

# PROGRAM & ABSTRACTS

**11<sup>TH</sup> INTERNATIONAL**

**Conference and Workshop**



on  
**LOBSTER**

**Biology & Management**

**Portland, Maine 4-9 June 2017**

# OUR SPONSORS

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(continued on back inside cover):

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Dear Participants,

On behalf of the Steering Committee, we are pleased to welcome you to the **11<sup>th</sup> International Conference and Workshop on Lobster Biology and Management**, hosted by the University of Maine and Boston University in Portland, Maine.

This ICWL, like those before it, promises to be an exciting week of scientific presentations and discussions, featuring presentations of interest to industry members, resource managers, biologists, economists and social scientists.

As large, charismatic species, lobsters of all stripes often find themselves at the center of scientific research and in the media spotlight. Lobster fisheries are important economic drivers of coastal communities around the world. Indeed, lobsters are poster children of a marine environment increasingly under the pressures of human exploitation and environmental change. The 200+ abstracts in this program reflect the activity of a vibrant international community of researchers and industry members striving to understand what makes lobsters tick and keep their fisheries sustainable.

We thank you all for attending this conference and invite you to enjoy the many pleasures of Portland, from its microbreweries to its portside restaurants to its fabulous vistas and islands. We hope that you immerse yourself in the technical program and enjoy interacting with the varied participants.

Welcome to Portland!

Richard A. Wahle, Ph.D.  
11<sup>th</sup> ICWL Co-Chair  
Research Professor  
University of Maine

Kari L. Lavalli, Ph.D.  
11<sup>th</sup> ICWL Co-Chair  
Senior Lecturer  
Boston University



## **Hosts**

University of Maine, Orono, Maine  
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## **Sponsors**

**Gold:** Maine Department of Marine Resources

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**Booth Advertising:** Zebra Tech, Island Institute, Gulf of Maine Research Institute, University of Maine School of Marine Sciences, Commercial Fisheries Research Foundation, Vemco

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**Dr. Kari Lavalli**, College of General Studies, Division of Natural Sciences & Mathematics, Boston University, 871 Commonwealth Avenue, Boston, Massachusetts 02215 USA

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**Ms. Cathy Billings**, The Lobster Institute, University of Maine, Orono, ME, USA

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**Dr. Raquel Goñi** – Instituto Español de Oceanografía, Palma de Mallorca, Illes Balears, Spain

**Dr. Alison McDiamird** – National Institute of Water and Atmosphere (NIWA), Wellington, New Zealand

## GENERAL INFORMATION

### **Registration Desk**

The Registration Desk in the Holiday Inn lobby will be open at the following times:

Sunday 3:00 – 8:00 pm

Monday 8:00 am – 5:00 pm (lunch break at 1:00 – 2:00 pm)

Tuesday 8:00 am – 5:00 pm (lunch break at 12:00 – 1:00 pm)

Wednesday 8:00 am – 1:00 pm

Thursday 8:00 am – 5:00 pm (lunch break at 12:00 – 12:45 pm)

### **Name Badges**

A name badge will be supplied to registered delegates that will enable them to attend the sessions. Single-day and Industry-Day registrants will have a coded name badge indicating the day for which they are registered. Only those wearing their name badge will be entitled to participate in the daily meals offered and the social events. Registered companions will be supplied with tickets to the events for which they are registered. Those not registered as delegates (i.e., members of the press or booth exhibitors) are not entitled to the daily meals offered.

### **Presentation Review**

Technical assistance will be available to upload presentations at the registration desk and at both conference stream rooms. Presentations should be uploaded the day before they are given.

### **Conference T-Shirts and Additional Tickets for Social Events**

Pre-ordered conference T-shirts can be picked up at the registration desk when checking in. A limited number of additional conference T-shirts will be available for US \$25 at the registration desk, but sizes are not guaranteed for those purchasing on-site. Additional tickets for the conference social events will also be available at the registration desk on a cash-only basis.

### **Breakfast and Lunch Tickets**

Delegates who have registered for the full conference, single-day, or Industry-Day will have meals supplied as follows: breakfasts (Monday, Tuesday, Thursday, Friday); lunches (Monday, Tuesday, Thursday, Friday). Registered companions may purchase breakfasts in advance of the conference for US \$80 through the website link. Because the hotel requires advance notice of the number of meals, this option is not available on-site.

### **Mid-Conference Wednesday Afternoon Activities**

The conference organizers have made special arrangements for the following activities on Wednesday of the conference. See conference website for details.

- **Brew-Bus** microbrewery tour in Portland
- **River Tripper** tour of Damariscotta River oyster leases and UMaine's Darling Marine Center by boat with cash bar, appetizers and the best oysters on the planet!
- **Shopping Shuttle to Freeport** for L.L. Bean and other outlet shopping.
- **Lucky Catch Lobster Fishing** tour from Portland followed by tour of **Ready Seafood Company's** lobster processing center on the Portland waterfront.
- **Scuba Diving** on the Maine Coast (Aqua Diving Academy, Portland)
- **Kayaking Casco Bay** (Portland Paddle)



Sign-ups for some of these activities will be available online prior to the conference and will require payment when enrolling. Most tours have limited space and are available on a first-come-first-served basis. Lucky Catch, diving, and kayak trips must be contracted directly with the individual vendors due to liability issues. The Ready Seafood tour is free and has no limit on enrollment. For updates and pricing, check the conference website at [www.11thicwl.com](http://www.11thicwl.com).

### **Accommodations**

All accommodation accounts must be settled at check-out. The Organizing Committee will not be responsible for accommodation accounts.

### **Social Events Schedule**

#### **Sunday, June 4<sup>th</sup>**

Meet & Greet

6:00 pm – 9:00 pm

Cash bar. Alcoholic and soft drinks, hors d'oeuvre

Cost: Included for Full Registrants and Registered Companions

Additional tickets: US \$20 per person

#### **Tuesday, June 6<sup>th</sup>**

Poster Session

7:30 pm – 9:30 pm

Cash bar. Alcoholic and soft drinks, hors d'oeuvre, carving station

Cost: Included for Full Registrants and Registered Companions

Additional tickets: US \$20 per person

#### **Wednesday, June 7<sup>th</sup>**

Mid-Conference Special Activities. See conference website for pricing and details.

- Brew-Bus Tour
- Damariscotta River Tripper & Darling Marine Center Tour
- Lucky Catch and Ready Seafood Co. tour
- Freeport Shopping Bus
- Scuba Diving
- Kayaking

#### **Thursday, June 8<sup>th</sup>**

Conference Lobster Bake on Peak's Island

5:45 pm – 10:00 pm

Board Casco Bay Line boats at dock at 5:45 pm

A traditional New England lobsterbake with alcoholic and soft drinks

Cost: US \$75 per person, pre-registration is REQUIRED

#### **Friday, June 9<sup>th</sup>**

Conference Farewell Social at Gulf of Maine Research Institute

4:30 pm – 7:30 pm

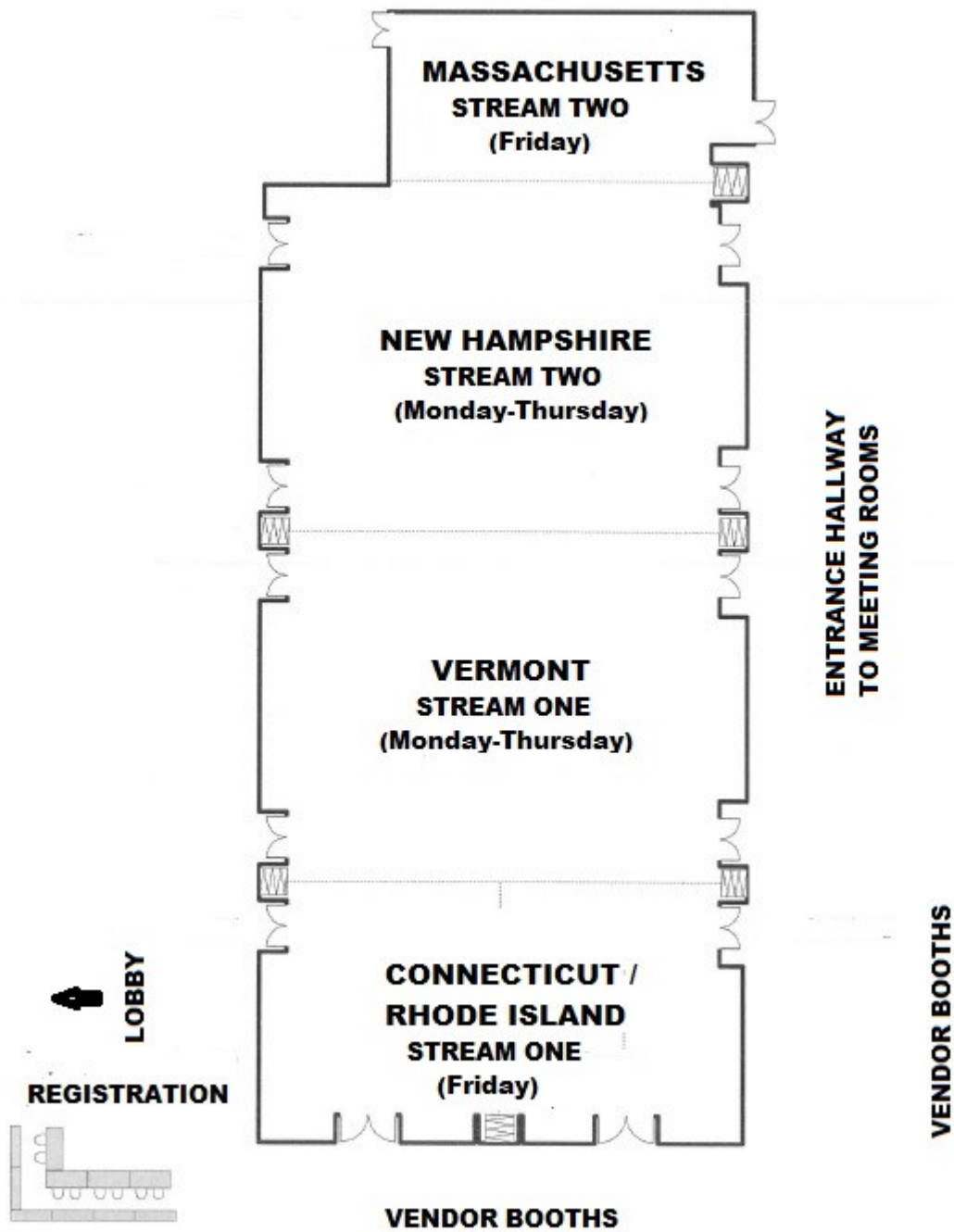
Cash bar. Alcoholic and soft drinks, hors d'oeuvre

Cost: Included for Full Registrants and Registered Companions

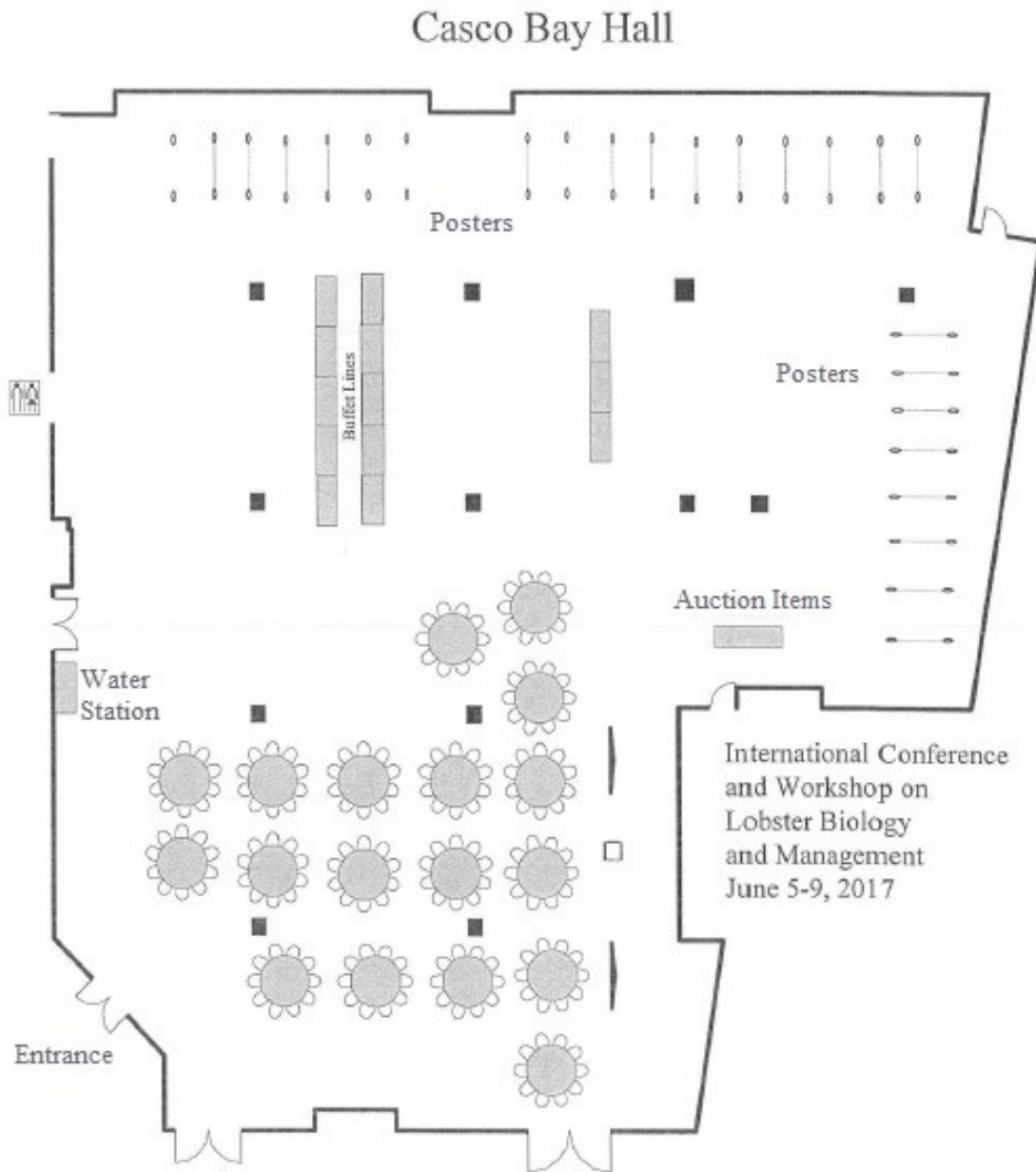
Additional tickets: US \$20 per person



## REGISTRATION, VENDORS, AND SESSION ROOMS



**BREAKFASTS, KEYNOTES, LUNCHESES, AND POSTER SESSIONS**





# 11<sup>th</sup> ICWL Program

## June 4-9, 2017

### Sunday June 4, 2017

3:00-8:00 pm	Registration, Holiday Inn by the Bay
6:00-9:00 pm	Welcome Ice Breaker, Holiday Inn by the Bay

### Monday June 5, 2017

*Sponsored by: Maine Department of Marine Resources – Gold Sponsor, Northeast Fisheries - NOAA, Northeast Sea Grant Consortium – Silver Sponsor, Clearwater Seafoods – Silver Sponsor, Boston University Marine Program, University of Maine*

8:00 am-5:00 pm	Registration, Holiday Inn by the Bay
8:30-10:00 am	BREAKFAST, Casco Bay Room
8:45 am	Welcome and Announcements – Casco Bay Room
9:00-9:30 am	Official Welcome, University of Maine President SUSAN HUNTER and US Senator ANGUS KING
9:45-10:45 am	Keynote Address: JELLE ATEMA - <i>Lobster Lessons in Marine Sensory Biology</i>
10:45-11:15 am	HEALTH BREAK

**Monday June 5, 2017 (continued)**

**Sponsored by: Maine Department of Marine Resources – Gold Sponsor, Northeast Fisheries - NOAA, Northeast Sea Grant Consortium – Silver Sponsor, Clearwater Seafoods – Silver Sponsor, Boston University Marine Program, University of Maine**

STREAM ONE - Vermont		STREAM TWO – New Hampshire
	<b>Behavior &amp; Neurobiology</b> <i>Chair: Ehud Spanier</i>	<b>Diseases &amp; Parasites</b> <i>Chair: Don Behringer</i>
11:15-11:30 am	Chemoreceptor proteins in lobsters, <i>Panulirus argus</i> and <i>Homarus americanus</i> : no GRs but lots of IRs differentially expressed across their major chemosensory organs – <b>Mihika Kozma</b> , V. Ngo-Vu, M. Schmidt, C. Derby	From puerulus to puberty: the stage-based effect of PaV1 on juvenile Caribbean spiny lobsters in Florida – <b>Donald C. Behringer</b> , Mark J. Butler, R.G. Muller
11:30-11:45 am	How to catch scampi: investigating the chemosensory behavior of New Zealand scampi – <b>Robert Major</b> , D. Taylor, S. Ogilvie, G. Connor, S. Connor, A. Jeffs	Incipient epizootic shell disease lesions in the American lobster carapace – <b>Joseph G. Kunkel</b> , M. Rosa, B. Tarbox, S. Hild, M.J. Jercinovic, A.N. Bahadur
11:45-12:00 pm	Investigating how changing environmental conditions may affect the chemosensory abilities of the Caribbean spiny lobster <i>Panulirus argus</i> – <b>Erica P. Ross</b> , D.C. Behringer	Laboratory studies on the effect of temperature on progression of epizootic shell disease in the American lobster <i>Homarus americanus</i> – <b>Britnee N. Barris</b> , J. P. Huchin-Mian, H. Small, P.A. O’Leary, P.M. Gillevet, J.D. Shields
12:00-12:15 pm	Hibernation of the slipper lobster <i>Scyllarides latus</i> in the Western Mediterranean – <b>David Diaz</b> , B. Hereu, E. Aspillaga, A. Muñoz, F. Bartumeus, R. Goñi	Survey of idiopathic blindness in lobsters from Narragansett Bay, RI – <b>Mitch Hatzipetro</b> , K.M. Castro, B. Somers, J. Shields
12:15-12:30 pm	The use of accelerometers to monitor the behavior of freely moving lobsters – <b>Steven H. Jury</b> , T. Langley, B. Gutzler, J. Carloni, J. Goldstein, W. Watson	Acute phase serum amyloid protein A expression is significantly increased during bacterial and microparasitic pathogen challenge in the American lobster ( <i>Homarus americanus</i> ) – <b>Fraser Clark</b> , M. Abergel, A. Loewen, S. Greenwood
12:30-12:45 pm	Comparison of movements of adult, sub-adult, and juvenile spiny lobsters ( <i>Panulirus argus</i> ) in South Florida using acoustic tags and tracking receiver grids – <b>Rodney Bertelsen</b> , M. Childress, T. Matthews	Quantifying the impact of epizootic shell disease on the American lobster using 35 years of mark-recapture data – <b>Maya L. Groner</b> , J. Shields, J. Hoening, D. Landers
12:45-1:00 pm	Is winter stranding of Mediterranean slipper lobsters an outcome of unique combinations of their behavioral ecology, bottom bathymetry and oceanographic conditions? – <b>Ehud Spanier</b> , E. Miller, D. Zviely	Exploration of the American lobster ( <i>Homarus americanus</i> ) immune response to bacterial and parasitic infection – <b>Fraser Clark</b> , S. Greenwood
1:00-2:00 pm	<b>LUNCH (PROVIDED)</b>	

Monday June 5, 2017 (continued)

Sponsored by: **Maine Department of Marine Resources – Gold Sponsor, Northeast Fisheries - NOAA, Northeast Sea Grant Consortium – Silver Sponsor, Clearwater Seafoods – Silver Sponsor, Boston University Marine Program, University of Maine**

	STREAM ONE – Vermont	STREAM TWO – New Hampshire
	<b>Behavioral Ecology</b> <i>Chair: Win Watson</i>	<b>Diseases &amp; Parasites</b> <i>Chair: Grant Stentiford</i>
2:00-2:15 pm	Virtual walking tours of the Bay of Fundy: combining archival tag data and an ocean circulation model to infer individual migration paths of lobster ( <i>Homarus americanus</i> ) in the Bay of Fundy – <b><u>Eric P. Bjorkstedt</u></b> , P.H. Hanley, B. Morse, R. Rochette	From hatchery to open sea: health and disease screening in juvenile European lobster ( <i>Homarus gammarus</i> ) – <b><u>Michelle J. Pond</u></b> , G. Stentiford
2:15-2:30 pm	Temperature-driven migration strategies of ovigerous lobsters, <i>Homarus americanus</i> : observations from archival tags and inferences from an individual-based model – <b><u>Patricia H. Hanley</u></b> , E.P. Bjorkstedt, B. Morse, R. Rochette	Fine-scale transition of microbiome during progression of shell disease in laboratory-reared juvenile American lobster – S. Feinman, A.U. Martinez, J.L. Bowen, <b><u>Michael F. Tlusty</u></b>
2:30-2:45 pm	Evidence that American lobsters carrying late-stage eggs move to deeper water prior to hatching – <b><u>Joshua T. Carloni</u></b> , J. Goldstein, W. Watson	The Lobster Black Death: characteristics of bacteria associated with tail fan necrosis in a wild spiny lobster population – H. Zha, <b><u>Andrew Jeffs</u></b> , Gillian Lewis
2:45-3:00 pm	The westward migration of one part of the European lobster population ( <i>Homarus gammarus</i> ) around Brittany in France – <b><u>Martial M. Laurans</u></b> , D.D. Leroy, L.L. Robigo	The gut microbiome of the European lobster ( <i>Homarus gammarus</i> ): in sickness and in health – <b><u>Corey Holt</u></b> , M. van der Giezen, C. Daniels, G. Stentiford, M. Pond, D. Bass
3:00-3:15 pm	‘In the Heat of the Moment’: effects of thermal stress on seasonal movements in slipper lobsters ( <i>Scyllarides latus</i> ) in the Eastern Mediterranean – <b><u>Jason S. Goldstein</u></b> , E. Spanier	Epizootic shell disease in the American lobster: changes in the microbial community in relation to temperature – <b><u>Jeffrey D. Shields</u></b> , J.P. Huchin-Mian, H.J. Small, B.N. Barris, J. Andrews, S. Dalmat, M. Sikaroodi, P.M. Gillevet
3:15-3:30 pm	Recruitment of juvenile American lobsters ( <i>Homarus americanus</i> ) to the fishery: can mud habitat be ignored? – <b><u>Kristin M. Dinning</u></b> , R. Rochette	Could the viability of <i>Panulirus argus</i> Virus 1 in seawater explain its Caribbean distribution? – <b><u>Abigail S. Clark</u></b> , T.B. Waltzek, D.C. Behringer
3:30-4:00 pm	<b>HEALTH BREAK</b>	

**Monday June 5, 2017 (continued)**

**Sponsored by: Maine Department of Marine Resources – Gold Sponsor, Northeast Fisheries - NOAA, Northeast Sea Grant Consortium – Silver Sponsor, Clearwater Seafoods – Silver Sponsor, Boston University Marine Program, University of Maine**

STREAM ONE - Vermont		STREAM TWO - New Hampshire
	<b>Behavioral Ecology</b> <i>Chair: Kari Lavalli</i>	<b>Diseases &amp; Parasites</b> <i>Chair: Charlotte Davies</i>
4:00-4:15 pm	Lobster – predator interactions in Maine: evidence for the importance of behavior and predator identity – <b>Graham D. Sherwood</b> , J.H. Grabowski	Parasites affecting Caribbean spiny lobsters ( <i>Panulirus argus</i> ): the role of habitat – <b>Charlotte E. Davies</b>
4:15-4:30 pm	Non-consumptive effects of black sea bass ( <i>Centropristis striata</i> ) on juvenile American lobster ( <i>Homarus americanus</i> ) population dynamics – <b>Marissa McMahan</b> , J. Grabowski	An assessment of rapid diagnostic techniques for idiopathic blindness in the American lobster, <i>Homarus americanus</i> , from Rhode Island waters – <b>Mitch Hatzipetro</b> , B. Somers, K.M. Castro, J. Shields
4:30-4:45 pm	Fending off predators and ocean acidification? Investigation of the complex exoskeleton of the California spiny lobster – <b>Kaitlyn Lowder</b> , J.R.A. Taylor, M. deVries	Isolation and utilization of probiotics to manage epizootic shell disease in American lobsters, <i>Homarus americanus</i> – <b>Melissa Hoffman</b> , K. Castro, G. Underwood, H. Ranson, D. Rowley, D.R. Nelson, M. Gomez-Chiarri
4:45-5:00 pm	Climate-related shifts in the distribution of American lobster and its predators in the Northeast U.S. – <b>Andrew Allyn</b> , K. Mills, A. Pershing, J.G. Schuetz	Phylogenomic characterization of <i>Panulirus argus</i> Virus 1 – K. Subramaniam, D.C. Behringer, <b>Abigail S. Clark</b> , N. Yutin, E. Clark, T.B. Waltzek
5:00-5:15 pm	Behavioral plasticity in the social behaviors of juvenile Caribbean spiny lobsters – <b>Michael J. Childress</b> , R.D. Bertelsen	
5:15-5:30 pm	Differential influence of coral reef degradation on feeding ecology of two sympatric spiny lobsters – <b>Enrique Lozano-Álvarez</b> , P.S. Morillo-Velarde, C. Barradas-Ortiz, F. Negrete-Soto, S. Aguiñiga-García, L. Álvarez-Filip, P. Briones-Fourzán	

**EVENING – ON YOUR OWN!**

Tuesday June 6, 2017

Sponsored by: MA-Division of Marine Fisheries, University of Maine, Brunswick Department of Agriculture, Aquaculture, & Fisheries, Canadian Consul General of Boston, Maine Maritime Museum

8:00 am-5:00 pm	Registration, Holiday Inn by the Bay	
8:30-10:00 am	BREAKFAST, Casco Bay Room	
8:40-9:40 am	Keynote Address: PAULO PRÓDOHL - <i>Pioneering Use of Genetic Tagging to Assess the Impact of V-Notching in the Management of European Lobster Homarus gammarus Stocks: Maine's Lobstermen Have it Right!</i>	
9:40-10:15 am	HEALTH BREAK	
	STREAM ONE - Vermont	STREAM TWO - New Hampshire
	Population Genetics & Connectivity Chair: Laura Beneston	Reproductive Biology Chair: Ann-Lisbeth Agnalt
10:15-10:30 am	Genomics as a promising tool for fishery management - <b>Laura M. Benestan</b> , L. Bernatchez, R. Rochette	The importance of keeping the big ones: management of Caribbean spiny lobster, <i>Panulirus argus</i> to conserve large individuals - <b>Gayathiri Gnanalingam</b> , M.J. Butler
10:30-10:45 am	A comparison of different methodologies for genotyping large number of individuals and their application for lobster management - <b>Quetin Rougemont</b> , Y. Dorant, L.M. Benestan, E. Normandeau, R. Rochette, L. Bernatchez	Can the French lobster female ( <i>Homarus gammarus</i> ) be considered a super female? - <b>Martial M. Laurans</b> , S.S. Fifas, J.J. Weiss, I.I. Schlaich, L.L. Robigo, V.V. LeGrand, A.A. Pengrech
10:45-11:00 am	Genome-wide SNP discovery and SNP panel development in European lobster ( <i>Homarus gammarus</i> ) - <b>Tom L. Jenkins</b> , C.D. Ellis, J.R. Stevens	Lobster hybrids in Scandinavian waters - Laboratory experiments on larval viability and competition with European lobster - <b>Susanne P. Eriksson</b> , L. Svanberg, H.L. Wood, G. Dahle, O. Maire, A. Powell, E. Farestvelt, A-L. Agnalt
11:00-11:15 am	Genetic and biological variations in local populations of European lobster ( <i>Homarus gammarus</i> ) in Norway - <b>Geir Dahle</b> , K.E. Jørstad, E. Farestveit, A-L. Agnalt	Survival, growth, deformities and sperm quality in hybrid offspring, from a crossbreeding in the wild between an American female and a European male - <b>Ann-Lisbeth Agnalt</b> , E. Farestvelt, E.S. Grefsrud, G. Dahle, K.E. Jørstad, P. Prodöhl
11:15-11:30 am	Assessing the population structure and connectivity of the Eastern Rock Lobster, <i>Sagmariasus verreauxi</i> , utilizing next-generation sequencing - <b>Laura N. Woodings</b> , N.P. Murphy, S.R. Doyle, N.E. Hall, A.J. Robinson, G.W. Liggins, B.S. Green, I.R. Cooke, J.J. Bell, J.M. Strugnell	Picturing the intimate details: using image analysis to examine the composition of male American lobster ( <i>Homarus americanus</i> ) ejaculates - <b>Tracy L. Pugh</b> , M. Comeau, K. Benhalima, W. Watson
11:30-11:45 am	Fine scale population structure and connectivity of the American lobster in Atlantic Canada investigated using genotyping-by-sequencing capture - <b>Yann Dorant</b> , L.M. Benestan, Q. Rougemont, E. Normandeau, R. Rochette, L. Bernatchez	The role of gamete limitation to the production of "abnormal clutches" by female American lobster, <i>Homarus americanus</i> , in eastern Canada - <b>Feng Tang</b> , B. Sainte-Marie, J. Gaudette, R. Rochette
11:45-12:00 pm	Sex matters in massive parallel sequencing: evidence for biases in genetic parameter estimation and investigation of sex determination systems - <b>Laura M. Benestan</b> , L. Bernatchez, J. Atema, S. Greenwood, F. Clark	Estimating the size at the onset of maturity for New Zealand scampi ( <i>Metanephrops challengeri</i> ) - <b>Alaric McCarthy</b> , I. Tuck, A. Jeffs, D. Taylor, S. Ogilvie, G. Connor, S. Connor
12:00-1:15 pm	LUNCH (PROVIDED)	



Tuesday June 6, 2017 (continued)

Sponsored by: MA-Division of Marine Fisheries, University of Maine, Brunswick Department of Agriculture, Aquaculture, & Fisheries, Canadian Consul General of Boston, Maine Maritime Museum

	STREAM ONE - Vermont	STREAM TWO - New Hampshire
	<b>Physiological Responses to Environmental Stressors</b> <i>Chair: Fraser Clark</i>	<b>Recruitment Processes</b> <i>Chair: Mark Butler</i>
1:15-1:30 pm	Searching for the molecular mechanisms underlying spiny lobsters sex determination and development – <b>Quinn Fitzgibbon</b> , J. Chandler, G. Smith, A. Elizur, T. Ventura	The great disconnect: is rising larval mortality the link to new lows in lobster settlement when egg production has never been higher in the Gulf of Maine? – <b>Joshua Carloni</b> , R.A. Wahle
1:30-1:45 pm	Linking rising pCO <sub>2</sub> and temperature to the larval development, physiology and gene expression of the American lobster ( <i>Homarus americanus</i> ) – <b>Jessica Waller</b> , R.A. Wahle, D. Fields, S. Greenwood	Evidence of metamorphosis of Caribbean ( <i>Panulirus argus</i> ) and spotted ( <i>P. guttatus</i> ) spiny lobsters in the Yucatan Current – <b>Patricia Briones-Fourzán</b> , J. Candela, L. Carrillo, F. Negrete-Soto, C. Barradas-Ortiz, E. Escalante-Mancera, E. Lozano-Alvarez
1:45-2:00 pm	Interactive effects of ocean acidification and temperature increase on shell development and gene expression in juvenile <i>Homarus americanus</i> – <b>Christine San Antonio</b> , M. Tlusty, R. Hannigan	Energetic constraints in spiny lobster recruitment – <b>Andrew Jeffs</b> , G. Liggins, M. Miller, G. Ballinger
2:00-2:15 pm	Effects of ocean acidification on the physiology of subadult American lobsters ( <i>Homarus americanus</i> ) – <b>Amalia M. Harrington</b> , H.J. Hamlin	Energy expenditure of migrating spiny lobster post larvae – <b>Luvia L. Garcia Echauri</b> , A. Jeffs
2:15-2:30 pm	Effects of combined exposure to ocean acidification and hypoxia or manganese on immunological, physiological and behavioral responses in Norway lobster ( <i>Nephrops norvegicus</i> ) – <b>Anna-Sara Krång</b> , H.K. Styf, B. Hernroth, S.P. Baden, F. Jutfelt, J. Mattsson, S. Eriksson	Optimizing an oceanographic-larval model for assessment of the puerulus settlement of the western rock lobster, <i>Panulirus cygnus</i> , in Western Australia – Ainslie Denham, M. Feng, <b>Nick Caputi</b> , S. de Lestang, J. Penn, D. Slawinski, A. Pearce, J. How
2:30-2:45 pm	European lobster <i>Homarus gammarus</i> in a high CO <sub>2</sub> environment – following individual larvae from stage I to stage IV – <b>Ellen Sofie Grefsrud</b> , A-L. Agnalt, S. Anderson, E. Farestvelt, I. Opstad, P. Dalpadado, Anders Mangor-Jensen	Spatial and temporal patterns of recruitment of the eastern rock lobster, <i>Sagmariasus verreauxi</i> , over 2 decades – <b>Geoffrey W. Liggins</b> , M. Miller, G. Ballinger
2:45-3:00 pm	Physiological impacts of seismic air gun exposure on spiny lobster ( <i>Jasus edwardsii</i> ) – <b>Quinn Fitzgibbon</b> , R. Day, R. McCauley, J. Semmens	A molecular approach to understanding metamorphosis in spiny lobsters – <b>Cameron J. Hyde</b> , Q. Fitzgibbon, A. Elizur, G. Smith, T. Ventura
3:00-3:30 pm	<b>HEALTH BREAK</b>	

Tuesday June 6, 2017 (continued)

**Sponsored by: MA-Division of Marine Fisheries, University of Maine, Brunswick Department of Agriculture, Aquaculture, & Fisheries, Canadian Consul General, Maine Maritime Museum**

	STREAM ONE - Vermont	STREAM TWO – New Hampshire
	<b>Population Dynamics &amp; Connectivity</b> <i>Chair: Brady Quinn</i>	<b>Trap Design &amp; Impacts</b> <i>Chair: Win Watson</i>
3:30-3:45 pm	Investigating the connectivity of the Caribbean spiny lobster using a multi-disciplinary approach – <b>Nan Yao</b> , Y. Zhang	Composition, quantity, and survival of incidental catch during the southern Gulf of St. Lawrence lobster ( <i>Homarus americanus</i> ) fishery – <b>Amélie Rondeau</b> , M. Comeau, P. Hanley
3:45-4:00 pm	Potential impacts of larval behavior and spatiotemporal variation in hatch on modeled connectivity by larval dispersal and settlement of American lobster – <b>Brady K. Quinn</b> , J. Chassé, R. Rochette	Technological advances for research in the New Zealand scampi fishery – <b>Shaun Ogilvie</b> , J. Radford, D. Taylor, R. Major, C. Batstone, A. McCarthy, S. Connor, G. Connor
4:00-4:15 pm	Stock structure and connectivity in the American lobster <i>Homarus americanus</i> : do benthic movements matter? – B. Morse, B.K. Quinn, M. Comeau, <b>Rémy Rochette</b>	Ka Hao Te Rangatahi: Innovations that improve economic outcomes in the New Zealand scampi fishery? – <b>Chris J. Batstone</b> , S. Ogilvy, D.I. Taylor, K. Heasman, R. Major, G. Paine
4:15-4:30 pm	Use of the American Lobster Settlement Index to examine recruitment and juvenile lobster population dynamics and inform the Gulf of Maine stock assessment model – <b>Burton V. Shank</b> , R.A. Wahle	Possible mechanisms that give rise to the saturation of ventless American lobster traps – <b>Win H. Watson</b> , E. Morrissey, T. Langley, J. Goldstein, S.H. Jury
4:30-4:45 pm	Spatio-temporal patterns and reproductive costs of abnormal clutches of female American lobster, <i>Homarus americanus</i> , in eastern Canada – <b>Feng Tang</b> , M.L. Haarr, B. Sainte-Marie, M. Comeau, M.J. Tremblay, J. Gaudette, R. Rochette	Optimizing trap design for New Zealand scampi – <i>Metanephrops challenger</i> – <b>David I Taylor</b> , M. Scott, J. Radford, R. Major, C. Batstone, A. McCarthy, S. Connor, G. Connor
4:45-5:00 pm	<b>Estimating juvenile abundances of the American lobster (<i>Homarus americanus</i>) in the Gulf of Maine: A comparison between GAM and GWR models – Katherine J. Thompson, B. Li, K.M. Reardon, Y. Chen</b>	<b>Effects of green crab (<i>Carcinus maenas</i>) on the food acquisition and catchability of the American lobster (<i>Homarus americanus</i>) in Newfoundland, Canada – Gemma Rayner, I.J. McGaw</b>
5:00-5:15 pm	The fecundity and early life stages of the New Zealand scampi <i>Metanephrops challenger</i> – <b>Kevin G. Heasman</b> , S. Ogilvie, R. Major, G. Paine, R. Paine, S. Connor, G. Connor, A. Jeffs	Norway lobster ( <i>Nephrops norvegicus</i> ) fishing grounds in western Norway fjords and coastal areas – seabed mapping and trap fishing experiments – <b>Knut E. Jørstad</b> , G. Søvik, Å. Bjordal, M. Theriault, I.F. Farestveit Jørsad, A-L. Agnalt
7:30-9:30 pm	<b>POSTER SESSION (CASH BAR &amp; CARVING STATION/FINGER FOODS)</b>	

Wednesday June 7, 2017

**Sponsored by: University of New England, University of Maine School of Marine Sciences, Bangor Savings Bank, VEMCO, Ocean Foundation, Florida SeaGrant**

8:00 am-12 pm	Registration, Holiday Inn by the Bay	
	STREAM ONE - Vermont	STREAM TWO - New Hampshire
	<b>Aquaculture</b> <i>Chair: Andrew Jeffs</i>	<b>Fisheries Science</b> <i>Chair: Kisei Tanaka</i>
8:30-8:45 am	The why, where, and how of spiny lobster aquaculture ( <i>Panulirus ornatus</i> ) – <b>Greg G. Smith</b> , Q. Fitzgibbon, S. Battaglone, C. Simon, E. Goulden, D. Cundy, A. Jeffs, C. Carter	An ecosystem approach to lobster stock assessments – <b>Adam M. Cook</b>
8:45-9:00 am	Aquaculture as a diversification strategy for lobster harvesters – <b>Caitlin M. Cleaver</b> , T.R. Johnson, S.P. Hanes, K. Pianka	Estimating tag induced mortality of southern rock lobster in the wild - How does variation in the size and the number of tagged lobsters affect the tag induced mortality estimations? – Z. Kordjazi, S. Frusher, C. Buxton, <b>Caleb Gardner</b> , T. Bird
9:00-9:15 am	Progress and obstacles in establishing rock lobster aquaculture in Indonesia – <b>Clive Jones</b>	Determining the care factor: what's the chance of seeing that tag again? – Matthew B. Pember, <b>Simon de Lestang</b>
9:15-9:30 am	Ongrowing of Caribbean spiny lobster ( <i>Panulirus argus</i> , Latreille 1804) in sea cages, in two Cuban farms – <b>Gerardo Suarez Alvaro</b>	Scampi grade data - recreating catch composition – <b>Ian D. Tuck</b> , B.W. Hartill
9:30-9:45 am	How does metabolic phenotype and social interaction affect growth disparity of spiny lobster? – A.D. Tuzan, <b>Quinn Fitzgibbon</b> , C. Carter, S. Battaglone	A new growth model for the Juan Fernandez rock lobster – <b>Billy Ernst</b> , P. Manriquez, A. Palma
9:45-10:00 am	Metabolic rate, manipulation and transportation of live spiny lobster, <i>Panulirus argus</i> , Latreille 1804 in Cuba – <b>Gerardo Suarez Alvaro</b>	The 'Hunger Games': how starvation affects attractiveness of lobsters used to bait traps in the Florida spiny lobster fishery – <b>Casey B. Butler</b> , J. Butler, T.R. Matthews
10:00-10:15 am	Determination of hemolymph biochemistry reference intervals in American lobsters ( <i>Homarus americanus</i> ) – <b>Andrea Battison</b> , J. Lavallée	<b>A quasi-stationary approach to estimating effective effort in the Maine American lobster (<i>Homarus americanus</i>) fishery – Robert E. Boenish, Y. Chen</b>
10:15-10:45 pm	<b>HEALTH BREAK</b>	

**Wednesday June 7, 2017 (continued)**

**Sponsored by: University of New England, University of Maine School of Marine Sciences, Bangor Savings Bank, VEMCO, Ocean Foundation, Florida SeaGrant**

	<b>STREAM ONE - Vermont</b>	<b>STREAM TWO – New Hampshire</b>
	<b>Aquaculture</b> <i>Chair: Clive Jones</i>	<b>Special Workshop: Caribbean Spiny Lobster Stock Assessment</b> <i>Chair: Yuying Zhang</i>
10:45-11:00 am	Lobster grower: towards mariculture of European lobsters – <b><u>Carly L. Daniels</u></b> , <i>C.D. Ellis</i>	Opening and Introduction
11:00-11:15 am	Sensitivity during the molting cycle in European lobster ( <i>Homarus gammarus</i> ) juveniles to the anti-parasitic agent teflubenzuron – <b><u>Ole B. Samuelsen</u></b> , <i>E.S. Grefsrud, E. Farestveit, R. Hannisdal, T. Tjensvoll, B.T. Lunestad, A-L. Agnalt</i>	Developing a size-structured stock assessment model for spiny lobster in the southeast United States <b><u>Yuying Zhang</u></b> , N. Yao
11:15-11:30 pm	Effect of holding conditions on the physiology of European lobsters, <i>Homarus gammarus</i> : exploiting a seasonal market – <b><u>Douglas M. Neil</u></b> , <i>A. Albalat, G.C. Dykes, H. Dubernet, J. Dick, C.J. Coates, L. Johnson, K. Todd</i>	
11:30-11:45 pm	Treatment of a laboratory model of shell disease in hatchery raised lobsters – <b><u>Anita Kim</u></b> , <i>C. Seid, M. Tlusty</i>	
11:45-12:00 pm	Evaluating parentage-based tagging for the identification of released hatchery lobsters – <b><u>Charlie D. Ellis</u></b> , <i>A.G.F. Griffiths, D.J. Hodgson</i>	Stock assessment of lobster <i>Panulirus argus</i> in fishing zones from Yucatán and Quintana Roo coasts, México – <b><u>Gloria Verónica Ríos-Lara</u></b>
12:00-12:15 pm	<b>AFTERNOON FREE TIME &amp; EXCURSIONS</b>	The fishery management and stock assessment of spiny lobster ( <i>Panulirus argus</i> ) in Cuba – <b><u>Ofelia Morales</u></b> , <i>R. Puga, R. Alzugaray, M.E. de León, L.S. Cobas, R. Piñeiro</i>
12:15-12:30 pm		
12:30-12:45 pm		Discussion
12:45-1:00 pm		
1:00-1:15 pm		
1:15-1:30 pm		<b>AFTERNOON FREE TIME &amp; EXCURSIONS</b>
1:30-1:45 pm		
1:45 – onward		

**Silent Auction Set Up – Wednesday through Friday Morning**

Thursday June 8, 2017

Sponsored by: New Zealand Rock Lobster Industry Council, Ready Seafood Co., East Coast Seafood, Little Bay Lobster, Clearwater Seafoods, Tangier Lobster Co. Ltd., UMaine System Research Reinvestment Fund

8:00 am-5:00 pm	Registration, Holiday Inn by the Sea	
8:30-9:30 am	BREAKFAST, Casco Bay	
8:30-9:00 am	Industry Day Welcome PATRICK KELIHER (Maine Dept. Marine Resources) & DAVID COUSENS (Maine Lobstermen's Association)	
9:00-9:45 am	Keynote Address - BOB STENECK - Escaping Maine's Gilded Lobster Trap: Thinking about Long-Term Strategies	
9:45-10:15 am	Health Break	
	STREAM ONE - Vermont	STREAM TWO - New Hampshire
	INDUSTRY DAY: Science - Industry Collaborations Chair: Curtis Brown	INDUSTRY DAY: Adaptive Harvesting and Management Strategies Chair: Susie Arnold
10:15-10:30 am	Massachusetts: the cross-roads for lobster - Beth and Dave Casoni (Mass. Lobstermen's Association)	A climate of change: fishermen, scientists, and managers share information to prepare for an uncertain future - Susie Arnold, N. Battista, H. Deese
10:30-10:45 am	Ready Seafood: 15 years of shipping lobsters around the world - Brendan Ready (Ready Seafood Co.)	Ecological sustainable development (or triple bottom line assessment) of western rock lobster fishery: What is optimal target of fishing? - Nick Caputi, S. de Lestang, J. How, F. Trinnie
10:45-11:00 am	Challenges of a changing industry- Eric Branton (Clearwater Seafood)	Through the eyes of industry: an investigation of how stakeholders in the lobster fishery synchronize their behavior with the spring lobster molt - Kevin W. Staples
11:00- 11:15 am	Improving quality and profitability in the New Zealand rock lobster fishery: utilizing science to make money - Malcolm Lawson	Management strategies to improve ecosystem services and increase industry profitability - Klaas Hartmann, C. Gardner, H. Revill
11:15-11:30 am	Global trade routes of lobster (Homarus spp.) - Joshua Stoll (UMaine), Beatrice Crona	Evaluation of modified lobster trap vents in the southern New England lobster fishery - Laura Skrobo, K. Castro, M. Hatzipetro, L. Dellinger, H. Henninger, D. Borden, B. Shank, B. Glen, M. Gibson
11:30-11:45 pm	Tablets and temperature loggers: collecting data with the CFRF lobster and Jonah crab research fleet - Anna Malek Mercer (Commercial Fisheries Research Foundation)	Not enough lobsters to go around!- Management challenges and solutions of regional stock rebuilding and resource sharing in the Tasmanian east coast rock lobster fishery - Hilary M. Revill, R. Pearn
11:45-12:00 pm	Costs and benefits of reducing soak time in the European spiny lobster (Palinurus elephas) trammel-net fishery - Sandra Mallol, D. Diaz, A. Muñoz, R. Goñi	A long-term unfished population exposes depleted status of Mediterranean lobster fisheries - Raquel Goñi
12:15-1:15 pm	LUNCH (PROVIDED)	

**Thursday June 8, 2017 (continued)**

**Sponsored by: New Zealand Rock Lobster Industry Council, Ready Seafood Co., East Coast Seafood, Little Bay Lobster, Clearwater Seafoods, Tangier Lobster Co. Ltd., UMaine System Research Reinvestment Fund**

