

The 9th International Conference and Workshop on

Lobster Biology and Management

Hosted by the Institute of Marine Research, Norway



INSTITUTE OF MARINE RESEARCH HAVFORSKNINGSINSTITUTTET

www.imr.no/icwl_bergen

PROGRAMME & ABSTRACTS



The $9^{\rm th}$ International Conference and Workshop on Lobster Biology & Management Bergen, Norway, 19–24 June 2011

Host:



Sponsored by: The Research Council of Norway

Supported by: Directorate of Fisheries (Norway) The Statsraad Lehmkuhl Foundation Bergen Aquarium The Crustacean Society Marine Biology Research

In cooperation with: Radisson Blu Hotel Norge SAS Ingvald Arne Meland Photography (www.ingvaldmeland.com)

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Convener

Dr. Gro I. van der Meeren, IMR, Austevoll research Station NO- 5392 Storebø, Norway

International Organizing Committee

Dr. Andrew Jeffs, Department of Marine Science University of Auckland Private Bag 92019 Auckland, New Zealand

Prof. Bruce Phillips, Dept. of Env. Science, Curtin university of Technology GPO Box U1987, Perth, Western Australia

Dr. Donald C. Behringer, School of Forest Resources and Conservation & Emerging Pathogens Institute,University of Florida, USA

Prof. Friedrich Buchholz, Head Dpt. Invertebrate Biology | Functional Ecology Alfred Wegener Institute for Polar and Marine Research Am Handelshafen 12, D-27570 Bremerhaven, Germany

Jason S. Goldstein, PhD. Candidate University of New Hampshire Department of Biological Sciences 46 College Road – Rudman Hall Durham, NH 03824 USA Prof. Mark Butler, Old Dominion University, Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23529, USA

Prof. Richard Wahle, University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, Maine 04573, USA

Prof. Steffen Harzsch, University of Greifswald, Zoological Institute, Dept. Cytol University of Greifswald Zoological Institute and Museum Dept. Cytology and Evolutionary Biology, Soldmannstrasse 23, D-17498 Greifswald, Germany

Dr. Steven Montgomery, NSW DPI, Cronulla Fisheries Research Centre of Excellence, New South Wales Department of Primary Industries, PO Box 21, Cronulla NSW 2230, Australia Dr. Thomas Breithaupt, University of Hull, Department of Biological Sciences, Hull, HU6 7RX, UK.

International Advisory Committee

Prof. Ehud Spanier Marine Biologist & Ecologist The Leon Recanati Institute for Maritime Studies & Department of Maritime Civilizations The Leon H. Charney School for Marine Sciences University of Haifa, Mount Carmel, Haifa 31905, Israel

Dr. Kari L. Lavalli, Boston University 871 Commonwealth Avenue Boston, MA 02215, USA

Dr. Jean Lavallee, AVC Lobster Science Centre Atlantic Veterinary College 550 University Avenue Charlottetown, PE Canada C1A 4P3, Canada Mr. Daryl Sykes NZ Rock Lobster Industry Council Private Bag 24 901 Wellington 6142 New Zealand

Dr. Raquel Goñi IEO - Centro Oceanográfico de Baleares Muelle de Poniente s/n 07015 Palma de Mallorca, Spain

Dr. Vidar Öresland, Institute of Marine Research Box 4 453 21 Lysekil, Sweden

Paul Kanciruk Student Travel Award Committee

Prof. Mark Butler (Chair), Old Dominion University, Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23529, USA

Dr. Raquel Goñi IEO - Centro Oceanográfico de Baleares Muelle de Poniente s/n 07015 Palma de Mallorca, Spain

National Organizing Committee

Ms. Kirsten Aas, Secretary leader, IMR, Asutevoll reseearch Station NO- 5392 Storebø, Norway

Ms. Elen Hals, Secretary, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Mr. Bernt Andreas Drange, Registration moderator, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Mr. Andreas Angermann, Correspondance moderator, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Mr. Petter Baarsden, Financial management, Flødevigen Marine Research Station Nye Flødevigveien 20 4817 His, Norway

Dr. Ann-Lisbeth Agnalt, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Dr. Even Moland, Flødevigen Marine Research Station Nye Flødevigveien 20 4817 His, Norway Dr. Alison MacDiarmid, Marine Ecology, NIWA, 301 Evans Bay Parade, Private Bag 14-901, Wellington 6021, New Zealand

Dr. Guldborg Søvik, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Dr. Ellen Grefsrud, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Dr. Felicia Keulder, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Dr. Alf Ring Kleiven, Flødevigen Marine Research Station Nye Flødevigveien 20 4817 His, Norway

Ms. Eva Farestveit, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Mr. Ole Ingar Paulsen, Dr, Ellen Grefsrud, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Mrs. Kjersti Turøy, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

Mr. Harald E. Tørresen, IMR, PB 1870 Nordnes, NO- 5817 Bergen, Norway

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General Information

Information/Registration desk

The Information and Registration desk will be located in the lobby of Radisson Blue Hotel Norge, and will be open at these times:

Sunday	1600—1800
Monday	0800–0630
Tuesday	0800–1700
Wednesday	0800–1230
Thursday	0800-1600
Friday	0800-1200

Presentation preview

Technical assistance will be available for both presentation room, and is available for uploading of the presentations. The presentations must be uploaded in due time before the scheduled presentation time, if possible a day before.

Conference shirts

Pre-ordered shirts can be picked up at the registration desk from Tuesday morning. A limited number of shirts will be sold at the registration desk, but sizes are not guaranteed.



