) and Population Dynamics & Connectivity (7 talks and 6 posters) focused on the ecology of early lobster life stages, particularly the settling stages that make up the earliest recruits to benthic populations. A common theme was tracking changes in lobster recruitment over time, and many presentations discussed monitoring programs used to do so. These included the American Lobster Settlement Index (used by **Shank & Wahle** and **Quinn** et al.), juvenile and sublegal trap surveys (talk by **Thompson et al.**, poster by **Baker et al.**), and various spiny or rock lobster settlement collector time series (talks by **Liggins et al.**, **Denham et al**., **Yao et al.**, posters by **Meerhoff et al.**, **Woodings et al.**, and 2 posters by **Diaz et al.**). These programs were used for forecasting fisheries recruitment, demonstrating effectiveness of stock conservation efforts, validating models of larval dispersal, and assessing factors leading to interannual changes in recruitment.

A talk by **Carloni** (New Hampshire Fish & Game Department, USA) **and Wahle** (University of Maine, USA) introduced the "Great Disconnect" observed recently in the Gulf of Maine between high numbers of adult and sublegal American lobsters (*Homarus americanus*) and high egg/larval production versus low numbers of settling stage IV lobsters. They examined a plankton time series from the 1980s onward and confirmed high recent stage I abundances but low stage IV numbers, implying some source of mortality in the plankton limiting recruitment to the settling stage. Two talks examined other aspects of this disconnect: **Thompson et al.** (Maine Department of Marine Resources, USA) looked at whether increased abundances of sublegal lobsters could be due to increased catchability of this stage in warming waters; and **Shank** (NOAA Northeast Fisheries Science Center, USA) **and Wahle** tried to incorporate settlement index data and post-settlement processes into stock assessment models to explain the disconnect and predict its future impacts. Declining settlement has worrying implications to the future of lobster stocks in Maine, but more study is needed to confirm this pattern and its causes (e.g., see talk by **Goode et al.** in the Climate Change session).

Three talks focused on processes impacting metamorphic and settlement success of spiny or rock lobsters. **Briones-Fourzan et al.** (Universidad Nacional Autonoma de Mexico) assessed the presence of late-stage phyllosomas and pueruli of two Caribbean spiny lobsters (*Panulirus argus* and *P. guttatus*) in the plankton. They identified the Yucatan current along Mexico's shelf break as a likely location of metamorphosis, where hydrodynamics concentrate food for the late-stage phyllosomas to build up reserves. Two related talks focused on the buildup and use of reserves in pueruli of Australian rock lobsters (*Sagmariasus verreauxi*, *Jasus edwardsii*). **Jeffs et al.** (University of Auckland, New Zealand) examined energetics of rock lobster pueruli arriving at NSW, Australia and found that nutritional condition of pueruli varied across years. This potentially reflected favourable versus poor environmental conditions in different

years for pre-metamorphic buildup of reserves for pueruli, or perhaps stress or use of reserves by pueruli during their settlement migration. **Echauri and Jeffs** (University of Auckland, New Zealand) used various techniques to determine temperature-dependent energy expenditure during puerulus settlement migrations and dispersal among stocks during this phase. Their work suggests climate-change related shifts in oceanography impact food availability or induce stress, that in either case cause poor nutrition in the puerulus stage, contributing to recent declines in settlement of some rock lobster stocks.

With changes occurring to lobster stocks throughout the world, research into their basic biology is more crucial than ever. A talk by **Hyde et al.** (University of the Sunshine Coast, Australia) outlined ongoing work to better understand molecular pathways involved in regulating metamorphosis of spiny or rock lobsters that will inform future aquaculture efforts. **Tang et al.** (University of New Brunswick, Canada) described spatial and temporal patterns in the occurrence of "abnormal" (i.e., incomplete) egg clutches among American lobster females in Atlantic Canada. They found evidence of potential losses to population egg production as great as 40%, underscoring the importance of accounting for this factor in future stock assessments. **Heasman et al.** (Cawthorn Institute, New Zealand) presented a study of the fecundity and early life stages of New Zealand scampi (*Metanephrops challengeri*), a species in a little-studied genus of clawed lobsters. This group of deep-water lobsters has life history traits characteristic of other fauna in that environment: they produce relatively few large eggs and have unusually abbreviated larval development. Such studies broaden our understanding of life history adaptations to the deep sea environment, and facilitate evolutionary comparisons with other lobsters.



Tammy Bo (UNB) at the ICWL poster session. (photo: A-L. Agnalt)

Several presentations also investigated lobster population structure, particularly by assessing the extent and importance of connectivity among lobster stocks. Three presentations examined connectivity of American lobsters. **Quinn et al.** (University of New Brunswick, Canada) enhanced a model of American lobster larval dispersal across the species' range with biological inputs on larval hatch time and behaviours. They found that these additions changed predicted dispersal and settlement, showing the importance of realistic inputs to modeling connectivity. **Morse et al.** (University of New Brunswick, Canada) compared dispersal of larvae predicted by Quinn et al.'s model to that observed by tagged benthic adults across one or multiple years in the southern Gulf of St. Lawrence, and found that both benthic and larval

dispersal may be important contributors to connectivity among lobsters in this region. A poster by **Churchill et al.** (Woods Hole Oceanographic Institute, USA) reported results of another larval dispersal model to estimate whether lobster larvae from the Gulf of Maine could recruit to southern New England lobster populations. They found that larvae could drift around Cape Cod or through Cape Cod Canal to this area, but surprisingly not from the more proximate Georges Bank, which has its own well defined circulation cell. Potential larval transport through the Cape Cod Canal was a novel finding, and this mechanism may help mitigate declines in southern New England stocks.

Five presentations were given on the study of connectivity in spiny or rock lobsters. **Yao et al.** (Florida International University, USA) presented an analysis of Caribbean spiny lobster (*Panulirus argus*) connectivity using stable isotopes and genetics in the Florida Keys. They found that recruits clustered into four groups, presumably coming from particular source areas each year, but with some differences in relative contributions of different sources estimated by different techniques. A poster by **Diaz et al.** (Instituto Español de Oceanografia, Spain) presented analyses of changes to settlement of *Palinurus elephas* in the Mediterranean through time, and detected large-scale synchrony implying a common larval pool and thus connectivity among areas in the region. **Meerhoff et al.** (Centro de Estudios Avanzados en Zonas Áridas, Chile) estimated connectivity of *Panulirus pascuensis* among Easter Island and adjacent localities. Using genetics and dispersal modeling they found potential dispersal among sites, including from a marine reserve to Easter Island. **Woodings et al.** (La Trobe University, Australia) used genetics to determine within and across-cohort variations in genetic composition of rock lobsters (*S. verreauxi*) in eastern Australia, and found considerable variability among sites within a year, and across years, showing the influence of oceanography or other annual events on recruitment. **Denham et al.** (Western Australian Department of Fisheries) described work in which they tweaked parameters of a larval dispersal model of the spiny lobster *Panulirus cygnus* to improve the match between predicted and observed settlement. They tested 19 models and identified larval input numbers, release time, and puerulus swimming as important factors influencing and improving model predictions.

An overarching theme of these sessions was the importance of the settling stage to recruitment. Presentations highlighted the many techniques being refined to investigate lobster population dynamics, but also the large degree of uncertainty in their predictions and implications. This uncertainty is due largely to the lack of information on many aspects of the biology and ecology of early life stages, particularly sources and rates of mortality in larvae and settlers. Related to this was the observation in clawed and spiny lobsters of decreased early benthic recruitment in recent years, likely related to changes in the marine ecosystem. These topics are priorities for future research, as knowing the causes of such changes is essential for the preservation of lobster fisheries. What is clear and important for policy makers to know is that lobster fisheries zones are not isolated units, but rather depend on other zones for at least some of their recruitment each year, so they cannot be managed effectively without understanding and accounting for this

connectivity. Further, low abundances of settling-stage lobsters observed in recent years may be an early warning sign of declining recruitment to lobster populations and lower catches in the future. Policy makers should be aware of these potential declines and aim to manage lobster fisheries with caution in order to sustain them into the future.