1:15-2:00 pm	<b>Keynote Address - MARK EDWARDS - Celebrating Two Decades Of Collaboration Between New Zealand Rock Lobster Industry Participants, Government Agencies, And Internationally Recognized Stock Assessment Scientists</b>	
	<b>STREAM ONE - Vermont</b>	<b>STREAM TWO - New Hampshire</b>
	<b>INDUSTRY DAY: Science - Industry Collaborations</b> <i>Chair: Curtis Brown</i>	<b>INDUSTRY DAY: Adaptive Harvesting and Management Strategies</b> <i>Chair: Nick Caputi</i>
2:00-2:15 pm	Uniquely Prince Edward Island: the island perspective on the lobster levy, marketing, and quality - <b>Melanie Giffin</b> (PEI Fishermen's Association)	An analysis of Maine lobster vessel-level profitability under changing conditions - <b>Alexa Dayton</b>
2:15-2:30 pm	A Network of Science and Industry for Sustainable Fisheries - <b>Jessica Cosham</b> (Fishermen & Scientist Research Society)	The effects of temporary exclusion of activity due to windfarm construction on a lobster ( <i>Homarus gammarus</i> ) fishery suggests a potential management approach - <b>Michael D. Roach</b> , M. Cohen, R. Forster, M.L. Johnson
2:30-2:45 pm	Post-harvest mortality related to high speed trap haulers - <b>Bob Bayer</b> (The Lobster Institute)	Threatened yet unknown: preliminary and fundamental ecological knowledge of the Easter Island spiny lobster - <b>Alvaro T. Palma</b> , I.A. Hinojosa, J. Aburto, C. Gaymer, B. San Martin, Michel Garcia
2:45-3:00 pm	Modernization of an industry peak representative association - <b>Kim Colero</b> , N. Sofoulis	Impact of increasing fishing effort efficiency under effort and quota management systems applied to the Western Australian rock lobster fishery - <b>Jim Penn</b> , S. de Lestang, N. Caputi
3:00-3:30 pm	<b>HEALTH BREAK</b>	

**Thursday June 8, 2017 (continued)**

**Sponsored by: New Zealand Rock Lobster Industry Council, Ready Seafood Co., East Coast Seafood, Little Bay Lobster, Clearwater Seafoods, Tangier Lobster Co. Ltd., UMaine System Research Reinvestment Fund**

	STREAM ONE - Vermont	STREAM TWO - New Hampshire
	<b>INDUSTRY DAY: Science - Industry Collaborations</b> <i>Chair: Curtis Brown</i>	<b>INDUSTRY DAY: Adaptive Harvesting and Management Strategies</b> <i>Chair: Teresa Johnson</i>
3:30-3:45 pm	<b>From lobsters to dollars: an economic analysis of the distribution supply chain in Maine - <u>Michael R. Donihue &amp; Annie Tselikis</u></b>	A risk equivalency tiered approach for the Torres Strait <i>Panulirus ornatus</i> fishery - <b><u>Eva E. Piaganyi-Lloyd</u></b> , R. Deng, R. Campbell, D. Dennis, T. Hutton, M. Tonks, M. Haywood
3:45-4:00 pm	The rocky lobster of the Atlantic French coast saved thanks to management: Involving fishermen to improve biological and ecological knowledge - <b><u>Martial M. Laurans</u></b> , E.E. Quemeneur	<b>Lobstermen behavior and market integration: the impact of rising ocean temperature and emerging Chinese demand on US American lobster landings and prices - <u>Jenny Sun</u></b> , F. Chiang, B. Franklin, B. Kennedy
4:00-4:15 pm	The challenges of developing spiny lobster fishery management policies in Florida incorporating close stakeholder involvement: a case study - <b><u>John H. Hunt</u></b> , W.C. Sharp, J.R. McCawley	Harmful algal blooms - a new phenomenon and management challenge for the Tasmanian rock lobster fishery - <b><u>Hilary Revill</u></b> , G. Pullen
4:15-4:30 pm	Lobster and ocean planning: a spatial characterization of the lobster fishery for the New England regional planning body - <b><u>Nick Battista</u></b> , R. Clark Uchenn, S. Belknap, G. Lapointe	An evaluation of fisher compliance with marine protected areas that prohibit lobster traps - <b><u>Gabrielle F. Renchen</u></b> , T.R. Matthews
4:30-4:45 pm	The trans-Atlantic trade in live lobsters: Should the EU build a wall? - <b><u>Magnus Johnson</u></b> , B.C. Pierce, S.P. Eriksson, A-L. Agnalt	The graying of Maine's lobster fleet and potential implications for social resilience - <b><u>Teresa R. Johnson</u></b> , M. Mazur
5:45-10:00 pm	<b>CASCO BAY CRUISE/LOBSTER BAKE ON PEAK'S ISLAND</b>	



Friday June 9, 2017

Sponsored by: St. Josephs College, Hamilton Marine, University of New Hampshire, Island Institute, Zebra Tech, Big Claw Winery, Gulf of Maine Research Institute

8:30-9:30 am	BREAKFAST, Casco Bay Room	
8:30-9:30 am	Keynote Address: MALIN PINKSY - <i>Ocean Animals on the Move: Consequences for Ecological and Human Communities</i>	
	STREAM ONE - Connecticut/Rhode Island	STREAM TWO - Massachusetts
	<b>Climate Change</b> Chair: <i>Arnault LeBris</i>	<b>Adaptive Harvesting and Management</b> Chair: <i>Burton Shank</i>
9:45-10:00 am	Climate vulnerability and resilience in the most valuable US fishery - <i>Arnault Le Bris, A.J. Allyn, K.E. Mills, J.G. Schuetz, Y. Chen, R.A. Wahle, M.A. Alexander, J.D. Scott, A.J. Pershing</i>	Methodological comparison for sampling shallow water populations of the western rock lobster ( <i>Panulirus cygnus</i> ) at Rottnest Island, Western Australia - <i>Emma-Jade Tuffley, T. Langlois, S. de Lestang, J. How</i>
10:00-10:15 am	Warming oceans and lower exploitation rates impacting the productivity of Australia's largest lobster fishery - <i>Simon de Lestang, M. Pember</i>	How do we prevent the benefits of rock lobster fisheries from being exported out of the community? - <i>Caleb Gardner, K. Hartmann, T. Emery, R. Leon, E. Ogier</i>
10:15-10:30 am	Climate-associated population change and resilience in Caribbean Spiny lobster - <i>Mark J. Butler</i>	Potential impacts on conservation discards in a growing lobster population in the Gulf of Maine - <i>Kathleen M. Reardon, C.J. Wilson, B. Shank</i>
10:30-10:45 am	Larval settlement-based fishery recruitment forecasts for the American lobster along a steep environmental gradient in a changing climate - <i>Noah Oppenheim, R.A. Wahle, D. Brady, A. Pershing</i>	Sustainability and certification - 15 years on - <i>Kim Colero, N. Sofoulis</i>
10:45-11:00 am	Implications of expanding thermal habitat to settlement-based forecasts of American lobster landings - <i>Andrew Goode, D. Brady, R.A. Wahle</i>	Evaluating the V-notching conservation measure in the Maine lobster fishery - <i>Mackenzie Mazur</i>
11:00-11:30 am	HEALTH BREAK	

**Friday June 9, 2017 (continued)**

**Sponsored by: St. Josephs College, Hamilton Marine, University of New Hampshire, Island Institute, Zebra Tech, Big Claw Winery, Gulf of Maine Research Institute**

	STREAM ONE – Connecticut/Rhode Island	STREAM TWO - Massachusetts
	<b>Climate Change</b> <i>Chair: Kathy Mills</i>	<b>Ghost Fishing – Trap/Gear Conflicts</b> <i>Chair: Kelly Whitmore</i>
11:30-11:45 pm	Forecasting the timing of Maine’s lobster fishery – <i>K. Mills, <b>Andrew Pershing</b>, C. Hernandez, S. Sherman</i>	Ghost fishing by derelict traps in the American lobster fishery – <i><b>Kelly Whitmore</b>, D. Perry, R. Glenn</i>
11:45-12:00 pm	Has time of settlement of postlarval American lobster, <i>Homarus americanus</i> , changed between 1993 and 2010? – <i><b>Diane F. Cowan, A.R. Solow</b></i>	Nutritional condition of Caribbean spiny lobsters, <i>Panulirus argus</i> in ghost traps – <i><b>Casey B. Butler</b>, B.C. Gutzler, T.R. Matthews</i>
12:00-12:15 pm	Impacts of mesoscale climatic variations on the abundance of <i>Homarus americanus</i> in the inshore Gulf of Maine – <i><b>Kisei Tanaka</b></i>	Determining post-release mortality for Atlantic cod discarded in the Gulf of Maine lobster fishery – <i><b>Brett B. Swezey</b>, M. Dean, H. Benoit, J. Mandelman, J.A. Sulikowski</i>
12:15-12:30 pm	Geographically varied relationships between American lobster and climate variables in the Gulf of Maine – <i><b>Bai Li</b></i>	Co-habitation of a large commercial fishery and a protected whale population undergoing a marked population increase – <i><b>Simon de Lestang</b>, J. How, B. Hebiton</i>
12:30-12:45 pm	Spatiotemporal variability in the spring molt phenology of American lobster in a changing Gulf of Maine – <i><b>Kevin W. Staples</b>, Y. Chen, D.W. Townsend</i>	The effect of deepwater trawling and discard practices on bottom scavenger abundance and diversity – <i><b>Margarida Castro</b>, M. Machado, V. Henriques, A. Campos, P. Fonseca</i>
12:45-1:00 pm	What is credible science? Learning from industry – <i><b>Jocelyn Runnebaum &amp; Elisabeth Maxwell</b>, K.E. Pianka, N.G. Oppenheim, J.S. Stoll</i>	
1:15-2:15 pm	<b>LUNCH (PROVIDED)</b>	
2:15-3:15 pm	<b>Session Summaries</b>	
3:15-4:00 pm	<b>Farewell Session: Awards, Closing Remarks, Announcements, Etc.</b>	
4:30-7:30 pm	<b>GMRI FAREWELL SOCIAL</b>	

## POSTER SESSION, Tuesday, June 6<sup>th</sup>, 2017

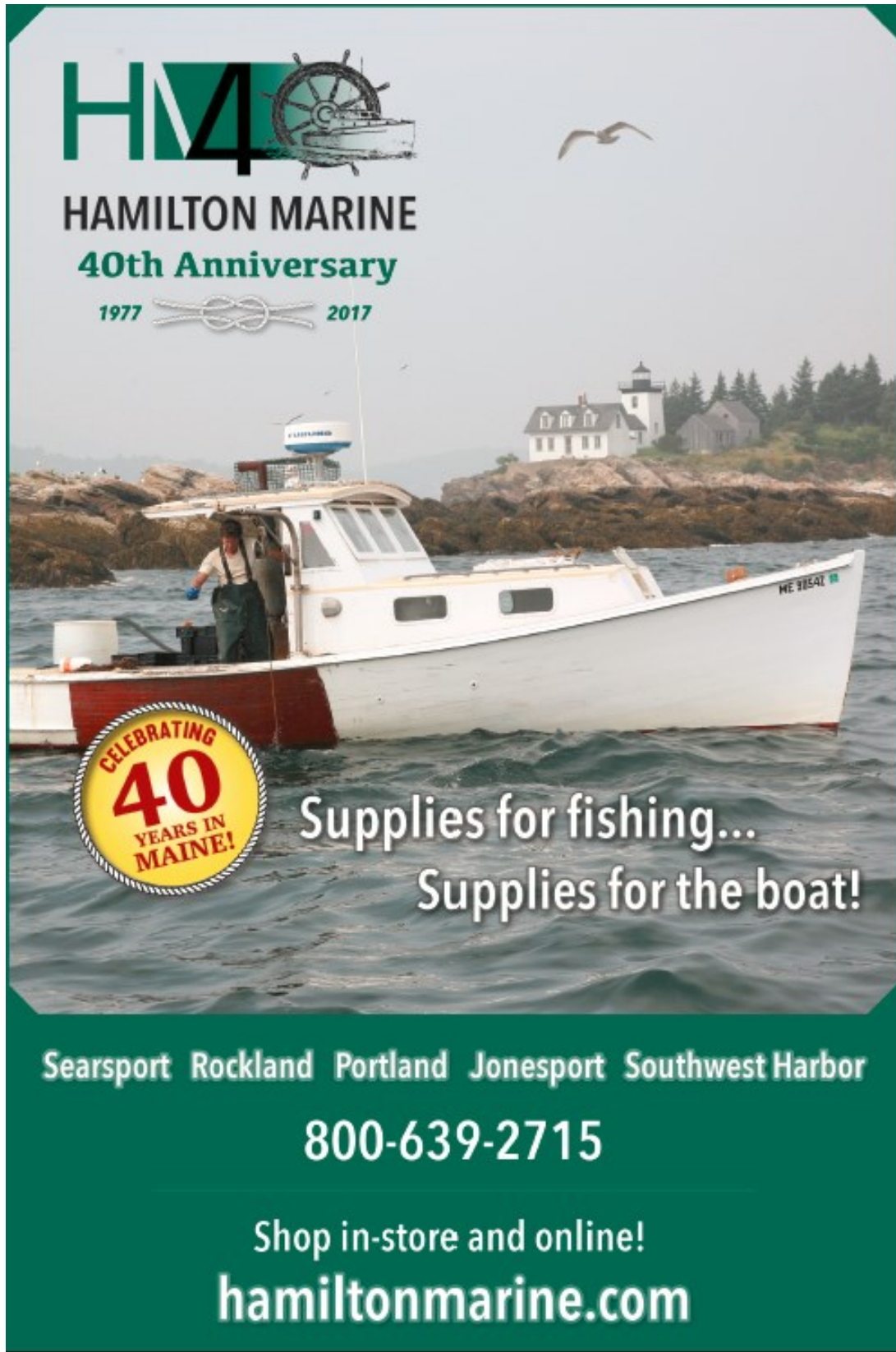
Casco Bay Room – posters will be available Tuesday – Friday morning

AQUACULTURE		
<b>P1</b>	<i>Ellis, Scolding, &amp; Daniels</i>	<b>Lobster Grower: Exploring Mariculture of Hatchery European Lobsters for Fisheries and Aquaculture</b>
<b>P2</b>	<i>González, Armenta, Manzano, Borrego, &amp; Domínguez</i>	<b>Growth of Lobsters <i>Panulirus inflatus</i> and <i>P. gracilis</i> Postlarvae Cultured in Oyster Boxes at Southeast Gulf of California</b>
BEHAVIOR & BEHAVIORAL ECOLOGY		
<b>P3</b>	<i>Baeza &amp; Childress</i>	<b>Microhabitat Sensing by the Pueruli of the Caribbean Spiny Lobster, <i>Panulirus argus</i>: Testing the Importance of Red Algae, Juveniles, and Their Interaction</b>
<b>P4</b>	<i>Bruce, Sutherland, Battaglini, Wafapoor, Freed, &amp; Atema</i>	<b>Visual Recognition of Familiar Dominant Opponents in the Lobster, <i>Homarus americanus</i></b>
<b>P5</b>	<i>Doherty, Kaplan, &amp; Atema</i>	<b>The American Lobster, <i>Homarus americanus</i>, Uses Vision to Evaluate Relative Opponent Size</b>
<b>P6</b>	<i>Gutzler, O'Dowd, White, Jury, &amp; Watson</i>	<b>Can American Lobsters Detect Light Without Their Eyes? Evidence for Extraocular Photoreceptors</b>
<b>P7</b>	<i>Lozano-Álvarez, Cid-González, Negrete-Soto, Barradas-Ortiz, &amp; Briones-Fourzán</i>	<b>Avoiding Diseased Conspecifics Versus Avoiding Predation Risk: Testing the Trade-Off Hypothesis in <i>Panulirus argus</i></b>
<b>P8</b>	<i>Rayner &amp; McGaw</i>	<b>If You Can't Beat Them, Eat Them: The Documentation of American Lobster Predation on the Invasive European Green Crab in Canada</b>
<b>P9</b>	<i>Watson &amp; Goldstein</i>	<b>An Update to the ICWL Book of World Lobster Records</b>
CLIMATE CHANGE		
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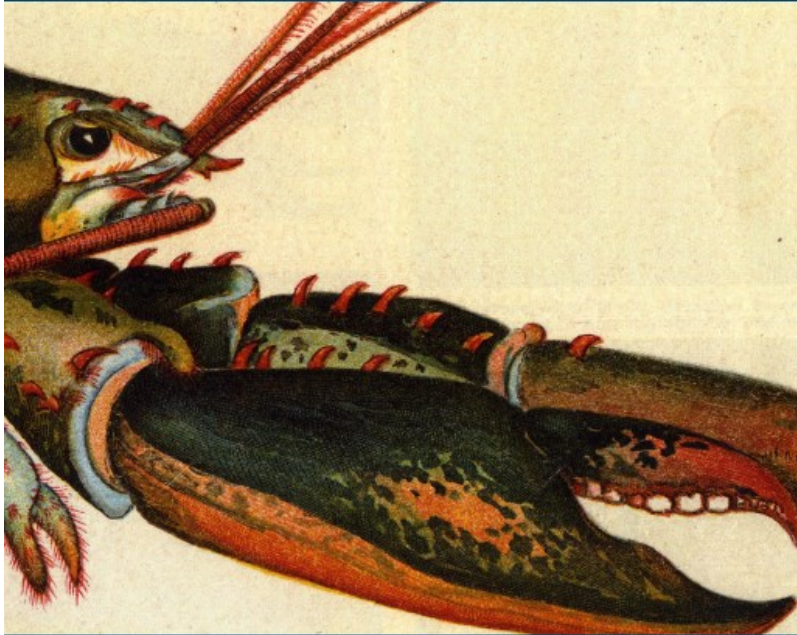
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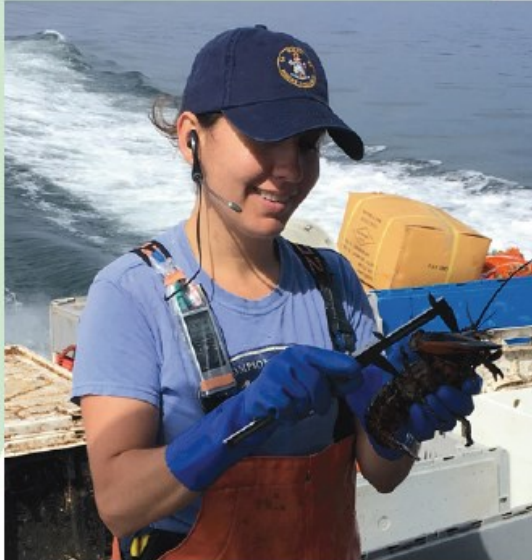
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# **KEYNOTE PRESENTATION**

## **ABSTRACTS**

**01-LOBSTER LESSONS IN MARINE SENSORY BIOLOGY**Jelle Atema ([atema@bu.edu](mailto:atema@bu.edu))*Boston University Marine Program, Boston, MA*

The natural history of the American lobster (*Homarus americanus*) was described in detail as part of the general interest in Marine Biology in the late 19th century, anchored in Woods Hole and later extended in St. Andrews, Canada. From the onset, a mixture of practical fisheries concerns and basic biological investigation motivated the research. A half-century ago lobsters gained prominence in biological analysis of underwater chemical sensing, including neurobiological, behavioral and ecological approaches. Lobsters served as early guides in understanding the central role of underwater chemical signals in social and feeding behavior. They made us recognize different chemical sensing organs, each with their unique signal filtering properties and behavioral functions. They showed the importance of water flow to odor dispersal, including their own “information currents”, and the severe constraints fluid motion places on odor signal analysis. They spurred construction of an electronic nose to measure the temporal resolution of chemoreceptor organs in odor plume analysis, later tested on an odor-tracking robot. Long-term field and naturalistic tank observations revealed their – now popularly known – social structure involving sheltering, dominance fights, individual recognition by urine signals, courtship displays, cohabitation, and mating behavior. Early life-history studies focused on larval dispersal and settlement. While most investigations focused on chemical signals, flow sensors were analyzed as part of antennule flicking and odor-flow coincidence detection. The role of lobster vision had long been sidelined assuming that its low-resolution anatomy made it less useful in light-limited environments. Surprisingly, vision contributes to opponent size estimates and individual recognition. Overall, lobsters continue to make major contributions to underwater sensory biology and their influence can be traced into many other model systems, including other crustacea, sharks and reef fish larvae. It has been my privilege to work with so many inspiring students and colleagues.

**02-PIONEERING USE OF GENETIC TAGGING TO ASSESS THE IMPACT OF V-NOTCHING IN THE MANAGEMENT OF EUROPEAN LOBSTER *HOMARUS GAMMARUS* STOCKS: MAINE'S LOBSTERMEN HAVE IT RIGHT!**Paulo Prodöhl ([P.Prodohl@qub.ac.uk](mailto:P.Prodohl@qub.ac.uk))*Queen's University, Belfast, Ireland*

V-notching is a common strategy used for the management of lobster stocks. It involves marking berried females with a small triangular “V”-notch, and subsequently returning them to sea. Since V-notched females are legally protected (i.e., they cannot be landed), this increases the spawning stock, total egg production and, potentially, the subsequent progeny recruitment. From the fishery manager's perspective, the challenge is to demonstrate proof of benefit. Traditionally, this information is derived from catch data. Comparison of landing statistics from areas where V-notched females are protected, versus unprotected areas, allows for an indirect estimation of the success of the procedure. However, given uncertainties related to fishing methods/effort, this approach may not be appropriate for obtaining reliable estimates. We report the results of a pioneering monitoring and assessment V-notching scheme using genetic tagging (microsatellite DNA profiling), involving a partnership between a local Lobster Fisherman's Co-operative (NELCO) in Northern Ireland and Queen's University Belfast. Since the scheme commenced in 2003, more than 26,000 berried lobsters have been genetically tagged. Comparison of the maternal genetic profile with that of the offspring enabled the identification of the paternal genetic contribution to the eggs (by subtracting the genetic contribution from the mother). Resulting family information was used to assign individual lobsters caught in the fishery in subsequent years (i.e., offspring or v-notched lobsters), thus allowing for the quantification of the direct contribution (i.e., proof of direct benefit) of the released animals to the population. The offspring of lobsters V-notched in 2003/04 began appearing in the fishery in small numbers in 2007 with numbers peaking in 2009. Results suggest that, between 2007 and 2013, 9-33% of all lobster landings by NELCO originated from the V-notching scheme. The data also provides novel insights into lobster population dynamics and biology (effective population size, dispersal patterns, size effect).



**03-ESCAPING MAINE'S GILDED LOBSTER TRAP: THINKING ABOUT LONG-TERM STRATEGIES**Robert Steneck ([steneck@maine.edu](mailto:steneck@maine.edu))*University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, ME*

Over the past 20 years, the economic diversity of marine resources harvested in Maine has declined by almost 70%. Today, over 70% of the value of Maine's fish and seafood landings is from highly abundant lobsters (2016 was another record in landings and value). Ironically, lobster bait, Atlantic herring, is the second most valuable species in Maine, although it is worth only 2.6% of Maine's commercial landings. Inflation-corrected income from lobsters in Maine has steadily increased by nearly 400% since 1985. Many fisheries managers, policy makers, and fishers view this as a success. However, this lucrative monoculture increases the social and ecological risks should anything happen to the lobster. In southern New England, disease and stresses related to increases in ocean temperature resulted in more than a 70% decline in lobster abundance, prompting managers to propose closing that fishery. A similar collapse in Maine may fundamentally disrupt the social and economic foundation of its coast. For these reasons, Maine's lobster fishery has been described as a "gilded trap". Gilded traps result when economically attractive opportunities outweigh concerns over associated social and ecological risks or consequences. Large financial gain creates a strong reinforcing feedback that deepens the trap. Avoiding or escaping gilded traps requires managing for increased biological and economic diversity. This is difficult to do prior to a crisis while financial incentives for maintaining the status quo are large. The long-term challenge is to shift fisheries management away from single species toward integrated social-ecological approaches that diversify local ecosystems, societies, and economies. This will be difficult, but perhaps this is something the fishing community should start thinking and talking about.

**04-CELEBRATING TWO DECADES OF COLLABORATION BETWEEN NEW ZEALAND ROCK LOBSTER INDUSTRY PARTICIPANTS, GOVERNMENT AGENCIES, AND INTERNATIONALLY RECOGNIZED STOCK ASSESSMENT SCIENTISTS: BUILDING, REBUILDING, AND CONSOLIDATING A SUSTAINABLE AND PROFITABLE ROCK LOBSTER INDUSTRY**Mark Edwards, Deputy Chief Executive ([Mark.Edwards@nzrocklobster.co.nz](mailto:Mark.Edwards@nzrocklobster.co.nz)), Daryl R. Sykes  
*NZ Rock Lobster Industry Council*

Since 1997, and having taken opportunities offered by agency support for a maturing rights-based fisheries management regime and Government policies in regards to contestable service provision, the NZ Rock Lobster Industry Council (NZ RLIC) has been the principal stock monitoring and stock assessment research provider to the NZ Ministry for Primary Industries, the principal fisheries management agency. The NZ RLIC is an industry-funded national umbrella organization that services and coordinates a consortium of nine regional commercial stakeholder organizations with membership comprising rock lobster quota share owners, fishermen, processors and exporters. On the twentieth anniversary of the NZ RLIC as a principal research contractor, the Maine conference presentation to be made by the NZ RLIC Deputy Chief Executive will review the role of the New Zealand industry as science providers and highlight several of the most productive and enduring initiatives which underpin the stock monitoring and assessment programs. New Zealand rock lobster industry's involvement in field work and data collection and, in cooperation with stock assessment scientists, its contribution to the development and implementation of Management Procedures to guide annual catch limits, have produced very positive outcomes to rock lobster fisheries and to the commercial and non-commercial extractive users who derive a range of social, cultural, and economic benefits from those fisheries. The close collaboration between science providers and industry has enabled significant revisions of stock assessment methodology incorporating industry-generated data, which, in turn, have provided greater certainty in yield estimates and quota allocations. The New Zealand industry has confirmed the benefits of the collaboration and continues to explore a more extensive application of the marriage between scientific disciplines and the collective skills and experience of career fishermen and women. The NZ RLIC promotes the fisheries first; from abundance all benefits flow.



**O5-OCEAN ANIMALS ON THE MOVE: CONSEQUENCES FOR ECOLOGICAL AND HUMAN COMMUNITIES**

Malin Pinsky ([malin.pinsky@rutgers.edu](mailto:malin.pinsky@rutgers.edu))

*Rutgers University, 14 College Farm Road, New Brunswick, NJ 08901*

Warming and other changes to the ocean are reshuffling marine ecosystems in ways that have become increasingly apparent around the globe. Interestingly, these impacts appear to be happening substantially faster in the ocean than on land, putting marine biologists and fisheries on the front lines of documenting, understanding, and adapting to the impacts of climate change. Many species are shifting poleward or deeper, and the American lobster is one of the clearest examples in the northeast U.S. However, substantial variation among species and among regions also exists. The concept of climate velocity has proven particularly useful for understanding this variation, while interactions among species and with fisheries fundamentally shape community responses to a changing environment. This talk will use a continent-scale dataset on the distribution and abundance of benthic species to illustrate these changes, the interactions among shifting species and fisheries, and the consequences for people.

# **ORAL PRESENTATION**

## **ABSTRACTS**

MONDAY, JUNE 5, 2017

**Behavior & Neurobiology****06-CHEMORECEPTOR PROTEINS IN LOBSTERS, *PANULIRUS ARGUS* AND *HOMARUS AMERICANUS*: NO GRS BUT LOTS OF IRS DIFFERENTIALLY EXPRESSED ACROSS THEIR MAJOR CHEMOSENSORY ORGANS**Mihika T. Kozma ([mtottempudi1@student.gsu.edu](mailto:mtottempudi1@student.gsu.edu)), Vivian Ngo-Vu, Manfred Schmidt, Charles Derby  
*Georgia State University*

Lobsters and other crustaceans have chemoreceptors across their body surfaces and use them for many behaviors. The antennules, a major chemosensory organ, have two parallel chemosensory systems differing in peripheral and central organization and function. The olfactory pathway has unimodal sensilla (aesthetascs) whose neurons project into chemotopically-organized neuropils lacking mechano-motor innervation. The antennular “distributed chemoreception” pathway has bimodal (chemo-mechano) sensilla whose neurons project into topotopically-organized neuropils with mechano-motor innervation. Both pathways mediate responses to food chemicals, but only the olfactory pathway detects water-soluble pheromones. The distributed chemoreception pathways of the antennules and legs mediate diverse chemotactile behaviors. A major class of chemoreceptor proteins in all protostomes, including crustaceans, is a variant subfamily of ionotropic glutamate receptors called Ionotropic Receptors (IRs). Another class is seven-transmembrane ionotropic receptors, Gustatory Receptors (GRs), found in all insects but so far found in only one crustacean genus, *Daphnia*. Our study examined chemoreceptor proteins in transcriptomes from antennules and legs of two lobsters, *Homarus americanus* and *Panulirus argus*, and compared these with transcriptomes from other decapods (especially *Callinectes sapidus* and *Procambarus clarkii*) and other arthropods. We identified IRs, but no GRs, in lobsters and other decapod crustaceans. Each species has 60-90 IRs. Most IRs are expressed in either antennules or legs, but not in both. The exceptions are IR co-receptors IR25a and IR8a, and three variant IRs including IR93a and IR76b that are highly conserved across species and are expressed in both antennules and legs. Immunocytochemical labeling shows that IR25a is expressed in most chemoreceptor cells, as expected for a co-receptor. Many more IR types are expressed in antennules than legs, which is correlated with antennules but not legs being sensitive to water-soluble pheromones. Further analysis will explore the diversity and distribution of these and other types of receptor proteins in lobsters and other decapod crustaceans.

**07-HOW TO CATCH SCAMPI: INVESTIGATING THE CHEMOSENSORY BEHAVIOR OF NEW ZEALAND SCAMPI**Robert Major<sup>1</sup> ([rmaj027@aucklanduni.ac.nz](mailto:rmaj027@aucklanduni.ac.nz)), David Taylor<sup>2</sup>, Shaun Ogilvie<sup>2</sup>, Geoffrey Connor<sup>3</sup>, Stephen Connor<sup>3</sup>, Andrew Jeffs<sup>4</sup><sup>1</sup>*University of Auckland*, <sup>2</sup>*Cawthron Institute*, <sup>3</sup>*Waikawa Fishing Co. Ltd.*, <sup>4</sup>*University of Auckland*

The New Zealand scampi (*Metanephrops challengeri*) is a commercially important crustacean that is harvested around New Zealand using bottom trawls. Research efforts are focused on developing new potting technology to reduce the environmental impacts associated with current trawling methods for harvesting scampi. The attraction of scampi to bait is critical to the effectiveness of baited pots; however, very little is known about the chemosensory and foraging behavior of this species. We investigated how scampi search for food, the effect of turbulence on the efficiency of food search behavior and the attractiveness of a range of different baits. Firstly, the length of time scampi spend during each of the phases of chemically-mediated food search behavior was highly variable regardless of the bait type tested. Secondly, scampi are significantly more efficient at searching for food in turbulent flow compared to laminar flow. Lastly, using a multi-choice flume, we identified that New Zealand pilchard (*Sardinops neopilchardus*) baits were significantly more attractive to the scampi than four other 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.

**08-INVESTIGATING HOW CHANGING ENVIRONMENTAL CONDITIONS MAY AFFECT THE CHEMOSENSORY ABILITIES OF THE CARIBBEAN SPINY LOBSTER *PANULIRUS ARGUS***

Erica P. Ross ([epross@ufl.edu](mailto:epross@ufl.edu)), Donald Behringer  
University of Florida, Gainesville, FL

Coastal ecosystems are some of most important ecosystems on the planet; however, they are also on the frontlines of environmental change. They are also often essential or nursery habitat for valuable fisheries such as the Caribbean spiny lobster, *Panulirus argus*, which supports the single-most valuable fishery in the greater Caribbean. In Florida Bay, extreme seasonal weather events combined with rising temperatures, ocean acidification, and loss of habitat increase stress on spiny lobsters. While we have a growing understanding of the effect of these environmental changes on the survival, growth, and movement of spiny lobsters, the effect on their chemosensory abilities has not yet been documented. Lobsters rely heavily on chemical cues for many biological and ecological activities from mating to predator avoidance and this study aimed to determine the effect of environmental changes (temperature, salinity, and acidification) on behavior and sheltering preference in *P. argus*. In control conditions, chemical cues from conspecifics were used by spiny lobsters to identify suitable shelter and cues from competitors, and diseased individuals were used to determine shelters to be avoided. In altered environmental conditions, lobsters did not significantly differentiate between conspecific, diseased conspecific, or competitor shelters. Globally, environmental conditions may change gradually, potentially permitting a degree of adaptation, but extreme events stand to alter the chemosensory abilities of crustaceans. These effects may be more prominent for crustaceans living in shallow nearshore areas where extreme events are more pronounced and more frequent.

**09-HIBERNATION OF THE SLIPPER LOBSTER *SCYLLARIDES LATUS* IN THE WESTERN MEDITERRANEAN**

David Diaz<sup>1</sup> ([david.diaz@ba.ieo.es](mailto:david.diaz@ba.ieo.es)), Bernat Hereu<sup>2</sup>, Eneko Aspillaga<sup>2</sup>, Anabel Muñoz<sup>1</sup>, Frederic Bartumeus<sup>3</sup>, Raquel Goñi<sup>1</sup>

<sup>1</sup>Instituto Español de Oceanografía, <sup>2</sup>Universitat de Barcelona, <sup>3</sup>Centre d'Estudis Avançats de Blanes

The Cabrera National Park (NPC) encompasses an archipelago in the Balearic Islands (Western Mediterranean) where the slipper lobster, *Scyllarides latus*, is afforded protection from fishing. During four years (2006 -2009) monthly monitoring in shallow waters (0-50 m) of the NPC failed to encounter *S. latus* during winter. This absence has been attributed either to hibernation, which would make individuals hard to spot, or to reproductive migrations. Our goal was to validate the later hypothesis against the hibernation hypothesis. We monitored 10 adults, 5 males and 5 females (76 to 110 mm CL), using acoustic telemetry. Lobsters were tagged and released without translocation in large caves, the preferred habitat during the summer mating season, at depths of 8 to 25 meters. The pingers used were Vemco V13TP (temperature and pressure), and 9 receivers made up the reception array encompassing 1.5 ha. Temperature data-loggers were deployed at the entrance and at deep shelters of the caves. Water temperature was significantly higher inside than outside the caves during winter. Monitoring of tagged individuals during the post-reproductive period (September-February) indicated very low activity in and around the shelters in the surveyed area. These results strongly support the hypothesis of hibernation, whereby *S. latus* would reduce home range to benefit from the higher winter temperatures in hidden shelters. This knowledge of the seasonal distribution of this vulnerable species will inform the design of suitable spatial protection measures in breeding areas, thereby achieving effective conservation of the species during all its benthic life.

## **O10-THE USE OF ACCELEROMETERS TO MONITOR THE BEHAVIOR OF FREELY MOVING LOBSTERS**

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Accelerometers are currently being used to monitor the activity of a variety of species, both in the laboratory and the field. In this study, we used both Onset HOBO accelerometer data loggers and Vemco V9A accelerometer transmitters to monitor the activity of American lobsters, *Homarus americanus*, in the laboratory, in enclosures in the field, and while freely moving in their natural habitat. While the data obtained was very useful for determining when animals were active, it was more difficult to interpret the actual distance they traveled or the intensity of their movements. In order to try and achieve this goal, we placed both types of sensors on animals in the laboratory and simultaneously obtained time-lapse digital videos of their behavior. The data obtained made it possible to convert the accelerometry data into measurements of both the time and intensity of lobster activity. As a result we were able to calculate how both the amount of activity (% of time active in day vs. night) and the intensity of activity (distance traveled per hour) changed on a seasonal basis. Our results show that accelerometry is a suitable method for monitoring the relative activity of lobsters and the results compare favorably with other published methods. Furthermore, the data obtained has provided insight into how the intensity and daily patterns of lobster activity changes on a seasonal basis.

## **O11-COMPARISON OF MOVEMENTS OF ADULT, SUB-ADULT, AND JUVENILE SPINY LOBSTERS (*PANULIRUS ARGUS*) IN SOUTH FLORIDA USING ACOUSTIC TAGS AND TRACKING RECEIVER GRIDS**

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We monitored movements of adult, sub-adult, and juvenile Caribbean spiny lobster (*Panulirus argus*) using acoustic technology in the Florida Keys. These studies were conducted from 2003 to 2016. Although great variation in movement patterns were found among individual lobsters, general patterns in daily movements, emigration movements, and den shifting were found. Adult lobsters generally showed a nightly foraging routine with emergence from daytime shelters at sundown, rapid movement until about midnight, reduced movement while foraging, then a second rapid movement around 3 am normally directed back toward the den they occupied that evening. The timing, directionality, and nightly repeatability of this movement pattern suggests that lobsters conducting nocturnal foraging behavior exhibited an ability to home toward favored denning sites from as far as 1 km. Approximately one-third of adult lobsters shifted dens nightly in complex reef environments, but den shifting was difficult to quantify. Emigration from local foraging grounds occurred for approximately 20 to 30% of individuals each month and was in any direction except towards land. Adult female lobsters conducted multi-day reproductive migrations toward deeper waters, releasing eggs, and subsequently return to their den. Sub-adult lobsters exhibited similar nightly foraging and den shifting behavior as adults. However, emigration from local foraging grounds, unlike adults, was unmistakably unidirectional toward the nearest adult habitat. Juvenile lobsters (25 to 50 mm CL) typically foraged near their dens; however, foraging to approximately 50 meters away and total movement of 300 meters or more can occur in any given night. Many juveniles showed distinct preferences in foraging and denning areas. Emigration was not observed. Homing ability was suggested by tracking data but was not clearly demonstrated.

**O12-IS WINTER STRANDING OF MEDITERRANEAN SLIPPER LOBSTERS AN OUTCOME OF UNIQUE COMBINATIONS OF THEIR BEHAVIORAL ECOLOGY, BOTTOM BATHYMETRY, AND OCEANOGRAPHIC CONDITIONS?**

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Although mass stranding of lobsters are known from several species of spiny and clawed lobsters, stranding of the Mediterranean slipper lobster, *Scyllarides latus*, is reported here for the first time for this species and for the whole scyllaridae family. Eight and twelve adult lobsters were found in two occasions, on a sandy beach of northern Israel, near a seasonal, shallow, rocky, complex habitat of this species, in January 2016. All stranded specimens were adults with no biofouling on their exoskeleton, indicating that they had recently molted in deeper water. Both strandings were recorded immediately following extreme wave storms. The maximum wave height was 9 meters with a wave time period of 11.8 seconds. The estimated breaker zone started at 7.2 m deep, located more than 400 m offshore on a relatively flat, bare, soft bottom substrate. It is postulated that lobsters, encountering such harsh storms on a relatively exposed terrain offshore, on their way back from their likely deep water fall migration to the shallower seasonal rocky habitats, were unable to avoid the powerful drag forces. Under such circumstances their antipredator adaptations of powerful clinging to rough bottom, using their strong legs to grasp the substrate and resist being dislodged, or sheltering in rocky caves and crevices, would not be effective against intense waves and currents and they were swept to shore. Also efforts to swim to a safe rocky shelter, using their powerful (up to 1 m/s and 3 Newtons), yet short term, "tail flip" escape swimming under such harsh hydrodynamic conditions likely failed to bring them to a safe haven. Damages detected on the corpses of the stranded lobsters, such as missing legs and part of the tail fan (telson) and flattened antennae, support this hypothesis. It is not clear whether these events resulted in unique and rare coincidence of the lobsters' location during their onshore migration, shelf bathymetry, and the timing of severe winter storms or that previous stranding remained unnoticed.

## Behavioral Ecology

### **O13-VIRTUAL WALKING TOURS OF THE BAY OF FUNDY: COMBINING ARCHIVAL TAG DATA AND AN OCEAN CIRCULATION MODEL TO INFER INDIVIDUAL MIGRATION PATHS OF LOBSTER (*HOMARUS AMERICANUS*) IN THE BAY OF FUNDY**

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Information on movement patterns of marine organisms is fundamental to the design and evaluation of spatially explicit management strategies, and can be especially important in regions spanning jurisdictional boundaries. To investigate migration of lobster (*Homarus americanus*) within the Bay of Fundy, we developed an individual-based model (IBM) of lobster movement, and used this model to evaluate potential movement paths for two ovigerous female lobsters that were fitted with archival tags and released in October 2013 off Grand Manan, N.B. in the Canadian Gulf of Maine. The tags popped off in July 2014 near Beaver Harbour, N.B. and Minas Basin, N.S., approximately 33 and 123 km from the tagging location, respectively. The model simulates movement on a daily time step in an environment defined by bathymetry and bottom temperature fields extracted from a realistically forced regional circulation model. Each day, a new location is chosen randomly from a distribution defined by distance from current location, temperature, and depth (relative to concurrent tag observations), and an increasingly strong constraint on movement towards a (known) destination. For each tagged lobster, several thousand movement paths were simulated and ranked by a cumulative joint likelihood that captures how well each path tracked the tagged lobsters' daily mean depth and temperature and the plausibility of each movement distance. Our results suggest that, in contrast to the difference in net distance moved, it is possible that both lobsters underwent extensive migrations, ranging over 100-150 km, that the lobster recovered in Beaver Harbour might have circumnavigated the island of Grand Manan and in doing so, it might have crossed (and re-crossed) the international border between the U.S. and Canada. These results further demonstrate that individual-based models offer a useful framework for linking archival tag data to environmental conditions as a means to infer geographic movement of marine organisms.



**O14-TEMPERATURE-DRIVEN MIGRATION STRATEGIES OF OVIGEROUS LOBSTERS, *HOMARUS AMERICANUS*: OBSERVATIONS FROM ARCHIVAL TAGS AND INFERENCES FROM AN INDIVIDUAL-BASED MODEL**

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It has been hypothesized that ovigerous lobsters, *Homarus americanus*, in the Gulf of Maine undertake seasonal migrations that maximize embryo development rates through exposure to the warmest available temperatures. Archival tags were used to record depth and temperature experienced by two ovigerous lobster from October 2013, when they were released in coastal waters off Grand Manan, N.B., through July 2014, when the tags surfaced near Beaver Harbour, N.B. and Minas Basin, N.S., approximately 33 and 123 km from the tagging location, respectively. To examine potential drivers of the observed temperature-depth histories, we built an individual-based model of temperature-dependent lobster movement in an environment defined by depth and daily mean temperature at depth extracted from an ocean circulation model (FVCOM) for a portion of the Bay of Fundy spanning the potential range of lobster movements. Lobster movement was modeled based on a range of potential values of i) daily vertical movements, ii) vertical distances over which lobster can detect temperature, and iii) “sensitivity” coefficients, a measure of how strongly lobsters seek to reach warmer temperature. Each candidate set of movement rules was used to simulate movement for 100 individuals under conditions corresponding to the period during which tagged lobsters were at large. We found that the depth trajectories of tagged lobster were matched best by simulations in which lobsters were restricted to vertical movement scope of +/-15m per day, detected temperature over entire range, and were unable to respond perfectly to temperature information throughout the water column, suggesting that observed migration behaviors represent an evolved response to maximize temperature that is not driven by temperature proximally. Implementing our best model in thermal environments from other years predicts a relatively consistent overall pattern in migration timing, but year-to-year variability may support additional comparisons to historical tagging or fishery data.

**O15-EVIDENCE THAT AMERICAN LOBSTERS CARRYING LATE-STAGE EGGS MOVE TO DEEPER WATER PRIOR TO HATCHING**Joshua Carloni<sup>1,2</sup>, Jason Goldstein<sup>1,3</sup>, Winsor H. Watson, III<sup>1</sup><sup>1</sup>*Department of Biological Sciences and School of Marine Science and Ocean Engineering, University of New Hampshire, Durham NH, <sup>2</sup>New Hampshire Fish and Game Department, Durham, NH, <sup>3</sup>Maine Coastal Ecology Center, Wells National Research Reserve, Wells ME*

Aggregations of egg bearing (ovigerous) American lobsters have been documented throughout the species range, but it is not clear why they tend to accumulate in these areas. One such aggregation occurs near the Isles of Shoals (IOS), New Hampshire. The overall goal of this study was to determine factors that may be responsible for their presence in this area. In 2013 and 2014, research traps were fished at three depth strata (5-15, 16-25, & 26-35 m) on similar substrates on both the eastern and western side of the IOS to quantify population demographics. Traps fished on the eastern side of the IOS caught significantly larger female lobsters and significantly larger females that were carrying eggs or showed signs of eggs that had recently hatched. Furthermore, catch rates of ovigerous lobsters were ~3 times higher on the eastern side. Interestingly, the catch rate of females carrying eggs that were hatching was five times higher in the deep-water stratum (26-35 m) compared to shallow areas (5-15 m). In contrast, late stage pre-hatch animals were ~2 times more abundant in shallow water. Thus, our working hypothesis was that female lobsters with eggs that were about to hatch moved to deeper water. In the summer of 2016 we used acoustic telemetry to test this hypothesis by monitoring the depth, activity, and location of seven egg bearing females (range=78-98 mm CL) with known egg development on the eastern side of IOS. Five of the seven lobsters that were tagged in shallow water showed movement towards deep water around the time we expected their eggs would be starting to hatch, which supported our hypothesis. These results suggest that lobsters may choose specific areas to brood their eggs and that one factor responsible for this site selection could be proximity to preferred hatching locations. Reasons why these deep areas might be favorable for hatching will be discussed.

**O16-THE WEST MIGRATION OF ONE PART ON THE EUROPEAN LOBSTER POPULATION (*HOMARUS GAMMARUS*) AROUND BRITTANY IN FRANCE**Martial M. Laurans<sup>1</sup> ([martial.laurans@ifremer.fr](mailto:martial.laurans@ifremer.fr)), Didier D. Leroy<sup>1</sup>, Laure L. Robigo<sup>2</sup><sup>1</sup>IFREMER, <sup>2</sup>CDPMEM22

The development of renewable energies in some zones provides funding for various studies. The C"te d'Armor fishing committee, thanks to such funding, has created in concert with fishermen, a V-notch program. At the same times, all lobsters released were tagged with a classical T-bar tag. After 4 years, 4% of the tagged lobsters have been re-captured by professional and recreational fishermen. The analyses of recapture data have revealed many interesting movements: the capacity of a significant number of lobsters to move long distances, all in a westward direction. From the available data, no difference between the sexes seems to appear. Finally, the capacity to move over large distances was acquired when the lobster, male or female, became mature. All of these new results are in contrast to others European studies. but have to be considered with the oceanographic environment around Brittany where strong currents exist. This global result justifies management rules at a large scale. All these new results will be presented and discussed considering the knowledges available until now.