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Social Events Schedule

Sunday 19 June 2011

Meet & greet 1800–2000 Institute of Marine Research A light meal and refreshments will be served

Tuesday 21 June 2011

Poster Session 1900–2100 Radisson Blue Hotel Norge Tapas and refreshments will be served

Wednesday 22 June 2011

Conference Cruise 1600–2100 SS "Statsraad Lehmkuhl", Soup will be served

Thursday 23 June 2011

Conference Banquet 1830–2300 Radisson Blue Hotel Norge



Social events and tours

Friday 24 June 2011

Confirmed post-conference tours:

Afternoon sightseeing and a light meal at IMR Austevoll Research Station.

Participation limited to 15 persons. Price: not above NOK 500. Minibus will transport the participators and local staff will show the facilities.

Mountain walk to the top of Ulriken, including an outdoor snack at the top of Bergen.

Price: not above NOK 500 (can be far less if you choose to walk all the way) It is a bus service to the Ulriken cable car service. If weather permits, we will also guide a walk along the footpath all the way up.

For the weekend 25 and 26 June:

Those who wants to get to see more of the city and the area around during the following weekend, we recommend to check out with the tourist office of Bergen.

Very popular tours we can recommend are:

Norway in a Nutshell' by Fjordtours, http://secure.fjordtours.com/tour/Tour.aspx Price: NOK 995

A daytrip with bus, fast ferry and train into the magnificent Sognefjord, up into the high mountains, returning through valleys and fjords to Bergen. This tour is also going the opposite way, through the valleys into the mountain and down into the Sognefjorden and back to Bergen. Since we know that some has already bought tickets for this tour on Saturday June 25th, we recommend the Bergen–Myrdal–Flåm direction if you want to see other participants on this trip.

A day in Hardanger, http://www.tidefjordcruise.no/index.cfm?id=342571 Price: NOK 750 Tours with coach/fast ferry out of Bergen and into the beautiful Hardanger fjord area, into the mountains if you like, and back to Bergen.

City Sighseeing, http://www.tidereiser.com/Citysightseeing-Bergen-Grieg Price: NOK 250 Guided coach tours within and around the city of Bergen, including to the home of the composer Edvard Grieg.

Museum visits: natural, historical or art museums are all available by foot within the city centre









Sunday June 19, 2011

4:00 pm	Registration, Radisson Blu Hotel Norge
6:00 pm	Meet & Greet, Institute of Marine Research, Welcome by the Director General of Fisheries; Liv Holmefiord

Monday June 20, 2011

8:00 am	Registration		
8:45 am	Announcement (posters to be put on display at any time)		
9:00 am	Welcome by G.I. van der Meeren, convener		
9:05 am	Official Opening by van der Meeren, Welcome by IMR: Managing Director Tore Nep	stad	
	Plenary speakers		
9:15 am	The role of scientific interaction in the recover of the Sagmariasus verreauxi, population	ation off New South Wales, Australia - S.S. Montgomery, G.W. Liggins	
9:45 am	Research on European lobster (Homarus gammarus) in Norway with focus local sto	ck enhancement and genetic aspects - <i>K.E. Jørstad</i>	
10:15 am	Marine Diseases: Ecologically relevant and consequential to lobsters - M. Butler , D	Behringer, J. Shields, C. Paris, T. Dolan, J. Moss, and R. Cowen	
10:45 am	Health Break		
11:05 am	Lobsters as part of Marine Ecosystems- A review - B. F. Phillips, R. Wahle, M. Jaini		
~ STREAM ONE ~ ~ STREAM TWO ~			
	Aquaculture seminar: Larval culturing Chairs: J. Goldstein & AL. Agnalt	Ecology and ecosystems Chairs: F. Buchholz & R. Goñi	
11.35 am	Lobster Aquaculture and Environmental Issues – A. Jeffs	Geography of top-down forcing in the Northwest Atlantic lobster-groundfish interaction: the role of predator diversity, identity and abundance- R.A. Wahle , C. Brown, K. Hovel	
11.55 am	Culture of temperate spiny lobsters (<i>Jasus edwardsii</i> and <i>Sagmariasus verreauxi</i>) phyllosoma in Tasmania: recent developments and the prophylactic use of chemical disinfectants– Q. P. Fitzgibbon and S. Battaglene	Understanding the ecosystem impacts of fishing for western rock lobster; a progress report - <i>L. M. Bellchambers</i> , <i>S. E Evans and J. J. Meeuwig</i>	
12.15 pm	Application of advanced rearing technology of <i>Panulirus japonicus</i> phyllosoma to <i>P. homarus</i> larvae – <i>K. Murakami, S. Sekine</i>	Why spiny lobsters still exist in the Mediterranean? A metapopulation approach for Palinurus elephas, an ancient overexploited species – D. Diaz , Goñi, M. Zabala, B. Stobart, O. Renoñes, C. Linares, M. Marí, P. Abelló	
12.35 pm	Bacterial manipulation in the gastrointestinal tract of early stage <i>Homarus gam-</i> <i>marus</i> : using biotic dietary supplements to improve culture success – C. Daniels	Environmental correlates of American lobster settlement at the sea surface as measured by satellites and oceanographic buoys – <i>M. Jaini, R. Wahle, A. Thomas</i>	
		Recruitment and management Chairs: B. Phillips & A. Kough	
12.55 pm	An examination into the use of ozone delivery to control bacterial assemblages and enhance the rearing performance of the early stages of the European Lobster reared under intensive conditions – <i>A. Powell, J. Scolding, D. Boothroyd, R.</i> <i>Shields</i>	Modelling Ocean circulation. Stokes drift and connectivity of western rock lobster population – <i>M. Feng. N. Caputi. J. Penn. D. Slawinski. S. de Lestang. E. Weller. A.</i> <i>Pearce</i>	
1:10 pm	Lunch		