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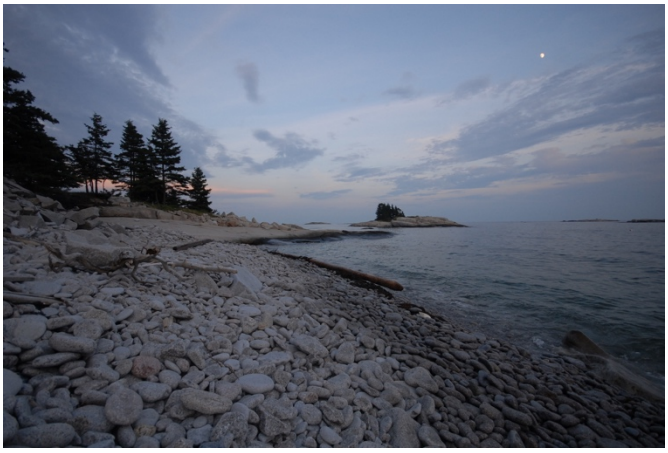
ICWL Sessions: Environmental Stressors & Climate Change

Chairs: Arnault Lebris and Fraser Clark

These two complimentary sessions combined a total of 18 oral presentations and 11 posters. The climate change session followed the keynote by **Dr. Malin Pinsky** (Rutgers University, USA) entitled "Ocean Animals on the Move: Consequences for Ecological and Human Communities".

Talks and posters presented in the climate change session provided a comprehensive overview of the direct effects of warming temperatures on lobster molt, growth, mortality, recruitment, and distribution. Presentations also highlighted the importance of the indirect effects of warming temperature, such as increased vulnerability disease. The indirect effects of climate change are still poorly understood, and thus represent a promising research avenue.

Several presentations evaluated the relative impacts of warming waters vs. other factors affecting lobster biology and population productivity, such as population density, predators' abundance, or fisheries management. For example, as illustrated by **Le Bris et al.** (Gulf of Maine Research Institute, USA) using a population dynamics model of American lobster (*Homarus americanus*), it appears that warming waters may act in synergy with conservation efforts to increase population productivity, as observed in the Gulf of Maine, or may hasten fishery collapse if conservation measures are not implemented, as experienced in southern New England. Using a new inverse-logistic growth model, **de Lestang** (Western Australia Fisheries and Marine Research Laboratories) showed that warming in addition to increased population density can reduce individual growth rates in the Western Australia rock lobster (*Panulirus cygnus*).



Cobble beach at Hurricane Island, Maine. (photo: RW)

A well-documented impact of increasing water temperatures is the variation in the extent of suitable habitat for juvenile and adult lobster (space and depth) that can have important consequences for population productivity. **Butler** (Old Dominion

University, USA) showed that sea-level rise can also lead to newly available habitats for lobsters has observed in the Caribbean for spiny lobster (*P. argus*). Including variation in the extant of suitable habitats might be key to obtain more robust prediction of fisheries landings as suggested by the settlement-based forecasts of American lobster landings (**Goode et al.**, University of Maine, USA).

A common theme across numerous talks was the development of quantitative tools to quantify and forecast impacts of climate change on lobster distribution, abundance, and fisheries at multiple scales. Some of the tools presented during the session included the popular species distribution models (**Tanaka**, University of Maine, USA), statistical models (**Staples et al.**, University of Maine, USA), and cohort-based population dynamics model (**Oppenheim et al.**, University of Maine, USA). The time scales of the presented forecasts varied from seasons (**Mills et al.**, Gulf of Maine Research Institute, USA), to several years (**Oppenheim et al.**) and to several decades (**Le Bris et al.**).

Importantly, the ongoing development of fisheries forecasts raises the questions of how to communicate such forecasts to the industry and the public, and how to use them in lobster fisheries management. Indeed, as demonstrated by students from the University of Maine (**Runnebaum, Maxwell et al.),** constant communications and collaborative research with the industry is key to produce credible and relatable science.

The session on Physiological Responses to Environmental Stressors highlighted the response of multiple lobster life stages to current and future increases in ocean acidification due to increasing ocean pCO_2. Several of these studies examined whole animal responses combined with in-depth transcriptomic analysis. The RNA-seq approach was highlighted for its significant promise for explaining the underlying biochemical and physiological pathways responsible for the observed phenotypes (e.g., **Fitzgibbon et al.** University of Tasmania, Australia, **Waller et al.** UMaine, and **San Antonio et al.** New England Aquarium, USA). Most of the RNA-seq projects are in the bioinformatic analysis portion of their project, but we look forward to comparing the changes in gene expression from these studies on the American lobster at different life stages.

Some presentations examined the effects of a single stressor (e.g, **Harrington and Hamlin** UMaine, USA), but a few highlighted the importance of looking at environmental stressors in combination (**Waller et al.**, UMaine and **San Antonio et al.,** New England Aquarium; **Krång et al.** IMR, Sweden). This combinatorial approach highlighted the compounding or synergistic effects that multiple stressors can have on lobster behavior, physiology and immune response. The final presentation of the session (2nd talk by **Fitzgibbon et al.**) examined the effect of seismic testing on benthic animals such as *Jasus edwardsii*. This study highlighted the importance of selecting the proper controls and highlighted the impact that heavy shipping traffic could be having on lobsters.

The presentations in this section demonstrated the importance of examining the significant effects that ocean acidification is already having on lobsters, and what the impact will be as pCO_2 continues to increase. One factor that became apparent was that

different models predict different ocean pCO_2 concentrations by 2100, and this was reflected in several of the presented studies using different pCO_2 concentrations. However, the fact that multiple labs are examining the effects at different pCO_2 concentrations will only further our understanding of the effects of ocean acidification.

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ICWL Industry Day: Industry-Science Collaborations

Chair: Curt Brown

Industry Day provided conference attendees with many different perspectives on lobsters from around the world. From marketing and sales to science and management, the wide range of talks shed light on how important lobsters of all shapes and sizes are to the global fisheries economy. While Industry Day technically ran during the Thursday of the conference, the industry side of things began informally during the Wednesday afternoon excursion portion when over 40 attendees walked down to Portland's working waterfront for a tour of Ready Seafood, an American lobster wholesale company that ships over 15 million pounds of lobster annually to customers around the world. It was a great experience for everyone involved to contrast the differing strategies with the huge volume associated with the lobster fishery in Maine and the incredible value that is captured from some of the Pacific spiny lobster fisheries.

Industry Day proper opened Thursday morning with successive presentations on the Maine lobster industry from the perspective of the harvester, manager and researcher. **David Cousens**, a longtime harvester and President of the Maine Lobstermen's Association, provided an industry perspective on how the fishery has changed during his lifetime and how climate change is impacting the timing of the lobster harvest in Maine. **Carl Wilson**, Director of the Bureau of Marine Science at Maine's Department of Marine Resources followed up with a presentation on how science drives the management of Maine's most valuable natural resource. **Dr. Robert Steneck**, Professor of Marine Science at the University of Maine, delivered the keynote address by speaking of the perilous over-reliance of Maine's coastal economy on lobster. Whereas in the past, harvesters in Maine could target different species, depending on the season, the depletion of a dirverse assemblage of groundfish and other species has led to lobster being the only game in town for most harvesters and communities. Dr. Steneck emphasized that while lobster stocks in Maine appear sustainable at the moment, anytime you have all your eggs in one basket, you risk losing everything should a downturn occur.