### 017-“IN THE HEAT OF THE MOMENT”: EFFECTS OF THERMAL STRESS ON SEASONAL MOVEMENTS IN SLIPPER LOBSTERS (*SCYLLARIDES LATUS*) IN THE EASTERN MEDITERRANEAN

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Water temperature significantly motivates lobster movements in many species and can vary widely over spatial and temporal scales. Providing insight into the thermal preferences (and refuges) that some lobsters seek remains a key tenet to our understanding of the behavioral ecology of these animals. The Mediterranean slipper lobster (*Scyllarides latus*) shows seasonal movements throughout its range and is subject to a changing thermal environment. We examined the seasonal movements of *S. latus* within a small marine reserve (Achziv Marine Reserve, AMR) off the coast of Israel and tested the hypothesis that *S. latus* engage in klinokinetic movements, thereby increasing their activity when subjected to temperatures outside their preferred range. We conducted a field survey in the AMR and tagged animals ( $n = 68$ ,  $CL_{avg} = 88.7 \pm 4.6$ ) using T-bar tags in a mark-recapture study to investigate their movements during their putative summer migration. Concurrently in the lab, we exposed a separate set of lobsters ( $n = 7$ ,  $CL_{avg} = 83.1 \pm 6.1$ ) to the same thermal profiles as in the field and assayed their locomotion using activity wheel and mesocosm setups. Our field results showed that lobsters tagged in shallow waters moved to deeper, cooler waters ( $\sim 30$ m) over the course of 2-2.5 months, traveling an average linear distance of 3.4 km (range = 1-5 km). Our lab results confirmed this pattern (under similar thermal profiles), but also revealed that warming water temperatures elicited an increased response in all lobsters, resulting in markedly longer movements (average = 5.4 km, over a similar timeframe). Overall, these preliminary findings suggest that recently increasing water temperatures in the eastern Mediterranean (likely due to climate change) may cause an uptick in lobster movements within and outside the confines of some marine reserves.

### 018-RECRUITMENT OF JUVENILE AMERICAN LOBSTERS (*HOMARUS AMERICANUS*) TO THE FISHERY: CAN MUD HABITAT BE IGNORED?

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Cobble seafloor is the preferred habitat of juvenile American lobsters (*Homarus americanus*), but it is scarce and patchily distributed over most of the species' range. Mud seafloor, although less preferred by juvenile lobsters, is far more abundant and if an appreciable density of juveniles live in mud habitat it could represent a meaningful contributor to the environment's carrying capacity for this species. In 2016 we estimated the density of juvenile lobsters ( $\leq 40$  mm carapace length) on cobble seafloor using artificial habitats ("collectors"), and on mud seafloor using a modified Devisme shrimp trawl, in a  $\sim 4$  km<sup>2</sup> mixed-seafloor embayment in the southwestern portion of Maces Bay, Bay of Fundy, Canada. Collectors deployed on 4 cobble patches for 4 months (July-October 2016), and trawls over a large area of mud seafloor (July and November 2016) caught all sizes of juvenile lobsters including newly settled young-of-the-year. Lobster catches on mud were ten times higher at night than day, reflecting increased nocturnal activity, and were three times higher during summer trawling (July) than late fall (November), likely reflecting seasonal behavioral changes. The average density of juvenile lobsters in collectors on cobble was 2.3 m<sup>-2</sup>, whereas the average density in trawls on mud was 0.043 m<sup>-2</sup> in July and 0.013 m<sup>-2</sup> in November. While juvenile densities were lower on mud, this habitat dominates Maces Bay. Accordingly, we plan to quantify the relative abundance of cobble and mud habitat in Maces Bay, and combine this information with our estimates of juvenile densities and estimates we will make of lobster survival, growth, and residency in each habitat. This will allow us to evaluate the relative contribution of cobble and mud habitat to benthic recruitment, and ultimately to fisheries recruitment, of American lobsters.

**019-LOBSTER-PREDATOR INTERACTIONS IN MAINE: EVIDENCE FOR THE IMPORTANCE OF BEHAVIOR AND PREDATOR IDENTITY**Graham D. Sherwood<sup>1</sup> ([gsherwood@gmri.org](mailto:gsherwood@gmri.org)), <sup>2</sup>Jonathan H. Grabowski<sup>1</sup>Gulf of Maine Research Institute, Portland, ME, <sup>2</sup>Marine Science Center, Northeastern University, Nahant, MA

American lobster (*Homarus americanus*) is the single most valuable fishery species in the United States with landings of over a half billion dollars in 2014 (up from \$80M in 1980). A portion of this phenomenal increase in landings may be due to what has been called the herring bait subsidy (i.e., the farming effect). Lobsters may also have been released from groundfish predation given the decline of important predators including Atlantic cod (*Gadus morhua*). While stomach content analysis alone does not suggest a strong linkage between groundfish predators and lobsters, lobsters may still be quite limited by the presence of large predators. We conducted a series of mesocosm experiments to explore the behavioral response of lobsters to large predators. In one, we observed lobster movements in a large, semi-natural embayment (~ 6 acres) with the aid of acoustic tagging technology. Lobsters were found to shelter less and forage over larger areas in the absence of cod compared to when cod were present. In another experiment, in a swimming pool sized mesocosm, we showed that lobsters respond again to the presence of cod (as well as sea raven, *Hemitripterus americanus*) by increasing sheltering behavior. However, in this experiment we also observed that lobsters do not alter behavior in the presence/absence of striped bass (*Morone saxatilis*). Here, we posited that lobster predator response is hard-wired and dependent on the feeding modality of the predator (i.e., benthic browser versus pelagic cruiser). We argue that the behavioral component to lobster - predator interactions is at least as important, if not more, than direct predation for influencing lobster population dynamics, but that this depends on predator species identity.

**020-NON-CONSUMPTIVE EFFECTS OF BLACK SEA BASS (*CENTROPRISTIS STRIATA*) ON JUVENILE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) POPULATION DYNAMICS**Marissa McMahan ([mcmahan.m@husky.neu.edu](mailto:mcmahan.m@husky.neu.edu)), Jonathan H. Grabowski

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The climate-induced warming of the world's oceans has begun to restructure marine communities and impact system productivity. One of the consequences of warming temperatures is that species often undergo geographic distribution shifts to avoid thermal stress, which can result in altered community composition and interactions among species that previously were geographically isolated. Black sea bass (*Centropristis striata*) historically ranged from the Gulf of Mexico to Cape Cod, but recently they have expanded north to midcoast Maine. Very little is known about the impact of this range expansion on benthic community structure throughout the coastal waters of the Gulf of Maine (GOM). To investigate the nonconsumptive effects of sea bass on juvenile lobster (*Homarus americanus*) behavior, we manipulated the presence of sea bass olfactory cues and observed the behavior of lobsters from three regions in the GOM with different exposure histories to sea bass. Specifically, we examined whether the presence of sea bass affected lobster shelter use and foraging behavior. Our results revealed that sea bass presence increased shelter usage and reduced foraging in lobsters, but that exposure history to sea bass influenced the strength of these behavioral responses. These results are the first documentation of the non-consumptive effects of sea bass on benthic community structure in the GOM, and will inform efforts to determine the impacts of sea bass on food web dynamics and fisheries productivity of native GOM species. Furthermore, this study aims to assist efforts to assess and manage this and other range expanding species that are entering coastal ecosystems.

**O21-FENDING OFF PREDATORS ... AND OCEAN ACIDIFICATION? INVESTIGATION OF THE COMPLEX EXOSKELETON OF THE CALIFORNIA SPINY LOBSTER**

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The California spiny lobster (*Panulirus interruptus*) is equipped with a multitude of predator defenses, especially the close-range defense of their armored exoskeleton. Structures such as the spiny carapace, rostral horns, and antennae are all part of the cuticular exoskeleton, but they likely experience different forces and loadings during predator interactions. Thus, parts of the exoskeleton that would benefit from specialization may have distinct material properties that stem from changes to their structure and composition. Here, we studied the ultrastructure, elemental composition, and mechanical properties of three structures of the exoskeleton (carapace spine, rostral horn tip, and antennae base) using SEM, energy-dispersive x-ray spectroscopy, and nanoindentation. We found that the horn tip consisted of an uncalcified outer region and an inner lamellar core, whereas the antennae base and carapace spine both had typical layered, calcified cuticle. The outer region of the horn was both significantly harder and stiffer than the epicuticle of the antennae base and the carapace spine, although this has not yet been attributed to a definitive cause. The antennae base had a thicker endocuticle than exocuticle, as is typical for crustacean cuticle. However, the carapace spine had a relatively thicker exocuticle than endocuticle and an overall thicker cuticle, which may be important for the carapace mechanics. Finally, these predator defenses were examined after exposure to ocean acidification conditions, which have the potential to reduce the functionality of the exoskeleton if composition or structure is altered. Preliminary analyses of animals exposed to four pH conditions indicate that changes to material properties are pH-level specific. These results provide insight into how spiny lobsters, and crustaceans in general, modify the cuticle for specific defenses and how ocean conditions may affect the defenses' functionality.

**O22-CLIMATE-RELATED SHIFTS IN THE DISTRIBUTION OF AMERICAN LOBSTER AND ITS PREDATORS IN THE NORTHEAST U.S.**

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Ocean temperatures in the Gulf of Maine have warmed rapidly over the past decade, and the seasonal cycle of temperatures has shifted towards earlier warming in the spring and later cooling in the fall. Warming temperatures have been associated with northward shifts in spatial distributions of many marine fish and invertebrate species in the region. In addition, changes in the seasonal cycle can affect migration timing of species that move inshore-offshore or north-south over the course of the year. The rates at which species distributions change in space and time vary by species, and these differential rates have important implications for trophic interactions and fisheries. American lobster provides one example of a species that may be affected by changes in the spatial distribution and migration phenology of its predators. In this presentation, we assess how the spatial distribution and migration timing of American lobster and its key predators have changed in the Gulf of Maine region as waters have warmed over the past decade. We also project distributions forward based on climate scenarios to understand how the overlap between lobsters and their predators will change in the future. Shifting predator-prey overlap has important implications for the treatment of natural mortality in stock assessment models and fishery management decisions. Our presentation will conclude by identifying ways in which fisheries management adjustments might help address issues of stock sustainability and fishery access for species such as American lobster that may be affected by climate-related distribution shifts.

## **O23-BEHAVIORAL PLASTICITY IN THE SOCIAL BEHAVIORS OF JUVENILE CARIBBEAN SPINY LOBSTERS**

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Caribbean spiny lobsters are socially gregarious due to strong attraction to conspecific odor cues which may reduce the risk of predation through increased efficiency in finding shelter (den finding) or cooperative group defense (den sharing). However, recent studies have found that conspecific attraction in juvenile Caribbean spiny lobsters has significantly decreased. What is unknown is whether this decrease is due to the loss of highly gregarious individuals from the population (selection) or a change in response to odor cues (plasticity). To examine this question, we measured conspecific attraction, aggression, and den sharing in juvenile lobsters from four locations in Florida Bay, FL, USA, that differed in shelter abundance, disease frequency, and juvenile lobster density. Laboratory studies confirmed that juvenile lobsters from Florida Bay have reduced conspecific attraction, but that habitat type was not significant. Conspecific attraction was also not correlated with aggression levels or frequency of den sharing. Furthermore, frequency of den sharing was shown to be responsive to positive rewards such as increased food quality or decreased disturbance suggesting high plasticity. A mark-recapture study conducted using both visual and acoustically tagged lobsters revealed that lobster den sharing in the field is more correlated with substrate composition than with shelter density or conspecific density. Furthermore, lobsters tagged while sharing shelters had higher frequency of future den sharing due to strong den fidelity rather than strong preference for conspecifics. Finally, a comparison of den sharing frequency in Florida Bay over the past 20 years suggests that while conspecific attraction has decreased, den sharing frequency has remained the same (50-60%). Taken together these results suggest that loss of conspecific attraction in juvenile spiny lobsters is the result of behavioral plasticity rather than selection against social phenotypes and that lobsters may use cues other than conspecific presence when choosing a den.

**O24-DIFFERENTIAL INFLUENCE OF CORAL REEF DEGRADATION ON FEEDING ECOLOGY OF TWO SYMPATRIC SPINY LOBSTERS**

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Caribbean coral reefs have undergone massive degradation, with local increases of macroalgae and reduction of architectural complexity associated with loss of reef-building corals. We explored whether coral reef degradation influences the feeding ecology of two co-occurring spiny lobsters: *Panulirus guttatus*, which is an obligate reef-dweller, and *P. argus*, which uses various habitats including coral reefs. We collected 15 lobsters of each species from the back-reef zones of two large reefs, “Limonés” and “Bonanza”, at Puerto Morelos Reef National Park (México). Limonés contains abundant colonies of reef-building corals and is less degraded and more architecturally complex than Bonanza, where most hard coral is dead. We measured the carapace length (CL), weight, and three condition indices (hepatosomatic index, HI; blood refractive index, BRI; and weight/CL ratio) of lobsters, and analyzed their stomach contents and stable isotope values ( $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ ). Lobsters of both species consumed many food types, particularly mollusks and crustaceans. In *P. guttatus*, CL, HI, BRI, and weight/CL did not vary with reef, but mean isotopic values did. Different  $\delta^{13}\text{C}$  values suggest differences in local carbon sources between these reefs and underline the habitat specialization of *P. guttatus*. Differences in  $\delta^{15}\text{N}$  suggest a higher trophic position for *P. guttatus* in the more degraded reef (Bonanza). In *P. argus*, none of the variables differed between reefs and its isotopic values exhibited a wider dispersion, potentially reflecting the much wider foraging ranges of *P. argus* compared with *P. guttatus*. Isotopic values obtained from 16 larger *P. argus* caught in the fore reef at 25 m in depth suggest that these lobsters foraged over different areas and had a higher trophic position than their smaller conspecifics from the backreef. Overall, the feeding ecology of *P. argus* would appear to be less influenced by coral reef degradation than that of *P. guttatus*.



## Diseases & Parasites

### O25-FROM PUERULUS TO PUBERTY: THE STAGE-BASED EFFECT OF PaV1 ON JUVENILE CARIBBEAN SPINY LOBSTERS IN FLORIDA

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By their very nature, pathogens take a toll on their hosts. That toll can vary widely depending on the relationship between the host and pathogen. Of course, scientists and fishery managers strive to know how much of a host population is lost to a pathogen, but that information can be elusive. Hence, mortality from pathogens is typically lumped together with other sources of natural mortality (e.g., predation) in population models. For pathogens without a definitive and measurable impact on their host or those that impact inaccessible life stages of the host, there is little recourse, but for those that cause direct and measurable host mortality the situation may be different. In Florida, we are fortunate to have a tractable system where we can access all life stages of the Caribbean spiny lobster *Panulirus argus* from pueruli to adults, all of which appear susceptible to the pathogenic virus PaV1. We quantified the impact of PaV1 on the metamorphosis and survival of pueruli, and the survival of benthic juveniles of incremental size classes from 20 – 70 mm carapace length. We also conducted experiments to determine the proportion of the juvenile population with subclinical infections (via qPCR) that eventually develop clinical and lethal infections, relative to those that remain subclinical indefinitely. Ultimately, these results will be tested in the Florida stock assessment model for the *P. argus* fishery to evaluate the effect of PaV1 mortality on the stock assessment results.

### O26-INCIPIENT EPIZOOTIC SHELL DISEASE LESIONS IN THE AMERICAN LOBSTER CARAPACE

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The causal factors leading to American lobster, *Homarus americanus*, Epizootic Shell Disease (ESD) are still not well understood. We are following a hot-spot of ESD that exists in the Gulf of Maine just offshore of Portland's Casco Bay. We are extrapolating the physical expressions of ESD from its obvious early visible stages to earlier stages invisible to the unaided eye. We are also paying attention to the possible states of vulnerability that might be detectable and explainable with various physical measurements. Medallions of carapace cuticle are obtained from carapace fixed with various protocols to minimize movement of mineral and macromolecular components. Minimal processing of the medallions is carried out to encourage approaches that would allow large sample sizes which would allow environmental surveys. One- and two-dimensional analytic maps of sections of the cuticle are obtained with Electron Microprobe to describe the elemental and composite composition of structures. MicroRaman Spectroscopy allows characterization of mineral crystal types of phosphates and carbonates as well as molecular bonding or organic structures. Atomic force Microscopy allows two dimensional maps of structural texture and hardness. The frequency and properties of the structures can be followed using the more rapid application of micro-Computed Tomography (microCT) to follow the density profiles of structures of interest through the lobster molting cycle. We observed density differences in the calcite layer, inner exocuticle and endocuticle and the frequency and structure of CaCO<sub>3</sub> structures in the endocuticle and membranous layer of carapace cuticle during stages of the molting cycle. Correlative microscopy of the 3-dimensional microCT defined and followed structures with the other physical techniques will lead to an improved understanding of the lobster cuticle structure. Detailing the structural differences that exist though development and under different environmental conditions may provide insight into the causes and vulnerabilities associated with ESD.

**027-LABORATORY STUDIES ON THE EFFECT OF TEMPERATURE ON PROGRESSION OF EPIZOOTIC SHELL DISEASE IN THE AMERICAN LOBSTER *HOMARUS AMERICANUS***

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Epizootic shell disease (ESD) is a persistent threat to populations of American lobster, *Homarus americanus*, off southern New England. The disease has negatively impacted commercial landings in the region. It is caused by a bacterial dysbiosis that occurs in association with increased water temperature and exposure to anthropogenic stressors. Temperature is a leading factor driving the severity and incidence of ESD. Our objective was to quantify disease processes (progression, molting dynamics, and mortality) at three rigorously controlled temperatures (6, 12, and 18 °C) over a five to six month period. We used image analysis to examine changes in lesion development over time. The disease progressed at all three experimental temperatures, but it had a significantly faster growth rate in the 18 °C Treatment. Mean progression rates varied from 8.6-10.4 mm<sup>2</sup> per day at the lower temperatures to over 25.6 mm<sup>2</sup> per day at 18 °C. The mean daily rates give conservative estimates for individual progression from light to moderate disease states; i.e., approximately 233 days at 6 °C and 95 days at 18 °C. Progression rates also showed considerable variability among affected lobsters. In some animals, ESD progressed rapidly, whereas in others it was very slow. We show that increased temperature leads to rapid progression of ESD but individual variation, probably modulated through immune defenses, can slow the disease and possibly enhance survival of affected lobsters.

**028-SURVEY OF IDIOPATHIC BLINDNESS IN LOBSTERS FROM NARRAGANSETT BAY, RI**

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Idiopathic blindness is a condition with an unknown etiology that has been previously described in lobsters from Long Island Sound. In 2008, idiopathic blindness was found in over 50% of the lobsters surveyed as part of a shell disease investigation. These were captured in June, July, and October from one location in Narragansett Bay, Rhode Island. Previous studies have diagnosed the condition using histological methods; however, recent work has shown that severe blindness can be diagnosed using an otolaryngoscope (o-scope). Grossly, the condition presents as patches of cloudy grey-colored regions in the eyes of afflicted animals. Live lobsters captured in the fishery from three sites in Narragansett Bay and Rhode Island Sound were assessed with the o-scope and categorized as either having no blindness or having obvious blindness. This research will give us the first demographic information about blindness in RI waters. The results of these investigations will help us better understand the prevalence and distribution of idiopathic blindness in lobsters.

### **O29-ACUTE PHASE SERUM AMYLOID PROTEIN A EXPRESSION IS SIGNIFICANTLY INCREASED DURING BACTERIAL AND MICROPARASITIC PATHOGEN CHALLENGE IN THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*)**

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The American lobster (*Homarus americanus*) fishery is a significant historical, cultural, and economic component of hundreds of rural communities in Atlantic Canadian and the North-Eastern United States. This industry generates billions of dollars (US) for the Canadian and American economies annually, and is the most important commercial fishery remaining in the Western North Atlantic. Hundreds of millions of pounds of American lobster will go into short and long-term holding as part of the chain of custody in the lucrative live-lobster market. However, lobsters that die before they reach their final consumer result in significant economic loss to the live-lobster holder or shipper. There are currently no clinical indicators of lobster health at the clinical or biochemical level that are capable of differentiating between sick and healthy lobsters. Previous high-throughput genomic studies have identified a potential biomarker of bacterial and microparasitic infection in the American lobster: Acute Phase Serum Amyloid Protein A (SAA). This acute phase protein is widely recognized as an important protein expressed early in the human immune response to infection; and has been used as a clinical diagnostic marker for immune activation in a variety of terrestrial and aquatic animal species. A custom polyclonal antibody for *H. americanus* SAA was generated to examine the protein expression of this potential biomarker. Western blot analysis clearly demonstrates that the magnitude of SAA protein expression is correlated with disease progression during pathogen challenge with the Gram-positive bacteria *Aerococcus viridans* var. *homari* and the microparasitic scuticociliate *Anophryoides haemophila*. This new evidence is a significant step forward in demonstrating a biomarker for immune system activation in the American lobster that could potentially be applied to multiple crustacean species.

### **O30-QUANTIFYING THE IMPACT OF EPIZOOTIC SHELL DISEASE ON THE AMERICAN LOBSTER USING 35 YEARS OF MARK-RECAPTURE DATA**

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Outbreaks of marine diseases are being detected with increasing frequency and can cause significant ecological, economic, and social impacts. Effective disease management requires monitoring of at-risk populations, accurate forecasting of future disease events, and development and implementation of measures to mitigate disease and downstream impacts. In the case of commercially fished species, fishing regulations frequently alter disease processes and can be utilized to reduce disease mortality or transmission. Such population management requires estimation of important disease characteristics and processes including incidence, progression and host mortality, all of which can be challenging in marine systems. Using Epizootic shell disease (ESD) in the American lobster (*Homarus americanus*) as a model system, we demonstrate how mark-recapture data can be used to estimate parameters critical for incorporating disease impacts and mitigation into fisheries management. Characterized by a bacterial dysbiosis of the cuticle, epizootic shell disease (ESD) has contributed to the collapse of the Southern New England (SNE) fishery. Lobsters are one of the most lucrative fisheries in North America; hence the collapse of the SNE stock has raised concerns that ESD will emerge in the Gulf of Maine and Georges Bank stocks. We used mark-recapture analyses of a 35-year dataset to estimate the impact of ESD on a subset of SNE lobster population. The extensive dataset allowed us to identify demographic groups most impacted by ESD. We calculated seasonal rates for disease progression, incidence and host survival and demonstrated how these parameters can be incorporated into population models. Our results stress that due to their longer intermolt periods, ovigerous females frequently reach 100% disease prevalence in the spring; this results in disproportionate effects on survival and fecundity. Additional analyses reveal that molting during periods of increasing prevalence can disrupt disease progression; however, temperature shifts may constrain molting to particular weeks of the year that may not align with these periods.

**O31-EXPLORATION OF THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) IMMUNE RESPONSE TO BACTERIAL AND PARASITIC INFECTION**Fraser Clark<sup>1,2</sup> ([fclark@mta.ca](mailto:fclark@mta.ca)), Spencer J. Greenwood<sup>2,3</sup>,<sup>1</sup>Mount Allison University, <sup>2</sup>AVC Lobster Science Centre, <sup>3</sup>University of Prince Edward Island

The American lobster (*Homarus americanus*) fishery is the most commercially important fishery in Canada, and supports the economies of hundreds of rural communities in Atlantic Canada and Quebec. Next-generation sequencing technologies, such as RNA-Seq, have enabled us to gain unprecedented amounts of information into regarding lobster physiology and immune response at the molecular level. Previous studies examining the *H. americanus* immune molecule repertoire have relied on RNA-seq experiments from whole uninfected larval stages. This experiment focused on deep sequencing of genes expressed from adult American lobster hepatopancreas tissue; the tissue recognized as primarily responsible for the generation of humoral immune factors. Disease challenges using the Gram-positive bacteria *Aerococcus viridans* var. *homari* and the microparasitic scuticociliate *Anophryoides haemophila*, coupled with RNA-seq, have allowed us to explore the humoral immune response of *H. americanus* to these pathogens. Multiple, antimicrobial peptide isoforms are differentially expressed during these infections along with a suite of immune genes associated with important humoral immune cascades and acute phase response. The expression profile of immune genes identified in this study provides additional evidence for a *H. americanus* immune response that is tailored to the pathogen causing infection. The combination of targeting hepatopancreatic gene expression and the use of pathogen challenges allows us to significantly increase our knowledge of the immune molecule repertoire and timing of expression in specific immune molecules during bacterial and microparasitic pathogen infection.

**O32-FROM HATCHERY TO OPEN SEA: HEALTH AND DISEASE SCREENING IN JUVENILE EUROPEAN LOBSTER (*HOMARUS GAMMARUS*)**Michelle J. Pond ([michelle.pond@cefasc.co.uk](mailto:michelle.pond@cefasc.co.uk)), Grant D. Stentiford

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The European lobster (*Homarus gammarus*) is a high value commodity with widespread distribution in the North East Atlantic. It forms a major component of the U.K. fishery and represents the highest unit cost species captured. Onshore hatchery systems and sea-based container culture (SBCC) technologies developed for production of juvenile supply to fisheries stock enhancement programs also show considerable promise for lobster aquaculture. As part of a large, ongoing field trial of SBCC of lobsters in the U.K., we are conducting a comprehensive health screen of juvenile lobsters, based upon pathology (histology, transmission electron microscopy) and molecular diagnostics. The survey design traces specific cohorts of juvenile lobsters through onshore hatchery production (National Lobster Hatchery, Cornwall) through periods of up to 3 years within SBCC in the open sea (St. Austell Bay, Cornwall). The survey also considers specific effects of various confounding factors such as season, container type, and position of SBCC in the water column. Relative to other crustacean taxa, there is little detailed information available for pathogens of juvenile life stages of *H. gammarus*. Further, certain pathogen groups (e.g. viruses) are currently absent from the symbiont profile of this host, likely due to lack of survey coverage rather than true absence. Here, we present the survey design, fundamental aspects of the pathogen discovery and description process, and preliminary findings (marking the first 6 months of SBCC). Data collected in this survey will form a fundamental component of a bio-economic model for potential SBCC of *H. gammarus* in European waters and, will deliver the first comprehensive insight in to symbionts and pathogens of elusive juvenile life stages of this iconic species.

**O33-FINE-SCALE TRANSITION OF MICROBIOME DURING PROGRESSION OF SHELL DISEASE IN LABORATORY-REARED JUVENILE AMERICAN LOBSTER**

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The American lobster (*Homarus americanus*) supports a valuable commercial fishery in the Northeastern U.S. and Maritime Canada; however, stocks in the southern portion of the lobster's range have shown declines due, in part, to the emergence of shell disease. Epizootic shell disease is a bacterially-induced cuticular erosion that renders even mildly affected lobsters unmarketable because of their appearance and, in more severe cases, can cause mortality. Despite the importance of this disease, the associated bacterial communities have not yet been fully characterized. We sampled two-year old, laboratory-reared lobsters that displayed signs of shell disease at the site of disease as well as at 0.5 cm, 1 cm, and 1.5 cm away from the site of disease to determine how the bacterial community changed over this fine spatial scale. Illumina sequencing of the 16S rRNA gene revealed a distinct bacterial community at the site of disease, with significant reductions in bacterial diversity and richness compared to more distant sampling locations. The bacterial community composition 0.5 cm from the site of disease was also altered, and there was an observable decrease in bacterial diversity and richness, even though there were not yet signs of disease. Given the distinctiveness of the bacterial community at the site of disease and 0.5 cm from the site of disease we refer to these communities as affected and transitional and suggest that these bacteria, including the previously proposed causative agent, *Aquimarina "homaria"*, are important to the initiation and progression of this laboratory model of shell disease. A new conceptual model to understand the progression of shell disease is presented.

**O34-THE LOBSTER BLACK DEATH: CHARACTERISTICS OF BACTERIA ASSOCIATED WITH TAIL FAN NECROSIS IN A WILD SPINY LOBSTER POPULATION**

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A population of the spiny lobster, *Jasus edwardsii*, at one location in New Zealand is affected by a relatively high incidence of tail fan necrosis. The disease appears as a blackening and erosion of parts of the tail fan of the lobster that can progress into areas of the abdomen and other appendages. The disease is known colloquially among fishers as black rot, tail rot, black tail, and black death. The results of past studies indicate the disease results from bacterial infection of injuries to the tail fan sustained during fishing or during containment. In this study, we characterized the bacteria associated with the surface of tail fan and in the haemolymph of lobsters both with and without the disease. In addition, we assessed the immune status of lobsters both with and without the disease. The results suggest the disease is the result of a suite of bacteria with unique set of characteristics that make them well suited to opportunistically exploiting the resources offered by lobster tail fans, especially when injured. Lobsters with tail fan necrosis appeared to show clear signs of being immune-compromised when compared to those without tail fan necrosis. The results of the study provide some useful direction on possible ways of tackling the disease in the population.

**O35-THE GUT MICROBIOME OF THE EUROPEAN LOBSTER (*HOMARUS GAMMARUS*): IN SICKNESS AND IN HEALTH**

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With the advancements in high-throughput sequencing technologies and bioinformatics, the field of vertebrate gut microbiology has exploded. There are a number of key papers that have identified the human gut microbiome as a major factor in regulating and/or contributing to human health in a variety of ways. Not only is the composition of bacterial populations within the gut recognized as a causative agent of obesity, but correlations have also been made between the gut microbiota and a range of other health conditions. This wealth of knowledge, however, does not continue into the realms of the aquatic invertebrates. Relatively little is known about the microbiome's effect on these animals and how it responds to perturbations within the host and the external environment. A handful of studies have begun to explore how this complex microbial community differs when comparing animals of contrasting environmental subjections (such as time, age, diet, and location); however, little work has been done on the European Lobster (*Homarus gammarus*). Using molecular and histological analysis, we are investigating the health of the species over a period of two years, using a novel sea-based container culture method and comparing this with hatchery-reared animals. By utilizing both amplicon-based and shotgun-metagenomic sequencing approaches, we are correlating health and positional information to taxonomic profiles within the guts of the animals to identify whether the gut microbiome has a role in determining health status of the lobsters and to highlight alterations that occur in an "mariculture"-based setting. Through the nature of the project we can also begin to identify patterns in the microbiota on a temporal scale and better understand how stable the microbiota is over time and how it progresses with the life-stage of the lobster.

**O36-EPIZOOTIC SHELL DISEASE IN THE AMERICAN LOBSTER: CHANGES IN THE MICROBIAL COMMUNITY IN RELATION TO TEMPERATURE**

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Populations of the lobster, *Homarus americanus*, off southern New England are threatened by epizootic shell disease (ESD). The etiology of ESD is a bacterial dysbiosis that occurs in relation to changes in environmental and anthropogenic stressors. Temperature is a key variable in ESD, but its effect has not been well characterized. We undertook a laboratory experiment to gauge the effect of temperature on progression of disease and changes in the microbial community over a six month period. We will present new findings on the microbial dysbiosis and the effect of temperature on the microbiome, as well as new insights into the epidemiology of the disease. High-throughput sequencing and principal co-ordinates analyses indicated three distinct communities present on lobsters: a community on diseased cuticle from diseased animals, a community on healthy cuticle from diseased lobsters, and a healthy or "normal" community on cuticle from healthy animals. Although the microbial communities on the lobster shell had high diversity indices, there were distinctive changes over time and among temperature treatments. Patterns in the hemolymph microbiota were also examined. Understanding the complex interplay among temperature, disease dynamics, and the lobster host is critical for understanding how ESD will continue to affect our important lobster resources.



**O37-COULD THE VIABILITY OF *PANULIRUS ARGUS* VIRUS 1 IN SEAWATER EXPLAIN ITS CARIBBEAN DISTRIBUTION?**

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The pathogenic virus, *Panulirus argus* Virus 1 (PaV1), infects most life history stages of the Caribbean spiny lobster (*Panulirus argus*) along coastal Florida, USA and throughout the Caribbean Sea. PaV1 is host specific and exhibits strong genetic connectivity across much of its range. While empirical studies have ruled out vertical transmission to larvae as the connectivity vector, theoretical modeling work has shown that postlarvae could be vectors of PaV1. Alternatively, similar models have shown that the passive transport of PaV1 virions could be a viable means for connectivity. The objective of this study was to measure the viability of PaV1 in seawater and confirm or refute model-based connectivity projections. Given that PaV1 is a non-enveloped virus and is likely capable of persisting in water longer than enveloped viruses, we hypothesized that PaV1 would remain viable beyond 14 days. To test this hypothesis, postlarval lobsters were collected from the Florida Keys and then screened for PaV1 using a TaqMan real-time quantitative PCR (qPCR) assay. Three PaV1-negative lobsters were added each day for seven days to water that had been previously inoculated with purified PaV1. Following a two-week incubation period, we detected active PaV1 infections in each exposed lobster. This indicates that the virus remained viable and capable of infection over the length of this trial. The qPCR results also revealed that the viral load in the lobsters decreased during the seven-day period suggesting that while some virions remained viable, as time passed, infections were initiated with fewer virions. We recently repeated this study with an extended trial duration to determine how long the virus remains viable outside of its host. Here, we present the results of this study. Identifying the viability of PaV1 will enhance our understanding of marine diseases and their connectivity.

**O38-PARASITES AFFECTING CARIBBEAN SPINY LOBSTERS (*PANULIRUS ARGUS*): THE ROLE OF HABITAT**

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In the Wider Caribbean region, the spiny lobster, *Panulirus argus*, is a keystone species and a major fishing resource. However, this species is host to a range of diseases: in particular, the pathogenic *Panulirus argus* Virus 1 (PaV1) and metacercariae of the digenean trematode parasite, *Cymatocarpus solearis*. PaV1, first discovered in 1999 and found mainly in juvenile lobsters, is thought to have caused significant losses to lobster stocks across the Caribbean and whilst *C. solearis* has only recently been noted, the effect of this parasite upon the physiology, behavior or fecundity of the host is unknown. The role of habitat is of great importance in the ecology of parasites and disease. Whilst there are no known vectors or reservoirs of PaV1 at present, in Bahía de la Ascensión, Quintana Roo, significantly higher levels of PaV1 have been found in densely vegetated habitats compared to poorly vegetated habitats, suggesting that marine vegetation could be a reservoir for PaV1. Conversely, the prevalence of *C. solearis* has been found to be higher in poorly vegetated habitats relative to densely vegetated habitats and in larger lobsters relative to juveniles: the inverse pattern of the prevalence of PaV1. We present preliminary results on the presence of both PaV1 and *C. solearis* in *P. argus* across two marine protected areas in the Mexican Caribbean; Bahía de la Ascensión and Puerto Morelos, in relation to habitat components and complexity, i.e., community structure, biodiversity and species richness.



**O39-AN ASSESSMENT OF RAPID DIAGNOSTIC TECHNIQUES FOR IDIOPATHIC BLINDNESS IN THE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, FROM RHODE ISLAND WATERS**

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Idiopathic blindness is a condition that has been identified in lobsters from western, central, and eastern Long Island Sound, New York, and Narragansett Bay, Rhode Island. Previous studies have diagnosed the condition using histological methods; however, the condition can be observed grossly with close examination of an affected animal's eyes. Our primary objective was to determine the suitability of using a non-destructive technique, an otolaryngoscope (o-scope), to assess blindness in lobsters. Grossly, the condition presents as patches of cloudy grey-colored regions in the eyes of afflicted animals. Using untrained volunteers, we assessed the inter-observer variability in diagnosing blindness and compared that with histological samples (see Ochs et al. abstract). Our secondary objective was to examine the suitability of using the o-scope for determining the prevalence and extent of the condition on live lobsters in the lobster fishery. Live lobsters from Narragansett Bay and Rhode Island Sound were assessed with the o-scope and categorized as having zero, light, moderate, or severe blindness. Each eye was examined by a trained observer. Although there was some variation in the assessment with the o-scope and histological diagnoses, the o-scope may be a useful tool for gauging moderate and severe cases of the disease.

**O40-ISOLATION & UTILIZATION OF PROBIOTICS TO MANAGE EPIZOOTIC SHELL DISEASE IN AMERICAN LOBSTERS, *HOMARUS AMERICANUS***

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Epizootic shell disease (ESD) in the American lobster, *Homarus americanus*, is a major challenge to the southern New England lobster industry. Currently, there are no practical tools for managing ESD in wild lobster populations. The goal of this study is to identify bacterial probiotics that could delay ESD progression in lobsters. The objectives of this project are 1) to isolate and characterize bacteria from lobsters that act as probiotics against ESD-associated bacteria, and 2) test the effect of probiotic treatment on the progression of ESD in live lobsters. So far, 24 candidate bacterial isolates have been identified from lobsters in Narragansett Bay as having probiotic characteristics against ESD-associated bacteria, *Thalassobius* sp., *Aquimarina homaria*, or a fish pathogen, *Vibrio anguillarum*. Groups of lobster postlarvae were treated with six of these candidate probiotic strains and one probiotic isolated from the eastern oyster, *Crassostrea virginica* (*Phaeobacter inhibens* S4), and challenged with *Thalassobius* sp. After 3 weeks, all postlarvae lobsters experienced some degree of shell disease except those exposed to two different candidate *Pseudoalteromonas* sp. strains and the negative control. Increased lesions were observed with one isolated candidate, indicating a potential pathogen. Based on the postlarvae probiotics screening, 3 candidate probiotics (S4, YP014, YP001) were chosen for testing their effects on progression of ESD in adult lobsters from Narragansett Bay over the course of 3 months. Probiotics were administered to individual lobster tanks twice a week and left to incubate for 15 minutes. Photos were taken of lobsters before and after the trial to compare severity of ESD. These results indicate that postlarvae challenges could be used to screen for potential probiotics that could delay the progression of ESD. Utilizing probiotics to combat ESD could have important applications fisheries management.

**O41-PHYLOGENOMIC CHARACTERIZATION OF PANULIRUS ARGUS VIRUS 1**

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*Panulirus argus* Virus 1 (PaV1) is the first pathogenic virus documented in the Caribbean spiny lobster *Panulirus argus*. The disease caused by PaV1 is widely spread in the Caribbean Sea. PaV1 is highly pathogenic to juvenile lobsters and >50% prevalence has been documented in local populations. Over the last decade, most PaV1 research has focused on understanding the pathology, epidemiology, and ecology of this disease. Despite the morphological similarities of the PaV1 virion to members of the families Herpesviridae and Iridoviridae, PaV1 remains unclassified due to the lack of genetic information. The recent advancement of Next Generation Sequencing (NGS) technologies has transformed the ability to sequence and characterize the genome of novel viruses. Using Illumina MiSeq NGS, we have sequenced the complete genome of the PaV1, which comprises 70,886 bp and encodes 52 potential open reading frames (ORFs). Comparative genomic analyses revealed the PaV1 genome contains 7 hallmark genes found in other nucleo-cytoplasmic large DNA viruses (NCLDV) including: the major capsid protein, DNA polymerase, primase-helicase, two RNA polymerase subunits, packaging ATPase, and disulfide-thiol oxidoreductase. Phylogenetic analyses based on DNA polymerase and packaging ATPase gene sequences revealed PaV1 is distinct from other NCLDV and likely represents the founding member of a novel family. The relationship of PaV1 to other NCLDV will be clarified in the future as more genomic sequences of related viruses become available.

TUESDAY, JUNE 6, 2017

**Population Genetics & Connectivity****O42-GENOMICS AS A PROMISING TOOL FOR FISHERY MANAGEMENT**Laura M. Benestan<sup>1</sup> ([laura.benestan@icloud.com](mailto:laura.benestan@icloud.com)), Louis Bernatchez<sup>1</sup>, Rémy Rochette<sup>2</sup><sup>1</sup>Laval University, Quebec, Canada, <sup>2</sup>University of New Brunswick Saint John

American lobster, *Homarus americanus* supports the largest commercial fishery in Eastern Canada and has therefore become a priority species in terms of conservation and management. This research aimed to gain important knowledge about the genetic structure and adaptive potential of *H. americanus* using a multidisciplinary approach, combining population genomics and marine ecology. Our first goal was to identify genetic units and assess their correspondence to the 41 management units presently in use. Our results revealed the presence of two regional entities (north/south) with, at a finer scale, 11 genetically distinguishable populations. We also demonstrated that it was possible to identify the origin of individuals blindly, with an average of 90% individuals correctly reassigned to the regional genetic unit where they were sampled. This high assignment success, unexpected for a marine species, could be used as a relevant traceability tool. Next, we assessed the impacts of environmental factors such as spatial distribution, ocean circulation, and sea surface temperature on the previously identified genetic structure. We showed that ocean currents had a greater effect on the putatively neutral genetic structure than spatial distribution, whereas annual minimum temperature appeared to explain a significant portion of the putatively adaptive genetic variation, even after subtracting the influence of the spatial distribution. More broadly, we improved the methods available in the field of seascape genomics by demonstrating the advantage of using db-MEM (vectors representing spatial distribution) and AEM (vectors representing ocean currents) into a multivariate statistical framework (RDA and sPCA) to uncover population connectivity patterns. Furthermore, we discovered three polymorphisms located in genes that may play a role in thermal adaptation of this species. Overall, our results provide a foundation for more collaborative research integrating evolution and marine ecology tools in the view of enhancing our understanding of marine population connectivity and local adaptation.

**O43-A COMPARISON OF DIFFERENT METHODOLOGIES FOR GENOTYPING LARGE NUMBER OF INDIVIDUALS AND THEIR APPLICATION FOR LOBSTER MANAGEMENT**Quentin Rougemont<sup>1</sup> ([quentinrougemont@orange.fr](mailto:quentinrougemont@orange.fr)), Yann Dorant<sup>1</sup>, Laura Marilyn Benestan<sup>1</sup>, Eric Normandeau<sup>1</sup>, Rémy Rochette<sup>2</sup>, Louis Bernatchez<sup>1</sup><sup>1</sup>Laval University, Quebec, Canada, <sup>2</sup>University of New Brunswick, Saint John

With the advent of massively parallel sequencing technologies, it is now possible to sequence and genotype individuals at very high depth, yielding large amount of sequencing data at the individual levels. While these methods provided unprecedented insights into evolutionary processes, accurate population genetic inferences may be best performed using a large number of individuals. This is especially true for species showing very shallow levels of genetic differentiation, such as marine species. However, the cost of sequencing at the individual level still remains too high for many non-model species with special conservation and management issues. Therefore, the development of new methods that allow for sequencing of thousands of individuals at realistic cost is required. Here, we empirically compared the power of such genomic approaches aiming to reduce the cost per individual. Using a set of six reference populations of American lobster for which fine scale population genetic clustering has already been studied, we compared the ability of: 1) a pool sequencing strategy; 2) a Restriction site-associated DNA (RAD) sequencing approach combined with a capture method (Rapture); 3) a traditional Genotyping By Sequencing method based on Ion Proton sequencing; and 4) a classical sequencing individual RAD method based on Illumina sequencing. We will present each method and their respective advantages in terms of bioinformatic tractability, as well as their ability to perform accurate population genetic inferences.

**O44-GENOME-WIDE SNP DISCOVERY AND SNP PANEL DEVELOPMENT IN EUROPEAN LOBSTER (*HOMARUS GAMMARUS*)**

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In marine species, inference of genetic structure and connectivity is not always trivial because of weak genetic differentiation and the often limited resolution associated with many traditional molecular markers. Fortunately, recent advances in sequencing technology have allowed the genotyping of hundreds to thousands of markers across the genome to become possible for non-model organisms. This study uses a high-resolution genome-wide technique to investigate the fine-scale genetic structure and connectivity of European lobster (*Homarus gammarus*), a species of economic and ecological importance whose populations have shown little genetic differentiation in previous studies using traditional genotypic methods. The feasibility of assigning individuals back to their respective populations based on their observed genetic profile is also under investigation. To meet these aims, we have sampled from sites across the northeast Atlantic range of *H. gammarus*, including around Britain and Ireland, the Channel Islands, the Bay of Biscay, Norway, and Sweden. We are using restriction-site associated DNA sequencing (RAD-seq) to identify polymorphic SNPs across the genome and a SNP panel is under development using ~192 of the most informative SNPs. This panel will enable the most powerful assessment of genetic structure and connectivity in *H. gammarus* to date. Our findings and the SNP panel will likely be of great benefit to stakeholders and the management of lobster fisheries. For example, the panel of SNPs could give managers the opportunity to monitor the genetic diversity and structure of their stocks over time. Moreover, a clearer picture of the extent of dispersal, localized recruitment, and connectivity in *H. gammarus* populations will enable regional fisheries managers to ensure that the conservation measures they impose are appropriate for the persistence of their lobster stocks and the prosperity of the fishery.

**O45-GENETIC AND BIOLOGICAL VARIATIONS IN LOCAL POPULATIONS OF EUROPEAN LOBSTER (*HOMARUS GAMMARUS*) IN NORWAY**

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 Institute of Marine Research, Bergen, Norway

In Norway, European lobster (*Homarus gammarus*) is found from the Swedish border in the southeast and all the way to north of the Arctic Circle to Stefjord (Tysfjord). The Institute of Marine Research has been monitoring lobster populations at several locations along the coast for several years, and here we will present and discuss the genetic as well as biologic variation between one population in southern Vinnes and the northern-most populations in Tysfjorden. The genetic data is part of a larger project producing a genetic baseline for the Norwegian lobster populations. We have screened ca. 2000 individuals from all locations along the coast using a battery of 12 microsatellite markers. In addition, we have recorded biological data from all individuals captured in pots or traps. The biological data in the two locations show large differences in size distribution, CL,  $84 \pm 13$ mm at Vinnes in the south and CL,  $80 \pm 9$ mm in Stefjorden in the North, and also size at maturity differs between the regions. The genetic study indicates temporal stability within each location, but large differentiation between the northern and southern locations. Even within small geographic distances in the north, we find genetic differentiation between populations.

**O46-ASSESSING THE POPULATION STRUCTURE AND CONNECTIVITY OF THE EASTERN ROCK LOBSTER, *SAGMARIASUS VERREAUXI*, UTILIZING NEXT-GENERATION SEQUENCING**

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The commercially important Eastern Rock Lobster, *Sagmariasus verreauxi*, has a disjunct distribution between the North Island, New Zealand (NZ) and New South Wales (NSW), Australia. It is also occasionally found in the coastal waters of Tasmania, Australia. The long planktonic larval phase of *S. verreauxi*, spanning 8-12 months, has been thought to facilitate long-range dispersal via ocean currents creating a high level of gene flow and connectivity throughout its range. Preliminary genetic work on *S. verreauxi* indicated a genetic break between the NSW and NZ populations; however, recent mtDNA data revealed genetic homogeneity between NZ and NSW. The structure and connectivity of *S. verreauxi* populations is yet to be clearly understood. Currently the *S. verreauxi* fishery is managed as two single, genetically independent stocks in NSW and NZ. The aim of this study is to determine the genetic structure and connectivity of *S. verreauxi* between NZ, NSW, and Tasmania and to examine the origin of recruits from the Tasmanian population. This study used double-digest restriction site-associated DNA sequencing to identify 667 neutral and 29 putative outlier single nucleotide polymorphisms (SNPs), which were used to genotype 90 lobsters collected from NZ, NSW, and Tasmania. Analysis of the neutral SNP panel detected genetic homogeneity across all regions ( $F_{ST}$  range = -0.010 to -0.011). However, the outlier SNP panel detected population differentiation between the 3 regions ( $F_{ST}$  range = 0.051-0.110). Comparable genetic diversity was detected across the regions ( $u_{He}$  range = 0.302-0.312). Results indicate gene flow does occur between NZ and Australia in a way that enables selective processes to differentiate the populations. We also determined that the Tasmanian population is not self-recruiting and is therefore currently reliant on gene flow from other populations for persistence.