	~ STREAM ONE ~	~ STREAM TWO ~
	Aquaculture seminar: Diet & Nutrition Chairs: K.E. Jørstad & P. James	
2:10 pm	Nutritional aspects of the aquaculture of the spiny lobster <i>Jasus edwardsii</i> – C.J. Simon , A.G. Jeffs	Preliminary assessment of the cause of the record low puerulus settlement in the West Australian Rock Lobster Fishery – N. Caputi . S. de Lestang. M. Feng. J. Penn. E. Weller. D. Slawinski. A. Pearce 1. A. Denham
2:30 pm	Comparison of manufactured pellet and trash fish feeds for production of spiny lobster (<i>Panulirus ornatus</i>) in sea-cages in Vietnam – L.L. Huong , H.M. Sang, N.T. Kien, N.K. Bich, C. Jones	Use of a spatial population-dynamic assessment model in the assessment and management of the West Australian Rock Lobster Fishery during a period of low recruitment – <i>S. de Lestang. P. Stephenson. N. Caputi. R. Fletcher</i>
2:50 pm	Physiological condition, survival and growth in the wild of hatchery-reared stage IV American lobster (<i>Homarus amricanus</i>) fed different lipid composition diets – L. Gendron , <i>R. Tremblay</i> , <i>J. Coté</i>	Sexual maturity in female American lobster – detecting major trends from the size of ovigerous females – M.J. Tremblay . M.A. Silva. A.R. Reeves. O.S. Pezzack. C. Denton
	Aquaculture seminar:	
	Culturing operations & growth Chairs: A, Jeffs & C. Daniels	Stock assessment and trends Chairs: B. Phillips & F. Keulder
3:10 pm	Preliminary assessment of the Tropical Spiny Lobster (<i>Panulirus ornatus</i>) aqua- culture under pond conditions in Australia – J. Shanks , C. Jones, L.A. Tuan	The Norwegian fishery and management of the lobster <i>Homarus gammarus</i> " – Trond Ottemo
3:30 pm	Spiny lobster aquaculture in Vietnam: constraints and opportunities – <i>L.A. Tuan</i> .	The Norwegian Nephrops fishery in Skagerrak and the Norwegian Deep – trends and monitoring – G. Søvik , S. Munch-Petersen, M. Ulmestrand
3:50 pm	Health Break	
4:10 pm	Review of Spiny Lobster Aquaculture in Indonesia – B. Priyambodo , C. Jones, S. Shanks	The French lobster fishery for 10 years – <i>M. Laurans</i>
4:30 pm	Genetic mapping to improve growth performance, survival and feed conversion ratio (FCR) for on-growing of European lobster in Recirculating Aquaculture Systems (RAS) – <i>A. Drengstig, -L. Agnalt, K. Jørstad</i>	Recent large-scale shifts in the spatial distribution of West Coast Rock lobster (<i>Jasus lalandii</i>) in South Africa – A.C. Cockcroft
		Fisheries Technology Chairs: W. Watson & A.K. Woll
4:50 pm	Ongrowing juvenile American lobsters (<i>Homarus americanus</i>) at sea using suspended polyculture methods in Nova Scotia, Canada – M. Theriault	Assessing and managing unaccounted fishing mortalities in the fishery for <i>Sagma-riasus verreauxi</i> in New South Wales, Australia – <i>G.W. Liggins</i>
05:10 pm	Lobster resource enhancement in Atlantic Canada through stage IV larvae seed- ing: the Homarus Inc. experience – D. Daoud , M. Mallet, R. Haché, M. Comeau	Finding the unreported catch in the Norwegian lobster (<i>Homarus gammarus</i>) fishery – A.R. Kleiven , E.M. Olsen, J.H. Vølstad, J.H.
05:30 pm	Biological and Economic Benefits of an American Lobster (<i>Homarus americanus</i>) Enhancement Project in Atlantic Canada – M. Comeau , M. LeBreton, M. Mallet	Trap efficiency comparisons between two trap designs used in the fishery for the American lobster, <i>Homarus americanus – J. Garland</i> , S. Frame
05:50 pm	Conditioning improves survival of hatchery-reared juvenile European lobster (Homarus gammarus) – AL. Agnalt , E. Farestveit, E.S. Grefsrud, A. Drengstig, A., K.E. Jørstad	Fishery and ecological indices for assessing alternative fishing methods: trap versus trammel nets in Mediterranean spiny lobster fishery – <i>S. Mallol</i>
06:10 pm	Can the rags to riches tale of spiny lobster live exports from NZ be applied to the king crab fishery in Norway? - P. James , S. Siikavuipio, S. Ruud	The Implementation of Electronic Logbook Technology for Different Crustacean Fisheries in Australia, USA and South Africa – A. Barkai , F. Felaar, G. Meredith, Z. Dantie, D. du Buys
06.30 pm	Finish for the day	