The rest of the day ran in two concurrent sessions with a wide range of talks from industry representatives, wholesalers, economists, scientists and others on topics ranging from harvesting methods to global trade policies. Despite the varying

geography, it was telling how many issues were held in common. Uncertainty caused by climate change was an underlying one. The dynamic between value and volume of the harvest in many lobster fisheries was discussed at length, with Maine and Canada at one end of the spectrum, representing high volume fisheries, and Australia and New Zealand at the other, with the most value by weight. Presentations on global trade focused on trade barriers, invasive species, shipping methods, and quality. Overall, each of the day's presentations reflected both unique local issues and common global challenges and opportunities.

The session on Industry-Science collaborations began with a presentation from **Beth and Dave Casoni** of the Massachusetts Lobstermen's Association, USA. They described the unique challenges that the Massachusetts lobster fishery faces at the "crossroads" of climate change given the fact that their state spans a huge gradient in both water temperatures and lobster abundance. **Brendan Ready** of Ready Seafood, USA, and **Eric Branton** of Clearwater Seafood, Canada, presented separately on the challenges of shipping lobsters globally and the important role that science plays in ensuring both sustainability and product quality.

The New Zealand lobster fishery is known world-wide for the quality and value of its lobster. **Malcolm Lawson** kicked off the afternoon with a keynote address on the increasing role that science is playing in increasing profitability for all involved in New Zealand's lobster industry. Back to *Homarus americanus*, **Josh Stoll** of the University of Maine talked about global trade routes of lobster and how undocumented sales and purchases or "black markets" can skew trade data. **Anna Malek-Mercer** of the Commercial Fisheries Research Foundation, USA, described how her organization is conducting collaborative research projects utilizing new technology to assist in collecting data on crab and lobster.

In honor of the Maine lobsterman, Portland. (photo: RW)

Sandra Mollol, (Instituto Español de Oceangrafía), described how reducing the soak time of trammel nets in the European spiny lobster (*Palinurus elephas*) fishery impacted both the quality and quantity of the catch and reduced bycatch. **Melanie Giffin** of the Prince Edward Island Fishermen's Association, Canada, presented on the work that the association is doing to through a levy on catches to market and promote the quality and uniqueness of PEI's fish and lobster products. **Jessica Cosham** of

the Fishermen and Scientist Research Society, Canada, presented on the successes of past and present collaborative research projects and how this collaborative research has led to improved relationships between science and industry. **Bob Bayer** of the Lobster Institute, USA, described work that he conducted on the impact of new high speed haulers on post-harvest mortality of the American lobster.

Industry Day chair, Curt Brown, interviews for local TV at the Ready Seafood plant. (photo: RW)

Kim Colero of the Western Australia Rock Lobster Council talked about how changes to the organization have led to improved relations with managers, politicians and the community as they have been able to self fund more of their operations as opposed to relying on government funding. **Michael Donihue** of Colby College in Maine presented on upcoming work he is conducting looking at the overall impact of the lobster fishery on Maine's economy beyond the dock. **Martial Laurans** spoke to the importance of involving the biological and ecological knowledge of fishermen to the local resurgence of the Atlantic French *Homarus gammarus* fishery. **John Hunt** of the Florida Fish and Wildlife Conservation Commission described the challenges of managing Florida's spiny lobster fishery given the conflicts between commercial and recreational harvesters and harvesters, managers and scientists and their current work to develop a consensus-based management strategy for the fishery.

Nick Battista of the Island Institute, USA, gave a presentation on ocean planning in Maine and the potential impacts on the lobster fishery. The spatial extent is poorly understood and severely underestimated in most ocean planning scenarios and Nick emphasized the importance of the lobster industry being a part of the process. **Magnus Johnson** of the University of Hull wrapped up the day with a presentation on the recent issue of *Homarus americanus* as a potential invasive species in European waters as a result of the trans-Atlantic trade in live lobsters.

The Industry Day Committee would like to thank all participants and sponsors for an informative and productive day.

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ICWL Industry Day: Adaptive Harvesting and Management Strategies

Co-chairs: Nick Caputi, Burton Shank, Susie Arnold and Teresa Johnson

The Industry Day session on Adaptive harvesting and management strategies contained 21 oral presentations which covered 6 spiny lobster fisheries and 2 clawed lobster fisheries across 5 countries.

This session highlighted a wide array of social and ecological sustainability issues important to fisheries managers and policy makers in the various lobster fisheries around the world. Understanding these challenges and potential adaptive strategies associated with them is critical for improved governance and sustainability. Some common issues covered by these presentations included: ecological issues, economics, social issues, area closures, climate change and management regimes.

The involvement of fishermen in discussions on climate change issues in Maine and how fisheries are managed in a changing climate was identified as an important initiative in increasing awareness of how these changes may affect coastal communities (**Arnold et al.**, Island Institute, USA). The economic assessment of the changing climate was further explored by a vessel-level profitability study that assessed the resilience of the community (**Dayton et al.**, Gulf of Maine Research Institute, USA). Some model scenarios were examined which take into account the predicted catch levels based on the American lobster settlement index. The effect of changes in the timing of fishing was also examined in this fishery (**Staples**, UMaine, USA), as was the effect of changing markets on the fishery (**Sun et al.** Gulf of Maine Research Institute, USA).

Lobster fisheries face many social challenges. Resource sharing between commercial and recreational sectors was identified as one of the key issues facing two of the spiny lobster fisheries in Australia with the open access of the recreational fishery identified as one of the major challenges (**Revill and Pearn**, Wild Fisheries Management, Australia). In Maine the increasing age of fishermen is a key social issue facing the industry, with oral histories highlighting the implications of this on the social resilience of the fishery (**Johnson and Mazur**, UMaine, USA).

The effect of lobster fishing on the broader ecosystem also received attention from a number of presentations. In Tasmania, Australia, the interaction between lobsters and sea urchins has been a focus due to overgrazing by the sea urchin which has extended its range and created kelp barrens (**Hartman et al.**, Univ. Tasmania). Bio-economic modelling was used to evaluate the trade-off between the ecological issue and industry profitability while the trade-off between socio-economic issues was also examined for this fishery (**Gardner et al.**). The Tasmanian lobster fishery was also affected by harmful algal blooms and management steps to address this issue were outlined (**Revill and Pullen,** Wild Fisheries Management, Australia). The successful mitigation of the interactions of lobster gear with whales and sea lions was the ecological issue examined in the West Australian lobster fishery (**Caputi et al.**, Western Australia Fisheries).

Beth Casoni, Executive Director of the Massachusetts Lobstermen's Association and her uncle, and former director, Dave Casoni. (photo: RW)

Area closures were examined in a number of fisheries for different reasons. The effect of area closures were examined for the *Homarus gammarus* fishery which was affected temporary closure due to a windfarm construction (**Roach et al.**, University of Hull, UK). A number of different sampling techniques were examined in open and closed areas in the western rock lobster fishery (**Tuffley et al.**, University of Western Australia) while the importance of good communication with fishers on the marine protected areas was highlighted for the Florida lobster fishery to achieve good compliance (**Renchen and Matthews**, Florida Fish and Wildlife Commission). Long-term marine reserves provided a reference point to assess the exploitation of *Palinurus elephas* in the northwest Mediterranean (**Goňi**, Instituto Español de Oceangrafía).

The sustainability of target stocks was the key issue examined in the study on threatened *Panulirus pascuensis* species in the south-eastern Pacific Ocean (**Palma et al**., FisioAqua, Inc., Chile), while the use of V-notching as a conservation tool was analysed in the American lobster (**Reardon et al.**, Maine Dept. Marine Resources, and **Mazur**, UMaine, USA).

Risk assessments represent emerging tools in the fishery, and they were the focus of presentations of the management of *Panulirus ornatus* based on the level of stock assessment data available (**Plaganyi-Lloyd et al.**, CSIRO Australia), while industry risks were identified in the assessment of the western rock lobster *P. cygnus* (**Colero and Sofoulis**, Western Rock Lobster Council, Australia).