**O47-FINE SCALE POPULATION STRUCTURE AND CONNECTIVITY OF THE AMERICAN LOBSTER IN ATLANTIC CANADA INVESTIGATED USING GENOTYPING-BY-SEQUENCING CAPTURE**

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The American lobster (*Homarus americanus*) supports the most important fishery in Atlantic Canada, making it critical to manage the fishery sustainably, including by defining biologically-meaningful management units. Recent developments in genomics enable us to better define the population structure of species with high gene flow, such as the American lobster, which is characterized by an extended pelagic larval stage, complex movements behaviors of benthic adults, and large census size. Following the work of Benestan et al. (2016), we investigated the concordance between the genetic structure of the American lobster and the boundaries of the current management units in Atlantic Canada, referred to as Lobster Fishing Areas (LFAs). We used a sampling design covering different spatial resolutions to collect 4,000 individuals distributed among 80 sites in 82% (37/45) of the American lobster LFAs. To address the challenges of genotyping such a large number of samples, we adapted a new RADseq capture protocol on Genotyping-By-Sequencing capture (GBS-capture) to sequence 10,000 targeted loci. This method is based on a capture step of DNA sequences in a GBS library using highly specific probes to target sequencing reads of preselected loci. Combining population genetic structure and admixture analysis, our study aims to refine previously documented patterns of genetic structure and population connectivity of *Homarus americanus*. This study will advance our understanding of biological units of the American lobster in Atlantic Canada, and their concordance with current management areas.

**048-SEX MATTERS IN MASSIVE PARALLEL SEQUENCING: EVIDENCE FOR BIASES IN GENETIC PARAMETER ESTIMATION AND INVESTIGATION OF SEX DETERMINATION SYSTEMS**

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Using massively parallel sequencing data from American lobster (*Homarus americanus*), we highlighted how an unbalanced sex ratio in the samples combined with a few sex-linked markers may lead to false interpretations of population structure and thus to potentially erroneous management recommendations. Multivariate analyses revealed two genetic clusters that separated males and females instead of showing the expected pattern of genetic differentiation among ecologically divergent (inshore vs. offshore) sampling locations. We created several subsamples artificially varying the sex ratio in the inshore/offshore and then demonstrated that significant genetic differentiation could be observed despite panmixia. This pattern was due to 12 sex-linked markers driving differentiation. Removing sex-linked markers led to non-significant genetic structure. We further characterized the putative functions of sex-linked markers. Given that only 9.6% of all marine/diadromous population genomic studies to date reported sex information, we urge researchers to collect and consider individual sex information. In summary, we argue that sex information is useful to (i) control sex ratio in sampling, (ii) overcome “sex-ratio bias” that can lead to spurious genetic differentiation signals, and (iii) fill knowledge gaps regarding sex determining systems.



## Physiological Responses to Environmental Stressors

### O49-SEARCHING FOR THE MOLECULAR MECHANISMS UNDERLYING SPINY LOBSTERS SEX DETERMINATION AND DEVELOPMENT

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Over the past four years, a collaboration between the University and Tasmania (Utas) and the University of the Sunshine Coast (USC) in Australia has focused on gaining a better understanding of the molecular mechanisms underlying spiny lobster sex determination and larval development. The collaboration is underpinned by expertise in larval biology at Utas and genomics research at USC. For the first time in a spiny lobster species, we identified the androgenic gland and its putative hormone, which is key for regulating crustacean masculinity. We also characterised the receptor and additional components in the endocrine pathway of the insulin-like androgenic gland hormone. Most recently in *Sagmariasus verreauxi*, we identified the first invertebrate sex-linked (Y-linked) Dmrt gene and quantified expression during embryogenesis to describe the sex determination period. We are now developing biotechnologies to establish sterile monosex populations, which could benefit growth, behavior, and biosecurity in aquaculture. Developmental research has focused on the key transitional period of metamorphosis. Where, when, and why metamorphosis occurs are important factors affecting recruitment success and, in the context of aquaculture, metamorphosis presents a critical bottleneck due to stage-specific sensitivities. Spiny lobster also provide a valuable crustacean model due to the transparent larvae in which timing of metamorphosis can be accurately predicted. Our research shows that the phyllosoma-puerulus metamorphic transition in *S. verreauxi* is accompanied by vast transcriptomic changes and that genes previously identified as regulating metamorphosis in other crustaceans do not change during the metamorphic transition. Future research aims to utilize physiological assays, combined with transcriptomics, comparative bioinformatics, *in situ* hybridization, immunohistochemistry, and *in vivo* assays to better elucidate the pathways and discover the key factors that regulate lobster metamorphosis.

**050-LINKING RISING pCO<sub>2</sub> AND TEMPERATURE TO LARVAL DEVELOPMENT, PHYSIOLOGY, AND GENE EXPRESSION OF THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*)**

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Few studies have evaluated the joint effects of elevated temperature and partial pressure of CO<sub>2</sub> (pCO<sub>2</sub>) on marine organisms. In this study, we investigated the interactive effects of an Intergovernmental Panel on Climate Change (IPCC) predicted temperature and pCO<sub>2</sub> for the end of the 21st century on key aspects of larval development of *Homarus americanus*. Our experiments showed that larvae (stages I-III) and postlarvae (stage IV) reared at the temperature projected for the Northwest Atlantic by the year 2100 (19 °C) experienced significantly lower survival, developed twice as fast, and had significantly higher oxygen consumption rates, than those in 16 °C treatments. Larvae from the high pCO<sub>2</sub> (750 ppm) treatment at 16 °C had significantly longer carapace lengths, and greater dry masses in stages I-III and C: N ratios in the postlarval stage. Postlarvae raised in the high pCO<sub>2</sub> treatment at 19 °C had significantly higher feeding rates and swimming speeds compared to postlarvae from the other three treatments. We also examined gene expression in postlarvae raised in each of the two pCO<sub>2</sub> treatments at 16 °C. We selected 13 annotated genes of interest (GOIs) that were differentially expressed between postlarvae from the two pCO<sub>2</sub> treatments. These preliminary results, in tandem with our other measurements, provide insight into how postlarvae compensate for the stresses of an end-century pCO<sub>2</sub> and maintain successful development. As is the case for most experiments of this nature, our results may have been biased by the fact that we were only able to conduct measurements on the small number of larvae that survived the experiment. Understanding how the most vulnerable life stages of the lobster life cycle respond to climate change is essential in connecting the geographic shifts projected by habitat models, and the underlying genetic mechanisms that drive their ecology.

**051-INTERACTIVE EFFECTS OF OCEAN ACIDIFICATION AND TEMPERATURE INCREASE ON SHELL DEVELOPMENT AND GENE EXPRESSION IN JUVENILE *HOMARUS AMERICANUS***

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The Intergovernmental Panel on Climate Change predicts ocean pH to drop 0.3-0.4 units by 2100 and surface water temperatures to increase by 2.6 °C to 4.8 °C degrees under a business as usual scenario. The Northwest Atlantic, like other cold water, high-latitude regions, is warming and becoming more acidified at a faster rate than lower latitudes, which puts much of the American lobster population at prime risk for experiencing the worst of these effects in a comparably very short period of time. Previous climate change research on the American lobster has been largely limited to single stressor (pH) lab experiments to determine the effects on growth, metabolic processes, and survival rates. The purpose of this study was to examine the interactive effects of elevated temperature and decreased pH on gene expression associated with shell development in early benthic juveniles, a naturally stressful life stage for the American lobster. The experiment specifically tested the expectation that the genes controlling for shell hardening, post molt timing, and production of proteins involved in shell biomineralization would be down regulated under experimental conditions. Juveniles were reared at the New England aquarium and transferred to the pH-stat CO<sub>2</sub> dosing system at UMass Boston where they were grown in four treatments (three replicates) using a 2 x 2 factorial design: pH of 7.6, 8.0 and temperature of 17 °C, 21 °C. RNA was isolated from the lobster carapace and prepped for sequencing following Illumina TruSeq Stranded mRNA Sample Preparation Guide. Results from the sequencing run are pending, but we anticipate completing relevant statistical analyses to fully evaluate the effects of experimental treatments on gene expression in shell development in time for the conference.

**052-EFFECTS OF OCEAN ACIDIFICATION ON THE PHYSIOLOGY OF SUBADULT AMERICAN LOBSTERS (*HOMARUS AMERICANUS*)**

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Increases in anthropogenic input of CO<sub>2</sub> into the atmosphere has caused widespread patterns of ocean warming (OW) and ocean acidification (OA). Both OW and OA will likely have major impacts on commercial fisheries and aquaculture, but OA may pose a particular threat to marine calcifying invertebrates. In the State of Maine, commercial fisheries landings are valued in excess of \$600 million, the majority of which is sustained by the American lobster (*Homarus americanus*) fishery. Previous research has examined the effects of OA and OW on larval lobsters, but little work has focused on the effects of climate change on subadult or adult stages. Here, we discuss preliminary results from a short-term study exploring physiological impacts of OA on subadults. We used Honeywell Durafet pH electrodes in combination with a LI-COR® LI-840A CO<sub>2</sub>/H<sub>2</sub>O gas analyzer and a PENTAIR Point Four™ RIU to monitor and maintain a constant pH of 7.6 and 8.2 across four replicate OA treatment and control tanks, respectively. Water temperature, dissolved oxygen content, pH, and salinity were assessed twice daily, total alkalinity was measured bi-weekly via titration, and the program CO<sub>2</sub>SYS was used to calculate carbonate chemistry within each tank. After 60 d of exposure, hepatopancreas, gill, and cardiac tissue samples were collected from 10 of 22 individuals for transcriptomic analysis using RNA-Seq, and hemolymph was drawn from all lobsters to explore variation in ecdysteroid expression. Cardiac performance in the context of thermal stress was also assessed in 12 lobsters using impedance pneumography. Preliminary analyses indicate that lobsters exposed to acidified water had lower Arrhenius Break Temperatures compared to control lobsters, suggesting physiological impairment. Our work aims to provide biological endpoints to evaluate OA impacts on lobster physiology, as well as provide a better understanding of how future changes in climate might affect this important species.

**053-EFFECTS OF COMBINED EXPOSURE TO OCEAN ACIDIFICATION AND HYPOXIA OR MANGANESE ON IMMUNOLOGICAL, PHYSIOLOGICAL AND BEHAVIORAL RESPONSES IN NORWAY LOBSTER (*NEPHROPS NORVEGICUS*)**

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Ocean acidification (OA) is a gradually increasing, ongoing process with great concern to marine biota. Yet we know very little about the combined effects of OA and other stressors such as spreading of oxygen depleted areas. The Norway lobster, *Nephrops norvegicus*, is one of the commercially most important fishery species in Europe. It is found on coastal soft bottom sediments subjected to periodic hypoxia. Hypoxia, in turn, infers increased bioavailability of the heavy metal manganese that normally is bound the sediment. In this comprehensive study, we investigated possible interactions between longer-term exposure to elevated pCO<sub>2</sub> at concentrations postulated by 2100, and more short-term exposure to hypoxia or manganese on different life stages of the Norway lobster. We demonstrate severe impacts at different organisation levels; from suppressed immune response to bacterial infection, to effects on embryonic heart rate, respiration, foraging behavior and CO<sub>2</sub> avoidance. Clearly, there are risks of great impact on lobster condition and biomass at these future stress scenarios. However, our results also demonstrate that susceptibility varies greatly between life stages and organization levels. Nevertheless, the combination of stressors often had the most severe effects, requiring future studies on interactions with pollutants and natural variables to better predict the influence OA will have on marine organisms.

#### 054-EUROPEAN LOBSTER *HOMARUS GAMMARUS* IN A HIGH CO<sub>2</sub> ENVIRONMENT – FOLLOWING INDIVIDUAL LARVAE FROM STAGE I TO STAGE IV

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Food availability and energy status play a significant role in how well some marine species cope with elevated CO<sub>2</sub> levels. The aim of our study was to compare survival and deformities in European lobster *Homarus gammarus* larvae exposed to two pCO<sub>2</sub> and food levels. Two experiments were conducted, each with 192 larvae kept individually in 0.8 L jars from stage I. The larvae were exposed to ambient or elevated pCO<sub>2</sub>: Experiment 1 – pCO<sub>2</sub> = 615/1234 μatm; pH<sub>tot</sub> = 7.85/7.57; temperature = 17.2 °C. and Experiment 2 – pCO<sub>2</sub> = 596/1283 μatm; pH<sub>tot</sub> = 7.84/7.54; temperature = 16.9 °C. The treatments were divided into two feeding regimes, low (LF) and high (HF), 48 individuals in each treatment. The number of enriched *Artemia* supplied per larvae were adjusted with developmental stage. Larvae were photographed to record deformities. In Experiment 1, individual larvae were fed 40-80 (LF) or 200-550 (HF) *Artemia* day<sup>-1</sup>. Experiment 1 lasted for 36 days and a total of 15 larvae survived, two from LF (both ambient) and 13 from HF (six from ambient, seven from elevated). Seven larvae reached stage IV, all from the HF groups (four from ambient, three from elevated). Deformities were observed in two larvae in each group. None of the larvae in LF/elevated developed into stage III. In Experiment 2, individual larvae were fed 100-50-100 (LF) or 500-200 (HF) *Artemia* day<sup>-1</sup>, adjusting the number of *Artemia* due to over-feeding. Experiment 2 lasted for 25 days and a total of 95 larvae survived, 78 in the LF and 17 in the HF. The LF larvae showed no difference in survival (~50%) with pCO<sub>2</sub> levels (while in the HF more larvae survived in the elevated treatment (76%) compared to the ambient (24%)). The first deformities were observed at about day 8 on stage II larvae. Deformities in the carapace were the most common, but also the tail fan, swimming/walking legs, and rostrum were present.

#### 055-PHYSIOLOGICAL IMPACTS OF SEISMIC AIR GUN EXPOSURE ON SPINY LOBSTER (*JASUS EDWARDSII*)

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The physiological effects of exposure to air gun signals used for seismic surveys on marine invertebrates are not well understood. Here we conducted a series of experiments where southern rock lobsters (*Jasus edwardsii*) were exposed to air gun signals using a 45 in<sup>3</sup> or 150 in<sup>3</sup> commercial grade air gun. The air gun configurations generated maximum SEL levels of 186-190 dB re 1μPa·s. Lobsters were sampled for reflex behavior and physiology at days 0, 2, 14, 120, and 365 post-exposure. No mortality was recorded in any of the experiments. Biochemical analysis of haemolymph showed little effect of exposure on 23 electrolyte ions, mineral ions, metabolites, organic molecules, and enzymes. Seismic exposure had a consistent and prolonged negative effect on lobster total haemocyte count for up to 120 days post-exposure. The righting reflex was generally impaired in exposed lobsters that was found to be correlated with damage to the statocyst, the mechanosensory organ responsible for balance and detecting gravity. In one experiment, however, non-exposed lobsters showed similar statocyst damage levels to that of exposed lobsters from the other experiments. Interestingly, the lobsters from this experiment were collected from a site with a higher level of anthropogenic noise. This series of experiments show that lobsters exposed to seismic air gun signals incur a moderate amount of disruption to their physiology and sensory biology of lobsters, though the ecological impacts remain unclear at this point.

## Population Dynamics & Connectivity

### 056-INVESTIGATING THE CONNECTIVITY OF THE CARIBBEAN SPINY LOBSTER USING A MULTI-DISPLINARY APPROACH

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The relationship between the spawning stock biomass and the recruitment has become an obstacle to satisfactory Caribbean spiny lobster stock assessment. The long pelagic larval stage and the current conditions in the Caribbean Sea led to the hypothesis that the Caribbean spiny lobster stocks are demographically open. Multiple approaches have been applied to investigate stock connectivity, among which microsatellite DNA analysis and stable isotope analysis are the two most applied methods. Fisheries scientists have used microsatellite markers to investigate the spiny lobster population structure in multiple locations in the Caribbean, while stable isotope analysis has never been applied to spiny lobsters before. In this project, both the microsatellite marker analysis and the stable isotope analysis were applied on the post-larvae lobsters that arrived at the Keys Florida from August 2014 to June 2015. Results consistently found that potentially multiple source stocks contribute to the Florida stocks. Comparing the results between two methods could reveal the connectivity among the stocks in the Caribbean, and provide spatial structure dynamics information for the future stock assessments.

### 057-POTENTIAL IMPACTS OF LARVAL BEHAVIOR AND SPATIOTEMPORAL VARIATION IN HATCH ON MODELED CONNECTIVITY BY LARVAL DISPERSAL AND SETTLEMENT OF AMERICAN LOBSTER

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Dispersal of planktonic larvae has the potential to connect American lobster (*Homarus americanus*) fisheries or sub-populations separated by tens to hundreds of kilometers. Predicting impacts of fishing and climate change on lobster abundances requires knowledge of the species' stock structure and dynamics, which are greatly dependent upon larval connectivity. Recent work with a biophysical model of larval dispersal across the species' range suggested that all fisheries management areas in eastern North America exchange larvae with others, which may suggest that lobster populations are relatively "open" and that interconnected fisheries belong to larger biological stocks. While previous work with this model included some biological information (temperature-dependent larval development and settlement, larval mortality rate), it did not account for other important aspects of lobster biology. Most importantly, variation in larval production (i.e., hatch) across the species' range and over time were not included. Spatial differences in hatch can change the relative importance of specific larval sources to settlement in specific sinks, while temporal differences impact the oceanographic conditions under which larvae disperse, changing their trajectories. Previous work also treated larvae as passive surface drifters, whereas recent studies demonstrated ontogenetic and diel changes in vertical positioning and horizontal swimming by larvae that likely reduce their dispersal in nature. We added observed or estimated (e.g., from landings) spatiotemporal variation in hatch and larval behaviors into our large-scale dispersal model, and then assessed the impact of these additions on (1) model predictions of connectivity by larval drift and (2) correlations between model-derived settlement predictions and observed benthic recruitment in nature. This work will contribute to improvement and validation of a modeling system that will eventually be used to identify lobster stock structure and dynamics to inform management.



## **058-STOCK STRUCTURE AND CONNECTIVITY IN THE AMERICAN LOBSTER *HOMARUS AMERICANUS*: DO BENTHIC MOVEMENTS MATTER?**

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In the marine environment, the long-range (10s to 100s of kms) dispersal of pelagic larvae is often assumed to be the dominant force behind connectivity among stocks or management units, with little consideration given to the contribution of benthic movements. This is the case in the American lobster, *Homarus americanus*, for which spatial connectivity has been estimated in a number of studies using bio-physical models of larval dispersal. In this study, we analyzed data from an extensive tagging study in the southern Gulf of St. Lawrence between 1980-1996, during which 37,579 adult lobsters from 14 locations were tagged and 6,296 were recaptured after 1-6 years at large. We compared the distances travelled by these adult lobsters to dispersal distances predicted for larvae released from the same 14 locations. The average yearly 90th percentile dispersal distances of larvae were 139 km and 57 km in the dominant downstream and upstream directions, respectively, and the same values for adult benthic movements were 18 km and 14 km only. However, using the six locations where a number of adults were recaptured in two consecutive years, we estimate that benthic movement values for lobsters after five years at large are 69 km and 71 km, representing 43% (downstream) and 120% (upstream) of annual dispersal values predicted for larvae from the same six locations. Given that (i) our estimates of pelagic and benthic movements are comparable, (ii) the dispersal of larvae is likely constrained by behaviors not accounted for by our model, (iii) benthic movements are not constrained by currents the way pelagic dispersal is, and (iv) lobsters are known to move relatively little in our study area compared to other parts of the species' range, we conclude that more attention should be given to benthic movements in estimating connectivity and stock structure in American lobster.

## **059-USE OF THE AMERICAN LOBSTER SETTLEMENT INDEX TO EXAMINE RECRUITMENT AND JUVENILE LOBSTER POPULATION DYNAMICS AND INFORM THE GULF OF MAINE STOCK ASSESSMENT MODEL**

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Stock assessments for American lobster in the U.S. currently rely on a length-based model that includes lobsters starting at about age 5 years, about three years before they reach legal size in the fishery. Thus, predictive capability of the model in this recruitment driven fishery is limited to about three years and there is a temporal disconnect between spawning biomass and recruitment. The American Lobster Settlement Index (ALSI) monitoring program uses suction-sampling to survey young-of-year and juvenile lobsters. ALSI data have been collected annually at fixed stations since 1989 and >50 sites are currently sampled annually in coastal Maine, New Hampshire, and Massachusetts. ALSI data could be included in the stock assessment model to improve recruitment estimates, cover the entire stock starting from settlement. and improve predictive capability. We evaluate several statistical methods for calculating newly settled and juvenile abundance indices from the fixed-station survey that account for variable sampling histories and the differences in spatial distribution of survey sites. We use mixture models and cohort analysis to estimate growth and mortality rates for juvenile lobsters and to track temporal and spatial variability. Simulation analyses are used to determine if the abundance indices, growth, and mortality information for young lobsters will improve stock assessments, projections, and help to identify ecological processes that influence eventual recruitment to the fishery. Finally, we examine the performance of the assessment model with and without the ALSI survey index and the effect of the ALSI index on the accuracy and uncertainty of assessment model projections.



**O60-SPATIO-TEMPORAL PATTERNS AND REPRODUCTIVE COSTS OF ABNORMAL CLUTCHES OF FEMALE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, IN EASTERN CANADA**

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Previous studies have documented ovigerous female American lobster, *Homarus americanus*, carrying “abnormal clutches” with eggs covering less than half of their abdomen. From 2011-2014, we worked alongside Lobster Node harvesters to quantify spatio-temporal patterns and reproductive costs of abnormal clutches among 138,738 egg-bearing female lobster sampled from 196 homeports spread across eastern Canada. Females with abnormal clutches were ubiquitous, being found in 90% of homeports. Their incidence was, however, relatively low, averaging 6% across sampling times and locations. The incidence decreased between spawning and 7-9 months after spawning, potentially due to complete brood failure in some females, and it then increased towards the end of the brooding period, potentially due to repeated catch-and-release during the fishery. In most regions, small females were more likely to carry abnormal clutches than larger females. We estimated population-level egg loss between late oogenesis and hatching of embryos at 47% - 51%, with approximately half being associated with “normal” clutches and half with abnormal clutches and complete brood failure.

**O61-ESTIMATING JUVENILE ABUNDANCES OF THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) IN THE GULF OF MAINE: A COMPARISON BETWEEN GAM AND GWR MODELS**

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The Regional Ventless Trap Survey (VTS) is a cooperative effort between industry and scientists to monitor relative abundances of sublegal American lobsters (*Homarus americanus*) in the Northwest Atlantic. The participating Gulf of Maine states (ME, MA, and NH) have deployed standardized survey traps lacking escape vents at randomly selected sites stratified by depth along the northeastern U.S. coastline since 2006 (NH started in 2009). Traps are set as trawls with three ventless traps per trawl and are hauled every three days, twice per month during the molting season (from June - September) annually. This is an ideal dataset for identifying spatiotemporal trends of juvenile abundances due to relatively standardized methods and the extent of survey coverage. The purpose of this study is to compare two methods of estimating the relationship between juvenile lobster abundance indices and environmental variables: a generalized additive model (GAM) and a geographically weighted regression (GWR) model. GAMs are global models that are commonly used to identify nonlinear relationships between species abundance/distribution and environmental factors with the assumption that samples are spatially independent, even though spatial correlation often exists. We hypothesized that the local GWR model will better account for spatial autocorrelation at a local scale. These models were applied to the VTS dataset and incorporated environmental variables such as bottom water temperature, sediment type, and salinity. We will conduct this analysis on a monthly basis to determine if the importance of environmental variables changes over the molting season. This study will identify the most appropriate method for evaluating the influence of environmental variables on juvenile lobster distribution from trap survey data, which will allow us to better understand the dynamics underlying the early life history of this economically-valuable species in the Gulf of Maine.

**O62-THE FECUNDITY AND EARLY LIFE STAGES OF THE NEW ZEALAND SCAMPI  
*METANEPHROPS CHALLENGERI***

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The New Zealand scampi, *Metanephrops challengeri*, is a deep water crustacean endemic to New Zealand waters. It is a commercially important species that is found at depths of 150 to 800 m. In this study, aspects of the reproductive biology, larval development, and aquaculture potential of this species were examined. Female scampi carry a small number of large eggs under their tails for an extended period resulting in well-advanced zoea upon hatching with a truncated pelagic duration. A particular focus of this study has been on rearing the hatchlings through their subsequent development stages to benthic juveniles. The identified zoeal stages of New Zealand scampi will be described, along with a comparison with the known larval development in other members of the *Metanephrops* genus.

## Reproductive Biology

### **O63-THE IMPORTANCE OF KEEPING THE BIG ONES: MANAGEMENT OF CARIBBEAN SPINY LOBSTER, *PANULIRUS ARGUS* TO CONSERVE LARGE INDIVIDUALS**

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The Caribbean spiny lobster, *Panulirus argus*, is an iconic species that supports one of the Caribbean's largest and most economically valued fisheries. However, the average size of adult *P. argus* in most areas has decreased over the last 30 years because large individuals are culled by fishers under management schemes that only set a minimum size limit. Large lobsters produce exponentially more eggs per clutch and more clutches per season, thus contributing disproportionately to a population's reproductive capacity. The loss of large individuals is therefore of concern for the sustainability of fisheries, and novel management schemes are needed to conserve large breeding animals. A combination of harvest slot limits and marine protected areas is one potential solution. But management focusing on maximizing reproductive potential requires detailed information on reproductive output and quality relative to lobster size, as well as an understanding of the wider ecosystem implications of increasing the abundance of large individuals. Such were our objectives in a series of laboratory experiments conducted in the Florida Keys, FL (USA). First, we tested the relationship between lobster size, gamete production, and larval quality over multiple mating events to examine the possibility of reproductive senescence. Rather than a decline in quality with female size or successive clutches, we found that the second and third clutches produced by large females were of higher quality. We also examined size-specific trophic interactions between *P. argus* and their prey, and discovered differences in consumption and prey preference relative to lobster size. These results highlight the importance of management tools that maintain large individuals in populations of *P. argus* so as to maximize reproductive success. But an increase in the abundance of large lobsters will alter lobster-prey trophic interactions and, in some situations, could threaten prey species that themselves are of conservation or fisheries value.

### **O64-CAN THE FRENCH FEMALE LOBSTER (*HOMARUS GAMMARUS*) BE CONSIDERED A SUPER FEMALE?**

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On the Atlantic French coast, many programs during the last decade have brought a wealth of data on the biology of lobster. The aim of the present work is to use the size sampling of catches to analyze at a more fine scale the seasonal and annual trend of the proportion of berried female in three different zones. The self-sampling of fishermen represents a large dataset with high quality for this type of study. Data from observers are a second source of data. And finally, the data from some tagging programs are important to understand or to confirm some hypothesis. In this study, around 50,000 measurements are integrated. A logistic model has been developed to establish the relationship between the body size and the proportion of ovigerous females. The results confirm that the proportion of berried mature female is very high each year and can reach 90 %. This value would indicate that the annual cycle for many mature females is to be berried every year in some parts of the French Atlantic coast. These results will be presented and discussed considering they are really different from some European studies or from the knowledges acquired on the American lobster.

**065-LOBSTER HYBRIDS IN SCANDINAVIAN WATERS - LABORATORY EXPERIMENTS ON LARVAL VIABILITY AND COMPETITION WITH EUROPEAN LOBSTER**

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The trans-Atlantic trade of live American lobster (*Homarus americanus*) is a transport pathway for introductions of the non-indigenous species to European waters. How it may affect European ecosystems and European lobster (*H. gammarus*) is currently under scrutiny. The two *Homarus* species can cross-breed and American females with hybrid eggs have in recent years been captured in Scandinavian wild fisheries. Here we present novel data on the early development of wild-bred hybrid *Homarus* compared to native lobsters. The hybrids have been studied for development (rate, deformities, size, morphology), hatching success, survival, swimming behavior, environmental tolerance and competition. Some reproductive barriers between the two original species are indicated, as deformities occur in a small proportion of the hybrids, which is affecting their performance. The hybrid larva showed intermediate morphological characters compared to American and European lobster, but comparable environmental tolerance and behavior to the European lobster larvae. Results demonstrate that hybrids can develop, hatch, and survive in European waters during early development. Thus, hybridization (i.e., cross breeding) may pose a threat to the wild European lobster through genetic contamination, decreased lobster production, and possible competition for resources. The results are discussed in relation to current stocks of native lobsters in Scandinavia and potential impact.

**066-SURVIVAL, GROWTH, DEFORMITIES AND SPERM QUALITY IN HYBRID OFFSPRING, FROM A CROSSBREEDING IN THE WILD BETWEEN AN AMERICAN FEMALE AND A EUROPEAN MALE**

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We report on the survival, growth, and deformities in offspring from a natural crossbreeding between American (*Homarus americanus*) and European lobster (*H. gammarus*). 10,700 hybrid larvae were hatched at IMR in April 2010. The average sizes of the four larval stages were in-between those seen in American and European lobsters. Intermediate stages were also found. A large proportion of the juveniles showed deformities that were maintained over time (i.e., molt to molt). While the color of surviving hybrid juveniles has varied among siblings and over time, the majority looked like European lobsters by January 2017. We also present data on sperm quality of the males. The difference in growth and coloration is extremely variable despite the fact that offspring are from the same mother and father, have been given the same feed, and kept at same temperature regime. The background of the hybrids dates back to October 2009 when an American ovigerous female was captured along the Norwegian coast. DNA analysis confirmed the species status of the female and that the egg clutch was the result from a crossbreeding with a European male. In addition to this particular female, several other American lobsters have been found on the wrong side of the Atlantic and, worryingly, in overlapping areas with European lobsters. Over the past 10-15 years, some 100 individuals have been captured in northern Europe, including many ovigerous females. Since 2009, DNA analysis have confirmed a total of six crossbreedings: two in Norway and four in Sweden. The question is whether these are the only ones. Neither country has a monitoring program for European lobster, so findings of introduced lobsters are based on reports by fishermen. The broad spectrum of potential effects and lack of knowledge makes it difficult to predict future consequences but lessons from invasive species call for precautionary measures.

### **O67-PICTURING THE INTIMATE DETAILS: USING IMAGE ANALYSIS TO EXAMINE THE COMPOSITION OF MALE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) EJACULATES**

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American lobster (*Homarus americanus*) management in the United States tends towards a female-centric approach, where legal-sized female lobsters have additional protections relative to males. This is based on the assumption that egg production is related solely to size-specific maturity and fecundity of the female. This, in turn, is based on the assumption that males produce a large amount of sperm on a continuous basis and optimally inseminate every female. However, concerns have recently arisen regarding sperm limitation in various exploited crustacean populations based on research into male reproductive contributions, suggesting that some underlying assumptions need to be re-examined. A male American lobster's ejaculate is comprised of a single tubular spermatophore containing a sperm mass surrounded by a primary spermatophoric membrane and acellular materials, with no associated seminal fluid. The goal of this study was to develop appropriate methods for quantifying the composition of spermatophores (% sperm, or the ratio of sperm to sperm plug) and the volume (mm<sup>3</sup>) of the sperm mass, which would facilitate analysis of mating experiments designed to test the potential for sperm limitation. Here we describe how we quantified these parameters using digital photography, histology, and image analysis techniques. The results indicate that males exhibit a large amount of individual variation in the size and composition of the spermatophores produced, and, in certain laboratory-controlled mating scenarios, did not always completely fill the seminal receptacle of their female partner. These methods of determining the composition of male ejaculates provide the first steps towards quantifying male reproductive contributions, calculating sperm:egg ratios, and understanding the potential for sperm limitation in this species.

### **O68-THE ROLE OF GAMETE LIMITATION TO THE PRODUCTION OF “ABNORMAL CLUTCHES” BY FEMALE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, IN EASTERN CANADA**

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Several studies have documented ovigerous female American lobster, *Homarus americanus*, carrying “abnormal clutches”, in which less than half of the abdomen is covered by eggs, and a recent large-scale collaboration between scientists and fishermen (the Lobster Node) reported that 5.9% of 93,899 ovigerous females sampled in Atlantic Canada (6.2% on average among 196 fishing ports) possessed such abnormal clutches. This phenomenon could be caused by a reduced production of oocytes by the females (i.e., oocyte limitation hypothesis) or insufficient sperm received by the females to fertilize all the oocytes produced (i.e., sperm limitation hypothesis). To address the oocyte limitation hypothesis, we estimated ovarian fecundity and clutch quality in 764 pre-spawn females collected from 10 locations across eastern Canada. To address the sperm limitation hypothesis, we estimated the prevalence of females with different “types” of sperm plugs in their seminal receptacle among 1,735 wild-mated females captured in the Bay of Fundy, and we determined the clutch quality of 103 wild-mated lab-spawned females possessing these different types of sperm plugs. All 764 pre-spawn females sampled were able to produce enough oocytes in their ovaries to form normal clutches, indicating that abnormal clutches are not related to reduced ovarian fecundity. In contrast, 4% of the 1,735 wild-mated females captured in the Bay of Fundy did not have a sperm plug sealing their seminal receptacle, and lobsters with such a sperm plug spawned a full clutch in the lab that became “abnormal” after two weeks. Results of this study support the hypothesis that sperm limitation is responsible for the production of abnormal clutches by female American lobster.

**O69-ESTIMATING THE SIZE AT THE ONSET OF MATURITY FOR NEW ZEALAND SCAMPI  
(*METANEPHROPS CHALLENGERI*)**

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Determining the size at the onset of maturity (SOM) for crustacea is important for understanding the reproductive strategy and fitness of a species as a determinant of reproductive output. Size at maturity may also vary with fishing pressure, growth, population density, and habitat characteristics. New Zealand scampi (*Metanephrops challengeri*) are a highly prized, commercially important crustacean that are caught through bottom-trawling. Relatively little is known about New Zealand scampi biology, distribution, and habitat characteristics in comparison to their northern hemisphere cousins due to the far greater depths at which New Zealand scampi reside (250-650m). This study estimates SOM for New Zealand scampi across the full distribution of the species for the first time. Sexual maturity in female scampi were based on tried methods including morphometric approaches, 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 account for geographical and temporal variations across all New Zealand fisheries management areas and over a period of approximately 30 years. The results are presented within the context of fisheries management and emerging aquaculture research.



## Recruitment Processes

### **070-THE GREAT DISCONNECT: IS RISING LARVAL MORTALITY THE LINK TO NEW LOWS IN LOBSTER SETTLEMENT WHEN EGG PRODUCTION HAS NEVER BEEN HIGHER IN THE GULF OF MAINE?**

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In the Gulf of Maine (GOM), landings of American lobster have quadrupled since the 1980s and are currently at record-breaking highs. Similarly, estimates of spawning stock biomass (SSB) are at historically high levels. In contrast, estimates of benthic recruitment of young-of-year lobsters, based on the American Lobster Settlement Index (ALSI), have been declining precipitously since 2012 and are currently at time-series lows over much of the GOM. We analyzed a unique long-term time series of larval abundance collected off the coast of New Hampshire via neuston tows to further explore linkages between time trends in broodstock, larval abundance and young-of-year recruitment. Neuston tows have been collected consistently by Normandeau Associates since 1988 as part of the environmental sampling for New Hampshire's Seabrook Nuclear Power Station. The neuston tow time series shows a significant increasing trend in stage I larvae, which is consistent with the mounting levels of SSB in the GOM over the same period. In contrast, the abundance of planktonic stage IV postlarvae from the same survey has shown a significant decreasing trend, and this decline correlates well with ALSI estimates of young-of-year lobsters quantified by divers using airlift suction samplers on the seabed. These results are the first to suggest a decoupling of the linkage between SSB and subsequent recruitment during the few weeks of planktonic larval development, and are consistent with the hypothesis that recent declines of young-of-year recruitment may be due to larval mortality or advection from coastal nurseries. These observations run counter to the alternative hypothesis that the observed decline in settlement density may be due to larval settlement spreading over a wider area of suitable habitat in a warming climate. We will discuss potential sources of larval mortality and transport that could be responsible for these recent declines.

**071-EVIDENCE OF METAMORPHOSIS OF CARIBBEAN (*PANULIRUS ARGUS*) AND SPOTTED (*P. GUTTATUS*) SPINY LOBSTERS IN THE YUCATÁN CURRENT**

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For spiny lobsters, the occurrence of final-stage larvae (phyllosomata), postlarvae (pueruli), and especially new (soft) pueruli in oceanic waters has been considered as indicative of metamorphosis zones. We explored where metamorphosis of Caribbean (*Panulirus argus*) and spotted (*P. guttatus*) spiny lobsters occurred in oceanic waters off the Caribbean coast of Mexico, where the continental shelf is <10 km in width. We conducted two cruises in autumn 2012 and spring 2013. We used a mid-water trawl at depths between 5 and 15 m and a surface (neuston) net at <1 m in depth. Both nets were trawled horizontally, simultaneously, and exclusively during the night, in points located along transects up to 100 km across the Yucatán current. Hydrographic fields were obtained from CTD data, and current fields by combining satellite altimetry data with data from four ADCPs anchored at different points over the study area. In all, we obtained 438 late phyllosomata (stages IX-X) and 1,058 pueruli of *P. argus*, and 26 late phyllosomata (stages X-XI) and 60 pueruli of *P. guttatus*. Metamorphosis occurred offshore of the shelf break with no apparent relationship with temperature, salinity, or distance from the coast. However, evidence of metamorphosis was more apparent within the core of the Yucatán current, where velocities were higher (up to 1.5 m/s), and which was closer to the coast in autumn, as well as along the edge of large mesoscale eddies propagating along the Yucatán current, that may create fronts potentially concentrating food for phyllosomata upon colliding with the shelf break. Interestingly, the pueruli of both species had a broad size range, but were significantly larger in spring than in autumn, suggesting a similar larval duration for both species if they were subjected to a similar environmental variability during their larval development.

**072-ENERGETIC CONSTRAINTS IN SPINY LOBSTER RECRUITMENT**

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A number of researchers have proposed that the settlement and recruitment of spiny lobsters is constrained by the energy-demanding shoreward migration of the non-feeding post-larval or pueruli stage. Furthermore, this hypothesis has been used in conjunction with ocean warming as one possible explanation for the recent decline in settlement and recruitment observed in some spiny lobster populations. In this study, we examined the nutritional condition of more than 1,500 pueruli of the eastern rock lobster, *Sagmariasus verreauxi*, arriving at four locations along a latitudinal gradient of the New South Wales coast in Australia over a two year period. The results show marked temporal and spatial differences in the nutritional condition of lobsters settling on the coast that may contribute to variability in the supply of juvenile lobsters surviving in coastal habitats. We discuss the results in relation to possible causes of the variations in nutritional condition observed in these early lobster stages.

**073-ENERGY EXPENDITURE OF MIGRATING SPINY LOBSTER POST LARVAE**

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Many spiny lobster populations around the world appear to be going into decline due to reduced settlement of their post-larvae or pueruli, and their subsequent recruitment into the adult population (Jeffs, 2010). One hypothesis for this decline is that climate change is impacting the ability of larvae to gather sufficient nutritional resources to support their non-feeding puerulus stage which is involved in migrating over long distances back into the coastal environment where they settle and become juveniles (Fitzgibbon et al., 2014). The purpose of this research is to examine the energetics of the pueruli phase of the life cycle of two species of spiny lobster from different ocean climates: eastern spiny lobster (*S. verreauxi*) from Australia (warm temperate) and Australasian red spiny lobster (*J. edwardsii*) from New Zealand (cool temperate). To determine the rate of energy spent while swimming, pueruli were subjected to swimming experiments, for different periods and temperatures, and the associated change in their biochemical condition was analyzed. By knowing the energy spent and the speed at which pueruli were swimming, the distance a pueruli can travel with a specific amount of lipid reserves can be estimated. This research also attempted to identify the location offshore from which the larvae metamorphose. To do this, the composition of pueruli legs were analyzed to try to identify a chemical signature from their natal waters; this was done by laser ablation inductively coupled plasma mass spectrometry. Knowing which offshore water mass pueruli originated from will enable us to develop estimates of the energetic costs of onshore migration for pueruli from various distances offshore in relation to other environmental factors, such as offshore winds and cross currents. Satellite tracking of water masses and water surface windflows can then be used to help forecast the likely distribution of pueruli arrivals on the coast.

**074-OPTIMIZING AN OCEANOGRAPHIC-LARVAL MODEL FOR ASSESSMENT OF THE PUERULUS SETTLEMENT OF THE WESTERN ROCK LOBSTER, *PANULIRUS CYGNUS*, IN WESTERN AUSTRALIA**

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An innovative oceanographic-larval modelling process has been used to investigate the major reduction in puerulus settlement for the western rock lobster (*Panulirus cygnus*) which occurred over 2006-2012 with the 2008/09 being the lowest recorded in 40 years. A range of models were developed utilizing 19 years of oceanographic data (1994-2012) and puerulus settlement from eight locations along the Western Australian coast. The approach fitted oceanographic-larval models to observed data, and differed from the more usual situation of assessing source-sink relationships without fitting to time series observations. The model optimization processes were achieved by sensitivity assessment of the parameters within the complex oceanographic-larval model and by comparing model and observed settlement, followed by adjustments using a simpler post-model statistical analysis of other biological parameters. The criteria for assessment of the models were the model settlement fit to the annual settlement and to the observed patterns of monthly and spatial distribution. The initial sensitivity analysis identified the important parameters as: (i) wind effect on the surface water movement; and (ii) level of puerulus swimming allowed in the model. The post-model analysis assessed the effect of varying the month of larval release, the abundance and spatial distribution of larval release, and the duration of larval development before settlement could occur. This indicated that the timing of (early) larval releases was a significant factor in settlement success. The models developed indicate that breeding stock sources at all locations along the coast are likely to be important to the final numbers settling. A mismatch between the time of spawning, larval development, and weaker onshore current systems needed to return the phyllosoma larvae close to the coastline where they can successfully metamorphose into puerulus, appears likely to be the primary cause of the low settlement period.

**075-SPATIAL AND TEMPORAL PATTERNS OF RECRUITMENT OF THE EASTERN ROCK LOBSTER, *SAGMARIASUS VERREAUXI*, OVER 2 DECADES**

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In the mid-1990s, a suite of management measures, including catch quotas and a maximum legal size, were introduced in New South Wales (NSW), Australia, to increase the population of the Eastern Rock Lobster, *Sagmariasus verreauxi*. This was in response to declining abundance and concerns about over-exploitation of this spiny lobster species. Rebuilding of the population, during the last 2 decades, has been monitored using a combination of fishery-dependent data sources and fishery-independent surveys, including an annual survey of the settlement of puerulus post-larvae. Since 1995-96, settlement of pueruli on seaweed-type collectors has been surveyed annually, during the first quarter of each lunar month between August and January, on 3 replicate collectors, at each of 3 fixed sites within each of 4 locations along the coast of NSW. The general objective of this survey was to monitor changes in abundance of recruits at these spatial and temporal scales to service specific objectives concerning: (i) rebuilding of the population and increasing recruitment; (ii) understanding the relationship between abundance of spawning stock and recruitment; and (iii) use of annual indices of puerulus settlement to predict subsequent recruitment to the fishery. Results of 4-factor analyses of mean puerulus abundance showed significant interactions among combinations of all factors: Location, Site, Year, and Month. Abundance of recruits was an order of magnitude greater at the 2 southern locations (Sydney, Ulladulla) than at the 2 northern locations (Coffs Harbour, Tuncurry). Peak settlements usually occurred during October, and less frequently during September or November. Abundance of pueruli varied greatly from year to year, but with an increasing linear trend (approximately doubling) across the 2 decades. The observed spatial and temporal patterns in puerulus settlement are discussed in terms of their contribution toward demonstrating population rebuilding, understanding a stock-recruitment relationship, and predicting subsequent recruitment to the fishery.

**076-A MOLECULAR APPROACH TO UNDERSTANDING METAMORPHOSIS IN SPINY LOBSTERS**

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The potential for spiny lobsters as aquaculture species has attracted significant research attention over the past decade, but the industry continues to be hindered by the lobster's complex lifecycle and unknown biological requirements. In the larvae, metamorphosis from the phyllosoma to the puerulus has been a particular stumbling block of industry development and, although the lifecycle has been closed with great efficacy in land-based culture systems, this critical life-stage remains problematic. In an attempt to introduce new perspective to this issue, we present a research project that aims to unveil the intricate mechanisms behind this metamorphosis using molecular methods with a bifocal approach. To establish a basis for current hypotheses, and for testing new ones, we plan to utilize *in vivo* experiments on cultured larvae approaching metamorphosis. Key metabolites, particularly those already associated with metamorphosis, will be administered to the larvae with the aim of revealing their role in the process. In parallel to this, we are analysing a comprehensive transcriptome from larvae undergoing metamorphosis. Genes of interest will be further examined for function with appropriate *in vitro* assays; for this purpose we are currently designing a receptor assay to examine the interactions between key nuclear receptors, which present themselves as likely candidates for regulatory components. By building up an understanding of the machinery controlling metamorphosis in the larvae, we aim to utilize the culture systems to test novel hypotheses with the ultimate goal of inducing and controlling metamorphosis. If such a hypothesis can be confirmed, then manipulation of larval development via feed or water may constitute a feasible method of managing this precarious life stage at a commercial scale. In a broader context, the outcomes of this project will both complement and challenge conventional knowledge around metamorphosis in crustaceans.

## Trap Design & Impacts

### 077-COMPOSITION, QUANTITY, AND SURVIVAL OF INCIDENTAL CATCH DURING THE SOUTHERN GULF OF ST. LAWRENCE LOBSTER (*HOMARUS AMERICANUS*) FISHERY

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Incidental catch or bycatch during commercial fishing activities can affect the marine environment by disrupting the ecosystem balance and biodiversity. Canada took the engagement of implementing conservation and management measures to address bycatch that will support the sustainable harvesting of aquatic species. Information on the bycatch level in the southern Gulf of St. Lawrence (sGSL) lobster (*Homarus americanus*) fishery is also required for the eco-certification of the fishery. To support both the Department of Fisheries and Oceans' mandate and the industry's eco-certification process, a field study was conducted in 2015 to gather baseline information on bycatch during the lobster fishery in the sGSL. Bycatch composition (species identification) and quantity (count and weight) were recorded during 76 fishing trips during the fishing season. Injury and vitality assessments were also performed on several species to estimate survival potential when released. Sorting time of traps during commercial activities was used to infer air exposure duration for the bycatch. Aside from sub-legal size lobsters and berried females, the most commonly encountered bycatch taxa (based on numbers) from the 20,199 traps sampled were rock crab (*Cancer irroratus*), cunner (*Tautoglabrus adspersus*), sea urchin (*Strongylocentrotus droebachiensis*), hermit crab (*Pagurus* spp.), and sculpin (*Myoxocephalus* spp.). Only 2.1% of animals assessed had minor non-life-threatening injuries while 0.1% had major injuries jeopardizing their survival. Also, 98% of animals assessed were showing signs of excellent vitality even after the 10 minutes observation period. Based on videos, the median sorting time of a trap was less than one minute, therefore limiting air exposure of the bycatch. Fishing practices in terms of highly selective and passive gear along with manual handling of the bycatch assure a low risk of bycatch mortality in the sGSL lobster fishery.