Tuesday June 21, 2011

8:00 am	Registration	
8:45 am	Announcements	
Plenary speakers		
8:30 am	Adaptations of Lobsters to Predators: A Review – K.L. Lavalli and E. Spanier	
9:00 am	Managing Lobster Resources under Stress (or what happens when the host, the pa K. Castro, M. Tlusty, J.S. Cobb, M.Gomez-Chiarri	thogens and the environment team up to create a natural disaster) $-$
	~ STREAM ONE ~	~ STREAM TWO ~
	Competition and predation Chairs: K.L. Lavalli & A.R. Kleiven	Diseases Chair: D. Behringer
9.30 am	Geographic variation in the outcome of agonistic interactions between adult invasive green crabs Carcinus maenas and juvenile American lobsters <i>Homarus americanus</i> in Atlantic Canada – M.L. Harr, <i>R. Rochette</i>	Shell disease in American lobster (<i>Homarus americanus</i>) from Norwegian waters – N. Sandlund , E. Karlsbakk, A.C.B. Einen, I.U. Fiksdal, E. Farestveit, K.E. Jørstad, AL. Agnalt
9.50 am	Is there evidence for starvation in Nephrops norvegicus in the field? – A. Watts , A. Albalat, R. McGill, P. Smith, J. Atkinson, D. Neil	A brief history of American lobsters (<i>Homarus americanus</i>) and gaffkaemia (<i>Aero-coccus viridians</i> var. Homari) in the UK – P. Stebbings
	Reproduction and reproductive behavior	
10.10 am	Increased reproductive opportunity: a potential benefit of seasonal aggregation for a little-gregarious spiny lobster – E. Lozano -Álvarez, E. Magallón-Gayón, P. Briones-Fourzán	Distinguishing disease impacts from larval supply effects in southern New England's lobster fishery collapse – R.A. Wahle , M. Gibson, M. Fogarty
10:30 am	Female mate choice and sperm allocation by males in a highly sedentary, habitat-specialist spiny lobster – <i>E. Magallón-Gayón, P. Briones-Fourzán, E. Lozano-</i> Álvarez	Myopspora metanephrops: the first description of a microsporidian parasite infec- tion in clawed lobsters – G.D. Stentiford , K.S. Bateman, H.J. Small, J. Moss, J.D. Shields, K.S. Reece, I. Tuckl.
10:50 am	Health Break Chairs: J. Atema & P. Bouwma	
11:10 am	The importance of conserving recruitment pulses in southern rock lobster (<i>Jasus edwardsii</i>) fisheries where puerulus settlement is low or highly sporadic – A. Linnane , <i>P. Hawthorne</i> , <i>M. Hoare</i>	Mineral fine structure defense of the American lobster (<i>Homarus americanus</i>) cuticle – J.G. Kunkel , W. Nagel, M. Jercinovic
11.30 am	Maternal influences on offspring size variation and viability in wild European lobster (<i>Homarus gammarus</i>) – E. Moland , E. M. Olsen, N.C. Stenseth	Diseases of rock lobsters and slipper lobsters in Australia and New Zealand – <i>B. Jones, N. Caputi</i>
11.50 am	Comparative analysis of gene expression profiles from the larval American Lobster, <i>Homarus americanus</i> — D. Hines K.Fraser Clark, A.Acorn, S.J. Greenwood	New approaches to understanding emerging marine diseases: The New England shell disease research initiative for American lobster – B. Somers , K.M. Castro, J.S. Cobb
12:10 pm	Optimising temperature for the larval culture of <i>Panulirus ornatus</i> – N.G. Sachlikidis , C.M. Jones	Caribbean spiny lobster connectivity and the role of larval dispersal in the spread of an emergent disease – A. Kough , <i>C. Paris, M. Butler</i>
12:30 pm	Lunch	Chairs: G. Stentiford & N. Sandlund
1:30 pm	Hormonal control of decapod reproduction: facts and perspectives – P.G. <i>Giulianini, A. Mosco, C. Guarnaccia, P. Edomi.</i>	Do casitas increase transmission of <i>Panulirus argus</i> Virus 1 (PaV1)? I. Variability in disease prevalence in Caribbean spiny lobsters occupying commercial casitas over a large bay – <i>R. Candia-Zulbarán, P. Briones-Fourzán, F. Negrete-Soto, C. Barradas-Ortiz, E. Lozano-</i> Álvarez
1:50 pm	Metapopulation dynamics, management areas and biological units of American lobster <i>Homarus americanus</i> in eastern Canada – M.H. Larsen , B. Quinn,G. Sigurdsson, K. Dinning,B. Morse, R. Rochette,	Do casitas increase transmission of <i>Panulirus argus</i> Virus 1 (PaV1)? III. Preliminary results of a controlled field experiment in progress – E. Lozano-Álvarez , P. Briones- Fourzán, R. Candia Zulbarán, F. Negrete-Soto, C. Barradas-Ortiz, J.P. Huchin-Mian
	Early life stages: dispersal. Retention and behaviour Chairs: L. Gendron & M. Theriault	
2:10 pm	Behavior of scyllarid phyllosoma larvae associated with medusa as revealed using in-situ video recording – <i>H. Sekiguchi, T. Tanaka</i>	Physiological characterization of juveniles of spiny lobster, <i>Panulirus argus</i> , infected naturally by virus (PaV1) – Herrera-Salvatierra N, Huchin-Mian JP, Briones-Fourzán P, Lozano-Álvarez E, Rodríguez-Canul R, Pascual Jiménez C.
2:30 pm	Stock separation in American Lobster is maintained by selection, genetic adapta- tion and behavior – J. Deppermann , J. Atema, J. Halverson, K. Radcliffe, A. M. Tarrant, G. Gerlach	PaV1 infection in the Florida spiny lobster fishery and its effects on trap function and disease transmission – D.C. Behringer , J. Moss, J.D. Shields, M.J. Butler IV
2:50 pm	American lobster benthic recruitment from New England to Newfoundland as measured by diver-based suction sampling and passive postlarval collectors – R.A. Wahle , C. Bergeron, J. Tremblay, C. Wilson, V. Burdett-Coutts, M.I Comeau, R. Rochette, P. Lawton, R. Glenn, M. Gibson	Ecological effects of <i>Panulirus argus</i> virus 1 (pav1) on caribbean spiny lobster condition, esponsib, and survival – D.C. Behringer, M.J. Butler IV, J.D. Shields