An ecosystem-based fisheries management (or triple bottom line) approach examining the ecological, economic and social issues was assessed for the West Australian lobster fishery through its change from a effort-controlled fishery to one based on individual transferable quota with maximum economic yield as its target (**Caputi et al.**, Western Australia Fisheries). Changes in fishing effort efficiency under effort and quota management were also presented for this fishery (**Penn et al.**, Western Australia Fisheries).

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ICWL Session: **Fisheries Science**

Chair: Kisei Tanaka

The Fisheries Science session of the 11th ICWL welcomed seven speakers from six countries who presented studies on southern rock lobster (*Jasus edwardsii*), mud borrowing lobster (*Metanephrops challengeri*), Juan Fernandez rock lobster (*Jasus frontalis*), spiny lobster (*Panulirus argus*), and American lobster (*Homarus americanus*). The session considered a variety of topics from ecosystem approach to lobster stock assessment to identification of uncertainties, as well as increasing biological realism in the input data.

The first presenter **Adam Cook** (Fisheries and Oceans Canada) developed a data-driven ecosystem indicator approach for providing more robust stock assessment advice for American lobster in Canada. The indicator approach considers stock assessment data inputs (abundance, distribution, size structure, sex ratio, recruitment) as derived ecological indicators (available habitat or reproductive potential) or ecosystem indicators (bottom temperature, Atlantic Multidecadal Oscillation, predator abundance). Furthermore, Cook presented a Principle Component Analysis-based analysis to identify coherent patterns and trends in multiple indicators over time. This indicator approach can provide contextual information to the existing stock assessment model, and policy relevant information, such as harvest and population trends.

Caleb Gardner and co-authors (University of Tasmania, Australia) estimated the rate of tag induced mortality (TIM) in the wild southern rock lobster population in Hobart, Tasmania, Australia. Using a long-term capture-mark-recapture study conducted since 2000, Gardner et al. developed a three-survey model to estimate *in situ* TIM, as well as the effect of the number of recaptured lobsters on TIM rates. The study highlighted the sensitivity in estimated TIM regarding the number of recaptured lobsters, and emphasized the difference between *in-situ* TIM and *in aquaria* TIM. A major benefit of this study was that it estimated TIM rate *in-situ* for the first time by comparing tag returns from multiple tagging years, and it highlighted the need for TIM rate to be estimated *in situ* as an essential part of existing tagging programs.

Simon de Lestang and Matthew Pember (Department of Fisheries, Western Australia) presented a summary of a tag-recapture study for the management of the western rock lobster, *P. cygnus*, fishery. The study showed that the recapture rate of tagged lobster was influenced by many factors including tag location, tagging position, catchability, and levels of fishing effort. As the management of the lobster fishery in Western Australia has recently transitioned into total allowable catch quota system, this study provides timely and policy-relevant information to develop reliable baseline estimates of lobster biomass and exploitation rates.

To improve assessment of New Zealand scampi stocks, **Ian Tuck and Bruce Hartill** (NIWA & University of Auckland) proposed to incorporate existing fishery observer-based catch composition data. The study explored the potential use of market-driven weight-based grades to reconstruct the scampi catch data. The fishery's length-structured assessment model is reliant on size and sex composition data of catches to inform fishery removals from the

Bai Li, Kisei Tanaka, Robert Boenish of the Chen lab (UMaine) leaving no survivors. (photo: RW)

population. To this end, this study showed that the use of market-based grade categories can quantify annual and seasonal consistency for a census of scampi catches. This study can potentially improve and augment the quality of grade composition data on observer trips as an assessment model input, and offers great potential to provide fleet wide "catch sampling" information.

Using multiple mark recapture datasets and a growth dataset on large lobsters, **Alvaro Palma** (FisioAqua Inc., Chile) and co-authors proposed a new growth model for quantifying somatic growth of the Juan Fernandez rock lobster, *Jasus frontalis,* stock in Juan Fernandez Archipelago. The comprehensive growth model can incorporate multiple sources of information and account for sex-specific assess molt frequency and annual size increments. The study found that males and females can molt up to 4 times within a 30-50 mm carapace length size range, but females stall their growth rate earlier than males. The key findings from this study shed insight on the Juan Fernandez rock lobster somatic growth and could potentially replace the current von Bertalanffy growth model.

Fishermen for spiny lobsters often leave a lobster in the trap to attract conspecifics. **Casey Butler** and co-authors (Florida Fish and Wildlife Research Institute, USA) examined the effects of long-term confinement on the attractiveness of nutritionally deprived lobsters as bait in the Florida spiny lobster, *P. argus,* fishery. Using Y-maze experiments and field-based trap experiments, the authors studied the response of lobsters to starved conspecifics. Lobsters were not significantly attracted to nutritionally compromised lobsters, but "*attraction*" decreased with duration of starvation. The study's 7-week trials showed that the duration of confinement had a considerable effect on the attractiveness of bait lobsters, and can reduce trap catch up to 40%. The commercial spiny lobster fishery in Florida is one of the top fisheries in the state that is worth more than 30 million USD a year. Given the socioeconomic significance of the fishery, these findings on the loss of lobster attraction with decreasing lobster health could have a significant impact on the fishery as it likely reduces the success of the fishery.

For the session's last presentation, **Robert Boenish and Yong Chen** (University of Maine, USA) developed an approach to spatio-temporally quantify effective fishing effort for the American lobster fishery in the Gulf of Maine. The study utilized seven years of fishery-dependent data and semi-parametric bootstrapped two-stage generalized additive model to standardize lobster catch per unit effort (CPUE) and estimate confidence intervals. The bootstrapped CPUE confidence intervals combined with high resolution landings data showed that the peak of effective effort during the most productive part of the fishing season preceded the peak of landings in all study years. The methodology developed by Boenish and Chen allows fishery managers to study fishery dynamics at enhanced resolution and improve spatio-temporal management precision.

Overall, the session reflected the emerging trends in recent efforts to account for environmental influences and biological details specifically with regard to the process included and their representation in the assessment and management of lobster fisheries. Moving forward, the next ICWL

would likely see an increasing number of studies addressing relationships between environmental components, lobster population dynamics and management strategies evaluation. Development of modeling framework that can simulate changes in both ecosystem and population dynamics can make useful recommendations for policy makers to implement effective ecosystem-based management of lobster fisheries.

I would like to thank all speakers in the Fisheries Science session for their interesting presentations and discussions. I look forward to seeing many of you again at the next ICWL conference.

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ICWL Session: **Aquaculture**

Co-chairs: Clive Jones and Andrew Jeffs

The Aquaculture Session of the conference comprised two sub-sessions including 10 oral presentations as well as two posters. The presentations represented a wide range of global locations, including Indonesia, Australia, Norway, Canada, USA, England and Scotland. Given the location of the conference in the north Atlantic and the relative commercial importance of *Homarus* among the many lobster genera covered at the conference, it was unsurprising that 8 of the 12 papers related to clawed lobsters – *Homarus* spp., and 4 to spiny lobster species. The topics that were covered were highly diverse and included treatments for shell disease, establishing baselines for health monitoring of lobsters, wild lobster interactions with salmon farming therapeutants, training in aquaculture for commercial fishers, and the role of physiological "personality" in determining performance in captive aquaculture of lobsters.

Field grow-out chambers for the European lobster. (photo: C. Daniels)

There were also a number of presentations on the continued emergence of lobster aquaculture technologies, including larval culture methods, wild seed collection and grow out systems for both clawed and spiny lobsters. However, it was clear from the presentations that the commercial scale lobster aquaculture remains slow to emerge anywhere in the world despite the increasing pressures and risks to wild lobster populations from harvesting and environmental change that were a common feature in many of the presentations throughout the conference.