### 078-TECHNOLOGICAL ADVANCES FOR RESEARCH IN THE NEW ZEALAND SCAMPI FISHERY

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The New Zealand scampi (*Metanephrops challengeri*) is a commercially-important lobster that is harvested in deep-sea New Zealand waters using bottom trawling methods. Research is being undertaken to develop new potting technology that is considered to deliver economic and environmental improvements over trawling. The research process has demanded the development of parallel technological advancements, needed to monitor prototype potting systems *in situ*. In this presentation, we will showcase some of the monitoring systems that have been developed, the usages of these systems, and data that has been obtained from the systems. Systems presented will include 1) A "Wet Tag" deployed within pots to measure physical environmental conditions, pot deployment location, depth, and soak time. Inherent with the wet tag system is an on-deck wireless datalogger that automatically receives data from the wet tags as the pots are retrieved onto the fishing vessel. 2) A video monitoring system deployed with pots, used to obtain deep-sea infrared video footage of scampi and other species interacting with the pots and with bait presentations systems. 3) A video system attached to the headline of scampi trawl nets, used to create new data on scampi abundance and distribution along the trawl lines.

**079-KA HAO TE RANGATAHI: INNOVATIONS THAT IMPROVE ECONOMIC OUTCOMES IN THE NEW ZEALAND SCAMPI FISHERY?**

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In 2013 Cawthron Institute and industry partners, Waikawa Fishing Company, were granted six years' of Ministry for Business Innovation and Employment (MBIE) funding to investigate two options: aquaculture and potting as new directions for New Zealand's scampi (*Metanephrops challengeri*) fishery beyond the practices of the current deep water trawl fishery. This presentation will address the economic outcomes of innovation that lie at the intersection of the biology and management themes of the conference. We describe a program of research by an indigenous Maori commercial fishing enterprise pursuing innovation designed to deliver environmentally friendly, commercial added value. The innovation is both active and disruptive: undertaken by a small fishing entity, it is designed to achieve major breakthroughs into new technological and commercial realms. The two interdependent thrusts to the research have the potential to induce change in the fishery value chain and challenges to the management domain. In this presentation, we detail the economic rationale for this research and report progress in the development of innovations for scampi aquaculture and pot fishing industries. Those innovations may lead to changes in the price of access to the fishery and, in turn, the economic value of the underlying quota share asset. Those effects are based on anticipation of enhanced profitability from operations through higher output prices and the differing production costs that the innovations promote. We use econometric analysis of time series of annual catch entitlement (ACE) prices from trades in scampi ITQ quota markets and other economic fisheries data to evaluate whether progress in the innovation process is correlated with changes in ACE prices, which, in turn, result in an enhanced economic valuation of the New Zealand scampi fishery.

**080-POSSIBLE MECHANISMS THAT GIVE RISE TO THE SATURATION OF VENTLESS AMERICAN LOBSTER TRAPS**

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Ventless lobster traps are currently being used by a number of state agencies to assess the abundance and size distribution of local lobster populations. However, like standard traps, ventless traps have been shown to saturate after 1-2 days, which might influence the accuracy of the data obtained. The goal of this study was to test four different hypotheses concerning the mechanisms that might be responsible for this saturation effect: 1) traps become filled to capacity; 2) antagonistic interactions reduce entries; 3) lobsters in the area fished become depleted; and 4) the bait deteriorates. SCUBA surveys before and after fishing traps revealed that there was no change in the number of lobsters surrounding lobster traps. Pre-stocking traps with lobsters did not influence catch on day one, indicating that they were not preventing new lobsters from entering. However, catch always appeared to plateau at ~ 30 lobsters, suggesting there is a physical- or behaviorally-based upper limit. If fresh bait was added to traps after 24 hours, then lobster entry rate immediately increased and the catch after 48 hours was higher than control traps with no bait replacement. Furthermore, if "old" bait was used from the onset, catch after 24 hours was less than controls. Finally, laboratory tests revealed that the amino acids in bait, which are likely important attractive odorants, decline by half after a 6-hour soak, even though the bait itself does not change weight. Together, these data suggest that the primary cause of trap saturation is loss of bait attractiveness, most likely due to the loss of the most attractive odorants. However, it should also be noted that catch always appeared to peak at about 30 lobsters, which could be due to space constraints or interactions between lobsters.



**081-OPTIMIZING TRAP DESIGN FOR NEW ZEALAND SCAMPI – METANEPHROPS CHALLENGERI**

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New Zealand Scampi (*Metanephrops challengeri*) are currently captured by trawling at depths of between 200-500 m, in a small (750-1100 t) but valuable fishery. A high level of bycatch is a feature of the fishery, with bycatch species making up approximately 80 percent of the catch. We have been testing the use of traps or “pots” to capture NZ scampi, as an economically and environmentally beneficial alternative to trawling. Initially, we tested four existing trap types used in European *Nephrops* fisheries, but had minimal success in the laboratory (6 percent caught) or in field trials. Laboratory experiments showed NZ scampi would not walk up and enter the traditional funnel shaped entrances used in *Nephrops* traps. Consequently, we tested how NZ scampi interact with various components of traps (e.g., entrance slope, entrance width, and height) with the aim of optimizing a trap design for NZ scampi. In this presentation we show the results of laboratory trials where catch rates were increased by up to 60 percent.

**082-EFFECTS OF GREEN CRAB (*CARCINUS MAENAS*) ON THE FOOD ACQUISITION AND CATCHABILITY OF THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) IN NEWFOUNDLAND, CANADA**

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The American lobster (*Homarus americanus*) is the most commercially important crustacean species in Canada; however, fishery landings in Placentia Bay, Newfoundland, have decreased by over 30% since the invasion of the European green crab (*Carcinus maenas*) in 2007. The effect of green crabs on the food consumption and catchability of lobsters was quantified in relation to crab density (n=0, 1, 5, 25) and water temperature (4 °C, 12 °C). Individual lobsters consumed less food at both temperatures when exposed to intermediate crab density (n=5). Interestingly, lobsters consumed more food at the low temperature (4 °C) than at 12 °C. In contrast, green crabs consumed more food at the higher temperature as they were more active and outcompeted the lobster for food. Behavioral interactions around the food source were also quantified: as crab density increased, the number of agnostic interactions increased at both temperatures. The effects of green crabs on the catchability of lobsters around a baited trap was also investigated, with crabs freely mobile outside the trap or contained within the trap. Lobsters were more likely to approach and enter the trap at 12 °C; however, they were also more likely to escape. There was an interactive effect between the species and the lobsters were less likely to enter or approach a trap if they interacted with crabs outside of the trap. The present results suggest that interactions between the green crab and adult lobsters may be influencing catch rates in Newfoundland.

**O83-NORWAY LOBSTER (*NEPHROPS NORVEGICUS*) FISHING GROUNDS IN WESTERN NORWAY FJORDS AND COASTAL AREAS – SEABED MAPPING AND TRAP FISHING EXPERIMENTS**

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*Nephrops norvegicus* (Norway lobster, langoustine, cigala) is a widespread and economically valuable crustacean in the northeastern Atlantic Ocean, ranging from Morocco in the south to the Lofoten Islands in northern Norway. The species is also found in the western part of the Mediterranean Sea, and is considered as one of the most important commercial crustacean in Europe, with an overall annual harvest between 50,000 – 80,000 tonnes. The Norwegian catches, in comparison, are very small, and knowledge about the distribution and abundance of *Nephrops* in Norwegian waters is very limited. The southwestern coastal area of Norway consists of numerous islands and many large and deep fjord systems that remain unexploited with regards to this species. This study combines detailed seabed topography mapping with traditional *Nephrops* trap fishing. Results demonstrate that the species also is distributed in favorable environments in some of the largest fjords in western Norway, such as the inner Hardangerfjord. Abundance and size distribution of these fjord lobsters are compared to results from coastal and offshore fisheries.

WEDNESDAY, JUNE 7, 2017

**Aquaculture****O84-THE WHY, WHERE, AND HOW OF SPINY LOBSTER AQUACULTURE (*PANULIRUS ORNATUS*)**

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Spiny lobsters, also known as rock lobsters, have a global distribution stretching from tropical to temperate climate zones, with more than 40 species commercially fished. Despite increased catch per unit effort in many fisheries, total landings have plateaued at 80,000 MT. A transitional spiny lobster aquaculture industry exists in Vietnam using wild caught puerulus or juveniles grown to market size in sea cages. Recently, seedstock of the preferred species, *Panulirus ornatus*, has become difficult to obtain with prices exceeding \$US15 per puerulus. The preference for *P. ornatus* is due to high consumer demand, ease of post-larval culture, and a fast growth rate (1kg in 15-18 months). With consumer demand for spiny lobsters growing in Southeast Asia, there is interest in creating a sustainable hatchery source of spiny lobster seedstock. The larval cycle of up to 10 spiny lobster species have been completed in laboratory settings; however, until recently, replicating these results at a commercial scale has not been possible. The University of Tasmania's Institute of Marine and Antarctic Studies (IMAS) has been working on spiny lobster larval culture for 18 years. During the last 6 years, IMAS scientists and research partners have focused on developing technology for commercial application for the culture of *P. ornatus*. There have been many obstacles in converting spiny lobster larval research to commercial production due to the species' complex larval phase, requirement for high quality water, susceptibility to bacterial diseases, specific nutritional requirements, and lack of appropriate manufactured feeds and commercial scale culture systems. Focused research at IMAS has overcome many of these hurdles and has allowed consistent pilot scale production of seedstock. The next stage is to move from pilot scale operations at the IMAS to testing the technology in a commercial setting. The availability of commercially produced spiny lobster seedstock could have a role in progressing habitat restoration and intensive aquaculture programs.

**085-AQUACULTURE AS A DIVERSIFICATION STRATEGY FOR LOBSTER HARVESTERS**

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Coastal communities in Maine are highly dependent on marine resources. Currently, the American lobster dominates commercial landings, representing approximately 81% of total landed value in Maine. Over-reliance on the harvesting of a single species indicates a precarious socioeconomic situation for coastal communities. The Aquaculture in Shared Waters project aims to build community resilience and support working waterfronts in Maine by training commercial fishermen in shellfish and seaweed aquaculture as a way to diversify their livelihoods. The training program is a collaborative effort between University researchers, Cooperative extension, and other aquaculture experts and has been offered three times to date with a fourth course currently underway. A total of 26 commercial lobster harvesters from 12 communities have participated over the past three years with an interest in learning how they can diversify their income derived mainly from the lobster fishery. Our applied social science research draws on participant observation, semi-structured interviews, and structured surveys to understand the motivation for diversifying commercial fishing operations and to explore perceived barriers. Overall, lobster harvesters were largely motivated out of an interest to decrease their dependence on the lobster fishery and continue to work on the water by incorporating aquaculture into their livelihoods. Lobster harvesters in the study do not expect that participating in aquaculture will change their traditional commercial fishing operation. Perceived barriers include costs of starting an aquaculture operation, successfully securing a lease, running a successful business, and uncertain markets to sell aquaculture products. This study is part of a longitudinal analysis that explores harvesters' experiences as they move forward with their plans to diversify their fishing operations to include aquaculture.

**086-PROGRESS AND OBSTACLES IN ESTABLISHING ROCK LOBSTER AQUACULTURE IN INDONESIA**

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On-growing of wild caught rock lobster pueruli first began in Indonesia in Lombok around 2004 as a derivative of seaweed and fish culture. In Ekas Bay in the southeast of Lombok, a small number of operators growing seaweed on floating frames or grouper in floating cages noticed pueruli settling on their apparatus. When they realized these were small lobsters, a few of them gathered the pueruli and stocked them to cages in the earliest attempts to on-grow them, and thus the Indonesian lobster farming industry was born. Despite the relatively high abundance of the naturally settling lobster seed, in the five years to 2009, no more than 50 tonnes of lobster were produced each year due to limited knowledge of effective farming practices and nutritionally deficient feed. The primary species was *Panulirus homarus*, and it was typically on-grown for less than 12 months to a mean size of 100 to 200g, fetching a farm-gate price of around 35,000 Indonesian Rupiah per kg, equivalent to less than \$US30. At the same time, Vietnam was experiencing rapid growth of its own rock lobster farming industry, which was producing more than 1500 tonnes of 1kg lobsters of the species *Panulirus ornatus*, which attracted a price exceeding \$US60 per kg. Collaborative research involving several Vietnam and Australian research agencies assisted the Vietnam lobster farming industry to best farming practices to achieve sustainability and optimal product quality. That research capacity was soon expanded to embrace Indonesia, in an effort to transfer the successful practices of Vietnam. Now in 2017, some 13 years after the first efforts to establish farming of lobster in Indonesia, growout production has declined to effectively zero. This paper describes the progress and constraints of Indonesian lobster aquaculture, and the opportunity and mechanisms available to see it reach its potential.

**087-ONGROWING OF CARIBBEAN SPINY LOBSTER (*PANULIRUS ARGUS*, LATREILLE 1804) IN SEA CAGES, IN TWO CUBAN FARMS**

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Two experimental marine farms for ongrowing of Caribbean spiny lobsters (*Panulirus argus*) were installed in Carahatas Bay and La Panchita, Villa Clara, Cuba. The first farm began in April 2012, with 30 kg of juvenile lobsters; after 13 months the farm reached a harvest of 290 kg of commercial sized lobsters. A second harvest was made during 2014, with 70 kg, of lobsters greater than 70 mm of CL mm and a survival of 80%. During the years 2013 to 2015, several harvests were made, totaling 1000 kg of adult lobster. The farmed lobster in Carahatas indicates a growth value of 0.34, which suggests that these lobsters grow faster than those in the natural environment that are subjected to fisheries. The values of the "k" growth rates did not show significant differences from April 2012 to October 2016. Values of up to 1.9 grams per day have been reported. As long as there is no guarantee of the capture of puerullis, juveniles of 20-25 mm CL should be used for farming, as recommended by the Vietnamese specialists. It should be noted that the studies carried out by different countries show that the mortality of juveniles used for farming is in the range of 55 to 60% and the fraction recruited for farming, which is only 5% of the catch of the fishery, shows a survival of 89-90%.

**088-HOW DOES METABOLIC PHENOTYPE AND SOCIAL INTERACTION AFFECT GROWTH DISPARITY OF SPINY LOBSTER?**

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Spiny lobsters can display large difference in growth rate, which is thought to be associated with agonistic behavior of dominant individuals controlling a disproportional share of food resources. Recently it become clear that variability in the metabolic physiology of individuals can an important factor influencing behavior and growth of marine organisms and thus is an important consideration for understanding intraspecific diversity of performance. However, the relationship between metabolic phenotype and growth has not been previously examined in any spiny lobster species. We investigated the possible effect of individual variation in metabolic rate and growth performance of juvenile Eastern spiny lobster (*Sagmariasus verreauxi*). In a laboratory experiment, juvenile lobsters were randomly distributed into two rearing conditions: individual (n=17) and communal (n=20). Growth performance, survival, and feed intake was greater for juveniles that were cultured communally, demonstrating that social interaction is important for promoting growth of lobsters. The relationship between growth and standard metabolic rate showed a positive correlation in individual cultured juveniles indicating a direct link between metabolic phenotype of individuals and growth. In communal culture, the influence of social interaction outweighed the direct relationship between metabolic rate and lobster growth. The results demonstrated that growth performance of spiny lobsters is affected by individual variation in metabolic status, but social behavior plays a more dominant role in determining the growth of individuals.

### 089-METABOLIC RATE, MANIPULATION AND TRANSPORTATION OF LIVE SPINY LOBSTER PANULIRUS ARGUS, LATREILLE 1804 IN CUBA

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During three years, experiments were carried out with live lobsters, *Panulirus argus*, in the laboratory and in various sea warehouse installations on the sea located along the southwestern coast of Cuba. The analysis showed that the metabolic rate of lobster was  $49.4 \pm 2.2$  mg O<sub>2</sub>.kg<sup>-1</sup>.h<sup>-1</sup> at 20°C for animals with a mean weight of 520 g, (50-1200 g). The assays to determine the necessary replacement of water indicate that each lobster, between 400 and 570 g of wet weight, needs between 20 to 60 liters per hour to normally metabolize. Their metabolic behavior indicates that they are animals of night habits, where feeding increases metabolism by up to 3.5 times its normal rate. Decreases in salinity in the environment causes a decrease in metabolism. The oxygen lethal limits studies indicates that approximately 1.6 mgO<sub>2</sub>L<sup>-1</sup> is the critical level, a value that should be avoided at the sea warehouse installations, fishpond on ships, or in earth installations because the animals lose all physiological functions, although they outwardly appear to be strong. We recommend that the period for holding of lobsters in the sea warehouses should not be longer than 36 hours, as a larger time increases the stress for the lobsters and decreases the quality of the exported live product.

### 090-LOBSTER GROWER: TOWARDS MARICULTURE OF EUROPEAN LOBSTERS

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 The National Lobster Hatchery, United Kingdom

Sea-based on-growing of hatchery-reared European lobsters (*Homarus gammarus*) in oyster spat baskets has shown considerable promise as a culture technique. Trials have established: 1) low energy requirements; 2) zero feed costs; 3) virtually fixed unit cost of production (compared to an escalating cost against time in land-based culture), and; 4) good short-term survival and growth rates. The promise of these early trials prompted Lobster Grower: a multidisciplinary collaborative research project (led by the National Lobster Hatchery, UK) which designed a novel sea-based rearing container to overcome technical barriers associated with the limitations and impracticalities of the oyster system. A follow-up project, Lobster Grower 2, is now testing both designs on a semi-intensive scale at an UK offshore shellfish farm. Approximately 45,000 juveniles will be deployed between 2016 and 2018, to include a proportion of controls, reared in hatchery aquaria facilities. Data will be collected on a combination of biological, ecological, histological, pathological, environmental and oceanographic factors while considering practical, operational, engineering, regulatory, economic and social elements associated with establishing and operating a mariculture site. Lobster Grower research is laying the foundations for semi-intensive culture of juvenile lobsters at sea. The natural feed supply and effects of this enriched environment on lobster development suggest that the method has considerable potential for (i) cost-effective and ecologically-conditioned on-growing to improve the effectiveness of releases to enhance capture fisheries, and (ii) the advent of sustainable aquaculture of this prized seafood species. With global seafood consumption expected to rise by 8% during the next decade this novel approach could promote growth in the production of European lobster without threatening pressured natural stocks, by refining hatchery stocking efforts and stimulating full grow-out aquaculture.



**O91-SENSITIVITY DURING THE MOLTING CYCLE IN EUROPEAN LOBSTER (*HOMARUS GAMMARUS*) JUVENILES TO THE ANTI-PARASITIC AGENT TEFLUBENZURON**

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<sup>1</sup>Institute of Marine Research, Norway, <sup>2</sup>National Institute of Nutrition and Seafood Research Norway

Teflubenzuron is an anti-parasitic agent used in the combat of sea lice in salmon farms, and the use has increased the last years in Norway. Teflubenzuron acts as a chitin inhibitor and is especially effective on the copepodite stages of sea lice. The drug is added to the feed and, through feed spill and feces, the chemical can spread to surrounding environment and potentially affect non-target crustaceans. In this study, we followed 37 European lobster juveniles (*Homarus gammarus*) through one molt cycle to assess their sensitivity to teflubenzuron. The lobster juveniles were monitored before the experiment started to obtain information of the length of the molting cycle. Juveniles ranging from 11 to 18 mm carapace length were separated into six groups, signifying different phases in the cycle. One pellet with 30 µg teflubenzuron, equivalent to 20 µg/g lobster (i.e. simulating fecal concentrations from treated salmon), was given to each of the lobsters. The experiment lasted 170 days to capture at least two molts. Mortality was 100% within 14 days in the group with juveniles given the medicated pellet 1-3 days before scheduled molting. For the juveniles given the medicated pellet 1-2 days after molting, mortality was 28.6%. However, these juveniles did not die until they molted for the second time, 120 days after ingestion of teflubenzuron feed. No mortality was found in the groups 20% and 40% into the scheduled molting cycle, indicating no or little chitin production in these phases. However, when the juveniles were 60 and 80% into the scheduled molting, mortality was found to be 33 and 67% respectively. Deformities were recorded as twisted walking legs, stiff abdomen and swollen carapace. Further, SEM of the exoskeleton will be analyzed. The findings clearly show that European lobster is highly sensitive to teflubenzuron, particularly just before molting.

**O92-EFFECT OF HOLDING CONDITIONS ON THE PHYSIOLOGY OF EUROPEAN LOBSTERS, *HOMARUS GAMMARUS*: EXPLOITING A SEASONAL MARKET**

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<sup>1</sup>University of Glasgow, <sup>2</sup>University of Stirling, <sup>3</sup>University of Swansea, <sup>4</sup>St Abbs Marine Station

The European lobster (*Homarus gammarus*) fishery in Scotland had a value of  11 M in 2015. Many fishers and merchants accommodate market fluctuations by holding on to livestock from the period of their greatest availability (mid-summer) to the time of greatest demand (around Christmas), when the product also attracts the highest price. Beard and McGregor (2004) stated that lobsters held at a low temperature (<10  C) do not require feeding as there is no significant deterioration in the flavor of the meat when cooked. However, it is not clear what impact the low temperature combined with starvation has on the physiological condition and immune-competence of lobsters, especially if they are held for a prolonged period of time (6 months). Therefore, we have assessed the combined effects of temperature and starvation on the physiological condition of *H. gammarus* held at 4, 8 and 12  C in flow-through systems over a 6-month period. Half of the lobsters at each temperature were fed a maintenance diet of cooked mussel (*Mytilus edulis*) and the remaining half had feeding withheld. Throughout the holding period body condition was assessed from a range of haemolymph assays. In addition, at the end of the trial the lobsters were sacrificed and tissue samples were taken to determine their physiological condition and immune-competence. We found that the effects of fasting on stored energy reserves (haemolymph proteins, hepatopancreas glycogen and lipid) and on a key indicator of immune-competence (circulating PPO) were much more extensive at 12  C than at the lower temperatures. These results will inform the improvements in stock-management that are necessary to maximize survival, ensure animal welfare, reduce the likelihood of bacterial diseases such as Gaffkemia and maintain good product quality.

Reference: Beard, T. W. and McGregor, D. (2004). *Storage and care of live lobsters. Laboratory Leaflet 66. CEFAS, Lowestoft. 28 pp.*

**093-DETERMINATION OF HEMOLYMPH BIOCHEMISTRY REFERENCE INTERVALS IN AMERICAN LOBSTERS (*HOMARUS AMERICANUS*)**

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Reference intervals for 25 hemolymph plasma biochemistry parameters were calculated utilizing 551 hemolymph samples from apparently healthy male and female American lobsters (*Homarus americanus*) collected as part of the Atlantic Lobster Molt and Quality project in Lobster Fishing Areas 25 and 26A in Prince Edward Island, Canada between 2007 and 2010. A classification system (Brix molt category) representing four different stages of the molt cycle was devised retrospectively using available data on Brix value, pleopod score, and carapace hardness. Energy-related indices such as cholesterol, triglyceride, total protein, and glucose tended to have strong positive correlations to the Brix value and each other, especially in male lobsters. Correlations involving triglyceride were less marked in female lobsters. Enzyme activity was usually low. These intervals reflect lobster condition in a very natural setting as lobsters were sampled on board fishing vessels within five minutes of commercial traps being hauled.

**094-TREATMENT OF A LABORATORY MODEL OF SHELL DISEASE IN HATCHERY RAISED LOBSTERS**

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The New England Aquarium's Lobster Research and Rearing Facility has been in operation for decades producing hatchery raised larvae and juveniles. Rearing of animals and monitoring them on a regular basis allows for interesting observations over time, one of which has led to studies on a laboratory-model of shell disease (LMSD) in hatchery raised juvenile lobsters. This form of shell disease is similar to that seen in lobsters held in captivity for exhibit purposes. A common concern for exhibits is the aesthetics of the animals, and crustaceans exhibiting shell disease symptoms are often removed. Animal care staff have had a growing need to be able to treat crustaceans in their care to prevent or slow shell disease symptoms. This talk will discuss rearing larval and juvenile lobsters as well as the effectiveness of disinfectant treatments in induced and non-induced disease symptoms in juveniles. Lessons learned and information as it relates to the wild population will be discussed.

**O95-EVALUATING PARENTAGE-BASED TAGGING FOR THE IDENTIFICATION OF RELEASED HATCHERY LOBSTERS**

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<sup>1</sup>National Lobster Hatchery, UK, <sup>2</sup>University of Exeter

Wild recaptures of hatchery-reared European lobsters (*Homarus gammarus*) have provided a proof-of-concept that the release of cultured individuals can enhance valuable capture fisheries. However, several recent hatchery initiatives have yet to monitor wild stocks for recaptures, in part due to unfavorable methods and processes associated with physically tagging released animals in order to distinguish them from natural conspecifics. Parentage-based tagging (PBT) is able to identify hatchery lobsters among admixed populations in the wild, although the methods' strength is dependent on the discriminatory power of the genetic markers used, and non-trivial errors can arise. To test the suitability of PBT using openly available microsatellite loci and parentage software, we quantified the power and error of assignment to hatchery parent candidates for admixed stock samples simulated from known genotypes. Assignment accuracy was generally improved when stock samples contained a greater proportion of hatchery individuals. Assignment solely via maternal candidate led to frequent false positives (>9.8% of allocations; >2.1% of natural stock) which increased in proportion to the number of candidates and always resulted in an overestimation of hatchery recaptures. In contrast, parent-pair assignment never overestimated the released component of the sample; false positives were greatly reduced (to  $\leq 2.0\%$  of allocations;  $< 0.3\%$  of natural stock) and hatchery stock size was estimated more accurately at all ratios of admixture. Parent-pair assignment yielded minor underestimates of the number of hatchery recaptures, but provided  $\geq 86.0\%$  power to distinguish hatchery and natural stock accuracy, and  $\geq 96.8\%$  power whenever hatchery recaptures comprised at least a fifth of sampled stock. Our results show that where false positives can be controlled, genetic PBT presents a powerful method for renewed monitoring of the contribution of released lobsters to admixed wild stocks, and can be a vital tool with which to inform the optimisation and appraisal of *H. gammarus* hatchery stocking programs.

## Fisheries Science

### 096-AN ECOSYSTEM APPROACH TO LOBSTER STOCK ASSESSMENTS

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Lobster landings in some regions of the Canadian range are at or near all-time highs. Multiple hypotheses of the causative factors of the productivity increases have been proposed; however, the mechanisms underlying the productivity changes remain elusive. Despite this, stock assessment scientists are required to provide advice to fisheries managers on the current state and future prospects for harvesting of stocks. In this paper, we present a data driven approach to depict the relationships in lobster stock productivity with environmental and ecosystem indicators that can be used to describe current stock status.

### 097-ESTIMATING TAG INDUCED MORTALITY OF SOUTHERN ROCK LOBSTER IN THE WILD – HOW DOES VARIATION IN THE SIZE AND THE NUMBER OF TAGGED LOBSTERS AFFECT THE TAG INDUCED MORTALITY ESTIMATIONS?

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Capture-mark-recapture (CMR) methods are commonly used for estimating demographic characteristics of crustaceans in the wild. In any tagging study, the effect of tag loss and tag induced mortality (TIM) should be investigated as both result in biased estimation of population parameters. While determination of TIM has traditionally been estimated in aquaria facilities or with caging studies, a long-term capture-mark-recapture study conducted since 2000 at the Crayfish Point Scientific Reserve (CPSR), Hobart, Tasmania, Australia, was used to estimate *in situ* TIM. A three-survey model was used that assumed the impact of tagging was most important immediately after the animal was tagged (within approximately 12 months) and thus occurs before the next survey. The average of TIM estimates for lobsters (combined sexes) was 35%. Estimates of TIM for lobsters were varied and dependent on the number of recaptured lobsters. To provide reliable estimates of TIM in this study at least 15 lobsters had to be captured in two subsequent surveys after the initial tagging survey. As tagging normally only marks a small proportion of a population, tag recovery rates are relatively low and the need to recover sufficient lobsters on two separate surveys is a major constraint of the method. Our results indicate that TIM can be both substantial and different from estimates derived from aquaria studies. If tagging studies are used to estimate population parameters, TIM needs to be determined to prevent over-estimation of the resource and inappropriate catch allocations.

**098-DETERMINING THE CARE FACTOR: WHAT'S THE CHANCE OF SEEING THAT TAG AGAIN?**

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 Department of Fisheries, Western Australian

Management of the Western Rock Lobster Fishery has recently moved from input controls to a total allowable catch. In an ambitious attempt to develop baseline information on lobster biomass and exploitation rates in a quota-based fishery, more than 40,000 tagged lobsters were released over two years. Far fewer were seen again. The recapture rate of tags was found to be influenced by a number of factors including tag location, catchability, and levels of fishing effort. However, by planting tagged lobsters in the catch of commercial fishers, we determined that the tag reporting rate was variable between individual fishers and fishing areas, a factor that needs to be taken into account when interpreting the results of tagging studies. We also discuss factors that maximize the likelihood of tag reports including the use of rewards, simplified tag reporting through a phone app, and timely notification of tag information back to fishers through an automated process of analysis and letter production using R.

**099-SCAMPI GRADE DATA – RE-CREATING CATCH COMPOSITION**

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<sup>1</sup>NIWA, <sup>2</sup>University of Auckland

Stock assessment of New Zealand scampi (*Metanephrops challengeri*) is undertaken using a two-sex, length-based population model where sex and length composition of catches form an important, but intermittently available data input. The scampi fishery is undertaken by freezer trawlers, on four to six week trips, with the catch frozen at sea for export. Fishery observers collect scampi catch composition data at sea on some trips, but the length of trips makes this expensive, limiting the spatial and temporal coverage possible. However, scampi catches have been sold in export market-driven weight-based grades throughout the history of the fishery, providing the potential to use grade catch composition, which is routinely recorded by fishing companies, and length composition by grade data to reconstruct the length and sex composition of catches. This research examines the consistency in grade composition, and approaches to use these data to reconstruct a census of scampi catches as an assessment model input.

**0100-A NEW GROWTH MODEL FOR THE JUAN FERNÁNDEZ ROCK LOBSTER**

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<sup>1</sup>University of Concepcion, <sup>2</sup>FISIOAQUA

Juan Fernández rock lobster (*Jasus frontalis*) is the most important natural resource for the inhabitants of Juan Fernández Archipelago (off central Chile). Despite its relevance for human well-being, basic aspects of its biology and demographic dynamics are yet to be determined. Assessing somatic growth is generally prioritized in any fishery research program, but for crustaceans, this may prove to be a challenge. The lack of growth marks restrains the analytical alternatives to estimate growth, leaving mainly laboratory, mark recapture, and modal decomposition analysis as plausible pathways. The de-facto growth model for the Juan Fernández lobster is a von Bertalanffy function, which we challenge by presenting new empirical data. We analyzed the somatic growth pattern of this species using basically three sources of information: (i) an intensive fishery-dependent mark-recapture program that started in October 2008 (T-bar tags) in Selkirk Island; (ii) a multi-year mark-recapture experiment (PIT tags) on young non-vulnerable lobsters in Robinson Crusoe Island; and (iii) size increment data from large-sized lobsters kept in aquariums for several years. Size increments were obtained from an unprecedented lobster size range (33 to 313 mm carapace length). Lobster somatic growth patterns were represented by Fabens and piecewise linear models. Using the Akaike Information Criteria we established that the best model for both sexes is the piecewise linear model, showing an evident departure from the Fabens model in both sexes. New evidence show that large lobsters keep growing at 2.5 mm per molt.

**O101-THE 'HUNGER GAMES': HOW STARVATION AFFECTS ATTRACTIVENESS OF LOBSTERS USED TO BAIT TRAPS IN THE FLORIDA SPINY LOBSTER FISHERY**

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*Florida Fish and Wildlife Conservation Commission*

The commercial lobster fishery for *Panulirus argus* in Florida uses traps to capture ~90% of the ~6 million pounds of lobsters landed commercially each year. Fishermen bait traps with live, undersized lobsters to lure other lobsters into the traps, based on their chemical attraction to one another. Traps are typically baited with two to three lobsters, with upwards of one million lobsters used as bait in traps at any given time. Though this use of live lobsters as bait is effective, the long periods of confinement results in starvation and mortality of many of these bait lobsters. We examined the effects of long-term confinement on the attractiveness of nutritionally compromised lobsters as bait. We used a series of Y-maze experiments to test the response of lobsters to conspecifics with reduced nutritional condition (i.e., lobsters starved for 3, 5, or 7 weeks) and a field-based trap experiment to test whether starvation of lobsters used as bait affected trap catch. Lobsters were significantly attracted to healthy conspecifics both in Y-maze experiments and the trap experiment; however, lobsters were not significantly attracted to conspecifics that were starved for three or more weeks. In chemical choice experiments, lobsters were no more attracted to starved lobsters than they were to plain seawater. Unbaited traps and traps baited with starved lobsters caught significantly fewer lobsters than traps baited with healthy lobsters. The long-term confinement of bait lobsters poses a double threat to the lobster fishery, by not only potentially reducing future lobster stocks, but also by reducing catch of lobster traps fishing during the current season.

**O102-A QUASI-STATIONARY APPROACH TO ESTIMATING EFFECTIVE EFFORT IN THE MAINE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) FISHERY**

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The fishery-dependent American Lobster (*Homarus americanus*) data collected in the Maine Department of Marine Resources sea sampling program cannot be used directly due to the non-random nature of sampling efforts. A standardized framework is developed in this study for estimating lobster effective effort (individual trap hauls) on a fixed spatiotemporal scale using fishery-dependent data. We employ environmental covariates in a two-stage generalized additive model framework and non-parametrically bootstrap to standardize lobster catch per unit effort (CPUE) and estimate confidence intervals for the years 2006-2013. Bootstrapped CPUE confidence intervals are combined with high resolution landings data to estimate confidence intervals of effective lobster effort. In all study years, we found the peak of effective effort preceded the peak of landings. Coast-wide from 2006-2013, effective effort increased modestly (9.1%) while landings increased dramatically (69.6%), suggesting that assessment of spatiotemporal fishery dynamics may provide important insights for future management in a changing Gulf of Maine. Characteristic east-west differences in catch and effort were present in all study years, further suggesting non-stationarity of biological, temporal, and geographic processes in the Maine Lobster fishery.



## Caribbean Spiny Lobster Stock Assessment Workshop

### **O103-DEVELOPING A SIZE-STRUCTURED STOCK ASSESSMENT MODEL FOR SPINY LOBSTER IN THE SOUTHEAST UNITED STATES**

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The spiny lobster fishery is one of the most economically important fisheries in the Caribbean. In the past decade, multiple stock assessment models have been developed to assess the stocks, such as the Catch-At-Age Model or the Delury Model. However, the complex life history and fisheries process of the Caribbean spiny lobster makes those models ineffective: the spiny lobster lacks calcified structures like otolith, vertebrae, and scales found in the fin fish species to mark age directly. Therefore, age-structured models could introduce uncertainty and error associated with the length-age transformation. Also, spiny lobster fisheries include both commercial and recreational fleets. The efforts for both fisheries display seasonality. Therefore, using year as time step as the current stock assessment model will ignore the variation between seasons. The objective of this study is to develop a size-structured model for spiny lobster in Southeast United States. This model describes seasonal sex-specific population dynamics of the spiny lobster. The uncertainty of the parameters and the sensitivity of the model will also be tested. The model performance will be tested on the simulated fisheries. Hopefully, this model will reduce the uncertainty due to the lack of information, improve the performance of stock assessment and provide management advice for the Florida stock.

### **O104-STOCK ASSESSMENT OF SPINY LOBSTER (*PANULIRUS ARGUS*) IN FISHING ZONES FROM YUCATÁN AND QUINTANA ROO COASTS, MÉXICO**

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Use of *Panulirus argus* spiny lobster in the Yucatán peninsula is carried out in a very extensive area, in which there are differences in terms of resource distribution, effort, catch methods, organizational level of fishing communities, policies management, and market. For assessment and management purposes, it has been proposed to divide the fishing zones and analyze the fishery based on the information existing in each one of them. In this paper, results obtained in recent stock assessments carried out for the Yucatan platform and the North-Northeast zone from Quintana Roo are presented. Stock assessment from Yucatán Shelf was constructed using a dynamic, non-linear, age-structured model, and for the North-Northeast zone (Holbox-Isla Mujeres) a surplus model was used. In the Yucatán Shelf, the vulnerable biomass estimated was of 1,050 t live lobster (350 t tail). The average exploitation rate for the same period was  $F = 0.43$  and  $F = 0.63$  for the year 2015. For the North-Northeast zone, estimates obtained for the carrying capacity were  $K = 2,331$  t tail (6,994 t live lobster), the growth rate was  $r = 0.150$ , and the Maximum Sustainable Yield would be 87 t tail (262 t live lobster). The results can be used for management purposes; however, it is necessary to incorporate alternative methods of analysis that allow the linkage of different levels of knowledge that have effects on the resource.

**O105-THE FISHERY MANAGEMENT AND STOCK ASSESSMENT OF SPINY LOBSTER  
(*PANULIRUS ARGUS*) IN CUBA**

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The Caribbean spiny lobster, *Panulirus argus*, the most valuable Cuban fishery resource, is managed with input, output, and biological controls that include: a state property limited entry regime, territorial rights to fishing enterprises, restrictions in the numbers of gear and boats, a 145-days closed season from February to June, permanently closed areas to protect juveniles and spawners, a legal minimum size of 76 mm carapace length (CL), a maximum legal size of 140 mm CL for females, a prohibition on taking berried females and females with spermatophores, and a Total Allowable Catch (TAC). The TAC is set annually depending on the previous stock assessment taking into account the environmental conditions, anthropogenic effects, and the index estimated of illegal catch in this fishery. Also the abundance index is independent of the fishery in a zone where there isn't information of the composition in catch.

Thursday, June 8, 2017

## INDUSTRY DAY: Industry Collaborations

### **0106-IMPROVING QUALITY AND PROFITABILITY IN A NEW ZEALAND ROCK LOBSTER FISHERY - UTILIZING SCIENCE TO MAKE MONEY**

Malcolm Lawson ([lawson\\_otatara@xtra.co.nz](mailto:lawson_otatara@xtra.co.nz))  
*CRA 8 Rock Lobster Industry Association*

Enduring financial returns to the lobster industry rely on two aspects: confidence in the fishery and confidence in the market. The CRA8 (Southland) fisheries management area is the largest in New Zealand in terms of rock lobster production and economic return. The CRA 8 rock lobster industry accounts for 35% of the total rock lobster exports from New Zealand. In recent years, the CRA8 Rock Lobster Industry Association has undertaken a number of projects for the following purposes: to ensure and increase profitability through improving the quality of the lobsters presented to the market; to increase our knowledge of the physiology of the species; and through the continued refinement of a management strategy (via an operational management procedure) that seeks to achieve maximum economic yield from the fishery. Each of these projects has utilized recognized science providers as researchers and advisors. For each of the industry-funded initiatives, the research providers have developed novel methods for research and analysis that had previously not been used in New Zealand. The design of the projects required close collaboration between the CRA8 industry organisation and the scientists to ensure that the reported results were consistent with the desired aims of the industry. The application of the results of the projects has significantly added to the economic returns for all sectors of the CRA8 industry. The presentation will describe the New Zealand context; detail the projects undertaken; detail the management strategy; describe the results, costs, and other benefits; and examine some of the lessons learned.

### **0107-GLOBAL TRADE ROUTES OF LOBSTER (*HOMARUS SPP.*)**

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<sup>1</sup>*University of Maine, Orono, ME*, <sup>2</sup>*Royal Swedish Academy of Sciences*

Aided by both advancements in technology and improved logistical capacity, seafood trade is becoming increasingly globalized. The distribution of seafood around the world creates employment opportunities, generates wealth, and increases market access. However, globalization also decouples markets from marine resources and harvesters, whereby making seafood-producing countries vulnerable to exogenous disturbances in distant places. We show that the structure of global seafood trade routes can play a key role in this decoupling process by masking the dependencies of producer-nations on particular markets. Our analysis traces the complex trade routes used to globally distribute lobster (*Homarus spp.*). In particular, we quantify the secondary trade of lobster between non-producer nations and the role these trade relationships play in obfuscating the growing dependency on China's market.

**0108-TABLETS AND TEMPERATURE LOGGERS: COLLECTING DATA WITH THE CFRF LOBSTER & JONAH CRAB RESEARCH FLEET**

Anna Malek Mercer ([amalek@cfrfoundation.org](mailto:amalek@cfrfoundation.org))  
 Commercial Fisheries Research Foundation

Despite the economic and cultural importance of the lobster and Jonah crab fisheries, research scientists, managers, and industry members agree that the data being used to assess these stocks lack sufficient spatial and temporal coverage, particularly in Southern New England. Specifically, there is a mismatch between the location of primary lobster fishing grounds in this region (10-200 miles offshore) and the location where data are being collected (0-3 miles from shore). Similarly, Jonah crab fishery management efforts are hampered by major gaps in the understanding of the catch composition and operational characteristics of the fishery. The Commercial Fisheries Research Foundation developed the Lobster & Jonah Crab Research Fleet in 2013 to begin addressing these data needs and, ultimately, inform the assessment and management of these valuable fisheries resources. Research Fleet participants use a specialized tablet app, digital calipers, and wireless water temperature sensors to record information about their lobster and Jonah crab catch and the environment as part of their routine fishing practices. Since 2013, the 15 fishermen participating in the Research Fleet have collected biological data from over 85,000 lobsters and 30,000 Jonah crab as well as coupled bottom water temperatures from the Gulf of Maine to the Mid-Atlantic. The data collected by the Research Fleet are integrated into federal biosamples databases and used extensively in the lobster stock assessment and Jonah crab management plan. Differing from many other sampling programs, the fishermen that participate in the Research Fleet retain ownership of their data and regularly receive personalized data reports. Ultimately, the project's approach will increase the transparency of the assessment process and promote the fishing industry's trust in the data sources being used and resulting management measures.

**0109-COSTS AND BENEFITS OF REDUCING SOAK TIME IN THE EUROPEAN SPINY LOBSTER (*PALINURUS ELEPHAS*) TRAMMEL-NET FISHERY**

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 Instituto Español de Oceanografía, Palma de Mallorca, Illes Balears, Spain

Improving fishing practices and gear technology is needed to minimize unwanted impacts of fishing activities on target and non-target species. In the western Mediterranean, the spiny lobster *Palinurus elephas* trammel net fishery contributes the largest annual income to artisanal fishermen, especially in the Balearic Islands and other archipelagos. After several unsuccessful attempts by the local administration to reinstate lobster pots abandoned more than a decade ago, mitigation measures on the less specific trammel-net gear and operations have been explored. In the trammel-net fishery, the catch includes fish species of high commercial value (e.g., red scorpionfish, John dory, forkbeard, and angler) that can significantly add to the income from the lobster catch. Nevertheless, the dynamics of the fishery is driven by lobster as the most valuable species and to optimize lobster yields, trammel-nets must remain deployed for 48 consecutive hours. This soak time is often too long for fishes as their value is reduced by predation while entangled in the nets. With the aim of exploring ways to improve the exploitation pattern in this fishery, we conducted a study to assess differences in catch quality and value in the trammel-net lobster fishery as a function of soak time. Here we present the results of a series of field experiments testing two net soak times, the traditional 48 h and the reduced 24 h, on lobster fishing grounds, while controlling for location, depth, and time period. Preliminary results suggest that shorter soak times can reduce bycatch discards by nearly 75% and avoid damaged spiny lobster in 38% of the total catch. Experiments like this are needed to avoid an unnecessary harvest of fishing resources as well as to optimize the long-term benefits obtained from the multispecies catch. Therefore, the results of this study will be considered by the local administration to implement a new management plan for spiny lobster fishery.

**0110-UNIQUELY PRINCE EDWARD ISLAND: THE ISLAND PERSPECTIVE ON THE LOBSTER LEVY, MARKETING, AND QUALITY**

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*Prince Edward Island Fishermen's Association, PEI, Canada*

As the voice of island fishermen, the Prince Edward Island Fishermen's Association (PEIFA) has a unique advantage over the other east coast provinces. The structure of the Association ensures all core fishermen are represented by one organization. This has assisted in the communication and implementation of the voting that took place to solidify the lobster levy in PEI, something island fishers are very proud of. By incorporating marketing and quality with the levy, the island's lobster industry is growing, learning, changing, and adapting to today's dynamic lobster industry.

**0111-MODERNIZATION OF AN INDUSTRY PEAK REPRESENTATIVE ASSOCIATION**

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*Western Rock Lobster Council, Western Australia*

The rock lobster fishery in Western Australia was previously reliant on government for funding of research projects and stock assessment and fishers were untrained in governance and stakeholder management. In the last five years, however, significant changes have occurred in the fishery and in management of that fishery. These include: reduced board size, independent board members, revised strategic plan and constitution, independent funding by industry, revitalised industry research program and funding, governance education and training for board and industry members, industry risk review, renewed focus on independent certification and sustainability, improved management of interaction with other species (e.g., whales and sea lions), attracting younger members, improved communications, and stakeholder management. We have seen exponential change in decision-making capacity and reputation with politicians, managers, and community through collaborative engagements, as well as significant improvement in community acceptance and license-to-operate through enhanced supply of lobster to local and regional markets.

**0112-A NETWORK OF SCIENCE AND INDUSTRY FOR SUSTAINABLE FISHERIES**

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*Fishermen and Scientists Research Society*

The Fishermen and Scientists Research Society (FSRS) is a non-profit organization helping fishermen get involved with collaborative research in order to contribute to more effective resource management. The organization was established following a survey of Eastern Nova Scotian fishermen who had a lack of trust in the Department of Fisheries and Oceans (DFO), and a willingness to get involved with industry-based research of the fisheries. The objectives of the organization, now in its 25th year, include collecting information relevant to the sustainability of the Atlantic marine fishery; promoting effective communication among stakeholders; engaging fishermen in research where and whenever possible, including research with other institutions; analyzing and distributing data; and instructing volunteers on proper data collection techniques. Projects adopted by the FSRS include the 4VsW Sentinel Monitoring Program, the Lobster Recruitment Index Project, and the Lobster V-notching Project, which will be discussed in further detail in this presentation. Through such projects, the FSRS works towards upholding its main goal; collecting accurate information to help protect fish stocks, and maintaining viable coastal communities and sustainable fisheries.