	~ STREAM ONE ~	~ STREAM TWO ~
		Disease workshop Lead by D. Behringer
3:10 pm	Recruitment of west coast rock lobster (Jasus lalandii) puerulus in relation to the upwelling environment at Lüderitz Bay, Namibia – F.J. Keulder , A.J. Booth, C.A.F. Grobler, P.J. Britz	Some interesting non-infectious ways to kill American lobsters – <i>J. Lavallée</i>
3:30 pm	Settlement of the American lobster <i>Homarus americanus</i> in the southwest Bay of Fundy: patterns and patchiness at different spatial scales – G. M. Sigurdsson , <i>R. Rochette</i>	<u>Workshop discussion</u> : Managing Disease in Fisheries and Culture – <i>K. Castro and J. Lavallée moderators</i>
3:50 pm	Local lobster subpopulations from limited adult migration and high larval retention – V. Öresland , M. Ulmestrand	
4:10 pm	Health Break Chairs: P. Bouwma & E. Grefsrud	A European Union Reference Laboratory for Crustacean Diseases: why now? — <i>G.D. Stentiford</i> <u>Workshop discussion</u> : Pathobiology and Molecular tools — <i>G.D. Stentiford moderator</i>
4:30 pm	Large dispersal potential yet restricted distribution: phyllosomas of the two lobster species (Decapoda, Achelata) present in Robinson Crusoe Island in the Juan Fernández archipelago – A.T. Palma , I. Cáceres-Montenegro, R.S. Bennett, S. Magnolfi, L.A. Henríquez. J.F. Guerra, K. Manríquez, R.E. Palma.	
4:50 pm	First record of the early benthic juvenile stage of the Mediterranean slipper lobster, <i>Scyllarides latus</i> – E.Spanier , K.L. Lavalli	Workshop discussion: Ecology of Disease – D.C. Behringer and M.J. Butler moderators
5:10 pm	Morphology	
	Morphometric differences between lobster (<i>Homarus americanus</i>) popula- tions at large and small spatial scales – K. Radcliffe , J. Atema, J. Halverson	
5:30 pm	Are the shield fan slipper lobster, <i>Evibacus princeps</i> , and the horse-shoe crab <i>Limulus polyphemus</i> a case of convergence evolution? – <i>E. Spanier</i> , <i>K.L. Lavalli</i>	
5:50 pm	Finish	

7:00–9:00 pm	Poster Session. M. Tapas

Wednesdav	June	22.	2011

Registration			
Announcements	Announcements		
~ STREAM ONE ~	~ STREAM TWO ~		
Management, fisheries and aquaculture: "Managing our own Ship": How	r collective action can add value to New Zealand rock lobster fisheries – <i>N. Gibbs</i>		
Management, fisheries and aquaculture; Lobster Research and Managem	nent in South and Southeast Asia – <i>Vijayakumaran, M.</i>		
Fisheries Management Chairs: S. Montgomery & G. Søvik	Behaviour Chairs: R. Wahle & E. Moland		
Spiny lobster fishery in Brittany (France), how the lack of management led to the quasi-collapse of the stock. Nevertheless, positive changes in management are putting in place – <i>L. Martial</i> , <i>J. Habasque</i> , <i>N. Caroff</i>	Does the behavior of lobsters in, and around, ventless and standard lobster traps influ- ence catch?— W.H. Watson III , S. Jury, A. Clark, T. Pugh, T. Langley, J. Goldstein		
Management of the CRA8 (Southern New Zealand) rock lobster fishery — the change from historical reactive government measures to indus- try led proactive strategies — <i>M. Lawson</i>	Egg-bearing lobster movements in coastal Gulf of Maine USA waters – Influence on egg development, larval hatch, and relevance in connectivity models – <i>J.S. Goldstein, W.H. Watson III</i>		
With rights comes esponsibilities – <i>L. Wichman</i>	Home range and activity patterns of wild European lobster (Homarus gammarus) stud- ied by acoustic telemetry and archival tagging – E. Moland , E.M. Olsen, H. Knutsen, K. Andvord, J.A. Knutsen, C. André, S.E. Enersen, N.C. Stenseth		
Health Break			
	Environmetal effects on recruitment Chairs: E. Spanier & J. Lavallee		
Growth models of European lobster and identification of critical management options for rebuilding local Norwegian populations – <i>E. Mjølhus, T. Kristiansen, AL. Agnalt, E. Farestveit, K.E. Jørstad</i>	Increase in the period of closure of lobster (<i>Panulirus</i> spp.) fishery and its effects on the catch of puerulus and juveniles in collectors of algae of the genus <i>Gracilaria flecheiras</i> beach, State of Ceara, northeastern Brazil – M. Ogawa , T.M. Neto		
POTBot: A cost effective approach to mapping habitats – M. Barrett Pember , S. de Lestang, and D. Slawinski	Effect of temperature on the time budget of stage IV larvae of the American lobster (Homarus americanus) – M. Chiasson , G. Miron, D. Daoud, M. Mallet		
Fisheries development and live holding Chairs: K. Castro & M. Burton			
The Norwegian Nephrops fishery on Møre – trap fishery and live handling – A.K. Woll , G. Søvik, W.E. Larssen	Impacts of seaweed bed dynamics on early benthic stages of the Japanese spiny lob- ster, <i>Panulirus japonicus</i> , and possible connections with sea warming – T. Yoshimura , <i>K. Yatsuya</i> , <i>S. Kiyomoto</i> , <i>S. Ara</i>		
	Biochemistry		
Going live: a science-industry collaboration to develop an Icelandic live lobster product – <i>H. Philp</i> , <i>G. Marteinsdottir</i>	A summary of hemolymph plasma biochemistry profile results from American lobsters (Homarus americanus) in Atlantic Canada (2007-2010) – A. Battison , J. Lavallée		
Open slot	Effect of photoperiod manipulation on the biochemical composition of the spiny lobster, Panulirus homarus – M. Vijayakumaran , J.T. Mary Leema, R.Kirubagaran, M.C.Remany, D. Magesh Peter		
Lunch			
	Announcements Announcements 		