Both production technology and policy settings are integral to advancing lobster aquaculture. For clawed lobster, hatchery technology is well established, but methods for on-growing of hatchery generated juveniles is uncertain. There are encouraging

preliminary results of cage-based grow-out of *Homarus* (**Carly Daniels**, The National Lobster Hatchery, United Kingdom), but larger scale production may be confined to stock enhancement of wild populations. There are important policy considerations involved in this, in regard to the genetics and health of the hatchery stocks. For the spiny lobsters, hatchery technology has been advanced (**Greg Smith**, University of Tasmania, Australia), but has been much more difficult to commercialise and existing spiny lobster farming is reliant on wild puerulus resources (**Clive Jones**, James Cook University, Australia). Policy around exploitation of such lobster seed resources will be critical for sustainable development.

The emergence of lobster aquaculture has the potential to take a great deal of pressure off wild populations in the same manner as wild shrimp populations were incidentally safeguarded to some degree with the

Vietnamese lobster farm (photo: C. Jones)

introduction of shrimp farming technology last century. In this regard, greater global co-ordination and focus on efforts to more rapidly advance lobster aquaculture was a clear conclusion for those attending this session.

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ICWL Session: Trap Design & Impacts

Chair: Win Watson

This session consisted of seven presentations concerning different species. Despite the fact we call them all lobsters, there are many differences between species, in terms of their abundance, habitats and behaviors, that strongly influence how we need to capture them. For example, *Nephrops* are much more scarce than American lobsters and reside in mud/sand habitats, rather than cobble and rock and scampi are much more hesitant to enter traps than some of the other lobster species. This necessitates using different strategies and gear in each of the fisheries. So, what did we learn in this session?

First, **Emily Rondeau et al.** (Fisheries and Oceans, Canada) presented data showing that bycatch in the American lobster fishery in the Gulf of St. Lawrence does not appear to be a large problem because 91% of the bycatch are sublegal lobsters and many of the other bycatch species are authorized bycatch. This is a much different from the situation in New Zealand with the scampi trawl fishery. **Shaun Ogilvie** (Cawthorn Institute, New Zealand) and his colleagues showed how they designed an exclusion

device to limit bycatch by trawls, which appears to have lots of promise. Second, they have been using cameras to help them understand more about the density of scampi on the bottom and the type of habitat where they are most abundant. Third, they have designed bait containers to limit the catch of hagfish and fourth, their observations of scampi interacting with traps in the laboratory have enabled them to greatly improve the design of the traps they are using to capture these skittish, but tasty, lobsters.

In contrast to the scampi fishery, sometimes too many American lobsters can enter traps, especially the ventless traps that marine resource agencies in the US and Canada have been using lately to obtain better abundance and size frequency data. Previous studies have shown that these ventless traps saturate after about 16-24 hours, which may impact the accuracy of the data obtained with typical 2-3 day soaks. **Win Watson** (University of New Hampshire, USA) and his colleagues presented data indicating that they saturate after 24 hours because their rate of entry slows down so that it is equal to their rate of escape. One of the major factors that appears to be responsible for this change in entry rate is the loss of bait attractiveness due to the rapid leaching of attractants.

Another factor that can influence catch is the presence of other species. Everyone continues to worry about the impact of green crabs on various lobster fisheries and in Newfoundland, catch of lobsters has declined 34% since the appearance of green crabs in 2007. **Gemma Rayner et al.** (Memorial University, Newfoundland, Canada) are still not sure how they reduce catch, but their data suggest that it might have to do with inhibiting the entrance of lobsters into traps.

Finally, another way to optimize catch, while minimizing costs, is to gain a better understanding of where the greatest densities of lobsters can be found. This is especially important for those species, such as *Nephrops*, that are not as abundant. **Knut Jørstad** (Institute of Marine Research, Norway) and his associates demonstrated how it is possible to gain such knowledge using a fairly low cost mapping and trapping approach.

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ICWL Workshop: Caribbean Spiny Lobster Stock Assessment

Chair: Yuying Zhang

Because of the social-economic importance of Caribbean spiny lobster *Panulirus argus*, workshops were held by various agencies from 1997 to 2006 to promote collaborations in managing and utilizing the fisheries resources at both national and regional levels. In this workshop, stock assessments scientists were invited to introduce their models that are used to estimate spiny lobster fisheries status and update model results.

The Southeast US stock used a size-structured model. The complex life history and fisheries process of the Caribbean spiny lobster makes the size-structured model more effective than the age-structured

models. As the spiny lobster lacks calcified structures to mark age directly, uncertainty and error could be introduced to the age-structured model during the length-age transformation. The stock assessment model also describes seasonal sex-specific population dynamics of the spiny lobster, which better describe the reality. The uncertainty of the parameters and the biological reference points have also been estimated. Both sensitivity and retrospective analyses indicate that the size-structured stock assessment model can provide management advice for the Southeast US stock.

According to **Dr. Gloria V. Rios** (National Institution of Fisheries and Aquaculture of Mexico), a dynamic nonlinear age-structured model is applied in the Yucatan Platform that located in the Northern Mexico. Results show high exploitation rates and extraordinary changes in biomass, however production in the fishing areas has been sustainable for a long period of time. A surplus model is applied in the North-Northeast Zone from Quintana Roo. The maximum sustainable yield is approximately equal to the production obtained per fishing season. The production as an indicator has shown sustainability in the last twenty years. The abundance estimation of Natural Protected Area Alacranes Reef is based on diving observations, and the density estimations are slightly higher than those obtained from previous studies. Future stock assessments should take the distribution of fishing effort, distribution of population exploited in the different areas, movement patterns of the resource and re-colonization of fishing areas into account.

The Caribbean spiny lobster, *Panulirus argus* (photo: P. Briones)

Attendees took this opportunity to exchange new ideas, expand networks, discuss about important biological features that should be considered in stock assessment and management. They also discussed the difficulties in stock assessment and management, and sought for possibility solutions. This workshop could enhance co-management the Caribbean spiny lobster at both national and regional levels. Similar workshops will continue to be held in other regional and international conferences.

As it is difficult to find reliable stock spawning biomass-recruitment relationships for independent stocks, the next question for fisheries scientists is to investigate accurate and precise demographic recruitment connectivity among Southeast US, Mexico and other Caribbean countries. Meanwhile, stock assessment scientists need to develop a meta-population framework to access the bias and uncertainty of current stock assessment models associated with various stock spatial structure scenarios. The results will help fisheries managers to promote the conservation, management and development of the Caribbean spiny lobster resources.

The chair wants to thank Florida Sea Grant for its support of this workshop. Appreciations should also be delivered to the organizers and audiences of the 11th ICWL, as well as those stock assessment scientists from Caribbean countries, who tried their best to participate this workshop, but couldn't make the trip due the bureaucratic, financial and/or visa constraints.

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RESEARCH NEWS

Oxygen consumption and critical point in the Caribbean spiny lobster *Panulirus argus*, latreille 1804

From: Gerardo Suárez Álvarez and Lucia Ocampo Victoria

This research was conducted because of the commercial industrial sector's need to know about the metabolic behavior of the spiny lobster, *Panulirus argus*, for better management of the resource, and to recommend optimal standards of storage and handling for live export. For these reasons, applied research was carried out on the respiratory performance of several groups of lobsters at different temperatures, to establish the standard values of oxygen consumption and the "critical point" (Pc), which represents the concentration of oxygen below which this species ceases to be oxygen-regulator to become oxygen-conforming. The metabolic rate in $mgO_2kg^{-1}.h^{-1}$, as a reflection of the metabolism, represents all the changes of matter and energy that occur in the experimental animal.