**0113-POST-HARVEST MORTALITY RELATED TO HIGH SPEED TRAP HAULERS**

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A study done by Basti et al. in 2008 showed that the use of high-speed, large, capstain trap haulers was related to post-harvest mortality. The mortality occurs approximately during the first 10 days post-harvest and most lobsters that survive for that first 10 days survive post harvest storage. Mortality was associated with clotted hemolymph and an enlarged “jelly” heart. The bacterium, usually found in the lobster gut, *Photobacterium indicum*, was associated with mortality. It was observed that if we treated post-harvest lobsters with oxytetracycline, either from a feed pellet or with direct administration into the stomach, they survived. We tested pressure change as a possible cause of mortality. Using a hyperbaric chamber, we caused rapid pressure change equivalent to those associated with high-speed haulers. After exposing lobsters to pressure change, they were placed in floating crates at Tidal Falls in Hancock, Maine. These lobsters survived, indicating that pressure change is not the likely cause of mortality. In reviewing some video of lobsters being hauled, it was observed that when a trap is hauled, lobsters are facing in various directions. It appeared that the lobsters that had their rostrum facing up could have water rush into the mouth, and then into the stomach, and disrupt the mid-gut. To test this, lobsters were given high pressure sea water using a feeding needle attached to a syringe. This treatment resulted in mortality and a “jelly” heart. It appears that high pressure water is the cause of mortality from using high speed haulers.

**0114-FROM LOBSTERS TO DOLLARS: AN ECONOMIC ANALYSIS OF THE DISTRIBUTION SUPPLY CHAIN IN MAINE**

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<sup>1</sup>Colby College, <sup>2</sup>Maine Lobster Dealers Association

This is the first-ever economic impact study of Maine's lobster supply chain. Maine's iconic lobster industry is arguably the most visible, and likely the most economically important asset for the State. In 2014 the industry landed 123.6 million pounds of lobster, valued at \$456.9 million – the highest-ever value of the lobster fishery in Maine. However, there is little known about the economics of the industry after the product leaves the dock. Every dollar accounted for in the value of the fishery represents revenue paid by a licensed Maine lobster dealer. Yet never before has there been a study of the economic impact of the contributions of the wide variety of lobster dealers and processors that participate in the supply chain. These businesses provide the capital that pays the harvesters for bringing lobsters to shore. The lobster dealer network also accounts for substantial investments in handling, transporting, processing, marketing, shipping, and selling this unique product that contributes so heavily to the Maine brand. Colby College Professor of Economics Michael Donihue is the principal investigator in leading a research team of students and collaborating partners in a detailed study of Maine's lobster distribution supply chain from the point of landing to the consumer, with a focus on the accompanying economic impacts in terms of the amount of money generated and the number of jobs supported across the State. The Maine Lobster Dealers Association (MLDA), is the key collaborating partner in creating a complete economic impact analysis of the lobster supply chain in Maine. The Maine Lobster Dealers Association (MLDA) will serve as the key collaborating partner in creating a complete economic impact analysis of the lobster supply chain in Maine. Primary support from MLDA was provided by the organization's executive director, Annie Tselikis.



### **O115-THE ROCKY LOBSTER OF THE ATLANTIC FRENCH COAST SAVED THANKS TO MANAGEMENT AND INVOLVEMENT OF FISHERMEN TO IMPROVE BIOLOGICAL AND ECOLOGICAL KNOWLEDGE**

Martial M. Laurans<sup>1</sup> ([martial.laurans@ifremer.fr](mailto:martial.laurans@ifremer.fr)), Erwan E. Quemeneur<sup>1</sup>

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The fishery of rocky lobster along the coast of France was very important for thousands of fisherman until 1960. Without any management, the stock steadily decreased to a very low level. Ten years ago, a little group of fisherman decided to change the situation. Today, some new managements rules have been decided and two important projects have been developed: a closed area and a national tagging program insured by fishermen. These two projects aim to improve the knowledge base of the biology and ecology of rocky lobster. From 2009, scientific surveys in the closed area show that this measure protects the rocky lobster based on documented increases in abundance. The high number of individuals tagged and recaptured several times has provided data on the growth and the movements of lobsters within a specific zone. From these first important results and the observation of a big recruitment pulse in 2014, a second project has been developed. Along the French coast, some fishermen have tagged 4,000 rocky lobsters from 400 to 700 gr during the period of 2015-2016. The first results show important migration from shallow waters to deep and have allowed us to complete a growth model for this species. These results are considered to be some of the more robust data on the species which will help to improve management of this species. The involvement of the community of fisherman is the source of these results. The presentation will focus on this dynamic and the results obtained until the present in comparison with the data acquired for other rocky lobsters in the world.

### **O116-THE CHALLENGES OF DEVELOPING SPINY LOBSTER FISHERY MANAGEMENT POLICIES IN FLORIDA – INCORPORATING CLOSE STAKEHOLDER INVOLVEMENT: A CASE STUDY**

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*Florida Fish and Wildlife Conservation Commission*

The Caribbean spiny lobster fishery in Florida is composed of multiple user groups. Its commercial fishing sector alone contains three distinct gear-specific user groups: trappers, divers, and bullynetters that are each socially and economically diverse. Additionally, there is a widely popular and intensive recreational fishery composed of divers and bullynetters. Although these user groups share a common desire for long-term sustainability of the fishery, they have specific and often competing self-interests. After decades of fishery management primarily focused on the commercial trap sector in which regulations were often developed without widespread support of the commercial industry, the Florida Fish and Wildlife Conservation Commission (FWC) was formed in 1999 and became the agency overseeing marine fishery management in Florida. In a shift in management philosophy, the FWC emphasizes close involvement of all potentially relevant stakeholder groups in the promulgation of its policies. To that end, the FWC undertook a comprehensive reevaluation of its lobster fishery management that included close stakeholder involvement. A stakeholder advisory board was assembled, whose objective was to build consensus on a shared long-term vision for the sustainability of the spiny lobster fishery by reflecting the various sectors of the fishery. That board worked with FWC resource managers and scientists through an in-depth conflict resolution process. This board developed consensus on broad-based topics, but when developing more detailed management approaches to specific issues, it did not achieve any resolution. User conflicts both within the commercial fishery and between the commercial and recreational sector, coupled with an historically adversarial relationship between the fishing community and fishery managers and researchers, hindered meaningful progress toward refining the management program. We will present issues faced by the advisory board as a case study to elucidate the challenges faced by Florida's resource managers in developing a consensus-based management strategy for the lobster fishery.

**0117-LOBSTER AND OCEAN PLANNING: A SPATIAL CHARACTERIZATION OF THE LOBSTER FISHERY FOR THE NEW ENGLAND REGIONAL PLANNING BODY**

Nick Battista<sup>1</sup> ([nbattista@islandinstitute.org](mailto:nbattista@islandinstitute.org)), Rebecca Clark<sup>1</sup>, Samuel Belknap<sup>2</sup>, George Lapointe<sup>3</sup>  
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The lobster fishery is synonymous with New England's coast, providing food, economic, and cultural value since the colonial era. Nowhere is this more evident than in Maine. For many coastal communities, the lobster fishery has provided stability and a sense of place that is more important today than in the past. Increased landings in the fishery, combined with reduced fishing opportunities in other fisheries, create a significant economic dependence on the lobster fishery. The area covered by the fishery has changed over the past 20-30 years with fishery landings shifting farther offshore and farther to the eastern portion of the range of U.S. lobster fishing. Information on the spatial characteristics of the lobster fishery are generally understood by the industry and managers, but are poorly quantified. Mapping of lobster fishing patterns has been an objective of regional ocean planning efforts. This effort has been hampered by lack of regional spatial characterization products with sufficient resolution or consistency to determine how other ocean uses, particularly place-based uses, would impact lobster fishing locally, sub-regionally, and regionally. We interviewed Maine lobstermen to better understand spatial use patterns in the lobster fishery, and how lobstermen view new and shifting uses of the ocean in the context of their lobster fishing businesses. Lobstermen were selected in all lobster management zones, with an emphasis on lobstermen who fish federal waters because the developing New England Regional Ocean Plan focuses on federal waters.

**0118-THE TRANS-ATLANTIC TRADE IN LIVE LOBSTERS: SHOULD THE EU BUILD A WALL?**

Magnus Johnson<sup>1</sup> ([m.johnson@hull.ac.uk](mailto:m.johnson@hull.ac.uk)), Barry Costa Pierce<sup>2</sup>, Susanne P. Eriksson<sup>3</sup>, Ann-Lisbeth Agnalt<sup>4</sup>  
<sup>1</sup>University of Hull, <sup>2</sup>University of New England, Biddeford, ME, <sup>3</sup>Department of Biological and Environmental Sciences, University of Gothenburg, Sweden, <sup>4</sup>Institute of Marine Research, Bergen, Norway

Environmental change and the rapid development of lobster fisheries in northern temperate regions has led to the globalization of their trade in both the processed and live sectors. It is now possible to buy live or frozen exported *Homarus americanus* in the EU for less than the equivalent local species (*H. gammarus*). In the EU there is good evidence that the regional trade in live lobsters is impacting the genotypes of populations in their intra-EU export destinations – a form of genetic pollution. Most recently, there have been increased reports of non-native *H. americanus* or hybrids being captured by commercial fishermen in EU waters. There have also been several reports of well-meaning members of the public illegally releasing significant numbers of live *H. americanus* from commercial suppliers. The potential consequences of the live lobster trade include inter-specific competition, genetic dilution of native stocks, disease transfer, and negative economic impacts on the local fishing industry. None of these impacts are in the best interests of the EU, the USA or Canada, especially given the overlay of accelerated climate change. The intricacies of the politically and economically challenging trans-Atlantic trade in live lobsters and priority areas for international research and cooperation will be explored.

## INDUSTRY DAY: Adaptive Harvesting and Management Strategies

### **0119-A CLIMATE OF CHANGE: FISHERMEN, SCIENTISTS, AND MANAGERS SHARE INFORMATION TO PREPARE FOR AN UNCERTAIN FUTURE**

Susie Arnold ([sarnold@islandinstitute.org](mailto:sarnold@islandinstitute.org)), Nick Battista, Heather Deese  
*Island Institute, Rockland, ME*

Maine coastal and island communities are at the forefront of experiencing the environmental and economic impacts of climate change. While the lobster fishery in Maine is at record levels and is considered sustainable, the fishery has undergone a major shift over the last 40 years and is projected to continue change in the future as water temperatures rise and conditions become less hospitable for lobsters. While the fishery is currently booming, almost all other fisheries are not. Between 1985 and 2005, the economic diversity of marine resources harvested in Maine declined by 70%. This makes our fisheries communities highly vulnerable to any changes that impact lobsters. To help communities and fishermen better prepare for these changes and to improve awareness amongst fisheries managers of how these changes might impact coastal communities, the Island Institute has engaged in climate and fisheries programming dating back to 2006. Fishermen are eyewitnesses to changes in the ocean environment and, thus, are key components to understanding what is happening on the water. Since 2006, we have hosted Fishermen's Climate Roundtables, an annual, day-long event where fishermen (predominantly lobstermen) come together and share observations from the past fishing season, discuss potentially longer-term, climate-related changes, and learn more about a topic of interest from an invited scientist. Based on the discussions amongst Climate Roundtables participants, we've designed A Climate of Change workshop and video series over the last four years, focusing on communicating the impacts of climate change and ocean acidification on fisheries and fishing communities. The series promoted conversations between community members, fishermen, scientists, and local and federal management agencies. This presentation will share key results from this programming as well as discuss the importance of privileging both scientific and traditional knowledge from fishermen in discussions about how fisheries are managed in a changing climate.

### **0120-ECOLOGICAL SUSTAINABLE DEVELOPMENT (OR TRIPLE BOTTOM LINE ASSESSMENT) OF WESTERN ROCK LOBSTER FISHERY: WHAT IS OPTIMAL TARGET OF FISHING?**

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*Department of Fisheries, Western Australia*

Triple bottom line assessment is the general long-term aim in management of many fisheries as it takes into account ecological, economic, and social criteria of the fisheries. However, few fisheries explicitly consider these criteria in their assessment and harvest strategies. While some measures of these management criteria cannot be optimized at the same time (e.g., maximize employment or maximize profit), an evaluation of these criteria may result in an optimal level of fishing. The western rock lobster fishery is examined as a case study for the triple bottom line assessment as it considers: (a) sustainability of the target species; (b) the economics of the fishery through the adoption of maximum economic yield (MEY) as its target in the harvest strategy; (c) an explicit commercial and recreational catch allocation ratio; (d) effects on ecosystem, habitat, bycatch, and protected species; (e) recreational catch rates; and (f) effect on employment and coastal communities based on number of vessels operating. The latter two indicators can be used as social indicators of the commercial and recreational fisheries. The effect of management on the local market is also considered. Sustainability is the main objective in the management of the fishery and we evaluate current egg production, as well as that projected over next 5 years to reach that objective. These projections are reliable as they are based on puerulus settlement, which has been demonstrated to be a good predictor of recruitment to the fishery 3-4 years later. The fishery has undergone major management changes since 2008 initially as a result of effort reductions (due to a series of low puerulus settlement) and then moving from an effort-controlled fishery to an individual transferable quota (ITQ) system in 2010. During this period, the fishery adopted MEY as its management target. This study examines the ESD implications of these changes.

**0121-THOUGH THE EYES OF INDUSTRY: AN INVESTIGATION OF HOW STAKEHOLDERS IN THE LOBSTER FISHERY SYNCHRONIZE THEIR BEHAVIOR WITH THE SPRING LOBSTER MOLT**Kevin W. Staples ([kevin.w.staples@maine.edu](mailto:kevin.w.staples@maine.edu))*The University of Maine, Orono, ME*

The lucrative American lobster (*Homarus americanus*, Milne Edwards) fishery relies on the spring molting event for the high volume of individuals newly recruited to the fishery. The mistiming of this event that experiences inter-annual variability by stakeholders could result in inefficient practices, yet there are few examples where mistiming on a coast-wide scale has occurred. We hypothesized that fishermen were employing a diverse set of strategies to prevent inefficient harvesting behavior and that these strategies included using social and environmental cues to approximate the timing of the spring molt for Gulf of Maine lobsters. This research utilizes the state of Maine landings program data and one-on-one interviews with fishermen along the coast to evaluate the techniques and ability of stakeholders to synchronize their behavior with the timing of the spring molt.

**0122-MANAGEMENT STRATEGIES TO IMPROVE ECOSYSTEM SERVICES AND INCREASE INDUSTRY PROFITABILITY**Klaas Hartmann<sup>1</sup> ([klaas.hartmann@utas.edu.au](mailto:klaas.hartmann@utas.edu.au)), Caleb Gardner<sup>2</sup>, Hilary Revill<sup>3</sup><sup>1</sup>*University of Tasmania*, <sup>2</sup>*Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Hobart, Australia*, <sup>3</sup>*Wild Fisheries Management, Department Primary Industry, Parks, Water and Environment, Tasmania, Australia*

The long-spined sea urchin (*Centrostephanus rodgersii*), is extending its range further south along the Australian coast into Tasmania. Overgrazing by the urchin has created extensive kelp barrens in its new range, resulting in dramatic loss of species biodiversity and primary productivity. Studies have identified southern rock lobster (*Jasus edwardsii*) as the key predator of the long-spined sea urchin and modelling suggests that at high densities, the lobster may exert sufficient predatory pressure to substantially reduce the extent of the kelp barrens being formed by the urchin. Due to urchin size, only large lobsters are able to prey upon them. As in most commercial fisheries, the large size classes of southern rock lobster have had the greatest reduction in biomass, to a level that is well below that required to control the urchin population. Consequently, to provide this ecosystem service, management changes were required to increase the abundance of large lobsters. A broad range of new management measures including spatial, temporal, size and catch limits were modelled with a bio-economic stock assessment model. Modelling quantified the trade-off between several key outcomes including large lobster biomass and industry profitability. This allowed us to identify a regional management approach that increased the biomass of large lobsters as well as increasing industry profitability. This management approach has now been in place for several years.

### **0123-NOT ENOUGH LOBSTERS TO GO AROUND? MANAGEMENT CHALLENGES AND SOLUTIONS OF REGIONAL STOCK REBUILDING AND RESOURCE SHARING IN THE TASMANIAN EAST COAST ROCK LOBSTER FISHERY**

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The Tasmanian rock lobster fishery operates predominately inshore around the state. A statewide total allowable catch applies with a resource sharing agreement for the commercial and recreational sectors along with other management regimes. Seventy percent of recreational catch comes from the east coast and this region also supports a fleet of small inshore commercial vessels. In 2011 east coast stocks were at historic low levels (~8% of virgin biomass) following an extended period of low recruitment. In 2013, a spatial management strategy to rebuild total biomass above 20 % virgin biomass by 2023 was supported by the government and stakeholders. Goals included increased catch rates and building stock resilience against future uncertainty of recruitment and climate change influences. After 18 months of extensive consultation on a wide range of options with commercial and recreational interests, a notional maximum catch limit was set including a pro-rata regional resource sharing arrangement, based on historical catch levels. Regional catch cap and season reductions were applied to the commercial sector as well as reduced seasons, reduced daily bag limits, and boat limits for the recreational sector. Three years in, the challenges have been in the detail and applying actual management restrictions rather than the overall strategy. Each sector has overrun and underrun its notional allocation, which has required adaptive management and exploring new options to further constrain catch. The paper explores in detail the management and political challenges experienced to date. One major challenge is the open access of the recreational fishery, and the capacity for participation and effort to increase as stocks rebuild and affect the rate of stock rebuilding. The paper also highlights lessons learned and future issues yet to be resolved.

### **0124-A LONG-TERM UNFISHED POPULATION EXPOSES DEPLETED STATUS OF MEDITERRANEAN LOBSTER FISHERIES**

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In the absence of a historical baseline, no-take marine reserves (MRs) can provide a reference to the unfished condition in exploited species of limited mobility. This study documents the recovery of the European spiny lobster *Palinurus elephas* population within a large no-take MR in the Northwestern Mediterranean, and uses it as a baseline to assess stock status in exploited fished grounds. Lobster indices of density and biomass within the MR continued to increase after 25 years of protection, a period close to the species' lifespan. Biomass indices more than doubled from years 10 to 25 inside the reserve while abundance increased less. This faster increase in biomass than abundance in the MR reflected individual growth and spillover of predominantly smaller lobsters to adjacent fished grounds. The extent of population depletion was inferred from biomass indices and the demographic structure in fished and unfished areas in terms of both fishery:MR biomass ratios and relative reproductive potential per unit area. In the MR the size-class of maximum egg production increased over time, in contrast to the stable and smaller sizes responsible for egg production in fished areas. Total mortality in fished areas estimated from recent size compositions was from three to four times the natural mortality estimated from size compositions inside the MR at the end of the study period. This experiment, albeit limited due to lack of replication and plausible confounding effects of environmental variability, emphasizes the value of long-term no-take areas as reference laboratories for investigating fishing effects.

**0125-EVALUATION OF MODIFIED LOBSTER TRAP VENTS IN THE SOUTHERN NEW ENGLAND LOBSTER FISHERY**

Laura Skrobe<sup>1</sup> ([lskrobe@uri.edu](mailto:lskrobe@uri.edu)), Kathleen Castro<sup>1</sup>, Mitch Hatzipetro<sup>1</sup>, Lanny Dellinger<sup>2</sup>, Heidi Henninger<sup>3</sup>, David Borden<sup>3</sup>, Burton Shank<sup>4</sup>, Bob Glenn<sup>5</sup>, Mark Gibson<sup>6</sup>

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The market for Jonah crabs in Southern New England (SNE) has been increasing in the past years, which has resulted in an increasing targeted effort. The poor condition of the inshore SNE lobster stock has also prompted fishermen to supplement their income with Jonah crab. The current lobster rectangular escape vent does not allow for maximum retention of crabs; they easily pass through the legal rectangular vent. The objective of this study was to develop an escape vent configuration that optimizes the catch of both legal lobsters and crabs but allows the release of sublegal lobsters and crabs. Initial tests of modified vent sizes were conducted in laboratory experiments and the catch efficiencies for lobster and Jonah crabs in the experimental traps were evaluated. Vent sizes studied were the current regulated vent (5 ¾ inches wide) and two experimental vents (3 ½ inches and 3 9/16 inches wide), as well as a ventless study as a control. The height was 2 inches for inshore pots and 2 1/6 inches for offshore pots. The size selection properties of the regulated and experimental traps for lobster and Jonah crab were then examined through field experiments. Selection curves were calculated for each vent using the SELECT method. In this presentation, only results from the inshore field data will be presented. The goal of the project is the development of an escape vent that can retain large marketable crabs while still fulfilling the requirement for release of sublegal lobsters (and sublegal crabs).

**0126-AN ANALYSIS OF MAINE LOBSTER VESSEL-LEVEL PROFITABILITY UNDER CHANGING CONDITIONS**

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The Maine lobster fishery has seen steady increases in landings since 2005. Policy reforms have limited entry to the fishery, but latent effort has nonetheless increased, limiting the efficacy of fishery managers to respond to changing conditions. Globally increasing demand for lobster has helped bolster prices and generic marketing activities, and innovations in live lobster transport have changed the market in yet poorly understood ways. The purpose of our study is to evaluate and model vessel-level profitability under changing conditions and assess the resilience of the community that depends on the lobster resource. We estimate profitability and technical efficiency of Maine's lobster industry for the fishing year 2010, using confidential firm-level data and survey responses for 1,007 fishermen. We then apply a retrospective analysis to evaluate future profitability and vessel participation in the fishery under changing conditions in the coupled natural and human system, such as changes in resource abundance and spatial distribution along Maine's coast. We specifically model scenarios of the catch levels predicted by the American Lobster Settlement Index, and assess firm level short-run profitability with sunk capital. We assume market price response associated with changes in supply and demand under current management and licensing policies, and evaluate overall industry long-run participation rates and implications for lobster fishery management. This research provides a quantitative assessment of the fishery economics in the form of a stochastic frontier production model. The Cobb-Douglas and Translog stochastic frontier production models were estimated using the maximum likelihood method. Empirical results show that the industry is not characterized by constant returns to scale, and reported societal benefits associated with employment levels have characterized the lobster production environment, over firm-level efficiency. This research analyzes the market integration and price transmission of U.S. and Canadian lobsters. We considered the timing of Maine lobster landings and the seasonality of the Canadian lobster supply to show to what extent these factors impact the lobster ex-vessel price and how prices respond to landings anomalies. The monthly ex-vessel prices, trade of live and processed lobster between U.S. and Canada are compiled to specify the inverse demand system.



### 0127-THE EFFECTS OF TEMPORARY EXCLUSION OF ACTIVITY DUE TO WINDFARM CONSTRUCTION ON A LOBSTER (*HOMARUS GAMMARUS*) FISHERY SUGGESTS A POTENTIAL MANAGEMENT APPROACH

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Offshore wind farms form an important part of the many countries strategy for responding to the threat of climate change, but their development can conflict with other offshore activities. Static gear fisheries targeting sedentary benthic species are particularly affected by spatial management that involves exclusion of fishers. Here we investigate the impact of short-term closures of large areas of fishing grounds on a significant European lobster (*Homarus gammarus*) fishery facilitated by the development of a large offshore windfarm. Long-term closures have been found to have negative or negligible effects on crustacean fisheries. We find that temporary closure offers some respite for adult animals and leads to increases in abundance and a right shift of the size spectrum of the target species in that area. Reopening of the site also allows the fishery to recuperate some of the economic loss during the closure of the site. We suggest that our results may indicate that temporary closures of selected areas may be beneficial and offer a management option for lobster fisheries.

### 0128-THREATENED YET UNKNOWN: PRELIMINARY AND FUNDAMENTAL ECOLOGICAL KNOWLEDGE OF THE EASTER ISLAND SPINY LOBSTER

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The spiny lobster *Panulirus pascuensis* is found in the southeast Pacific Ocean, including Pitcairn and Easter Islands. In spite of these popular locations and the fact that extraction of this species goes back to the first Polynesian inhabitants of the region, knowledge of the lobster's basic ecology is surprisingly scarce. On a recent multi-level effort, the Millenium Nucleus for Ecology and Sustainable Management of Oceanic Island (ESMOI) that aims to conserve the island's natural resources, our assessments confirm the threatened status of *P. pascuensis* issued by the IUCN. Our study considered: (i) habitat-specific visual surveys guided by local experts, (ii) use of artificial post-larvae collectors, as well as (iii) the review of historical accounts in order to discuss the factors behind the ongoing decline in population size of this species. While the extraction effort before modern times was mainly for subsistence, it is in the late 20th century (~1980) that this decline accelerated due to growing tourism activity and the onset of different extraction techniques. In addition to the direct survey of 12 sites around Easter Island, where an average of 0.5 lobsters per 30 min diving effort were found, preliminary results of a survey of an isolated rocky outcrop, some 500 km to the east of Easter Island (Salas y Gomez), exhibited relatively higher abundance of lobsters (5 lobster per 30 min dive). However, this abundance was not as high as anticipated and lobsters only inhabited highly structured habitats (large caves). Such overall low population size suggests that the isolation/endemism, together with the diminished parental stock and long larval span are restricting the recovery of this valued and unique lobster species.

**0130-IMPACT OF INCREASING FISHING EFFORT EFFICIENCY UNDER EFFORT AND QUOTA MANAGEMENT SYSTEMS APPLIED TO THE WESTERN AUSTRALIAN ROCK LOBSTER FISHERY**

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 Department of Fisheries, Western Australia

Effort efficiency changes for the period from the early 1980s to 2016 have been re-assessed in an attempt to improve the reliability of the commercial fishery catch rate based indices of abundance used to monitor the performance of the important Western Australian rock lobster fishery. This study covers the period of successful Total Allowable Effort (TAE) management from the 1980s to 2010 and the subsequent individual transferable quota (ITQ) management from 2011. Previous depletion-based assessments of fleet efficiency changes have been updated to allow the time series of commercial catch and effort to be improved. In addition, the standardized abundance indices from the six independent breeding stock survey (IBSS) locations instituted in 1990 have been compared with industry catch rates on adjacent grounds to provide an alternative assessment of effort efficiency increases in the deeper water sectors (> 20 m) of the fishery where most of the coastal breeding stock occurs. While nominal effort in the fishery has been decreasing at intervals since limited entry was implemented in 1963, exploitation rates have increased as efficiency improvements have continued through fisher activities/innovations not able to be directly controlled by the management legislation. In deeper water areas, higher increases in efficiency have been estimated using the a standardized catch survey time series, which has the potential to affect the catch rate based breeding stock reference points used for management. However, significant decreases in harvest rate occurred in the late 2000s following the substantial reductions in TAE implemented because of reduced recruitment, and these continued when TAC management was implemented and lobster abundance increased substantially. The likely factors influencing effort efficiency in the fishery, including the management system itself, are reviewed and the methods for calibration of effort to improve catch rate based management performance indicators are discussed.

**0131-A RISK EQUIVALENCY TIERED APPROACH FOR THE TORRES STRAIT *PANULIRUS ORNATUS* FISHERY**

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 CSIRO

The Torres Strait tropical rock lobster (TRL) *Panulirus ornatus* fishery is a culturally and economically important fishery and the Australian Commonwealth has an obligation under the Torres Strait Treaty to protect the traditional way of life and livelihood of Islanders as well as to promote employment opportunities for Traditional Inhabitants. Management of the fishery is complicated by the high natural recruitment variability, and diving surveys have been used for the past 28 years to monitor changes in the size of the recruiting population. Recently, stakeholders have requested flexibility to increase or decrease the future frequency and intensity of fishery-independent surveys. To accommodate potential changes in the amount of monitoring information available and number and timing of surveys and, hence, changes in the associated level of confidence in the scientific advice for decision-making, a hierarchical tier system is being developed. Tier systems broadly aim to reduce the risk when data are poorer, and ideally aim for risk equivalency such that different tiers have the same risk of depleting the stock below pre-specified levels. This is achieved by adjusting catch limits upwards or downwards based on the available data and assessment type, with the adjustment factors referred to as buffers or discount rates. This talk provides an overview of the four Tier system under development for TRL, where Tier 1 represents the highest quality of information (including mid-season and pre-season surveys) and Tier 4 the lowest. Each tier has its own empirical Harvest Control Rule (eHCR) to which appropriate discount factors are applied. The implications for data collection and management are discussed.

### **0132-LOBSTERMEN BEHAVIOR AND MARKET INTEGRATION: THE IMPACT OF RISING OCEAN TEMPERATURE AND EMERGING CHINESE DEMAND ON U.S. AMERICAN LOBSTER LANDINGS AND PRICES**

Jenny Sun ([jsun@gmri.org](mailto:jsun@gmri.org)), Frank Chiang, Bradley Franklin, Brian Kennedy  
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Record high ocean temperatures in the Gulf of Maine in 2012 pushed the start date of the Maine lobster fishing season three weeks earlier than normal and led to record landings. June and July 2012 saw more than double the volume typical for the period, which resulted in a 40% decrease in ex-vessel prices and significantly reduced profitability in the fishery. This study examines how the lobstermen's decisions regarding the timing of fishing effort and location of lobster landings are affected by ocean temperatures, distance fished from shore, price, and seasonality. Weekly lobster landings and the number of fishing trips in Eastern, Central, and Western Maine were merged with NERACOOS buoy temperatures to investigate how ocean warming impacts the timing of landings. We also compiled data documenting the U.S. and Canadian trade in fresh and frozen lobster from 1990 to 2016. This dataset reveals how both U.S. and Canadian lobster exports to the emerging Chinese market expanded after 2012 and continued to increase in subsequent years. U.S. export value increased from \$128 million in 2014 to \$158 million in 2015. Canadian exports rose from \$117 million in 2014 to \$193 million in 2015. Although complete data for 2016 is not yet available for confirmation, it is expected that the export value for both U.S. and Canadian markets reached a record high in 2016. An inverse demand system is estimated to evaluate the impacts associated with the supply shocks and the price transmissions between boat prices and export prices caused by the integrated global market. The study provides an example of the resilience and adaptation of a coastal ecological-economic system in response to increasing ocean temperature.

### **0133-HARMFUL ALGAL BLOOMS: A NEW PHENOMENON AND MANAGEMENT CHALLENGE FOR THE TASMANIAN ROCK LOBSTER FISHERY**

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Prior to 2012, regular harmful algal blooms (HAB's) in shallow sheltered areas of SE Tasmania had impacted the abalone fishery, but not rock lobster. In 2012, a harmful algal bloom caused by a species previously not recorded in Tasmania, impacted a number of fisheries including the rock lobster fishery. High biotoxin levels were detected in the hepatopancreas organ (tomalley) in samples from a number of east coast locations, just before the scheduled opening of the commercial and recreational fisheries. Ninety-five percent of lobsters harvested commercially are exported live to China, which has a maximum permitted biotoxin level applied to all imported seafood. Protecting market access and minimizing the risk of a widespread southern rock lobster recall became the number one management priority. An equally high priority was managing and communicating a new public health risk to the recreational fishery (~20,000 fishers). This presentation describes how the 2012 emergency response has developed into a comprehensive co-management (industry/government) biotoxin monitoring and management program, which has subsequently been used to manage significant blooms in 2015 and 2016. Management of the commercial fishery is further complicated by resource sharing issues and equity issues between the commercial and recreational sectors in the east coast stock rebuilding zone. This presentation also discusses how the new management challenges and impacts on the fishery have been addressed in close cooperation with the commercial and recreational peak bodies, with limited resources and minimal budget. Future issues, particularly how to utilize new research to improve the cost effectiveness of the monitoring program and minimize closures without increasing risk of a product recall, are highlighted in what may be a new paradigm for the Tasmanian east coast fishery.

**0134-AN EVALUATION OF FISHER COMPLIANCE WITH MARINE PROTECTED AREAS THAT PROHIBIT LOBSTER TRAPS**

Gabrielle F. Renchen ([gabby.renchen@myfwc.com](mailto:gabby.renchen@myfwc.com)), Thomas R. Matthews  
*Florida Fish and Wildlife Conservation Commission*

Compliance with marine protected area (MPA) regulations is considered a primary determinant of MPA success, even though few studies have directly quantified it. The Florida Keys have several types of MPAs that are managed by different state and federal agencies. This study evaluated lobster trap use in three types of MPAs that protect coral reef habitat and prohibit lobster trap fishing, but utilize different methods to identify the boundaries. In September 2014 and 2015, during the height of the lobster fishing season, the number of traps in each MPA were identified and trap location coordinates were recorded. Trap marking regulations allowed us to identify the owner of each trap. An education effort was also conducted during the September 2014 surveys to promote better recognition of these MPAs. This consisted of attaching a courtesy notice to each trap buoy observed within MPAs to inform fishers that their trap was in a prohibited area. All commercial lobster trap fishers were also mailed information identifying MPAs that prohibit traps. The highest number of traps and trap owners were observed in MPAs that did not have buoys marking the boundaries. Traps observed inside unmarked MPAs were typically distributed throughout. In contrast, the number of traps observed was lower in marked MPAs, with traps mostly concentrated near the boundaries. Fewer fishers placed their traps within MPAs after the targeted educational effort. Similarly, the number of traps was lower. The results of this research highlights the need for improving communication between fishery managers and fishers impacted by changing regulations, and the need for addressing habitat protection in the context of fisher behavior and increased trap use at boundaries when designing MPAs.

**0135-GRAYING OF MAINE'S LOBSTER FLEET AND POTENTIAL IMPLICATIONS FOR SOCIAL RESILIENCE**

Teresa R. Johnson ([teresa.johnson@maine.edu](mailto:teresa.johnson@maine.edu)), Mackenzie Mazur  
*University of Maine, Orono, ME*

The American lobster (*Homarus americanus*) fishery is the most valuable commercial fishery in the state of Maine (USA). The fishery is known for a governance system characterized by collective action due to a co-management system established on the basis of informal and formal management rules. Its recent history has been one of increasing abundance and landings. It is considered to have many of the “pre-conditions” necessary for an enduring sustainable institution. Although current lobster landings are historically high, and have been for a while, concern exists regarding the future of the fishery and the communities it supports due to threats from myriad ecological and social changes. An analysis of license data shows an increasing average age of fishermen in this fishery, primarily because fewer new or younger entrants are allowed into the fishery. Oral history interviews with lobstermen reveal a key threat facing this fishery – the differences in perceptions and behavior among generations of lobstermen. This “graying of the fleet” has significant implications for the social resilience of the fishery, or the ability of the fishery to respond to future social and ecological changes. Oral history interviews not only allow researchers to understand the potential impact of graying the fleet, but also can help aid in the resilience of the fishery by protecting the social memory needed for adaptive behavior.

FRIDAY, JUNE 9, 2017

**Climate Change****O136-CLIMATE VULNERABILITY AND RESILIENCE IN THE MOST VALUABLE U.S. FISHERY**

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<sup>1</sup>Marine Institute, Memorial University, <sup>2</sup>Gulf of Maine Research Institute, <sup>3</sup>University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, ME, <sup>4</sup>NOAA Earth System Research Laboratory

Managing fisheries in an era of increasing climate impacts requires robust projections that integrate interacting human and natural drivers of resource productivity. Using a mechanistic model that links ocean temperature, predator density, and fishing to population productivity, we show that increasing temperatures have led to the collapse of the American lobster fishery in southern New England and to record landings in Maine. While temperature explains the divergent trajectories of these two adjacent stocks, conservation measures taken in the north but not in the south amplified the contrast between them. Projections under expected warming suggest that the American lobster fishery is vulnerable to future increases in temperature, but efforts to preserve the stock's reproductive potential can mitigate the negative impacts of increasing temperature. This study demonstrates that although global climate change will lead to major changes in marine systems, locally adapted precautionary management measures can confer resilience to commercial fisheries.

**O137-WARMING OCEANS AND LOWER EXPLOITATION RATES IMPACTING THE PRODUCTIVITY OF AUSTRALIA'S LARGEST LOBSTER FISHERY**

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The growth of *Panulirus cygnus* was examined using a number of non-linear functions to over 25 years of tag-recapture data. Of the functions used, the inverse-logistic model provided the best fit to the tag-recapture data. The implementation of the non-linear growth model was capable of accounting for and explaining variation in the growth rates of lobsters of different sexes, those that experienced different water temperatures, population densities, movement behaviors, and geographic positions. Whether a lobster had migrated was found not to impact its growth rate, while its sex, water temperature history, associated population density, and general geographic position (coastal or offshore islands) all impacted growth rates significantly. Female lobsters grew slower than males, warmer water temperatures resulted in increased growth rates in sub-adults and earlier maturation and subsequent slower growth rates in larger lobsters. Increased population densities and occupying the waters offshore of the Abrolhos Islands both significantly reduced overall growth rates. Waters throughout the Western Rock Lobster fishery show a progressively warming trend and, due to recent management changes, current lobster densities are over four times greater now than a decade ago. As a result, growth rates of lobsters and thus the biomass increases through growth have declined in recent years.

**0138-CLIMATE-ASSOCIATED POPULATION CHANGE AND RESILIENCE IN CARIBBEAN SPINY LOBSTER**

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 Old Dominion University, Norfolk, VA

Spiny lobsters worldwide have demonstrated a remarkable resilience to changes in their environment during the Anthropocene, most notably eutrophication of coastal waters and a dramatic shift in the mortality of adults attributable to the direct and indirect effects of fishing. Lobsters now face the additional challenge of adapting to a rapidly changing environment the likes of which have not occurred during the last 50 million years. Will they prove resilient to those perturbations as well? Assessing that probability is a daunting task because the ramifications of climate change go well beyond those directly attributable to rising temperature and acidity in the sea. The survival and dispersal of lobster larvae, benthic habitat availability and suitability, prey abundance and composition, disease dynamics, and predatory regimes (natural and human) are all likely to change and thus challenge the seemingly obdurate resiliency of spiny lobsters. Drawing on data for the Caribbean spiny lobster and conditions in the Caribbean and Florida, I will attempt to synthesize the ramifications of an alternative environment on the persistence of *Panulirus argus*.

**0139-LARVAL SETTLEMENT-BASED FISHERY RECRUITMENT FORECASTS FOR THE AMERICAN LOBSTER ALONG A STEEP ENVIRONMENTAL GRADIENT IN A CHANGING CLIMATE**

Noah Oppenheim<sup>1</sup> ([oppenheim.noah@gmail.com](mailto:oppenheim.noah@gmail.com)), Richard A. Wahle<sup>2</sup>, Damian Brady<sup>2</sup>, Andrew Pershing<sup>3</sup>  
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Accurate prediction of fishery recruitment is a key goal of fisheries science, made especially challenging by a changing environment. The American lobster (*Homarus americanus*) is the most valuable fishery in the U.S. and has undergone dramatic shifts in recent decades that were largely not predicted by stock assessments. These changes are suspected to be linked to climate change. Settler-recruit relationships, which track cohorts after larvae have settled to the sea bed, have proven useful for recruitment forecasts in several crustacean species and may prove effective where traditional stock assessment methodologies under-perform. Here we describe recent developments of a fishery recruitment forecasting model that employs the American Lobster Settlement Index (ALSI), a comprehensive annual diver-based survey, spanning nearly three decades, that quantifies the abundance of young-of-year lobsters as they populate coastal nurseries. The settlement index sets initial year-class strength, and local bottom temperature regimes were used to vary cohort growth. Observed variability in shell disease prevalence was used to scale spatial and temporal changes in natural mortality. We developed forecasting models for 13 study areas along the steep coastwise environmental gradient from southern New England to Atlantic Canada. For 11 of these areas, our predictions were significantly correlated with temporal trends in observed lobster landings, a strong indicator of fishery recruitment. Our models accurately predicted the collapse of southern New England's fishery as well as the dramatic expansion of the Gulf of Maine's fishery in a hindcast simulation. We have used these models to develop landings projections for the next several years. Forecasts for the Gulf of Maine suggest moderate to significant declines in landings within the next five to eight years, but no sign that southern New England will rebound. We anticipate multi-year projection models such as this will contribute to the stock assessment process and help stakeholders buy time to make informed decisions on the prosecution and management of this iconic fishery.



### **O140-IMPLICATIONS OF EXPANDING THERMAL HABITAT TO SETTLEMENT-BASED FORECASTS OF AMERICAN LOBSTER LANDINGS**

Andrew Goode ([andrew.goode@maine.edu](mailto:andrew.goode@maine.edu)), Damian Brady, Richard A. Wahle  
*University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, ME*

The American lobster, *Homarus americanus*, fishery is the most valuable single-species fishery in the USA and Canada, and more than 90% of the USA share comes from the Gulf of Maine (GoM). New recruits to the fishery comprise approximately 85% of annual landings, and therefore landings are a reasonable indicator of the productivity of the fishery. The American Lobster Settlement Index (ALSI) was established in 1989 to record the interannual variability and overall trends in year class strength at the time larvae settle to the seabed, some 6-9 years before they enter the fishery. Widespread recent downturns in GoM settlement densities, as measured at shallow water monitoring sites, have raised concerns over future declines in landings. However, it is possible that the ALSI alone may underestimate year class strength if the area of suitable nursery habitat has expanded in a warming climate. Previous studies indicate lobster larvae prefer to settle where temperatures exceed ~12°C. Until recently, much of the eastern GoM has not exceeded this temperature. The availability of habitat above this thermal threshold, in combination with the ALSI, may give better estimates of year class strength. In our analysis, we use modeled bottom temperatures from the Finite-Volume Community Ocean Model (FVCOM) to evaluate yearly changes in the area of seabed above the 12 °C threshold during the settlement season for 12 sub-regions of the GoM. Forecasts using the product of ALSI and the expanding area of thermal habitat translate to less severe declines in landings than would be predicted on the basis of ALSI alone. Although not all factors contributing to variable fishery recruitment can be accounted for, incorporating thermal habitat with ALSI may provide more realistic estimates of recruitment to the American lobster fishery.

### **O141-FORECASTING THE TIMING OF MAINE'S LOBSTER FISHERY**

Kathy Mills<sup>1</sup> ([kmills@gmri.org](mailto:kmills@gmri.org)), Andrew Pershing<sup>1</sup>, Christina Hernandez<sup>2</sup>, Sam Sherman<sup>3</sup>  
<sup>1</sup>*Gulf of Maine Research Institute*, <sup>2</sup>*MIT/Woods Hole Oceanographic Institution*, <sup>3</sup>*Princeton University*

American lobster supports one of the most valuable fisheries in the United States, with a landed value in 2015 exceeding \$600 million. Although U. S. lobstermen can fish throughout the year, the New England climate, lobster biology, and fleet dynamics create a strong annual cycle, with catch rates rising rapidly in early summer and landings peaking in late summer. When this annual cycle is disrupted, it can impact the fishery and supply chain. During a marine heat wave in 2012, an early onset of high volume landings in Maine, combined with high landings in Canada, led to a price collapse that severely stressed the fishery. Since that time, we have been forecasting the phenology of Maine lobster landings. Using temperatures at 50 meters depth from four NERACOOS buoys in the Gulf of Maine, we can reliably forecast the date when the Maine lobster fishery will shift into its high-landings summer mode, with prediction accuracy peaking in April. This presentation will describe the current statewide forecast, its performance across regions of the state, and further developments of the forecast model that are currently underway. While we have demonstrated the technical capacity to forecast the timing of the uptick in landings in Maine's lobster fishery, we are currently working to understand how this information is being used by different segments of the lobster industry. Connecting forecast information to decisions faced by harvesters, dealers, processors, and marketers is essential if the forecast is to truly be useful. We will describe efforts to identify these connections and how this process of gaining focused stakeholder input is shaping the development, presentation, and communication of future forecast information.

### 0142-HAS TIME OF SETTLEMENT OF POSTLARVAL AMERICAN LOBSTER, *HOMARUS AMERICANUS*, CHANGED BETWEEN 1993 AND 2010?

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<sup>1</sup>The Lobster Conservancy, Friendship, ME, <sup>2</sup>Woods Hole Oceanographic Institution, Woods Hole, MA

Data from an 18-year time series of juvenile American lobster, *Homarus americanus*, is examined to determine if timing of the postlarval lobster settlement season changed. The Lobster Conservancy census and mark/recapture study has quantified year-round abundance of juvenile lobsters on a monthly basis for nearly two decades (1993-2010). Analysis of this data set should reveal changes in timing of events such as settlement, molting, and growth. Prior analysis has shown that the abundance of “settlers”, defined as postlarval lobsters measuring 3.5-6.4 mm CL, increased by an order of magnitude between 1993 and 2010. The questions here are: (1) can we detect a shift in timing? and, if so, (2) can we determine what has driven the change? Postlarval lobsters (3.5-6.4 mm CL) represent a discrete size class. Although most prevalent in August and September, we have recorded postlarval lobster presence in all months except for May and June. In some years, postlarval lobsters settle in just one month and in other years multiple months. For example, in 2000 postlarvae were found only in August while in 2005 they were abundant in all months except for May, Jun, July, and December. While our general feeling is that temperature and sea level changes have had an influence on timing of settlement, we are unsure if the data will provide statistically defensible evidence. The presentation will provide the results and allow for discussion.

### 0143-IMPACTS OF MESOSCALE CLIMATIC VARIATIONS ON THE ABUNDANCE OF *HOMARUS AMERICANUS* IN THE INSHORE GULF OF MAINE

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American lobster (*Homarus americanus*) supports one of the most valuable fisheries in the United States. While both abundance and distribution of *H. americanus* are hypothesized to be influenced by some climate-driven environmental factors, studies that quantify the impacts of climatic variations on the abundance distribution of *H. americanus* are limited. In this study, we developed a Tweedie-generalized additive model (GAM) to quantify season, sex-, and size-specific abundance distribution of *H. americanus* in the inshore Gulf of Maine as a function of key abiotic variables. To evaluate potential effects of climatic variations on the abundance distribution of *H. americanus*, the Tweedie GAMs were coupled with the output from a regional circulation model to hind- and forecast the abundance distribution of *H. americanus*. The results showed a northeastward shift in the centroids of *H. americanus* climate-niche during spring over the past 30 years (1982-2013), and predicted significantly higher relative *H. americanus* abundance under the warm climate scenario. This study provides a hind/now/forecasting coupled climate-niche model to evaluate spatial and temporal variability in the abundance distribution of *H. americanus*, which could be used to improve management of the Gulf of Maine lobster stock given its sensitivity to the surrounding environment and ongoing climate-driven changes in the NW Atlantic marine ecosystem.