16:00 pm

Conference Cruise

Thursday June 23. 2011

8:30 am	Registration	
8:454 am	Announcements	
	~ STREAM ONE ~	~ STREAM TWO ~
9:00 am	Plenary: MPA: Responses of the spiny lobster Palinurus elephas to 20 years of protection in a temperate marine reserve: R. Goñi	
9:40 am	Plenary: Neurobiology: Basic structure and function of the nervous system in lob	osters and their decapod relatives: a review: S. Harzsch
	MPA Chairs: M. Butler & P. Briones-Fourzán	Neurobiology. Sensory Biology and Behaviour Chair: T. Breithaupt
10:10 am	Marine protected areas for lobsters – why bother? – A. Sundelöf	Emerging complexity in olfaction: lessons from the lobster nose – E.A. Corey, Y. Bobkov, Y., B.W. Ache , (40 min)
10:30 am	Lobster reserves in coastal Skagerrak: a field laboratory for science and man- agement – E. Moland , E.M. Olsen, H. Knutsen, A.R. Kleiven, J.A. Knutsen	
10:50 am	Health Break	
11:10 am	Population age structure of the Caribbean spiny lobster, <i>Panulirus argus</i> , in a marine protected area in Florida Keys, USA – <i>K.E. Maxwell</i> , <i>T.R. Matthews</i> , <i>R.D. Bertelsen</i> , <i>C.D. Derby</i>	Crushing defeat remembered – J. Atema, D. Shi, H. Braverman
11:30 am	Movement patterns and exploitation rates of Caribbean lobsters in fishing zones within MPA's in Mexico – K. Ley-Cooper , S. De-Lestang, B. Phillips.	How predator kairomones and substrate quality affect and influence the behaviour response of the European lobster (<i>Homarus gammarus</i>) – K.L. Nilsen , G. I. Van der Meeren, P. Jakobsen
	Physiology Chairs: J. Garland & P. Guilianini	Chair: B. Ache
11:50 am	Examination of protein expression during ovary maturation in American lobsters (<i>Homarus americanus</i>) – R. Summerfield , A. Battison	Seasonal changes in the daily activity of American Lobsters (<i>Homarus americanus</i>): The influence of temperature and photoperiod - T.G. Langley , W.H. Watson III
12:10 pm	Effect of temperature and body size on long-term emersion and re-immersion responses of the American lobster, <i>Homarus americanus</i> – J. Garland , <i>R. Uglow</i>	Class-level vs. true individual recognition in the American lobster (<i>Homarus ameri-</i> canus) – F. Gherardi, F. Cenni, L. Aquiloni
12:30 pm	Physiological assessment of American lobsters (<i>Homarus americanus</i>) held in a specialized live seafood transport system – M. Burton , A. Battison, J. Lavallée	Spiny lobster sound production: Antipredator behavior helps lobsters survive vari- able environments – P.E. Bouwma , M.J. Childress
12:50 pm	Lunch	
		Neurobiology. Sensory Biology And Behaviour workshop Leader T. Breithaupt
2:00 pm	Sex-specific differences in <i>Nephrops norvegicus</i> haemolymph total protein during the moult cycle – <i>H. Philp</i> , <i>G. Marteinsdottir</i>	Lobsters as model systems in sensory- and neurobiology: research challenges for the twenty first century
	Growth-related physiology Chairs: M.J. Tremblay & A. Watts	
2:20 pm	Protein synthesis in wild-caught Norway lobster (<i>Nephrops norvegicus</i> L.) – E. Mente , C.G. Carter, R.S. (Katersky)Barnes, I.T. Karapanagiotidis	
2:40 pm	Health Break	
3:00 pm	Impact of endosulfan on growth, histology and metabolic rates in juveniles of American lobster (<i>Homarus americanus</i>) - D. Daoud , W. Fairchild, P. Jackman, K. Benhalima, M. Comeau, B. Bruneau, D. Chabot, M. Mallet	
3:20 pm	Nutritional Condition of the American lobster, <i>Homarus americanus</i> , at differ- ent stages of the moult cycle – M. Ciaramella , A. Battison, B. Horney, R. Summerfield	
3:40 pm	Temperature matters: moving toward a degree-day model for the growth of the American lobster – C. Bergeron , R. Wahle, Y. Chen, P. Lawton	
4:00 pm	Finish	·

6:30 pm	Banquet night
	Refreshments
	Jazz concert with the Science Fair: Oded ben-Horin, Thomas Dahl & Stein Inge Brækhus (everybody are Please be seated at the table during the concert)
	Dinner
	Entertainment: Musical lecture by J. Atema
	Dessert
	Dance. Per Pahr band
	Banquet finishes 11:30 pm
	(Time for a tour out in the night. and the Norwegian mid-summer festival)

Friday June 24. 2011

	Plenary
9:30 am	Farewell session
9:45 am	Award ceremony
10:00 am	Summary and conclusions from the Disease workshop
10:20 am	Summary and conclusions from the Neurobiology. Sensory biology and Behaviour workshop
10:40 am	Summary from the Aquaculture seminar
11:00 am	Photo session
11:20 am	Announcements
11:30 am	Presentation of the 10 th International Conference and workshop on Lobster Biology and Management