To measure metabolic rate, 221 measurements of oxygen consumption were made. We measured an average mass-specific rate of 46.9 mg O_2 $kg^{-1}.h^{-1}$ at 20 ^oC for lobsters with an average weight of 520 g (5 years of age). According to Fig. 1, metabolic rate declines with larger size and older age (Winberg, 1950). This is due to the fact that smaller individuals need to consume more energy per unit body mass to metabolize normally. The critical point for 22^0C was 1.63 (±0.17 SD) $mg.L^{-1}$, and for 29^oC of 1.30 (±0.11 SD) $mg.L^{-1}$ with a statistical significance of 0.05. (Groups of individuals with an average weight of 607±60 g and 620±67 g, respectively). Lobsters can be oxygen-regulating to a level reached in the Pc, below which the individuals become oxygen-conforming or depending on the concentration of the medium. Pc has been reported consistently between 2.0 and 0.9 mgL^{-1} for a range of crustaceans (Ocampo, 2001).

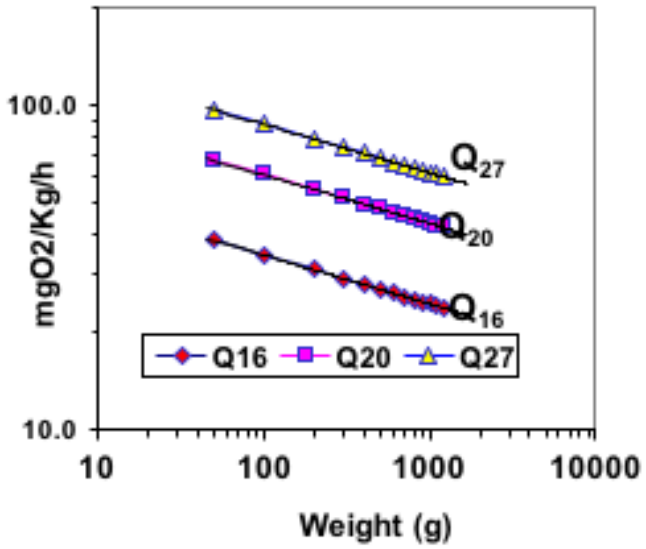

Figure 1. *P. argus* metabolic rates versus body weight at three temperatures 16, 20, and 27 °C.

A representation of the Pc is in Fig. 2, constructed as the result of all the experimental observations, represented by the two lines and their point of intersection between 0.7 and 0.8 mg. L^{-1}. This demonstrates that lobster should not be subjected to overcrowding in ponds or cages because in a short time they will consume the oxygen available and normal performance is affected. Below this value lobster metabolic rate becomes dependent on the oxygen level of the medium. The equations of both lines, significant for a 95% probability, as well as their coefficients of determination, are presented in Fig. 2.

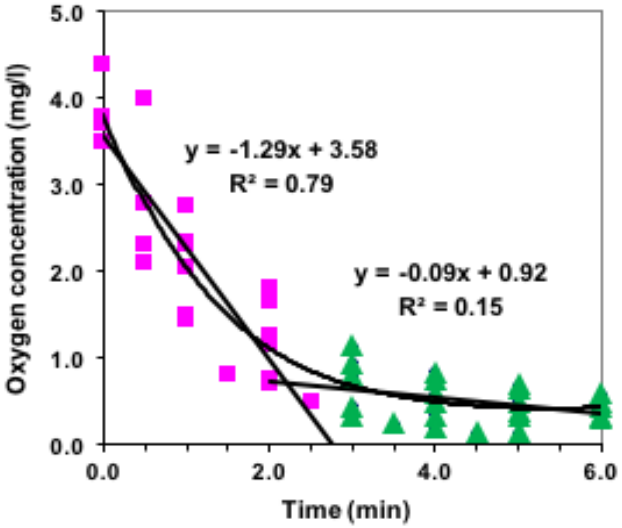

Figure 2. Determination of the Oxygen Critical point (P_C) as the interaction of two slopes on a plot of oxygen depletion over time.

Figure 3 shows the variation of the observed and calculated metabolic rate, as a function of the available water exchange per sample, where the optimum volume of flow corresponds to 62 to 66 Lh^{-1}. This is the amount of water required per lobster weighing between 500 and 600 grams, to carry out its functions normally without causing stress. For the purposes of storage in cages or ponds this is the supply of water required for the best possible quality and survival. remembering that larger specimens will need more water exchange (Suárez and Xiquéz, 1969). The observed values were adjusted to a polynomial of degree 4. The resulting equation that explains this model is:

$$\mathbf{mgO_2.kg^{-1}.h^{-1} = -\ 9.21 + 1.16 * (L.h^{-1}) - 6.78 * (L.h^{-1})^2 + 1.37 * (L.h^{-1})^3 - 8.26}$$

The R^2 indicates that the adjusted model explains 98% of the variability of the data.

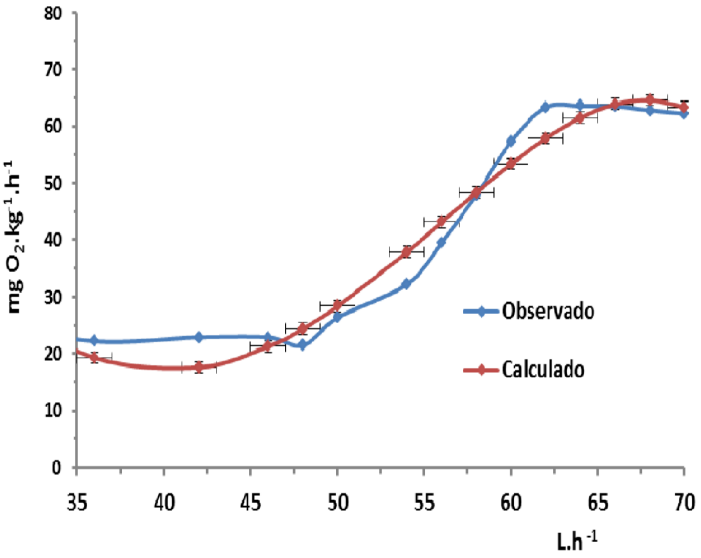

Figure 3. Metabolic rate (mg O_2.kg^{-1}.h^{-1}), according to the water change (Litres.h^{-1}), for lobsters between 500 and 600 grams of wet weight. The error bars typical of the calculated curve are presented. (R^2=0.98)

In summary, the mean metabolic rate of *P. argus* was determined as 46.9 mg O_2.kg^{-1}.h^{-1} at 20 °C, for individuals with an average weight of 520 g. At an older age, a lower value of the metabolic rate corresponds; strictly adhering to the parabolic relationship of metabolism, and this is due to the fact that smaller individuals need to consume more energy per unit mass to metabolize normally. At lower temperatures the animals have lower metabolic rates and oxygen consumption. The critical point Pc was determined between 0.7 and 0.8 mg.L^{-1} to keep live lobsters in captivity for experimental or purposes, without causing stress, and a water replacement rate of 50-60 L per specimen must be offered.