**O144-GEOGRAPHICALLY VARIED RELATIONSHIPS BETWEEN AMERICAN LOBSTER AND CLIMATE VARIABLES IN THE GULF OF MAINE**Bai Li ([bai.li@maine.edu](mailto:bai.li@maine.edu))*University of Maine, Orono, ME*

Key environmental variables (e.g., bottom water temperature) are widely considered to influence the spatial distribution of American lobster (*Homarus americanus*). Generalized linear or additive models, as traditionally practiced, are used to predict lobster distributions with an assumption that the relationships between species and environmental variables are stationary and independent. However, given the mobile nature and dynamic spatial interactions between lobsters and environmental variables, the relationships may vary spatially in a large study area. We developed a season-, sex-, and size-specific geographically weighted regression (GWR) model to explore the spatial non-stationarity of American lobster distribution in the GOM. The model was developed using lobster density and environmental data from the Maine-New Hampshire Inshore Bottom Trawl Survey (2000-2014). Model results showed varied relationships between the western and eastern GOM that indicated spatial non-stationarity in the lobster distribution. From our analysis, bottom water temperature showed a significant positive relationship with lobster in the eastern GOM and a non-significant relationship in the western GOM. These findings suggest that there might be other factors influencing the lobster distribution in the western GOM. The non-stationary relationships between environmental variables and American lobster highlight the limitations of using traditional global models to estimate the distribution of American lobster in a large marine ecosystem. This study provides a novel tool to evaluate spatial non-stationary distribution of a species with respect to changes in climate conditions.

**O145-SPATIOTEMPORAL VARIABILITY IN THE SPRING MOLT PHENOLOGY OF AMERICAN LOBSTER IN A CHANGING GULF OF MAINE**Kevin W. Staples ([kevin.w.staples@maine.edu](mailto:kevin.w.staples@maine.edu)), Yong Chen, David W. Townsend*University of Maine, Orono, ME*

The American lobster (*Homarus americanus*, Milne Edwards) fishery in Maine is mainly a recruitment fishery with most landings consisting of individuals newly molting into the fishery. The timing of the annual molt is critical to the fishery, with adverse economic effects resulting if molting occurs too early, as in 2012. We hypothesized that the spatial and temporal variability of the lobster molt is linked to variability in cumulative bottom temperature effects in the Gulf of Maine (GoM). The hypothesis was tested by using logistic models to quantify and evaluate the spring molt seasons of GoM lobsters and then using general linear model analysis to explore potential relationships to temperature. Cumulative average bottom temperatures in the GoM were derived from the Northeast Coastal Ocean Forecasting System (NECOFS) hindcast modelled using the Finite Volume Community Ocean Model (FVCOM) and the quantification of the spring molt was derived using lobster sea sampling data from the Maine Department of Marine Resources.

**O146-OCEAN ACIDIFICATION THREAT TO JUVENILE LOBSTER SURVIVAL AND RECRUITMENT**

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<sup>1</sup>University of Quebec at Rimouski, <sup>2</sup>Department of Fisheries and Oceans Canada, <sup>3</sup>Homarus Inc.

Ocean Acidification (OA) is the progressive decrease of oceanic pH and changes in carbonate chemistry caused by the uptake of excess atmospheric CO<sub>2</sub>. The ongoing decrease in pH is known to affect the physiology and life-history traits of marine crustaceans, like the economically important American Lobster (*Homarus americanus*). The lobster's complex life cycle includes a pelagic to benthic transition at which time an energetically costly metamorphosis occurs during molt in order to progress from larvae to juvenile recruits. This vulnerable transition phase likely constitutes a bottleneck in lobster recruitment, and thus in population sustainability, with the effects of OA despite minimal tolerance of metamorphosed juveniles to pH decreases is virtually unknown. This study aims to identify the impacts pCO<sub>2</sub>-induced pH decreases on the life history and physiological traits on the first juvenile stages following metamorphosis (stage IV and V). Juvenile lobsters were held in one of seven pH levels (between 8.1 and 7.12), representative of predicted end-century ocean conditions and potential low pH extremes. Lobster health (deformity degree), life history (survival, development rates), and physiological traits (metabolic rate, carapace mineralization, and mitochondrial function) were determined. Preliminary results suggest an increase in the degree and incidence of deformity as well as developmental rates. These patterns can apparently be explained by low pH impacts on physiological traits. Our results point to potential negative effects on the species recruits, foreshadowing reduced recruitment and preventing the persistence beyond juvenile stages under future low pH scenarios.

## Adaptive Harvesting & Management

### **O147-METHODOLOGICAL COMPARISON FOR SAMPLING SHALLOW WATER POPULATIONS OF THE WESTERN ROCK LOBSTER (*PANULIRUS CYGNUS*) AT ROTTNEST ISLAND, WESTERN AUSTRALIA**

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Wild populations of lobsters are sampled for numerous reasons, including fisheries stock assessments, as well as studies on their ecology and biology. The two most prevalent methods for sampling shallow water populations of lobsters are the use of lobster pots (traps) or diver based surveys. While many studies have investigated the inherent biases and uncertainties for each of these methods separately, no thorough comparisons of techniques had been completed. This study considered four pot designs and two types of diver surveys (transects and timed surveys) in their capacity to effectively sample populations of the western rock lobster, *Panulirus cygnus*, at Rottneest Island, Western Australia. Methods were tested for their ability to: 1) capture a large number of individuals, 2) demonstrate accurate sensitivity to changes in relative abundance, and 3) sample a large proportion of the population size composition. To test accurate sensitivity to changes in abundance, the study utilized both expected gradients in abundance across no-take marine reserves and tag-recapture derived population estimates. The methods examined performed variably against the aforementioned criteria. The standard commercial pots and timed dives were able to sample the greatest number of lobsters per day. The trends in abundance produced by pot methods were more similar to the predetermined patterns than those produced by the diving methods. The two modified pots and the two diving methods sampled the largest proportions of the population size composition. When compared across all three criteria, the “meshed recreational pots” were identified as the most efficient and representative of the methods examined. These pots sampled on average 177 lobster per day, accurately reflected the expected abundance gradients across marine protective zoning, were in agreement with legal sized tag-recapture-based population estimates, and captured a large range of lobster sizes. The study concluded that while the diving methods were able to sample a large size range of lobsters, abundance estimates from diving methods can be inaccurate. The abundance patterns detected by the diver based methods were highly variable, and produced markedly different patterns from the population estimates based on tag recapture analysis. We suggest that this is likely due to variation in habitat and oceanographic conditions, which confound gradients in abundance. This finding is of great importance, as diving methods are at least one of, if not the most common method utilized in ecological surveys of rock lobsters.

**O148-HOW DO WE PREVENT THE BENEFITS OF ROCK LOBSTER FISHERIES FROM BEING EXPORTED OUT OF THE COMMUNITY?**

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<sup>1</sup>*Institute of Marine and Antarctic Studies, University of Tasmania*, <sup>2</sup>*Department of Agriculture, Australian Government*

Commercial fisheries rely on access to a public resource so it is reasonable for the public to expect to see a benefit. Commercial access is often justified by benefits of employment or food for the community; however, these benefits are not always relevant in lobster fisheries such as the Australian examples explored in this presentation. Australian lobster product is mainly exported so the public gets little consumption benefit, while employment is actively minimized using catch share management (ITQ) to promote technical efficiency and increase economic yield. This strategy has successfully reduced employment in all Australian lobster fisheries so that economic yield has typically increased several fold. This higher economic yield would theoretically benefit the public owners of the resource if it were retained in the community, such as through royalty payments or by development of new industries. However, the economic yield of Australian lobster fisheries is increasingly being exported, for example, by companies outside the jurisdiction buying and renting out catch shares. This trend of Australian lobster fisheries exporting benefit has become a significant concern for industry groups, but they typically question whether there are any solutions. In fact, there are numerous options available and they are explored in this presentation. They include controls on foreign ownership, taxation approaches, and social structures.

**O149-POTENTIAL IMPACTS ON CONSERVATION DISCARDS IN A GROWING LOBSTER POPULATION IN THE GULF OF MAINE**

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The practice of V-notching to protect reproductive female lobsters has been a cornerstone of lobster conservation in Maine since the 1920s. The Atlantic States Marine Fisheries Commission Lobster Stock Assessment model has incorporated V-notch rates to produce conservation discard estimates for all managed areas for the past two assessments. Since 1985, the Maine Department of Marine Resources has monitored the characteristics of the discards of the lobster fishery through an at-sea sampling program. Over the past 30 years, the lobster landings in Maine have skyrocketed from 20 million pounds in the 1980s to a record 130 million pounds in 2016. The V-notching rates appeared to be stable, but, in the past decade, the catch rates of V-notched females have increased, especially in eastern Maine. Considering a different metric, since a peak in 2008, the rate of ovigerous females already bearing a notch has exhibited a downward trend. Is this a change in fishery behavior or a population shift of proportions? Using the estimates from the ASMFC Lobster Stock Assessment model (2015) of the legal population and conservation discards, we explore trends over time to assess the growing population changes and possible impacts to the conservation discards.



### **O150-SUSTAINABILITY AND CERTIFICATION - 15 YEARS ON**

Kim Colero ([kim@colero.com.au](mailto:kim@colero.com.au)), Nic Sofoulis  
*Western Rock Lobster Council, Western Australia*

The Western Rock Lobster commercial fishery was the first wild-caught fishery in the world that was independently certified by the Marine Stewardship Council. Fishing practices have changed dramatically in that period via: introduction of quota and year round fishing, removal of race to fish, improved efficiencies and reduced costs, and a conservative approach to determining and recommending annual Total Allowable Commercial Catch. A comprehensive review of industry risk issues now includes: an extensive program of trials and use of mitigation measures to reduce whale entanglements (reduced from 17 per annum to 2 per annum for over two consecutive years), renewal of industry license for export of live lobsters for 3 years (previously only provided for 2 years), an ongoing program to identify and capture costs and benefits of certification, improvements in community acceptance and license to operate, and changing market dynamics, including commencement of Australia/China free Trade agreement in 2019.

### **O151-EVALUATING THE V-NOTCHING CONSERVATION MEASURE IN THE MAINE LOBSTER FISHERY**

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*University of Maine, Orono, ME*

The American lobster (*Homarus americanus*) fishery is the most valuable commercial fishery in the state of Maine and, as such, supports a large number of families across very diverse communities. Maine lobstermen are known for their conservation ethic, which is largely due to the V-notch conservation measure. Although the current Gulf of Maine lobster population has been at record high abundances, the Maine Department of Marine Resources has found that the proportion of egg-bearing females that are V-notched is decreasing. This may have a negative impact on the lobster population and fishery, especially if lobster recruitment were to decline in future years. Evaluating V-notching levels in the Maine lobster fishery is an important platform from which to understand how the conservation measure impacts fishery dynamics. In this study, an individual-based model (IBM) was used to evaluate how the Gulf of Maine lobster catch and population may change at different levels of V-notching. To better understand the V-notch practice as a conservation measure, interviews will be conducted with lobstermen to better understand lobstermen's perceptions and behavior relevant to this conservation tool. This research will provide important insight into the conservation and management of the economically important Gulf of Maine lobster stock.

## Ghost Fishing – Trap/Gear Conflicts

### 0152-GHOST FISHING BY DERELICT TRAPS IN THE AMERICAN LOBSTER FISHERY

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 Massachusetts Division of Marine Fisheries

Current Massachusetts regulation requires that every lobster (*Homarus americanus*) trap has at least one biodegradable ghost panel designed to release within one year to reduce the impacts associated with ghost fishing by derelict traps. We tested this assumption by deliberately abandoning standard commercial lobster traps in two locations, Cape Cod Bay and Buzzards Bay, MA, and monitoring their condition and catch with bimonthly dives. Traps set in Cape Cod Bay were disabled in approximately nine months with the onset of frequent and intense winter storm events. However, after over two years in the water, 66% of study traps “lost” in Buzzards Bay, MA were still fishing. The simulated derelict traps caught on average 19 ( $\pm 2.5$ ) lobsters/trap/year in Cape Cod Bay and 8.5 ( $\pm 1.3$  SE) lobsters/trap/year in Buzzards Bay, of which at least 4.8 ( $\pm 0.8$ ) and 3.6 ( $\pm 0.5$ ) per trap/year were dead at each site, respectively. Mortalities of other commercially important species included *Gadus morhua*, *Pseudopleuronectes americanus*, *Tautoga onitis*, *Centropristis striata*, and *Cancer borealis*. While mortality rates in derelict American lobster traps are comparatively low in contrast to other trap fisheries, the fishery is more expansive with over 4 million U.S. traps fished annually. Massachusetts’ commercial lobster fishers surveyed in 2011 reported annual trap loss rates of 1% to 5%. This equates to an estimated 7,000 to 17,000 traps lost in a single year (2010) in Massachusetts waters alone. Storms, vessel traffic, fishing activity, and conflict with other types of fishing gear were identified as primary mechanisms for gear loss. It is clear that ghost fishing has both resource and economic impacts and represents a threat to the sustainable management of the lobster fishery, and that the current design of ghost panels may not be an effective solution.

### 0153-NUTRITIONAL CONDITION OF CARIBBEAN SPINY LOBSTERS, *PANULIRUS ARGUS* IN GHOST TRAPS

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Ghost fishing occurs when lost or abandoned fishing gear continues to capture animals, resulting in both lethal and sublethal effects on the captured individuals. Ghost fishing lobster traps in the Florida spiny lobster fishery cause the death of hundreds of thousands of lobsters annually, a problem exacerbated by the quantity of lost traps and the long duration the traps persist before decaying. We compared the nutritional condition of Caribbean spiny lobsters (*Panulirus argus*) found in ghost traps in the Florida Keys to those found in natural shelters, and deployed experimental lobster traps to follow the effects of confinement on individual lobsters over time. To determine if starved lobsters can recover after escaping confinement, we deprived lobsters of food and then re-fed them in the laboratory. Our results indicated that lobsters from ghost traps were in poorer nutritional condition than lobsters from natural habitats. Lobsters in ghost traps were lethargic, and exhibited a higher incidence of injuries and chitinolytic bacterial shell disease. As the duration of confinement increased, lobsters in the experimental ghost traps experienced declines in hemolymph protein concentration and became less likely to escape the traps. While resumption of feeding resulted in recovery by 50% of the animals, 50% were unable to recover and died. Although lobsters might escape traps, their nutritional condition may not recover quickly, suggesting these lobsters may remain vulnerable to predation and less desirable to the fishery.

**0154-DETERMINING POST-RELEASE MORTALITY FOR ATLANTIC COD DISCARDED IN THE GULF OF MAINE LOBSTER FISHERY**

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Atlantic cod, *Gadus morhua*, has experienced heightened fishing-induced mortality since the 1990s, leading to the lowest population abundances in recorded history. Although rigorous commercial and recreational limitations have been established in an attempt to restore this species, population levels remain at all-time lows. A potential issue affecting the recovery of cod populations is the unaccounted discard mortality experienced within Northwest Atlantic fisheries. With over 4 million fished traps, the lobster industry represents Maine's largest fishery and has recently been suggested as a major contributor towards the increased mortality rates of cod within this region. For example, preliminary data suggests that discard rates as high as 1.32 cod/trip may exist. Additionally, recent evidence suggests individuals that experience multiple capture events may have elevated rates of mortality due to chronic stress. To evaluate the post release mortality of cod within commercial lobster gear, an acoustic array measuring 30km<sup>2</sup> was established off of Cape Porpoise. Data were collected from June to October 2016, resulting in 55 cod captured over 57 fishing trips (consisting of 10,455 individual trap hauls). Acoustic transmitters were placed on 30 individuals, which were all detected throughout the array, and three of which were later recaptured within lobster gear. Preliminary results indicate injury conditions upon capture ranging from absent (68%), to minor (20%), or deceased upon haul (12%). Discard mortality will be assessed by correlating vitality condition upon capture with the observed or absence of movement throughout the acoustic array.

**0155-CO-HABITATION OF A LARGE COMMERCIAL FISHERY AND A PROTECTED WHALE POPULATION UNDERGOING A MARKED POPULATION INCREASE**

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 Department of Fisheries, Western Australia

Commercial fisheries are being placed under progressively greater scrutiny by the more "ecologically-aware" government and public sectors. Export approvals for Australian commercial fisheries are based on the achievement of a number of ecologically-based performance indicators, and domestic sales at a number of major outlets now require all seafood to be responsibly sourced, based on third party assessments such as the MSC. The Western Rock Lobster (WRL) fishery, which exports the majority of its catches, recently had conditions placed on its export license following an unprecedented increase in the entanglements of migrating humpback whales (*Megaptera novaeangliae*). The humpback whales off Western Australia, whose population is increasing at over 10% p.a., migrates north along the coast in May - July and back south along the coast from August - October. Historically the WRL fishery was closed from July - November 14, but with the introduction of quotas in 2010 and the economic benefits of fishing year-round, the fishery no longer closes. Whale entanglement increased from ~ 1 annually prior to quotas to 17 in 2013. To ensure continued export approval, MSC certification, and their "social license to fish", the WRL fishery has instigated a number of fishing gear changes, which collectively have reduced the likelihood of a whale becoming entangled by over 65% while maintaining good lobster catches. In addition, specific technology has been developed to greatly increase entangled whales chances of swimming free.

**0156-THE EFFECT OF DEEPWATER TRAWLING AND DISCARD PRACTICES ON BOTTOM SCAVENGER ABUNDANCE AND DIVERSITY**

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Deepwater trawling for crustaceans, operating off the southern coast of Portugal, generates large amounts of discards. The purpose of this study was to understand the physical and biological impacts on the bottom, and the effect to the scavenger community, of the release of large quantities of organic matter. Lines of 20 baited traps covered with mosquito net were used to sample the scavenger community. They were placed along 7 stations, 3 corresponding to non-fishing areas and the remaining 4 on commercial fishing grounds. The identification of the areas with and without trawling activity was done by analyzing fleet activity (Vessel Monitoring System data) and interviews with trawler skippers. In each station, the traps lines were set parallel to the shoreline at the same depth (about 550 m). The taxonomic classification of discards was made, whenever possible, down to the species. The number of identified species was 99, belonging to 5 phyla (Annelida-9 sp, Arthropoda-73 sp, Chaetognatha-1 sp, Chordata-3 sp, Echinodermata-3 sp, and Mollusca-10 sp). The order Amphipoda was the best represented, with 22 families and 39 species. The most common species was the amphipod *Scopelocheirus hopei* followed by the isopod *Natatolana borealis*. The diversity and distance among stations was evaluated and one station, representing non-towed grounds, was shown to be separated from the others. This station had the highest diversity and abundance. The hypothesis that trawling and discarding increases scavenger abundance could not be verified.

**(replaces 0146)**

**0157- WHAT IS CREDIBLE SCIENCE? LEARNING FROM INDUSTRY**

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Researchers have heavily relied on unidirectional science communication (i.e., the deficit model) to disseminate findings. This type of science communication has been shown to create greater knowledge gaps within society, rather than reducing them, because of unequal resource distribution (i.e., income, education, and learning ability). More recently, the deficit model is also thought to only be effective when the receiving audience recognizes science as the epistemological authority on that subject. To explore an alternative method of communicating with industry, five UMaine graduate students set out to create the Maine Marine Resource Exchange. This was a one day symposium designed to engage stakeholders in a diversity of ways and to give opportunity to graduate students to get feedback on their research. This also provided opportunity to discuss varying views of credible research. We found that conversations about credible research centered around collaborative research projects that involved industry and generated co-produced knowledge. These conversations specifically focused on communication and relationships as necessary elements to producing relatable science, which seemed to emerge as more credible to industry stakeholders. We found this to be a continuous process, each element feeding into the other. We propose that collaborative research initiatives should think about each of these elements and devise plans to address them in their own endeavors.

# **POSTER PRESENTATION**

## **ABSTRACTS**

## Aquaculture

### **P1-LOBSTER GROWER: EXPLORING MARICULTURE OF HATCHERY EUROPEAN LOBSTERS FOR FISHERIES AND AQUACULTURE**

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Hatchery-reared European lobsters (*Homarus gammarus*) have shown promising growth and survival when on-grown through post-planktonic life stages in oyster spat baskets in the sea. Building on these encouraging trials, a collaborative UK project – Lobster Grower – has designed a novel sea-based rearing container to overcome impracticalities of the oyster system, and is now testing both designs on a semi-intensive scale at an offshore shellfish farm. During 2016, over 13,000 juveniles have been deployed into containers and 900 animals reared in hatchery aquaria facilities as controls, with similar deployments scheduled for 2017 and 2018. Through a combination of biological, ecological, histological, pathological, environmental and oceanographic monitoring, the project is collecting an array of data relevant to the upscaling and optimization of clawed lobster mariculture, including information on semi-wild *H. gammarus* throughout life stages which remain largely unstudied in nature. A number of practical aspects associated with operation are also under consideration, including juvenile life stage at deployment, container depth and position, loading and handling processes, deployment time and season, mooring mechanism, the characterization of settlement community and juvenile diet, and economic factors. Preliminary results suggest that early juvenile growth rates are comparable in both sea-based containers, and surpass those of hatchery controls (83% vs 56%), with comparable survival across the following 50 days (98% vs 100%). Lobster Grower research is laying the foundations for semi-intensive culture of juvenile lobsters at sea. The lack of supplemental feeds and effects of this enriched environment on lobster development suggest that the method has considerable potential for (i) cost-effective and ecologically-conditioned on-growing to improve the effectiveness of releases enhancing capture fisheries, and (ii) the advent of sustainable aquaculture of this prized seafood species.

### **P2-GROWTH OF LOBSTERS *PANULIRUS INFLATUS* AND *P. GRACILIS* POSTLARVAE CULTURED IN OYSTER BOXES AT SOUTHEAST GULF OF CALIFORNIA**

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The growth of lobsters *Panulirus inflatus* and *P. gracilis* postlarvae cultured in oyster boxes was determined using postlarvae collected in the southeast of the Gulf of California, using Sandwich-type manifolds for later stocking into growth modules (oyster boxes). Measurements of cephalothorax length (CL) and weight (TW) were performed. The best model to describe observed growth was selected using Schnute model, modified by Montgomery, to apply it to the follow-up of mean lengths by time intervals and the two types of additive and multiplicative errors, as well as the Akaike index. In addition, relationships between CL and TW were made to determine the type of growth present in collected postlarvae. Relative growth was compared with the Student-t test. In the Mazatlán Bay case 1 of the Schnute model with additive error was selected and estimated values for  $k= 5.7$  and  $E= 24.9$  mm CL were obtained for *P. inflatus*. In the growth curve, an increase of 9.5 (0.8 g) to 24.1 mm CL (12.0 g) was observed over 9 months. In the Cospita estuary the model that was most adjusted was case 2 for *P. inflatus* and *P. gracilis* postlarvae, with values of  $k= 3.4$  and  $E= 44.6$  mm and  $k= 3.8$  and  $E= 44.2$  mm CL, respectively, also showed isometric growth ( $b > 3$ ;  $p > 0.05$ ). On the other hand, both in Mazatlán Bay and in the Cospita estuary, the associated fauna available to the lobster postlarvae is composed mainly by crustaceans and mollusks. In the analyzed periphyton, the main groups found were diatoms, dinoflagellates, cyanobacteria, and crustaceans. Therefore, it can be concluded that the associated fauna, periphyton, and temperature can influence the growth of lobster postlarvae stocked in oyster boxes.



## Behavior, Neurobiology, & Behavioral Ecology

### **P3-MICROHABITAT SENSING BY THE PUERULI OF THE CARIBBEAN SPINY LOBSTER *PANULIRUS ARGUS*: TESTING THE IMPORTANCE OF RED ALGAE, JUVENILES, AND THEIR INTERACTION.**

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Although our knowledge about the early life of the Caribbean spiny lobster *Panulirus argus* has increased considerably during the last decades, little is known about chemical sensing used by pueruli during settlement. Considering previously reported benefits of inhabiting red algae *Laurencia* spp. (e.g., increased growth rate) and costs of living in close proximity to early benthic juveniles (e.g., increased mortality rate), we predicted that the settling pueruli of *P. argus* will be attracted and repulsed by metabolites produced by red algae and early benthic juveniles (EBJ), respectively. We also expected that any preference for *Laurencia* will cease if this cue was presented together with metabolites produced by conspecific given the reported costs of associating with them after settlement. Our results disagree with the expectations above. Pueruli did not display any preference or avoidance of red algae and EBJs, respectively. Unexpectedly, settling stages were attracted to water with metabolites produced by both red algae and EBJs. We also examined the influence of conspecific and red algae abundance on pueruli settlement in Florida Bay, the most important nursery ground of *P. argus* in the USA. In partial agreement with our experiments, field data indicated that juvenile lobster density had a positive influence on pueruli settlement as did a synergistic effect of juvenile lobster density and *Laurencia* algae cover. Altogether, our field and laboratory data suggest that the interplay of various environmental cues drives settlement of the Caribbean spiny lobster and is more complex than originally thought. Additional studies on the settling behavior of *P. argus* pueruli are needed to improve our understanding of the relationship between recruitment and fishery stocks in this heavily exploited species.

### **P4-VISUAL RECOGNITION OF FAMILIAR DOMINANT OPPONENTS IN THE LOBSTER, *H. AMERICANUS***

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American lobsters can recognize familiar individual opponents. Blocking olfactory information greatly reduces this ability, and suggests that it is mediated primarily by odor. However, visual cues are suspected to play an additional role. In this study, lobsters were blindfolded to test their ability to visually recognize familiar dominant opponents. After a first fight between un-manipulated, equally sized males, losing lobsters blindfolded in second fights displayed more aggression towards known dominants that control animals with normal vision, indication that animals with blocked vision had an impaired ability to recall the identity of a familiar opponent. However, the dominance relationship remained intact in most cases, suggesting that vision is coupled with olfaction in the process of individual recognition. This raises questions about which morphological traits lobsters use as visual signals.

**P5-THE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, USES VISION TO EVALUATE RELATIVE OPPONENT SIZE**

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Previous research has shown that claw size and carapace length affect the outcome of agonistic engagement in *H. americanus*, but it remains unknown how lobsters can assess size differences to reduce or avoid physical damage in a fight they are likely to lose. This study looks to determine if the American Lobster can use vision to assess its opponent's difference in crusher claw size. Until recently, the role of vision in social interactions was not critically examined because its resolution was considered insufficient in a subtidal environment. Following up on the discovery that lobsters can recognize familiar conspecifics solely with vision, we staged fights between two random lobsters of various crusher claw sizes to see at which size difference they would back off. Then in one set of fights, the lobster of larger crusher claw size was blindfolded and in a second set the lobster of smaller crusher claw size was blindfolded. We recorded (1) if the lobsters engaged with one another, (2) the latency of the losing lobster's first retreat, and (3) if the lobster with the greater crusher claw size won. Visually intact lobsters from each data set retreated at a similar range of latencies. Blindfolded smaller lobsters retreated significantly later than the blindfolded larger lobster group. There was no significant difference in retreat latency between the control group and the blindfolded larger lobster group. These results suggests that visual cues affect the retreat time of relatively smaller lobsters, causing them to fight significantly longer when blindfolded than when intact. The typical "meral spread" threat display could provide the significant size information by showing the bright yellow underside of the claws. The result suggests that lobsters can (visually) evaluate opponent size compared to its own size and that the "meral spread" signal evolved for this assessment function.

**P6-CAN AMERICAN LOBSTERS DETECT LIGHT WITHOUT THEIR EYES? EVIDENCE FOR EXTRAOCULAR PHOTORECEPTORS**

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Although there have been multiple reports of extra-ocular photoreceptors in a number of crustaceans, it is not clear if American lobsters have this ability. In order to address this question, we conducted three different experiments and all of them strongly suggest that American lobsters can detect changes in light intensity using extra-ocular photoreceptors, either located in their ventral nerve cord or distributed throughout their body. First, we painted the eyes of juvenile lobsters and then recorded their movements to determine if they could still entrain their daily activity rhythms to a light:dark cycle. In most cases, they did so, suggesting they could sense the light in some other manner. Next, we covered different body parts and used a cardiac assay to determine if they could detect a shadow passing over them. Animals with everything covered but their abdomen would still respond with a change in heart rate, suggesting the presence of photoreceptors in that area. Covering the abdomen appeared to reduce, but not eliminate, this response, raising the possibility of additional photoreceptors distributed elsewhere in or on their body. We are also testing the effect of different wavelengths of light (blue, red, white) using the same assay, to provide insight into the type of photopigment that might be involved. Finally, we used immunohistochemistry to identify about 2-8 neurons in each abdominal ganglion containing the light sensitive protein, cryptochrome. Taken together, these data suggest that American lobsters do, in fact, have the ability to sense changes in light levels with extra-ocular neurons and that these photoreceptors can influence lobster behavior.

**P7-AVOIDING DISEASED CONSPECIFICS VERSUS AVOIDING PREDATION RISK: TESTING THE TRADE-OFF HYPOTHESIS IN *PANULIRUS ARGUS***

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Caribbean spiny lobsters are known to avoid shelters harboring PaV1 (*Panulirus argus* Virus 1) diseased conspecifics, yet in locations where “casitas” (large artificial shelters) are used, cohabitation between healthy and diseased lobsters is common. Because casitas work better where natural shelters are scarce, two hypotheses (not mutually exclusive) have been raised to explain this counterintuitive finding: A) that in shelter-poor habitats, healthy lobsters make a trade-off between avoiding diseased conspecifics and avoiding predation risk, or B) that the large shelter space of casitas allow healthy and diseased lobsters to cohabitate without physical contact. To test these hypotheses, we conducted four experiments (Exp1-4) using seawater mesocosms fitted with two casitas each. Exp1: one casita empty and one harboring either a diseased (treatment) or a healthy (control) tethered conspecific; Exp2: both casitas harboring either a diseased (treatment) or a healthy (control) tethered conspecific; Exp3 and Exp4: same as Exp1 and Exp2, respectively, but with a predatory triggerfish present. We then introduced six free-ranging healthy lobsters into each tank (3 replicates per each treatment and control) and checked the casitas for lobsters after 48 H. In the absence of triggerfish, free-ranging lobsters used empty casitas and those harboring healthy conspecifics, but avoided casitas harboring diseased conspecifics, with all lobsters remaining in the open in the Exp2 treatment. In contrast, in the presence of triggerfish, lobsters used empty casitas and those harboring healthy and diseased conspecifics, with few remaining in the open in the Exp4 treatment. Thus, whether lobsters share casitas harboring diseased conspecifics depends to some degree on availability of alternative shelter and immediacy of predation risk. However, in casitas harboring diseased lobsters, snapshots taken with an underwater camera showed that free-ranging lobsters were usually in the opposite side. Therefore, the results support both the trade-off and the large shelter space hypotheses.

**P8-IF YOU CAN'T BEAT THEM, EAT THEM: THE DOCUMENTATION OF AMERICAN LOBSTER PREDATION ON THE INVASIVE EUROPEAN GREEN CRAB IN CANADA**

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The European green crab (*Carcinus maenas*) first invaded the east coast of North America in the 1800s and has been found in the diet of the American lobster (*Homarus americanus*) in some areas. Green crabs are used as bait in lobster fisheries in Nova Scotia, Canada but predation has not yet been quantified in Newfoundland, where crabs were first reported just 10 years ago. The aim of the current study was to determine if lobsters from Newfoundland would recognize and prey upon this new species, and if so did the green crabs reach a size refuge where they became too big to handle. Lobsters from Newfoundland were compared with those from Nova Scotia which have coexisted with green crabs for over 60 years. An individual juvenile (~40mm), sub-adult (40-65mm) or adult (~65mm) carapace width (CW) green crab was introduced into a tank with a single lobster. There was no significant effect of lobster origin on crab predation, and that sub-adult crabs were the favored size range. The lobsters consumed some adult crabs, but very large crabs (> 72mm CW) were injured and not eaten. The experiments were repeated adding a shelter as a potential refuge for green crabs and adding an alternative food source (fish flesh). When a shelter was added to the experimental tank lobsters consumed more, or inflicted more damage to the crabs, probably due to an increase in antagonistic interactions over acquisition of the shelter. When fish was added fewer crabs were consumed, and those that were consumed were the smaller juveniles. The present results suggest that green crabs can be an important prey item for lobsters and have the potential to be used as bait in the Newfoundland lobster fishery.

**P9-AN UPDATE TO THE ICWL BOOK OF WORLD LOBSTER RECORDS**

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At the 8th ICWL, a repository of lobster records was first established (*Lobster Newsletter*, Vol. 21(1), 2008). Approximately 30 entries were received, ranging from the culinary career award “the most species eaten in lifetime (Ehud Spanier) to “the most lobsters captured in a single trap” (Sara Ellis, 117). We also learned that Carl Wilson recaptured the same lobster 7 times, Cindy Lewis went on 210 collecting dives in one year and Peter Lawton captured a 217 mm CL male lobster while diving. A few lobsters also made the Record Books such as a 32 mm CL spiny lobster egg and an American lobster that traveled 800 km. This year our goal is to share more records with the lobster community and update the ICWL Book of Lobster Records. Please come visit this poster prepared to enjoy previous entries, share your own record(s), and perhaps get a place in the Record Book (be prepared to provide any data (graphic or otherwise) to substantiate your claim(s). If you want to get a head start, and maybe have one of your records included in the poster, send it to us.

## Climate Change

### **P10-DEVELOPMENT OF AMERICAN LOBSTER EMBRYOS EXPOSED TO OCEAN ACIDIFICATION**

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Global change drivers such as ocean acidification (OA) have been shown to impact the growth and physiology of larval and juvenile European lobster (*Homarus gammarus*) and settled American lobster (*H. americanus*). However, the effects of OA on embryonic development have not yet been studied. This is a critical knowledge gap, as shifting environmental conditions may affect embryo development rates, and subsequently impact the timing, rates and patterns of larval release, as well as larval quality, survival, dispersion and settlement. To explore the effects of OA on embryos development, thirty ovigerous female American lobster were exposed to five  $p\text{CO}_2$  levels ranging from current average atmospheric/sea-surface water conditions ( $\sim 400 \mu\text{atm}$ ) to 100-year projected conditions ( $\sim 1500 \mu\text{atm}$ ) and ambient temperatures from February 2016 until the embryos hatched (between June and August 2016). Newly hatched larvae were then transferred to ambient seawater and larval growth was measured from Stage I to Stage IV. Clutch fullness was measured prior to the onset of  $p\text{CO}_2$  exposure and near-hatch in June to assess changes in fecundity. Lipid composition of the embryos, size of the yolk, and Perkins' eye index were measured on a monthly basis in an attempt to correlate metrics of energy utilization and a developmental proxy with time of hatch. Metabolomics and lipidomics fingerprinting were also measured prior to the onset of  $p\text{CO}_2$  exposure and near-hatch in June to acquire a mechanistic understanding of the impact of OA on embryos metabolism. Results of these analyses and potential application to lobster population and fishery management will be discussed.

### **P11-EFFECTS OF REGIONAL TEMPERATURE CYCLES ON LARVAL AMERICAN LOBSTERS (*HOMARUS AMERICANUS*): IS THERE A TRADE-OFF BETWEEN GROWTH AND DEVELOPMENTAL STABILITY?**

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The American lobster (*Homarus americanus*) sustains the most economically valuable fishery in the Gulf of Maine and Atlantic Canada. Lobster biology and distribution are influenced by ocean temperature, which has increased rapidly and exhibited more frequent abrupt warming events in recent decades. Warming events are linked to mass mortality and disease in Southern New England, resulting in a dramatic population decline. There is concern that this decline may spread northeastward into the Gulf of Maine lobster population, as this region continues to warm faster than 99% of the global oceans. Here, we explore how altered seasonal temperature regimes affect the growth, survival, and development of larval lobsters. We collected egg-bearing females and reared lobsters from hatch under one of three seasonal temperature regimes corresponding to Southern New England, Southern Maine, and Northern Maine. These regimes were further broken down into four nominal temperature categories: 14, 16, 18, and 22°C. We recorded the rate of development across the three larval stages (I-III) and the postlarval stage (IV). Survival was estimated as the proportion of initially stocked larvae that successfully metamorphosed to the postlarval stage. Postlarvae were photographed, and ImageJ software was used to measure morphological differences across treatments. Finally, we assessed total hemocyte count in a subset of postlarvae across treatments. Larvae in the 18 and 22°C treatments grew significantly faster than larvae of 14 and 16°C treatments, and survival was positively correlated with temperature. All larvae exhibited some degree of asymmetry in morphology, and total hemocyte counts were significantly lower in larvae raised in the 18°C compared to all other nominal temperature categories. Together, these data suggest that warmer temperatures may facilitate faster growth in larval lobsters at the expense of developmental stability.

**P12-SETTLEMENT AND RECRUITMENT IN THE SOUTHERN ROCK LOBSTER, *JASUS EDWARDSII*: THE INFLUENCE OF OCEANOGRAPHIC FEATURES AND PUERULI BEHAVIOR IN A CLIMATE CHANGE SCENARIO**

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Understanding settlement and recruitment may assist management and conservation of economically important species. The rock lobster, *Jasus edwardsii*, supports valuable fisheries in Australia and New Zealand. Settlement levels of pueruli have been monitored on artificial collectors with a long-term program in both countries. Patterns in settlement at some sites appear to be driven by environmental processes. However, a lack of correlation with environmental variables at other sites and the strong swimming ability of the pueruli, suggested that settlement may be influenced by the pueruli's ability to orient onshore in combination with other environmental processes. However, no behavioral experiments have been reported on pueruli of this species, nor have broad scale settlement data analysis been conducted. Also, climate-change has led to loss of kelp habitats in some regions raising the concern of this change. Here we used a combination of broad scale data analyses, and laboratory and field experiments to assess the influence of environmental variables and puerulus behavior on settlement and post-settlement survival. Settlement was found to be affected by regional scale oceanic processes measured by the SOI, DMI, and SAM, although outcomes varied among regions. At a local scale, waves, wind, and current have some influence on settlement, with SST being less important, but these trends were not consistent among sites. Experiments showed that pueruli were attracted to chemical cues from coastal waters. Underwater reef noise attracted pueruli during calm seas. Kelp habitats increased settlement and survival. These results highlight the complexity of settlement and survival where larval behavior and oceanographic process interact at different scales. Overall, environmental conditions that reduce settlement strength in one region often increase settlement in other suggesting resilience to climate change at the scale of the entire fishery. However, local habitat changes are expected to affect future recruitment at a local scale.



### **P13-DEVELOPMENT AND HIERARCHICAL ARCHITECTURE OF CALCIUM CARBONATE STORAGE STRUCTURES (GASTROLITHS) IN AMERICAN LOBSTER**

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The complete renewal of the exoskeleton (cuticle) in a hormonally regulated molting cycle is essential for the growth and survival of arthropods. Most crustaceans harden this exoskeleton by calcification, mainly with CaCO<sub>3</sub>. Different groups (amphipods, isopods and decapods) develop distinct strategies to store calcium ions and to make them instantly available to start the process of calcification after molting. For example, crayfish, lobsters, and land crabs form unique carbonate structures called gastroliths in the cardiac stomach walls during premolt. Although various mineralogical, structural, and chemical aspects of gastroliths were documented in crayfish and land crabs, detailed information about the lobster gastroliths is still missing. Herein, using X-ray microcomputed tomography, we show that in contrast to crayfish compact gastroliths, the mature gastroliths of American lobster (*Homarus americanus*) have composite, columnar organization. Individual columnar units (few millimeters long) show ca. 3 μm fine-scale increment bands suggesting sub-daily calcification activity, taken that the examined gastroliths developed within less than two months (ultrasound imaging documentation). The mineral bands are composed of amorphous calcium carbonate (ACC), which after gastrolith dissection often transform into calcite. Both ACC and secondary calcite have nanocomposite organization (Raman spectroscopy and FE-SEM analyses, respectively) consistent with crayfish gastroliths. In a preliminary experiment, effects of seawater acidification (pH 7.2 vs. 8.1 in control) were assessed on gastrolith development: only in normal pH conditions, cultured lobsters developed mature gastroliths, whereas none were fully formed in animals cultured in acidified conditions. Assuming that similar shifts in timing of gastrolith formation may result from the worst-case scenario for anthropogenic ocean acidification, the lobster molting cycle, and consequently the lobster survival might be threatened.

### **P14-THE POTENTIAL EFFECTS OF ACIDIFIED SEAWATER ON AMERICAN LOBSTER CHEMOSENSORY-MEDIATED BEHAVIORS**

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Ocean and coastal acidification (OCA) changes the carbonate chemistry of seawater, leading to a decreased pH, and is a measureable trend that has been increasing in recent years. While OCA has been shown to have an influence on several different aspects of crustacean physiology, and development the goal of this study was to determine if, and how, OCA might affect chemosensory-mediated behaviors in American lobsters. In the first experiment we measured the time it took for juvenile lobsters (45-60 mm CL) to find bait in a modified Y-maze, both in ambient seawater and in seawater with a reduced pH (produced by bubbling carbon dioxide). Reducing the pH (~7.4) did not have an impact on the movements of lobsters but, after bait was added, it took these animals significantly more time to move into the area containing the bait than when they were in ambient seawater (pH= ~8.1). These findings suggest that OCA might alter the way odorants interact with lobster olfactory receptors. To address this hypothesis we recorded the responses of chemoreceptors on lobster claws to a variety of substances in both normal and low pH saline. We found that lowering the pH reduced the responses to several potential odorants, such as hydroxyproline. These data, taken together, indicate that OCA may have a pronounced impact on lobster behaviors that rely on their chemosensory system, such as foraging for food and mating.

**P15-MECHANISTIC UNDERSTANDING OF CLIMATE DRIVEN RANGE SHIFTS: USING THERMAL TOLERANCES OF ROCK LOBSTER TO PREDICT FUTURE RANGE SHIFTS**

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Ocean warming is affecting marine species worldwide, with one of the most observed changes being alterations to species geographical distributions. Understanding what drives these range shifts is key to predicting what may happen with future warming. This study takes a mechanistic approach to understanding climate-driven range shifts, looking at the metabolic and escape responses of spiny rock lobster and how they may change under different temperature scenarios. We examined the metabolic physiology and escape response of the puerulus and juvenile stages of *Jasus edwardsii*, a common Tasmanian species of spiny rock lobster, and *Sagmariasus verreauxi*, a species of spiny rock lobster extending its range into and further south in Tasmania. The puerulus stage of the spiny rock lobster life cycle is an important transitional stage between the larval and juvenile stages and understanding how ocean warming may affect its aerobic and swimming capacity allows us to better predict future scenarios of population dynamics. *Jasus edwardsii* individuals of both life stages were tested at 16, 18, 20, 22, 24, and 26 °C, and *S. verreauxi* individuals were tested at 22, 24, 26, 28 and 30 °C. Intermittent flow respirometry was used to determine aerobic scope (AS), excess post-exercise oxygen consumption (EPOC), and recovery times. Escape velocities were determined from high speed stereo-video footage. The comparison between the physiologies of the two species indicates that *S. verreauxi* has higher thermal tolerances than *J. edwardsii*, and this may facilitate further expansion of this range-shifting species into Tasmanian waters with future ocean warming.

## Diseases and Parasites

### **P16-DEVELOPMENT OF RAPID DIAGNOSTIC TECHNIQUES FOR IDIOPATHIC BLINDNESS IN THE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, FROM EASTERN LONG ISLAND SOUND**

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Idiopathic blindness is a condition with an unknown etiology that afflicts ~50% of the lobsters in Long Island Sound (LIS). The condition has been described from LIS and Narragansett Bay, but not from Maine. Grossly, the condition presents as patches of cloudy grey-colored regions in the eyes of afflicted animals.

Histologically, the ommatidia (the complex of photoreceptors and optic nerve fibers) show signs of altered pigment distribution, necrosis of the optic nerves and rhabdoms, and hemocyte infiltration through the protective basement membrane. Severe lesions show areas with no remaining ommatidia, and nearly complete loss of associated optic nerves. The purpose of this study is to assess a rapid, non-destructive, diagnostic technique for assessing blindness in lobsters. We compared the use of an otolaryngoscope (o-scope) with stereomicroscopy on live, frozen, and histologically fixed eyes. Live lobsters from Narragansett Bay, RI, and off southern MA were assessed with the o-scope and categorized as having zero, light, moderate, or severe blindness. Right eyes were analyzed via standard histological procedures. Left eyes were frozen and stored at -80 °C and then later thawed and reassessed for blindness. Comparisons among the methods were made using correlation and regression analysis. In addition, we examined inter-observer variance in the use of the o-scope among staff and fishermen. Initial results indicate that the etiological agent of idiopathic blindness is present throughout a large portion of the Sound, and that lobsters are probably continually exposed to it. The results of these investigations will help us better understand the prevalence and distribution of idiopathic blindness in lobsters. [We thank Lanny Dellinger and Al Eagles for lobsters from RI, and Aaron Cebula and Mike Trainor for eyes from lobsters from southern MA.]

### **P17-IMPACT OF THE ABSENCE OF GAFFKEMIA ON LOBSTER HARVEST IN MAINE**

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Lobster landings in Maine have increased from roughly twenty million pounds for the 50 years prior to 1990, at which time the catch began to increase exponentially. Landings reached over 121 million pounds in 2015 (with a record high 127 million pounds in 2012). Some theorize the increase can be explained, in part, by the absence of the major ground fish predators that have been overfished. Others point to warming in the Gulf of Maine as a contributing factor. This study discusses a factor that has not previously been considered, but is likely contributing to the increased lobster abundance. Until the early 1990's, Gaffkemia, a fatal bacterial disease caused by *Aerococcus viridans* var. *homari*, was endemic in the lobster population. Since the mid-1990's, there have been no documented outbreaks of this fatal pathogen. Our project models the influence of the absence of Gaffkemia on lobster fisheries. We are working with Stella Architect software to model Maine's lobster fishing in zone D. The inputs to the model include harvest data and bottom water temperature. Lobsters that would have died of Gaffkemia survive and accumulate, adding to the breeding and harvestable population. We compare the model's results based on parameters that reflect the absence or presence of Gaffkemia in order to estimate the potential significance of this effect.

**P18-CHARACTERISTICS OF RECENT INCREASES OF EPIZOOTIC SHELL DISEASE IN THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) FOR THE INSHORE GULF OF MAINE**

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The epizootic shell disease (ESD) that has persisted in southern New England since the mid-nineties appears to be increasing with higher incidences observed in recent years in the Gulf of Maine. The Maine Department of Marine Resources Sea Sampling Program has been monitoring for shell disease since 2003 in the commercial catch. Until 2010, the observed levels of ESD were consistently below 0.1 percent of the sampled catch but then peaked in 2013 at 2.25% in certain areas. We explore the spatial and biological characteristics of the affected catch in the Gulf of Maine.

**P19-MOLECULAR AND ULTRASTRUCTURAL CHARACTERIZATION OF A MICROSPORIDIAN PARASITE INFECTING THE CARIBBEAN SPINY LOBSTER *PANULIRUS ARGUS* FROM FLORIDA**

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The Caribbean spiny lobster (*Panulirus argus*) supports the most economically valuable fishery in the Caribbean. Previous studies have documented the discovery of a rare microsporidian parasite infecting two spiny lobsters from southeast Florida. Histopathology and limited transmission electron microscopy revealed spore characteristics that were consistent with the genus *Ameson*, whose members are known to infect marine crustaceans. However, the parasite was never identified to species level. In 2014, an additional spiny lobster from southeast Florida (Key Largo) displaying abdominal muscle tissues with an apparent 'cooked' appearance was discovered. This lobster was confirmed to have an advanced infection of ovoid-shaped microsporidian spores (~ 1.6 × 1.1 μm in size) within the host muscle cell cytoplasm. Transmission electron microscopy revealed multiple life stages of a monokaryotic microsporidian closely resembling the previously identified specimens. Mature ovoid spores were observed to have 7-8 turns of a polar filament arranged mainly in one rank but occasionally in two. Molecular analysis of partial SSU rRNA sequence data from the 2014 sample and from one of the earlier cases showed that both sequences were identical and indicated a close affiliation with other *Ameson* species, placing the parasite from the spiny lobster in a clade with *Ameson michaelis*, *Ameson pulvis* and *Nadelspora canceri*.