Oral Presentations Abstracts

Monday 20 June 2011

PLENARY SPEAKERS

The role of scientific interaction in the recover of the Sagmariasus verreauxi, population off New South Wales, Australia S.S. Montgomery and G.W. Liggins (steven.montgomery@industry.nsw.gov.au)

Research on European lobster (Homarus gammarus) in Norway with focus local stock enhancement and genetic aspects Knut E. Jørstad (knut.joerstad@imr.no)

Marine Diseases: Ecologically relevant and consequential to lobsters Mark Butler, Donald Behringer, Jeffrey Shields, Claire Paris, Thomas Dolan, Jessica Moss, and Robert Cowen (mbutler@odu.edu)

Lobsters as part of Marine Ecosystems — A review

Bruce F. Phillips¹, Rick Wahle² and Mahima Jaini²
1. Department of Environment & Agriculture Curtin University Western Australia
2. School of Marine Sciences University of Maine USA



STREAM ONE

Aquaculture seminar: Larval culturing

Lobster Aquaculture and Environmental Issues

Andrew Jeffs

a.jeffs@auckland.ac.nz (University of Auckland)

The global supply of marine lobsters from fisheries is at full capacity, however, the global consumer demand for lobsters continues to increase. Aquaculture and enhancement is beginning to emerge as a commercially viable alternative to increase the global supply of lobsters. However, to date very little attention has been paid to the environmental impacts of these activities, or how important the environment is for the health and condition of cultured lobsters. The aim of this work is to overview the available information on environmental management of lobster aquaculture and enhancement, and use this to provide some directions for future and management.

Culture of temperate spiny lobsters (*Jasus edwardsii* and *Sagmariasus verreauxi*) phyllosoma in Tasmania: recent developments and the prophylactic use of chemical disinfectants

Q. P. Fitzgibbon and S. Battaglene

Quinn Fitzgibbon <quinn.fitzgibbon@utas.edu.au> (Institute for Marine & Antarctic Studies)

Spiny lobster propagation research has been undertaken for more than ten years on two temperate planurid species endemic to southeastern Australia; southern rock lobster, Jasus edwardsii and eastern rock lobster, Sagmariasus verreauxi. Australia's first successful culture of J. edwardsii from egg to juvenile was in our laboratory in 2004 and for S. verreauxi in 2006. Excellent progress in culture has been made based on improved understanding of health management, abiotic requirements and larval behaviour and physiology. Background information on propagation research is presented focusing on microbial control and the use of chemical disinfectants for larval health management. In a series of experiments the prophylactic use of benzalkonium chloride, sodium hypochlorite and hydrogen peroxide were examined on the survival, growth and bacteriology of early-stage phyllosoma. High concentrations of all chemicals disinfectants were acutely toxic. Lower doses of some chemicals improved survival. However, it was often associated with a chronic suppression of growth. The use of some chemical disinfectants appears beneficial for controlling bacterial disease in phyllosoma culture. Sustained use of chemical disinfectants can also negatively affect phyllosoma culture performance through chronic toxicity, disruption of beneficial bacterial flora and facilitation of resistant bacterial strains. The benefits and disadvantages of chemical disinfectants will be discussed in relation to other control methods to minimize bacterial disease in phyllosoma culture.

Application of advanced rearing technology of Panulirus japonicus phyllosoma to P. homarus homarus larvae

Keisuke Murakami & Shintaro Sekine

Keisuke Murakami <kmphy11@affrc.go.jp> (National Research Institute of Aquaculture, FRA)

Japan has a century history in attempting artificial seed production for the Japanese spiny lobster *Panulirus japonicus*. At Minamiizu Station, Fisheries Research Agency, we succeeded in producing more than 500 juveniles of P. japonicus in 2007, in which the survival rate from hatching to the first juvenile was higher than 80 %. To date, complete larval development has been reported only in four species (*P. japonicus, P. longipes bispinosus, P. penicillatus* and *P. argus*) of the genus Panulirus. In our preliminary attempt at 1998, we could obtain pueruli of *P. homarus homarus*, in which the larval period ranged from 166 to 235 days with an average of 200.7 days (unpublished) but the survival rate was extremely low (1-2 %). A decade later, we applied advanced rearing techniques of *P. japonicus* larvae to those of *P. h. homarus*. The larvae started to metamorphose into pueruli at 103-192 days after hatching (126.5 days in average) and survival rate was considerably improved (c. a. 30 %). Controlling photoperiod and water circulation system might have contributed to duration and rate of metamorphosis.

Bacterial manipulation in the gastrointestinal tract of early stage Homarus gammarus: using biotic dietary supplements to improve culture success Carly Daniels

Carly Daniels <carly.daniels@nationallobsterhatchery.co.uk> (The National Lobster Hatchery)

Juvenile lobsters were fed one of four diets; control (basal diet void of biotic supplementation), basal diet + Bacillus, basal diet + MOS, basal diet + Bacillus and MOS. At the end of the trial samples were

taken for microbial analysis of gastrointestinal (GI) communities, at 8 and 48h post feed. Alteration to the GI bacterial populations of lobsters, caused by the dietary supplementation of biotics, was revealed by DGGE fingerprinting. GI microbial population shifted away from that of control fed lobsters in those fed diets supplemented with biotics. However, GI microbial populations in MOS fed juveniles appeared to shift back towards that of the control 48h after feeding. A stabilisation in microbial communities was also found between replicates of the same diet, which was greatest at 48h post feed, particularly in Bacillus fed juveniles. Bacterial species diversity was also increased in the GI tract of lobsters fed biotics; particularly Bacillus + MOS fed individuals. This was supported by culture based analysis which demonstrated increased total bacterial counts along with reduced Vibrio levels. Increased growth was observed in all biotic supplemented diets in comparison to the control diet; measured by weight, carapace length, weight to carapace length ratio, specific growth rate, moult frequency and food conversion ratio. Enhanced immune status was also recorded in Bacillus fed juveniles either with or without MOS supplementation. The addition of biotics to the diet of *H. gammarus* from early juvenile stages positively affected culture success, providing modifications to the GI bacterial community ecology, enhancing immune status, growth and survival.