ACKNOWLEDGEMENT

Thanks to all workers in the fishing industry of Cuba and scientific personal by CIBNOR, México

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American lobsters across the Atlantic

From: Susanne P Eriksson, Fayez Alsaleh, Matz Berggren, Anna-Sara Krång, Adam Powell, Linda Svanberg, Hannah L Wood

Alien *Homarus americanus* have been confirmed in a number of European countries, including Sweden, Norway and the UK (Jørstad et al. 2011, Stebbing et al. 2012, Swedish Agency for Marine and Water Management 2016). In Sweden, the first wild-captured animal was confirmed in 2008, and since 2014 the species has been caught annually during the lobster fishing season. *H. americanus* successfully reproduces in both Sweden and Norway, and females are caught with viable eggs resulting from either conspecific mating or cross-breeding with European males (*Homarus gammarus*). The repeated captures of *H. americanus* in Europe raise concerns about the possible impact on both the European lobster, as well as other native crustaceans. Each introduction of this alien species poses a potential risk of genetic contamination and / or competition for resources. The populations of the European lobster are currently estimated to be at an historical low in both Sweden and Norway, and therefore potentially more sensitive to impact (Sundelöf et al. 2013). Since the two species have been geographically and reproductively separated from each other since the Pleistocene, the species have developed certain reproductive barriers (Hedgecock et al. 1977). Early crossbreeding attempts in the laboratory were only successful when *H. americanus* males mated with *H. gammarus* females (Andouin and Leglise 1972, Carlberg et al. 1978, Hedgecock et al. 1978). However recently it has been proven that *H. americanus* female lobsters and *H. gammarus* males mate successfully in the wild in both Sweden and Norway, where *ca* 30% of berried *H. americanus* captured carry hybrid eggs. When kept in ambient conditions the hybrid clutches hatch equivalent numbers to the native *H. gammarus* clutches (Fig. 1), resulting in thousands of hybrid larvae with each successful reproduction. One of the most obvious deleterious characteristics seen in the hybrid offspring is that 22±9 % (N_{clutch}=3) of the larvae are deformed. Many of the

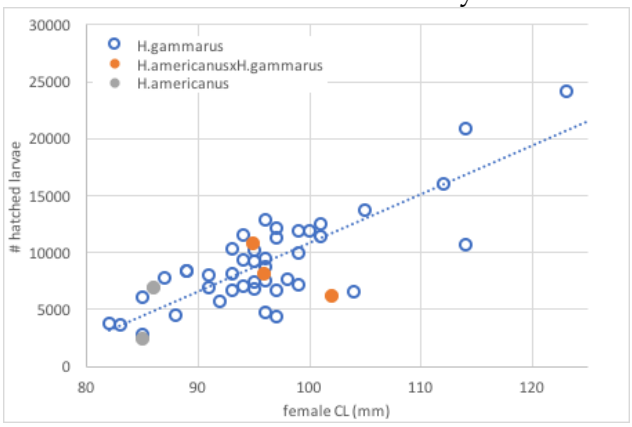

Figure 1. The hatching success of female *Homarus* lobsters, carrying con-specific or cross-bred offspring. All females were kept in the laboratory during egg incubation at ambient Swedish water conditions.

larvae and young juveniles are, however, apparently healthy and viable and may survive to adulthood. Since *H. gammarus* and *H. americanus* have many morphological common features, it is only through genetic sampling that the three genotypes of lobsters can be separated with 100% certainty (Jørstad et al. 2007). Researchers at the University of Gothenburg (Sweden), Institute of Marine Research (Norway) and the University of Bordeaux (France), are collaborating to produce scientific data that can anticipate the consequences of possible

establishment of *H. americanus* across European ecosystems. In Sweden, during the last two years, we have run experiments on tolerance, competition and growth in the early life stages of the three genotypes (Fig.2).

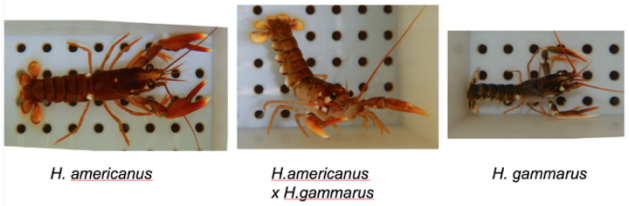

Figure 2. Juvenile lobsters of the same age, raised in ambient Swedish water conditions. (photo: C. Daniels)

Establishment of *H. americanus* or hybrid populations in Europe can be ascertained if juveniles (or subadults) of a size smaller than live imports (trade animals) are found in the wild. Although lobster juveniles are easily caught in their native habitat in North America (e.g. Wahle et al. 2004), similar attempts in European waters have so far not been successful (e.g. Mercer et al. 2001).

However, the quest for lobster juveniles (of any genotype) in the field has yet again been initiated using an especially designed Berggren-trap, deployed in areas where habitat is likely to be favorable to juvenile lobsters (Factor 1995, Wahle et al. 2004), and in the vicinity of *H. americanus* hot-spot areas.

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Generating new biological and ecological knowledge in the New Zealand scampi *(Metanephrops challngeri)* fishery

From: Shaun Ogilvie, David Taylor, Kevin Heasman, Chris Batstone, Robert Major, Alaric McCarthy, Karen Middlemiss, Sara Jamieson, Glenice Paine, Richard Paine, Stephen Connor, Geoffrey Connor, John Radford, Andrew Jeffs, Ian Tuck

New Zealand scampi (*Metanephrops challengeri*) (Fig 1) are a highly valuable lobster species which are widely distributed on the continental shelf of New Zealand in depths of about 250-550 m (Tuck et al., 2015) (Fig 2). Scampi are fished in waters of around 300 m depth by bottom trawling with triple rigged otter trawls. Access to the scampi fishery in New Zealand is managed by the Quota Management System (QMS), and roughly 1000 t of scampi are caught per year, valued at US$13M. Even though NZ scampi have been the target of this fishery for over 30 years, relatively little research has been done on this species, and most of our knowledge comes from variations in catch rates and trawl surveys (Tuck, 2015).

Figure 1. New Zealand scampi (*Metanephrops challengeri*). (photo: A. McCarthy)

Similar to other deep-sea bottom trawl fisheries, the New Zealand scampi trawl

fishery generates high levels of bycatch, impacts the sea floor and requires large amounts of fuel (Anderson, 2012).

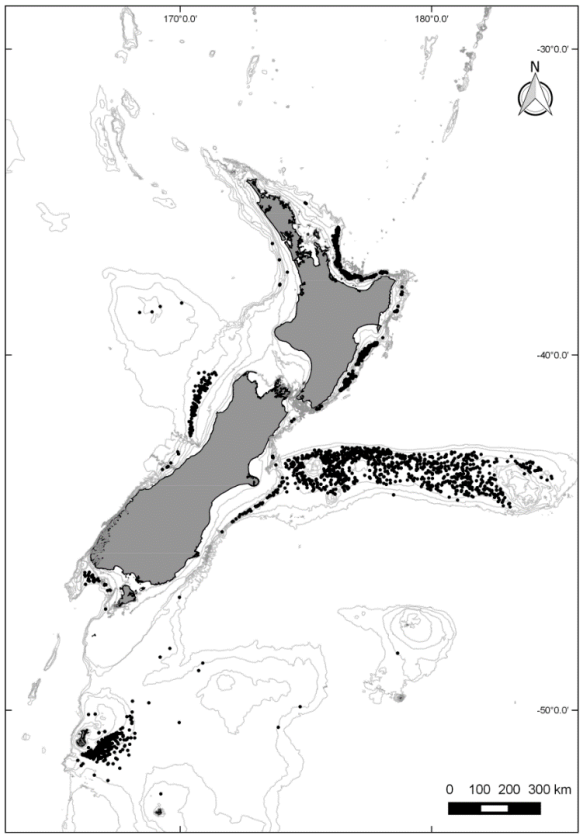

Figure 2. Map of locations where *Metanephrops challengeri* have been caught by research trawls undertaken by NIWA around New Zealand 1964-2008. Generated using data from www.iobis.org

It was these characteristics that inspired the Waikawa Fishing Company, in collaboration with the Cawthron Institute, Zebra-Tech Ltd and the University of Auckland, to develop new sustainable fishing and aquaculture technologies to improve the utilisation of this resource. The rationale for this sustainable approach to utilising the New Zealand scampi resource is tied closely to the *Māori* (the indigenous people of New Zealand) worldview of *kaitiakitanga*, which promotes stewardship of resources for future generations. The project has three pillars: to develop potting technology targeting scampi, to identify effective baits for the pots, and to investigate the aquaculture potential of the species. In researching these three pillars the programme has generated new knowledge about New Zealand scampi, which could also be applied to other *Metanephrops* lobsters.