**P20-A STATISTICAL MODEL FOR MONITORING SHELL DISEASE IN INSHORE LOBSTER FISHERIES: A CASE STUDY IN LONG ISLAND SOUND**

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The American lobster (*Homarus americanus*) fishery is being threatened by the expansion of shell disease. Species Distribution Models (SDMs) designed to improve the efficiency and precision of monitoring programs have been advocated as an important tool in mitigating the harmful effects of the disease. The objective of this study was to develop a SDM to enhance existing shell disease monitoring efforts in the US lobster fishery that could (1) identify potential disease-associated biotic and abiotic factors, and (2) estimate the spatial variation in shell disease prevalence. In this case study, a delta-generalized additive modeling (GAM) approach was applied to existing bottom trawl survey data collected from 2001-2013 in Long Island Sound. The spatial distribution of shell disease prevalence was strongly influenced by interactive effects of latitude and longitude, supporting previous work that suggested a geographic origin of the disease in eastern Long Island Sound. Bottom salinity, bottom temperature, and depth were also influential factors in determining the spatial variability of shell disease prevalence. The delta-GAM projected high disease prevalence in locations with low sampling efforts. Moreover, a spatial discrepancy was found between modeled disease hotspots and survey-based disease gravity centers. This research provides a modeling frame that can be applied to more effectively monitor the spatial extent and spread of shell disease into the future.

## Environmental Stressors

### **P21-AN ASSESSMENT OF STRESS AND POST RELEASE MORTALITY IN ATLANTIC COD (*GADUS MORHUA*) CAPTURED IN THE COMMERCIAL LOBSTER FISHERY**

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Atlantic cod (*Gadus morhua*) populations, once one of the most important commercial species in the Gulf of Maine (GOM), have been decimated by overfishing in our recent history. In order to restore these populations we must consider all of the ecological, environmental, and anthropogenic influences that have an impact on their populations. This study focuses on the stress associated with capture in lobster gear and how it relates to subsequent mortality of cod. Sampling trips with a commercial lobster fisherman from Cape Porpoise, ME were taken beginning in the summer of 2016. One mL of blood was drawn from each of the 11 cod that were captured in lobster gear. The secondary blood stress parameters glucose, hemoglobin, lactate, and hematocrit were tested on board the fishing vessel. Mean values for these parameters were  $42.8 \pm 20.9$  mg dL<sup>-1</sup>,  $1.265 \pm 0.41$  mmol l<sup>-1</sup>,  $6.145 \pm 0.53$  g/dL, and  $30\% \pm 4.15\%$  respectively. When compared to baseline values from other studies, results herein revealed that cod were relatively non-stressed. Throughout the spring of 2017, I will also be using blood radioimmunoassay to determine concentrations of cortisol, a primary indicator of stress, which will then be compared to secondary blood parameters to establish relationships between stress and mortality. Sampling will continue throughout the summer of 2017 to increase sample size to further quantify the effects of capture in lobster trap gear.

### **P22-THE EFFECT OF CASITAS ON *PANULIRUS ARGUS* MORTALITY, GROWTH, AND SUSCEPTIBILITY TO DISEASE IN THE BAHAMAS**

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The fishery for *Panulirus argus* in The Bahamas - which is the largest in the Caribbean - was historically trap-based, but in the 1990s casitas surpassed traps as the primary type of fishing gear. Yet, casitas are unregulated in The Bahamas (i.e., neither permitted or banned) and their effects on fishery sustainability are unknown. Concerns about whether overcrowding of lobsters within casitas detrimentally alters lobster growth, disease, or mortality prompted our study in which we compared these attributes in lobsters within traps versus casitas. Tethering and videography were used to compare lobster mortality and predation risk at casitas and in the natural environment. We also compared the nutritional condition, growth, injury, and prevalence of disease in lobsters within casitas and traps. We found no difference in predation on subadult and adult lobsters in casitas compared to natural areas, although predators were far more abundant near casitas. Lobsters in casitas were in better health than those in traps, with higher blood protein indices and lower prevalence of shell disease; the PaV1 virus was absent in our samples. Starvation experiments in which lobsters were held in traps for time periods similar to those when traps were left underwater during the closed season, revealed significant health problems after three weeks, with dire health afflictions after 6-12 weeks. In summary, we found no evidence that casitas negatively affect subadult and adult *P. argus* in The Bahamas, but our study revealed that traps pose a risk to the fishery if not properly managed.



**P23-INTERACTIVE EFFECTS OF pCO<sub>2</sub> AND TEMPERATURE ON THE PHYSIOLOGY, BEHAVIOR, AND SURVIVAL OF EARLY LIFE STAGE HOMARUS AMERICANUS: COMPARING SUBPOPULATIONS OF NEW ENGLAND**

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Anthropogenic carbon released into the atmosphere has led to the warming and acidification of the world's oceans, most prominently in the northern latitudes, and including the Northwest Atlantic. This phenomenon will have important implications for commercial fisheries within the region. As an important species culturally, economically, and ecologically, the American Lobster (*Homarus americanus*) is one of the many valuable species that is exhibiting a northward range shift as a result of changing ocean conditions. Understanding the interactive effects of ocean warming and acidification on this species' most vulnerable early life stages is important to predict its response to climate change on a stage-specific and population level. Our study will be the first to compare the responses of lobster larvae to the joint effects of elevated pCO<sub>2</sub> and temperature across three sub-populations spanning New England's steep north-south temperature gradient (Rhode Island, Midcoast Maine, and Eastern Maine, USA). Using a common garden experimental design, we will subject pre-settlement larval and post-larval stages to different combinations of ambient, end-century projected, and extreme pCO<sub>2</sub> concentrations (400 ppm, 750 ppm, 1200 ppm), as well as ambient and projected end-century temperatures (16°C and 19°C). We will measure important components of larval performance including survival, growth, oxygen consumption, carbon-to-nitrogen ratio, swimming speed, feeding behavior, and gene expression.

**P24-EFFECTS OF THE ORGANOPHOSPHATE CHLORPYRIFOS ON SURVIVAL OF THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*)**

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American lobster (*Homarus americanus*) harvests from the Northumberland Strait within the southern Gulf of St. Lawrence, Canada, have been in decline since the 1990s. Larval lobster life-stages exist in the pelagic zone of the Northumberland Strait and are therefore vulnerable to agricultural runoff of pesticides. The organophosphate chlorpyrifos, a pesticide that targets arthropod pest insects, has been shown to affect the survival of some larval decapod crustaceans, yet no data exists on the impacts to *H. americanus*. Using 48-hour acute exposures, with concentrations ranging from 0.03 – 2.01 µg/L, the 48 hr median lethal concentration of chlorpyrifos was established to be 1.56 ± 0.50 µg/L for stage IV American lobster. During sublethal exposures, biological parameters such as intermolt period, specific growth rate, molt increment, and gene expression were also measured. General linear model analysis ( $\alpha = 0.05$ ) determined that intermolt period was significantly increased and both specific growth rate and molt increment were significantly decreased in the 0.82 µg/L chlorpyrifos treatment when compared to the control treatment (0.03 µg/L chlorpyrifos). RNA sequencing was performed using Illumina HiSeq 4000 PE100 and subsequent confirmation of expression of genes of interest was performed via RT-qPCR. In the current study, gene expression was used to determine pathways being affected by sublethal chlorpyrifos exposures. Unique patterns of gene induction may serve as a potential diagnostic tool to further examine the impacts of pesticides on lobster.

**P25-EFFECTS OF THE ORGANOPHOSPHATE AQUACULTURE PESTICIDE AZAMETHIPHOS ON STAGE I AND STAGE IV AMERICAN LOBSTER (*HOMARUS AMERICANUS*) LARVAE**

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Salmon aquaculture and the American lobster (*Homarus americanus*) industry are two economically important industries in Atlantic Canada. Both industries exist in the marine ecosystem and have potential to interact. Salmosan® (active ingredient azamethiphos) is an organophosphate aquaculture pesticide used to treat Atlantic salmon for infestations of parasitic sea lice (*Lepeophtheirus salmonis*). Crustaceans such as the American lobster have been shown to have a low tolerance to contaminants when compared to other aquatic organisms. Salmosan® is known to be lethal to adult lobster at relatively low concentrations (100 µg/l) and few studies have been carried out on the pesticide's effects on the health of larval lobsters. Three hour exposures using stage I and IV *H. americanus* larvae were carried out using a range of azamethiphos (as Salmosan®) concentrations between 0.04 – 71.11 µg/L. Median lethal concentrations at 3 hours were determined to be  $5.87 \pm 2.01$  µg/L for stage I and  $20.45 \pm 12.77$  µg/L for stage IV. Post-exposure, surviving stage IV larvae were raised to stage V and sublethal parameters including intermolt period, specific growth rate, molt increment, and global gene expression were determined. General linear model analysis ( $\alpha = 0.05$ ) determined that intermolt period was significantly increased in the 13.00 µg/L azamethiphos treatment when compared to the control (<0.05 µg/L azamethiphos). Molt increment and specific growth rate were not significantly affected. RNA sequencing was performed using Illumina Hiseq 2500 PE125 and subsequent RT-qPCR was performed to confirm expression of genes of interest. Gene expression was used to establish effects on biological pathways of *H. americanus* in order to determine unique gene induction patterns. Established gene induction patterns may be used as a potential diagnostic tool for pesticide exposure in lobster.

## Fisheries Management

### **P26-NORTHEAST FISHERIES OBSERVER PROGRAM: OBSERVER COVERAGE, DATA COLLECTION AND BIOLOGICAL SAMPLING OF THE AMERICAN LOBSTER FISHERY, AN OVERVIEW 2012-2016**

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All federally permitted vessels required to file federal vessel trip reports (VTRs) are eligible to carry an observer certified by the National Marine Fisheries Service (NMFS), as a condition of the permit. The federally permitted lobster fleet in the Northeast and Mid-Atlantic is unique among other federal fisheries as the majority of the fleet are not required to submit VTRs. As a result, observer coverage is directed toward federally permitted vessels that submit VTRs and report fishing lobster gear. The NMFS, along with state and regional partners, are working to modify the Standardized Bycatch Reporting Methodology (SBRM) omnibus amendment in order to provide more equitable coverage of the lobster fleet. The SBRM describes the methods and processes used to monitor bycatch for all fishery management plans as required by the Magnuson-Stevens Fishery Conservation and Management Act. Potential changes will include expansion of the sampling frame to include all federally permitted lobster vessels. Once amended, the NEFOP will be assigned seadays consistent with the SBRM process and data will be collected that further represent the fleet. The observer program collects an extensive suite of biological, gear, and other fishery dependent data during inshore and offshore lobster trips. These data are used by scientists and managers at NMFS, the Atlantic States Marine Fisheries Commission (ASMFC), industry members, and others. Biological sampling protocols are regularly updated based on feedback from industry members, observers, scientists, and managers to better match their data needs and the realities of working on a lobster vessel. Since 2012, the NEFOP has observed over 450 lobster trips and collected biological sampling data from over 300,000 lobsters and crabs in addition to important information for stock assessment and management purposes.

### **P27-SETTLEMENT INDICES AS PREDICTORS OF COMMERCIAL CATCHES OF THE EUROPEAN SPINY LOBSTER *PALINURUS ELEPHAS* IN THE NORTHWESTERN MEDITERRANEAN SEA**

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Predictions of the size of the commercial catch based on settlement magnitudes have proven valuable in stock assessment and adaptive management of spiny lobsters all over the world. This study assesses the relationship between settlement strength (post-*pueruli* density) and recruitment strength (catch per unit effort of lobsters at first harvest) of the European spiny lobster *Palinurus elephas* in exploited fishing grounds from the Northwestern Mediterranean. Over the last 18 years, post-*puerulus* settlement has been monitored by scuba-diving in several locations of three NW Mediterranean regions. Recruitment strength data were obtained over the last 15 years from onboard sampling of commercial catches in the Balearic Islands lobster fishing fleet (Majorca and Menorca) and in the fleet operating in the Columbretes Islands fishing grounds (NW Mediterranean). Regression analyses were performed on the series of mean annual settlement and recruitment indices. Several delay periods between the series were tested to find the best-fit, and a highly significant correlation was found when using a 3-year time-lag (settlement index and catch of 3-year-old individuals). The results confirm that post-*puerulus* monitoring may be used as a robust indicator of recruitment strength and, hence, of future fishery performance. Therefore, settlement indices offer a valuable tool for the proactive management of this valuable but dwindling resource in the study area. An interesting next objective would be to expand this study to other regions in both the Mediterranean and Atlantic where decades ago *P. elephas* supported highly valuable fisheries. In the short term, our objective is to convince local fishery managers to adopt the European spiny lobster settlement index as a key tool for managing the fisheries for the future.

## P28-EVALUATION OF *HOMARUS GAMMARUS* CATCHES AND POTENTIAL IN A MEDITERRANEAN SMALL-SCALE FISHERY

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The European lobster fishery is important for the fishing communities throughout its range. In the Mediterranean, *Homarus gammarus* (Linnaeus, 1758) is not targeted and is rather a by-catch from trammel net targeting the common spiny lobster. Given the equivalent high commercial value, it is nevertheless potentially interesting in order to diversify crustacean-fishing activities. In Corsica island (France, NW Mediterranean), the overall fleet is artisanal and fully representative of the Mediterranean small-scale fisheries. The aim of this study was to have a better understanding of the exploitation pattern and to obtain the first ecological information about the European lobster population around Corsica. We analyzed: (1) total annual production in the island; (2) size distribution; (3) the catch per unit of effort (CPUE); and (4) the potential abundance. Data were collected by scientific observers on-board fishing vessels for 8 consecutive years from 2006 until 2013, during a net monitoring program. Total annual catches were estimated to 6.7 tonnes, representing about 1.2% of total captures at the national level. Length frequencies indicated that exploitation focused on large individuals: 93% of lobsters sampled were beyond the MLS. CPUE varied significantly as a function of month, strata, and depth. Our spatial approach revealed a heterogeneous catch distribution and identified important catches in the south area, which could be due to locally more suitable habitats for adults coupled with important larval pool coming from the Bonifacio Strait Natural Reserve. A fishery independent survey was performed over 2013 and 2014 in West Cap Corse using a lobster specific trap; it displayed an extremely low catch rate, which confirmed the low abundance for this area. Such results showing an overall relatively low abundance (compared to the south) coupled with life history traits characteristics of the species highlight the low potential of *Homarus gammarus* as a targeted species for fisheries development.

## P29-THE CHALLENGES OF THE MSC CERTIFICATION: A CASE STUDY USING A LOBSTER SMALL-SCALE FISHERY

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The Marine Stewardship Council (MSC) certification is a market-based instrument recognizing sustainable fishing practices through a public, third-party assessment. MSC standards evaluate: (1) the target species, (2) the ecosystem impact of the fishery, and (3) the management system. The Mexican spiny lobster (*Panulirus argus* Latreille, 1804) small-scale fishery was MSC-certified in 2012. The annual catch is estimated at 280 t and its main market is domestic. Using a questionnaire survey among fishermen and in-depth, semi-structured interviews with fishery leaders, the study assesses socioeconomic issues, technical barriers, and perceptions regarding MSC certification. Increasing market-share was a main motivation to pursue certification. From the surveyed fishermen, a majority of the households were dependent on at least half of their monthly income from the fishery. Fishermen are organized into six cooperatives that have spatial property rights and self-management ability driven by strong social cohesion. Technical barriers involved: (1) lack of scientific-based information on specific issues (i.e., stock assessment and ecosystem structure); (2) absence of a formalized harvest strategy including harvest control rules; (3) high costs associated with certification; and (4) lack of long-term agreements with management bodies to meet certification conditions. MSC certification was negatively perceived by most fishermen since it may not offer economic incentives for the fishery, but it may increase management costs. However, certification may be a diagnostic tool to identify the improvements required to move the fishery toward better performance.

**P30-DIRECTLY AGEING THE CARIBBEAN SPINY LOBSTER, *PANULIRUS ARGUS*, USING THE GASTRIC MILL**

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Robust fisheries management of crustaceans has been hampered in part by our inability to directly age individuals. Like other crustaceans, lobsters grow through a process of ecdysis long believed to result in the loss and replacement of all calcified structures. As such, conventional ageing methods were thought to be inapplicable. However, Kilada et al. 2012 demonstrated that age could be accurately estimated in four temperate decapods by counting bands deposited in the eyestalk and ossicles of the gastric mill. The technique has since been applied to a few other crustaceans, but no tropical species. In the Caribbean, the tropical spiny lobster *Panulirus argus* supports one of the region's largest and most economically valuable fisheries whose management would benefit if the age and size of individuals could be differentiated. Here we present the results of an ongoing study to verify use of the gastric mill and eyestalks to directly age *P. argus*. We have discovered clearly distinguishable bands in the mesocardiac and zygotic ossicles of the gastric mill that differ logically between animals of different sizes and known age. Lobsters tagged with calcein retain these tags through several molts and we are using marked bands in the gastric mill to validate band counts. In an ongoing experiment, we are also testing whether the deposition of bands is influenced by the frequency of ecdysis or temperature, or is simply a function of chronological age. Thus far, the results have been promising and suggest that a direct method for ageing *P. argus* could well be possible in the near future.

**P31-USING DEGREE DAYS TO DEFINE YOUNG-OF-YEAR STATUS IN THE AMERICAN LOBSTER SETTLEMENT INDEX**

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The American Lobster Settlement Index (ALSI) began in 1989 in midcoast Maine. Since then this survey has expanded to include more than 100 sites from Rhode Island to Newfoundland. Utilizing diver suction sampling and vessel deployed collectors the ALSI is currently the only survey looking at the initial benthic life stage of lobsters. A primary goal of the ALSI collaborative is to create a predictive model of future lobster recruitment to the fishery based on the relative strength of the settlement signal. The first step in determining the annual settlement signal is assigning sampled lobsters to a year class based on carapace length. This is done by looking at the upper size limit of the first mode in the size frequency histograms. Changing water temperatures and variations in sampling dates may confound the definitions of Young-of-the-Year (YOY) annually and regionally. For example, should some portion of the next mode be included in the size definition because a particular sample site was bathed in warmer water for a longer period of time? In order to standardize these different thermal regimes and determine potentially longer development times, we will calculate the number of degree days up until the time of sampling by individual site for the Maine subset of the broader index and make more targeted size definitions. Impacts of this method on defining YOY will be evaluated and presented for possible use in the ALSI collaborative.

## Gene Expression

### P32-NUCLEAR RECEPTOR INTERACTIONS AND THEIR ROLE IN CRUSTACEAN MOLTING AND METAMORPHOSIS

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Molting and metamorphosis are critical processes in arthropod development that often hamper crustacean aquaculture endeavors. Exposing the endocrine pathways leading to these events could resolve challenges encountered in larval culture. Solutions for commercially viable aquaculture of spiny lobsters have long been pursued due to their persistently unmet market demand and limited fishery. Recent advancement has successfully closed the lifecycle in three commercially relevant species in Australia. The elongated, well-defined progression towards metamorphosis presents spiny lobsters as a great model for studying molting and metamorphosis. It is known that ecdysone release triggers a molt, while metamorphosis is inhibited by the juvenile hormone. However, the molecular mechanism which links these two hormones remains obscure. What is known is that both hormones act through nuclear receptors that function as ligand-induced transcription factors. Interactions between nuclear receptors modulate their DNA-binding response, resulting in a multitude of transcriptional outcomes from relatively few inputs. By taking advantage of spiny lobsters as biological models, we have produced a transcriptome that spans metamorphic events and has led to hypotheses of receptor interactions. We present a prospective series of *in vitro* experiments that are aimed at unwinding the interplay between key nuclear receptors central to the ecdysone response and the role they play in this fundamental regulatory pathway. The great variability and adaptive potential of nuclear receptor interactions makes it a likely candidate for integration of ecdysone and juvenile hormone pathways, and could thus form a master key to manipulate metamorphosis.

### P33-IMPACT OF WATER TEMPERATURE ON *HOMARUS AMERICANUS* GENE EXPRESSION

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The American lobster, *Homarus americanus*, inhabits almost the entirety of the North Atlantic East coast and is adapted to water temperatures that range between 0 °C to 20 °C. With increasing concerns for the impact of changing water temperatures, a controlled laboratory study was designed to begin to explore the impacts of temperature on gene expression. The present study used a lobster-specific oligonucleotide microarray containing 14 592 genes to examine the transcriptomic profiles of *H. americanus* held at four different water temperatures 10 °C, 15 °C, 17.5 °C, and 20 °C. One-way ANOVA analysis (with  $\alpha = 0.01$  and the proportion of false significant genes  $< 0.05$ ) identified 789 significantly differentially expressed genes. Hierarchical clustering of the significant genes revealed distinct transcriptomic profiles between *H. americanus* held at each temperature. Of the significantly differentially expressed genes only 46% were annotated; gene ontology analysis however revealed that temperature had significant effects on gene expression in a number processes including development, immunity and metabolism. Ubiquitin and DEAD box ATP-dependent RNA helicase showed increased expression with increasing temperature, whereas cathepsin A isoform B decreased in expression with increasing temperature. Several ribosomal proteins (S13, S3, L39) were also significantly differentially expressed. Microarray results were verified using RT-qPCR on a select number of genes. Results from this study begin to characterize how temperature influences *H. americanus* on a broad molecular level.



## Functional Morphology

### P34-LANDMARK ANALYSIS OF AMERICAN LOBSTER SHAPE IN THE GULF OF MAINE

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The American Lobster carapace shape is studied in 3-dimensions by Geometric Morphometrics. A Microscribe G2X 3D digitizer collects homologous landmarks recognizable in all specimens, chosen from suture convergences and muscle attachments on the carapace. Offshore sampling of lobster populations were made aboard NOAA Ship *H.B. Bigelow* cruise legs on Northeast Bottom Trawl Surveys and digitized at sea. Inshore population samples were obtained from day-trip lobster boats and digitized on land. Collected landmark coordinates were analyzed using the R Geomorph library as well as custom written R-scripts. Shape was found to vary depending on size, sex, and population location in the Gulf of Maine and Georges Bank. The multivariate matrix of aligned carapace landmarks were analyzed by multivariate ANOVA and fractions of the total shape variability were explained by quantitative covariates such as size and discrete factors such as sex and population membership. A relationship tree connects populations and sexes in a smooth manner.

### P35-DESCRIPTION OF THE SETAE ON THE PEREIOPODS OF SCYLLARID LOBSTERS, *SCYLLARIDES AEQUINOCTIALIS*, *S. LATUS*, AND *S. NODIFER*, WITH OBSERVATIONS ON THE FEEDING SEQUENCE DURING CONSUMPTION OF BIVALVES AND GASTROPODS

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The morphological and behavioral aspects of slipper lobster feeding have remained largely unexplored. Using Scanning Electron Microscopy (SEM), the gross morphological structure of all segments of the pereopods were described for three species of scyllarid lobsters: *Scyllarides aequinoctialis*, *S. latus*, and *S. nodifer*. Five types of setae within three broad categories were found: simple (long and miniature), cuspidate (robust and conate), and teazel (a type of serrulate setae). Setae were arranged in a highly organized, row-like pattern on the ventral and dorsal surfaces. Cuspidate setae were found on all surfaces of all segments. Simple setae were found only on the dactyl, whereas teazel setae were concentrated on the lateral-most edge of the alate carina on the merus in *S. aequinoctialis* only. Comparisons among species demonstrate that *S. nodifer* bears the same setae and setal pattern as *S. latus*, but *S. aequinoctialis* differs. The setal patterns of slipper lobsters contrast with those of nephropid and palinurid lobsters, likely due to the more rigorous use of the pereopods in accessing their food. Feeding sequences of *S. aequinoctialis* on bivalves were videotaped, analyzed as Markovian chains, and showed a complex suite of behaviors involving contact chemoreception by the antennules as part of an initial assessment of food items, followed by mouthpart and leg probing, and eventual wedging behavior as previously described for *S. squammosus*. Feeding sequences of *S. latus* on gastropods and bivalves also demonstrate extensive use of the pereopods (instead of the mouthparts) first to pry these prey items from the substrate and then to remove the foot. Use of antennules for food assessment and recruitment of many of the pereopods for food handling with minimal use of mouthparts also contrasts with the feeding sequences typical of nephropid and palinurid lobsters and may be an important adaptation.

**P36-THE SLIPPER LOBSTER, *SCYLLARIDES LATUS*, USES APATITE AND FLUORAPATITE TO PROTECT ITS SENSORY ORGANULES**Kari L. Lavalli<sup>1</sup> ([klavalli@bu.edu](mailto:klavalli@bu.edu)), Joseph G. Kunkel<sup>2</sup>, Ehud Spanier<sup>3</sup><sup>1</sup>*Boston University, College of General Studies, Boston, MA*, <sup>2</sup>*Biology Department, University of Massachusetts, Amherst, MA and Center for Land Sea Interaction, Marine Science Center, University of New England, Biddeford, ME*, <sup>3</sup>*The Leon Recanati Institute for Maritime Studies & Department of Maritime Civilizations, The Leon H. Charney School for Marine Sciences, University of Haifa, Haifa, ISRAEL*

The cuticle of arthropods has been intensely studied not only to better understand the properties of a natural composite material, but also to understand how structural properties and mineral contributions to this composite offer a durable protective covering from predator and microbial attack. Thus far, most marine cuticular studies have focused on the American lobster, *Homarus americanus*, or several crab species, but have largely ignored other types of lobsters, such as spiny or slipper lobsters that have exoskeletons differing in both structural properties (i.e., amount of trabeculae present in pits and spines) and resistance to structural failure. Using an electron microprobe, we analyzed various segments of the exoskeleton of the Mediterranean slipper lobster, *Scyllarides latus*, to determine the mineral content in discrete domains of cuticle. EMP analysis determined that the cuticle of *S. latus* is similar to that of *H. americanus* in that it contains carbonate apatite in canal linings and in the areas surrounding sensory organules (setae). The slipper lobster also uses a fluorapatite mineral that further adds strength to the shell. Results will be discussed in the context of what this means for defense against attack and differences in environmental water chemistry and resilience to climate change.

**P37-LOBSTER'S LIVING BIOTOPE, MORPHOLOGY AND BEHAVIOR: CAN THESE CONNECTIONS BE USED TO LEARN MORE ABOUT REALLY CONCEALED LIFE STAGES?**Gro I. van der Meer<sup>1</sup> ([grom@imr.no](mailto:grom@imr.no)), Astrid K. Woll<sup>2</sup><sup>1</sup>*Institute of Marine Research, Bergen, Norway*, <sup>2</sup>*Woll Naturfoto, Midsund, Norway*

The natural living biotope of all animals is reflected on their body shape and by their behavior. In European lobster (*Homarus gammarus*) it is well established that they are nocturnal predators and scavengers, can easily move both forwards and backwards, and shelter in caves and burrows. Their slender, long bodies are a perfect fit for life in rocky and complex bottoms, while the antennules and antennae provide them with excellent taste and touch senses, respectively, for navigating their dark world. Other decapod species, although mostly nocturnal, have other body shapes: heavy chelae and a wide and flattened body in the edible crab (*Cancer pagurus*); spiky carapace, long appendices, and slender claws in king crabs (*Paralithodes camtschaticus*); and something intermediate as reflected by squat lobsters (Galathoidea) that are elongated, but also flattened, with a flexible tail that is usually tucked underneath the body. These are all examples of functional morphology and habitat ecology. Still, in the European lobster early life stages, no documentation on the natural living biotope is known. Even with more than a century of hatchery reared lobsters, the present knowledge of the juveniles are all from lab-studies. We have some anecdotal information and observations of laboratory-hatched young-of-the-year juveniles in tanks, with various levels of habitat constructions provided. Searches in nature have been futile. These searches have been based on knowledge of the larger lobsters of more than 50 mm carapace length. We want to make some pure speculations on why we still cannot find the wild juveniles, and use what we know of their morphology and behavior to suggest where they may be and what may be alternative methods for looking for the missing link - small, juvenile European lobsters.

**P38-EVIDENCE OF GEOGRAPHIC VARIATION IN CRUSHER CLAW SIZE OF AMERICAN LOBSTER (*HOMARUS AMERICANUS*)**

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In American lobsters, *Homarus americanus*, inter- and intra-gender competition in lobsters is highly dependent on the animal's ability to use its appendages, particularly its large claws, to gain access to resources. This may be particularly true for males competing with other males for access to females. Therefore, claw size may respond, over evolutionary and/or ecological time scales, to geographic variation in competition for mates. In this study, we measured the body (carapace length) and crusher claws of over 5,000 male and female lobsters from inshore water along the Atlantic coast. We found significant geographic variation in claw size in both genders, when standardized for body size, and this variation was markedly more pronounced in males than in the females. Variation in claw size was not simply related to water temperature, as the relation between body-size-adjusted claw size and latitude was opposite in male and female lobsters. For example, male lobsters in the Bay of Fundy and Gulf of Maine had smaller size-adjusted crusher claws than those in the Gulf of St. Lawrence, whereas the opposite pattern was true for females. Our findings support the hypothesis of geographically varying selection on claw size, and they suggest that sexual selection might be an important driver of this variation, given the greater variability in males than females. Future studies should investigate in greater detail the potential mechanisms underlying the small-scale patterns in variation in American lobster claw size revealed in this study.

## Growth & Development

### P39-THE USE OF ENERGY STORES IN THE TRANSITION FROM FINAL LARVAL STAGE TO FIRST-STAGE JUVENILE OF THE CARIBBEAN SPINY LOBSTER, *PANULIRUS ARGUS*

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*Panulirus argus* has 10 phyllosoma stages that develop in oceanic waters. The final stage (FX) metamorphoses into a non-feeding (lecithotrophic) postlarva, the transparent “nektonic puerulus” (NP), which actively swims towards the shore and settles in shallow coastal vegetated habitats. After settlement, “transparent benthic pueruli” (TBP) become “pigmented pueruli” (PP) and eventually molt into “first-stage juveniles” (J1), which resume feeding. To determine the amount of energy stores used in the development from FX to J1, we examined the content of total proteins, total lipids, and lipid classes in multiple individuals of each stage in two different seasons corresponding to the primary (autumn) and secondary (spring) peaks in coastal pueruli settlement. We collected FX and NP during two oceanographic cruises in the Mexican Caribbean in autumn (November 2012) and spring (April 2013). During the same seasons, we obtained TBP, PP and J1 from artificial collectors permanently deployed in two Mexican coastal locations. On average, the percentage of total lipids (relative to the dry weight of individuals) decreased progressively with development, from 26% in FX to 7% in J1 in the autumn (a 73% decrease), and from 25% to 6% in the spring (a 76% decrease), with the greatest decrease occurring between FX and TBP in both seasons (~ 45% in autumn 2012 and ~ 53% in spring 2013). In all stages, phospholipids accounted for ~80–87% of total lipids. Unlike lipids, the percentage of proteins did not decrease progressively with development, exhibiting higher and similar levels in NP, TBP and PP, and lower levels in FX and J1. However, total lipids and proteins decreased significantly between PP and J1, reflecting the high energy demand required to fuel the molting process as found in other palinurids and underlining the importance to J1s of resuming feeding soon after the molt.

### P40-OXYGEN CONSUMPTION AND CRITICAL POINT IN THE CARIBBEAN SPINY LOBSTER, *PANULIRUS ARGUS*, LATREILLE 1804

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The metabolic rate of the spiny lobster *Panulirus argus* was estimated at 49.4 mg O<sub>2</sub> kg<sup>-1</sup> h<sup>-1</sup> at 20 °C for specimens of 520 g of average weight. Studies on the water replacement required for its normal functioning and survival indicate that each lobster needs between 20 to 60 liters of sea water per hour to metabolize normally. Research on the metabolic rate indicated that the habits of lobster are nocturnal, and if they are fed, the respiratory metabolism increases by 3.5 times its standard value. This report indicated that for aims of storage of unit in cages or pools, without affecting its survival, the following model will be used:  $\text{mgO}_2 \cdot \text{kg}^{-1} \cdot \text{h}^{-1} = -9.209849 + 1.160395 \cdot (\text{L} \cdot \text{h}^{-1}) - 6.782791 \cdot (\text{L} \cdot \text{h}^{-1})^2 + 1.326459 \cdot (\text{L} \cdot \text{h}^{-1})^3 - 8.225767$ . We found that decreases in salinity affect the respiratory behavior making it decrease. The lethal limit of oxygen was determined experimentally between 0.70 and 0.80 mg O<sub>2</sub> · L<sup>-1</sup> as the critical value.

## Population Dynamics & Connectivity

### **P41-FISHERMEN AND SCIENTISTS RESEARCH SOCIETY: LOBSTER RECRUITMENT PROJECT 2015 2016**

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The Lobster Recruitment project began in the spring of 1999. The goal of the project is to provide an index of the number of lobsters that will molt into the legal sizes in the coming seasons. The project was initiated by the Fishermen and Scientists Research Society (FSRS) in cooperation with the Invertebrate Fisheries Division (currently named Population Ecology Division), DFO at the Bedford Institute of Oceanography (BIO). The initial phase of the project was planned for five years; however, after reviewing the project's usefulness, it is scheduled to continue for the foreseeable future. This project involves over 130 volunteer fishermen from LFAs 27-35 who fish standardized traps and take measurements of the lobster caught. These measurements are recorded in a logbook using a specially designed gauge with 15 different size increments. Participating fishermen also monitor bottom temperatures with a mini-log temperature gauge in one of the standard traps. These bottom water temperatures are forwarded to the oceanographers at BIO and are a great addition to their coastal temperature monitoring database. The lobster information gathered has been used by Fisheries and Oceans Canada (DFO) in their lobster stock assessments and has helped to greatly understand the lobster populations around the Scotian Shelf area of Nova Scotia.

### **P42-DO LOBSTER LARVAE RELEASED OVER THE GULF OF MAINE AND GEORGES SUBSIDIZE THE LOBSTER STOCK OFF SOUTHERN NEW ENGLAND?**

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The lobster harvest off the southern coasts of Rhode Island and Massachusetts (in Lobster Management Area-2; LMA-2) experienced a significant decline in the early 2000's and has been at historically low levels since 2003. This decline has been accompanied by a sharp decrease in the settlement and early-stage survival of post-larval lobsters. A concern is that the supply of juvenile lobsters to suitable settlement habitat in LMA-2 may have shrunk due to temporal and spatial shifts in egg release within LMA-2 associated with warming ocean temperatures. To better understand factors that control and limit juvenile lobster recruitment in LMA-2, we have conducted bio-physical modeling of the development and transport of lobster larvae released from points distributed over LMA-2 as well as over Georges Bank and the Gulf of Maine coastal region. A goal was to determine the extent to which the juvenile lobster stock in LMA-2 may be subsidized by the delivery of lobster larvae released in other regions. Our results indicate a small, but potentially important, delivery of juvenile lobsters to LMA-2 from release locations on southern Georges Bank and in the western Gulf of Maine. This source of juveniles appears to vary seasonally, being greatest in the late summer and early autumn. It also exhibits significant interannual variability associated with both variations in the large-scale regional circulation and in the local wind-driven flow in LMA-2. As a cautionary note, we find that the model results are highly sensitive to variations of the parameters representing larval growth as a function of temperature. The uncertainty in the estimates of larval delivery from remote release locations is largely due to uncertainty in these parameters.

### **P43-UNDERSTANDING SETTLEMENT DYNAMICS OF THE EUROPEAN SPINY LOBSTER (*PALINURUS ELEPHAS*) IN THE MID-WESTERN MEDITERRANEAN**

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It is generally accepted that the dispersal capacity of lobster larvae is directly linked to the duration of their pelagic phase. During the 5-month long dispersal phase of *Palinurus elephas* phyllosomas, both dispersion and survival are shaped by environmental and hydrographic conditions. Ongoing studies of spatial and temporal patterns of puerulus settlement in the NW Spanish Mediterranean indicate temporal synchrony at a 100 km scale. To shed light on the scale of drivers of settlement success, we expanded the study area to the Mid-northwestern Mediterranean and during four years (2013 to 2016) surveyed locations around islands separated up to 750 km (Mallorca Is – Corsica Is) by scuba diving. To integrate small-scale spatial variability, in each location we sampled three sites separated by < 500 m. Settlement indices at the two islands were similar in both magnitude and temporal pattern, lending weight to the hypothesis of a common larval pool in the NW Mediterranean basin and of a negligible effect of local environmental conditions. The similarity of the magnitude of the settlement indices in the two regions also suggests similar settlement habitat or cues for habitat selection. These results highlight the need of coordinated management efforts at a larger scale than anticipated.

### **P44-PANULIRUS PASCUENSIS LARVAL CONNECTIVITY BETWEEN MOTU MOTIRO HIVA MARINE PARK AND EASTER ISLAND: IMPLICATIONS FOR MANAGEMENT**

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*Panulirus pascuensis* is the endemic lobster from Easter Island that is also present in Pitcairn Island and Salas y Gómez Island where a 150,000 km<sup>2</sup> no-take Motu Motiro Hiva Marine Park has recently being created. It is an important fishery resource for inhabitants of Easter Island. However, harvesting has affected its abundance and the size of individuals has been reduced, suggesting possible overexploitation. In order to investigate the larval connectivity between Easter Island and Motu Motiro Hiva Marine Park, we evaluated the genetic connectivity and a bio-physical model (IBM) has been implemented based on outputs of the Regional Oceanic Modelling (ROMS) at the resolution of ~3 km over the period 2000-2015. As a first step, some aspects of the simulated circulation is validated from satellite observations highlighting the larger level of mesoscale activity in the model compared to observations. We then evaluated the sensitivity of the distribution of the adults to the bathymetry and depth (depth of larval liberation: 0-50 m and 50 to 200 m depth), planktonic development length (PDL, 6, 8, 10 and 12 months). We also studied how the interannual variability affects the degree of self-recruitment and connectivity between these areas. The genetic analysis showed largest effective population sizes in Salas y Gómez Island when compared with Easter Island, and asymmetric connectivity, with more migrants from Salas y Gomez to Easter Island (5 fold). From the oceanographic modelling, an asymmetric connectivity also was observed, with more larvae being transported from Motu Motiro Hiva Marine Park to Easter Island at both strata. At the surface, we observed a peak in connectivity in 2008 and 2012 for 6 months PDL. Our results support the importance of Motu Motiro Hiva Marine Park in the seeding of *P. pascuensis* larvae to Easter Island.



**P45-IS EVERYTHING ALWAYS THE SAME? TEMPORAL GENETIC STABILITY OF EASTERN ROCK LOBSTER PUERULUS WITHIN AND BETWEEN COHORTS**

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Settlement of post-larvae is often geographically and temporally variable in the marine environment. This variability can be observed in terms of changes in abundance and within the genetic structure of settling individuals. Variability in settling individuals is commonly observed for species, such as the commercially important Eastern Rock Lobster, *Sagmariasus verreauxi*, which exhibits high fecundity, high early mortality, and long pelagic larval durations. On-going monitoring of *S. verreauxi* puerulus settlement has shown that lower abundance of settlers occurs at sites of the northern limits of *S. verreauxi* settlement, while higher abundance occurs at southern sites. There is also temporal abundance variance within the settlement window, which occurs from August to December, with peak abundance generally observed in October. While the patterns of settler abundance is well resolved for *S. verreauxi*, the genetic structure for the settling puerulus is unknown. By assessing the genetic structure of the puerulus, a better understanding of whether events such as sweepstake reproductive success and natural selection are occurring and whether they occur consistently within a cohort and across cohorts from different years. The aim of this study was to determine the genetic structure and its temporal stability of *S. verreauxi* puerulus that recruit into the New South Wales Fishery in eastern Australia. Samples were collected monthly from 4 locations along the NSW coast across two consecutive years. The locations included two northern sites with low abundance and two southern sites with higher abundance. SNPs were obtained via double digest Restriction Associated DNA Sequencing (dAD Seq). Population structure will be determined through bioinformatic examination of the differences in the relative frequencies of alleles from each location, as well as within a settlement period and between settlement periods of the two years. The geographic structure and temporal stability of the *S. verreauxi* puerulus will be presented and the possible causes of these patterns will be discussed.

**P46-EVALUATING LONG TERM ESLSI (EUROPEAN SPINY LOBSTER SETTLEMENT INDEX) IN THE WESTERN MEDITERRANEAN**

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The European Spiny Lobster Settlement Index (ELSI) is a component of annual monitoring program of the European spiny lobster *Palinurus elephas* that quantifies the arrival of postpuerulus in three Western Mediterranean locations separated by +100Nm. Long term monitoring of early benthic juveniles helps understand the variability of the recruitment process and to predict year-class strength from a 3-year vantage point. This predictive capability of the ESLSI allows a proactive management of the fisheries for this valuable, but overfished species in the region. Also, this data set encompassing the NW Mediterranean basin and a series of +10 years, allows us to investigate correlations between settlement success and oceanic and atmospheric variables. In 1997 the first post-settlers of *P. elephas* were found in the coast of the NE Iberian Peninsula and the monitoring program was initiated in 1998. Three regions were surveyed every summer: coastal NE Iberian Peninsula (Catalonia) and the archipelagos of the Columbretes and Balearic Islands. In the last 18 years, a total of 24 locations and more than 60 sites have been surveyed. The complete series encompasses 16 years (2000-2016), 12 locations and 38 sites, sampled routinely by underwater visual censuses (UVC) to estimate settlement index strength. In 2004, a spiny lobster artificial collector was successfully designed to complement the UVC estimates. Stations of artificial collectors have been in operation experimentally in the Balearic Islands since 2009 and in Corsica since 2016. The collectors remain underwater year-round and are surveyed during summer peak settlement months (June-August). The next step for the ESLSI team members will be to consolidate the artificial collector stations and expand UVC censuses to other regions in both the Mediterranean and Atlantic where *P. elephas* is, or was, an important species ecologically and economically for the local fisheries.

## Reproductive Biology

### P47-A NOVEL METHOD FOR CHARACTERIZING AMERICAN LOBSTER SPERMATOPHORE COMPOSITION AS A MEASURE OF POTENTIAL REPRODUCTIVE OUTPUT

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Changes in the thermal environment of inshore Southern New England (SNE), in combination with a number of diseases including a high incidence of shell disease, have been implicated in the decline and recruitment failure of the SNE lobster stock. We hypothesize that sub-lethal effects of physiological stress resulting from high water temperatures have resulted in reduced reproductive output in SNE lobsters. One indicator of this decline might be insufficient or low quality sperm being passed to females. As climate change is expected to persist, stressful environmental conditions could spread northwards into the highly productive Gulf of Maine (GOM) lobster stock, making it critical to understand how physiological stress induced by a changing climate might affect reproductive output. As a first step towards examining this question, we have developed two methods for quantifying the number of sperm in a spermatophore. The first method involves homogenizing spermatophores, removing an aliquot, staining sperm with acridine orange, and then using ImageJ to quantify the number of sperm from images obtained from a fluorescent microscope. The second method involves quantifying the amount of DNA in a spermatophore, using a Qubit fluorometric system, after determining the amount of DNA in each sperm. The advantages and disadvantage of each method will be discussed.

### P48-TESTING THE AUTODIAMETRIC METHOD TO QUANTIFY OVARIAN FECUNDITY IN AMERICAN LOBSTERS

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A core objective in any fishery management plan is to maintain reproductive capacity of the stock to avoid recruitment overfishing. Typically, stock assessments use proxies of reproductive capacity such as abundance indices and spawning stock biomass as they are easier to quantify. Work conducted by the Lobster Node and Bay of Fundy Lobster Assessment Program has revealed processes (sperm limitation, egg loss, massive resorption) that challenge the paradigm that stock reproductive capacity is necessarily proportional to spawning stock biomass or abundance indices. A better understanding of processes involved in stock reproductive output would help identifying effective harvest control rules to mitigate limiting factors for reproduction, and reduce the uncertainties surrounding reproductive stock status. This requires first an ability to effectively evaluate reproductive potential such as ovarian fecundity. However, ovarian fecundity in lobster is rarely quantified directly, as traditional approaches such a gravimetric method are tedious. We tested autodiametric method to quantify ovarian fecundity in the American lobster more easily. This method is based on a relationship between oocyte density (i.e. number of oocytes per gram of ovary) and mean oocyte diameter and was initially developed for groundfish. Once the relationship is known, ovarian fecundity is simply estimated by measuring the average oocyte diameter and the ovary wet weight. Primary results show a tight relationship between oocyte density and diameter. Estimated fecundity based on both methods are well correlated ( $R^2 \sim 0.9$ ). This method shows great potential to quantify ovarian fecundity in lobster, and could be easily used in conjunction with size-at-onset-maturity studies that are based on ovary development.

**P49-TRACKING THE DEVELOPMENT OF INDIVIDUAL AMERICAN LOBSTER EMBRYOS TO MORE ACCURATELY PREDICT TIME OF HATCH**

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Connectivity among American lobster populations influences stock structure and recruitment dynamics, knowledge of which is important to the management of lobster fisheries. Connectivity via larval drift is generally estimated using dispersal models, which are sensitive to variation in the timing of larval hatch. This study will develop and test a technique to estimate the development of individual embryos (separated from a female's clutch) in order to improve our ability to predict hatch time of lobster embryos and connectivity estimates over large geographic areas. We will raise ovigerous female lobsters (n=6) and individual embryos (n=20/female) in two separate labs located in southwest New Brunswick, Canada, one at ambient (7–13 °C) and the other at constant (12 °C) temperature, from February to August 2017. Every week until all larvae hatch, we will measure the Perkins Eye Index (PEI) and yolk area of 20 randomly selected embryos from each female and of all 120 individually-raised embryos. We will (i) determine whether embryos isolated from a female's brood develop at same rate and hatch at same stage as embryos raised in a brood attached to a female; (ii) quantify the contribution of intra- and inter-brood variability in development rates and stage at hatch to the temporal distribution of hatch to assist future sampling programs; (iii) determine whether PEI or yolk area provides the better metric of embryonic development and "stage" at hatch; and (iv) determine the extent to which our ability to predict observed hatch is improved by randomly allocating to different embryos, through simulations, the variability in development rates and stage at hatch observed during the study. Improving predictions of American lobster embryonic development and time of hatch can be used to improve estimates of larval release time in nature, thereby improving modelled connectivity between lobster stocks via planktonic dispersal.

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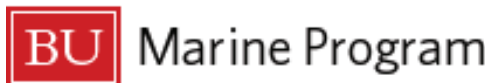
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