Potting technology

To develop potting technology to capture NZ scampi, initial experiments were completed using pots designed for the ecologically similar Norway lobster (*Nephrops norvegicus*) found in Europe. These pots had limited success and resulted in high amounts of bycatch, particularly hagfish (*Eptatretus cirrhatus*) (Major et al., 2017b). Additionally, these European pots had minimal success in the laboratory (6 percent capture rate). Laboratory experiments showed scampi would not enter the traditional funnel shaped entrances used in *Nephrops* traps. Consequently, we tested how scampi interact with various components of traps (such as entrance slope, entrance width and height) with the aim of optimising a trap design for this species. We have confirmed proof of concept of pot design in a laboratory setting. The next step is to investigate the distribution of scampi and any habitat correlates that can be used to determine sites of high scampi density suitable for field deployment of the new pot design.

Bait technology

Effective baits to be used in the scampi specific pots were investigated using a series of bioassays that focused on the chemosensory behaviour of scampi (Major et al., 2017a), on the effect of turbulence on the efficiency of food search behaviour

(Major & Jeffs, 2017), and the attractiveness of a range of different baits. The results of these studies elucidated that firstly, the time scampi spent during each of the phases of chemically-mediated food search behaviour was highly variable regardless of the bait tested. Secondly, scampi are significantly more efficient at searching for food in turbulent flow versus laminar flow. Lastly, using a multichoice flume, we identified that New Zealand pilchard (*Sardinops neopilchardus*) baits were significantly more attractive to the scampi than a number of alternative natural seafood baits. The combined results of these experiments suggest that scampi are opportunistic scavengers that venture out of their burrows during periods of higher tidal flow to search for food and therefore pots should be fished during periods of tidal flow. Furthermore, oily fish appear to be the most suitable bait for scampi due to higher attraction.

Aquaculture

To assess the aquaculture potential for scampi, aspects of the reproductive biology, larval development, and size of onset of maturity have been examined. Compared to other lobster species, female scampi carry a small number of relatively large eggs under their tails for an extended period, resulting in an advanced zoea hatching with a truncated pelagic phase. We have identified pre-zoea, zoea 1, zoea 2 and post larval stages for this species (Fig. 3). Of the 18 extant *Metanephrops* species only four, *M. thomsoni*, *M. sagamiensis, M. japonicus* and now *M. challeng*eri, have had their larval stages confirmed. Three of these species (*M. thomsoni*, *M. sagamiensis,* and *M. challengeri*) show the same larval assemblage (i.e., pre-zoea, Zoea I, Zoea II followed by metamorphosis). In contrast, *M. japonicus* has been shown to have a more abbreviated larvae history in that it metamorphoses directly from pre-zoea to post larvae (Okamoto, 2008). The longest a *M. challengeri* postlarva has been maintained in our rearing system has been 15 months, and this individual, christened *Camilla,* became a minor celebrity after a visit by Prince Charles (Gee, 2016).

We have also assessed the size of onset of maturity for this species, using morphometric approaches, including the minimum size of ovigerous females and size at which 50% of females display eggs. Morphometric measurements to investigate SOM in males were also explored with varying success. The results suggest that onset of maturity for females varied between 39.8- 56.9 mm orbital carapace length. Differences in the size of onset of maturity were observed due to fisheries management areas, depth and temperature. This has implications for aquaculture, enabling the identification of ideal temperatures for growth and potentially a faster maturing stock to be used for broodstock.

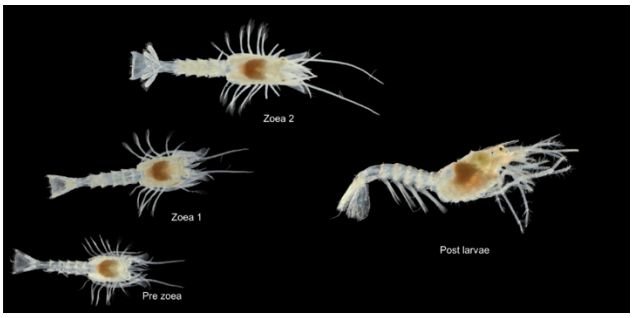

Figure 3. Larval stages of NZ scampi (*Metanephrops challengeri*). (Photo: J-C. Stahl, Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand)

Future work

Research is ongoing for all three pillars of the project. For the potting technology we will be testing our new pot design in areas of appropriate scampi habitat and density. The attractant research will focus on genetic gut

content analysis of scampi, which may guide the identification of new bait materials. The focus for the aquaculture pillar is to refine and upscale larval production to supply larger numbers of post-larvae for future research and commercialisation. In conclusion, while the primary focus of this research programme has been commercial application, the new knowledge generated has greatly increased our understanding of the biology and ecology of New Zealand scampi, which will greatly assist with the sustainable management of these lobsters into the future.

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ADVERTISING

ANNOUNCEMENTS

12th International Conference and Workshop on Lobster Biology and Management Perth Australia 2020

From: Nick Caputi and Matt Taylor

While this Lobster Newsletter is focused on reporting the outcome of the successful 11th ICWL held in Portland in June 2017, planning is underway for the 12th ICWL workshop. The Department of Primary Industry and Regional Development (DPIRD) and the Western Rock Lobster Council (WRLC) are pleased to be hosting the 12th workshop in Western Australia in 2020. The Fisheries Research and Development Corporation (FRDC) have indicated their strong support for the workshop.

The lobster workshop series began in Western Australia 40 years ago when a group of 37 lobster biologists from 6 countries met in Perth, Australia to discuss and compare their work on lobster ecology, physiology, and early stock management protocols, and to find common themes amongst the different species that were commercially fished. In recent years participation has risen to about 150-200 people from 20 countries and 2020 will see the workshop return to where it all began.

At this stage the likely time is October/November 2020 and the likely location is Fremantle which is a major port for the western rock lobster fleet, 20 km from Perth, the capital city of Western Australia. We will keep you informed as soon as these are confirmed. We will be launching the 12th ICWL website in early 2018 which will be updated as planning progresses.

The western rock lobster fishery in Western Australia is the largest single species fishery in Australia with a value of AUD$400 million and it has a long history of research, management and compliance which is highly regarded. The WRLC and DPIRD are looking forward to hosting scientists, managers and industry participants in Western Australia in 2020.

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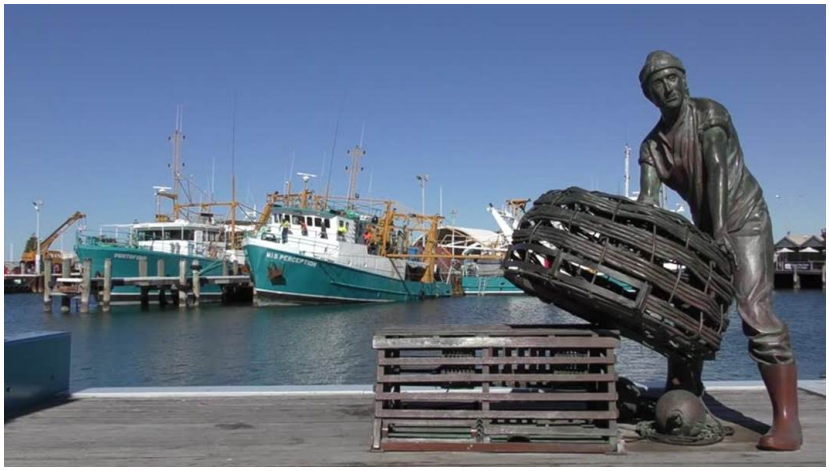

Statue in honor of Fremantle's pioneering rock lobster fishers.

The Lobster NEWSLETTER

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The Lobster Newsletter is published electronically once or twice yearly.

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