An examination into the use of ozone delivery to control bacterial assemblages and enhance the rearing performance of the early stages of the European lobster reared under intensive conditions.

Powell A. Scolding J. Boothroyd D. Shields R

dominic boothroyd <info@nationallobsterhatchery.co.uk> (National Lobster Hatchery)

Ozone has not been widely used in the culture of the European lobster, despite its extensive application in aquarium and aquaculture facilities world-wide. With rising energy costs, a low carbon alternative to ultraviolet sterilisation is desirable, this study therefore sought to examine the use of ozone as an aid to lobster culture, through microbial control. Laboratory scale experiments exposed lobster larvae and postlarvae to a range of ozone treatments which reduced bacterial loading of the animals and system water. Preliminary findings from post-larval studies also indicated beneficial effects of ozonation in biofilm control within post-larval rearing cells; however some reduction in growth rate and moult frequency was observed at the highest redox levels. Results from laboratory scale trials were used to conduct a set of commercial scale validations. Commercial scale validation of ozonation at a concentration of 15ppb total residual oxidants (TRO) showed good potential to reduce bacterial loading of both larvae and water and to increase survival, although growth was significantly reduced during the later larval stages. It was concluded that regulated ozonation could significantly increase post larval recruitment. Two post-larval commercial scale trials were performed to assess bacterial loading and growth rates between ozonated and non-ozonated systems. These trials showed that while growth was reduced during the short larval rearing stage, downstream juvenile development was un-affected by prior or current ozonation and bacterial loading by Vibrio spp. of both the water and animals was generally reduced in ozonated systems.

Aquaculture Seminar: Diet and nutrition

Nutritional aspects of the aquaculture of the spiny lobster Jasus edwardsii

Cedric J. Simon Andrew G. Jeffs

Cedric Simon <cedric.simon@utas.edu.au> (TAFI, University of Tasmania)

The development of effective culture systems and formulated diets is essential for advancing the large-scale commercial aquaculture of spiny lobsters. To date fresh natural foods have consistently produced better growth than formulated diets. This paper provides an overview of key findings of recent research on juveniles of the spiny lobster, *Jasus edwardsii*, aiming at addressing these bottlenecks. The research was performed as part of a PhD at the University of Auckland and N.I.W.A., New Zealand. Sea-cage culture was found to provide significant growth advantages over tank culture, particularly by addressing some of the inadequacies of formulated diets via supplemental nutrition from biofouling. Reduced food consumption due to the poor attractiveness of formulated diets has been suggested to account for the slow growth of lobsters in previous studies. The findings of the current research suggest that food consumption may also be significantly constrained by gut throughput. A small foregut capacity, expansion of the formulated diet post-ingestion, lengthy foregut filling (1-2 h) and clearance time (10 h), combined with slow intestine evacuation (>24 h) and slow appetite revival (>18 h) were found to impair consumption. Improving the digestibility of formulated diets would help maximise the amount of nutrient assimilated per meal. Carbohydrate sources such

as gelatinised starches, dextrins, carboxymethylcellulose and raw wheat starch were found to be the best digested, but their contribution to the overall nutrition of cultured spiny lobsters remains unclear. Several potential solutions to improve spiny lobster nutrition are discussed and future research areas of interest are outlined.

Comparison of manufactured pellet and trash fish feeds for production of spiny lobster (*Panulirus ornatus*) in sea-cages in Vietnam

Le Lan Huong, Huynh Minh Sang, Nguyen Trung Kien, Nguyen Kim Bich, Clive Jones Clive Jones <clive.jones@deedi.qld.gov.au> (Queensland Government)

Over 15 years of lobster aquaculture industry development in Vietnam, the food used has consisted of low value trash fish species. This traditional feeding practice may contribute to environmental contamination which in turn may have caused an increase in the prevalence of disease in farmed lobsters and reductions in productivity and production. Manufactured diets provided in pellet form have been defined which support good growth under experimental conditions. Pellet diets are likely to have a much lower environmental impact, may help to reduce the incidence of disease and be more cost-effective than trash fish. A sea-cage trial was established to compare pellet and trash fish feeds for lobster production and environmental impact. Four cage farms each with 4 replicate cages were deployed in Bây Lagoon, Nha Trang Bay, Vietnam. Two farms were fed with pellets, and two with trash fish. 40g lobsters (Panulirus ornatus) were stocked to the cages at 10/m² and farmed using standard industry practices. Survival averaged 84% at 3 months and there was no significant difference between treatments. The average weight of lobsters at day 189 in cages fed trash fish was 320.19 ± 12.0 , significantly higher than for pellet fed lobsters at $268.5g \pm 6.7$. Taking into account food conversion ratios, the pellet feed treatment appears to be more cost-effective. Lobster production and environmental monitoring will continue until lobsters achieve a market size (1kg), and analysis of the full trial data will be necessary before drawing conclusions about the relative efficacy of pellets and trash fish.

Physiological condition, survival and growth in the wild of hatchery-reared stage IV American lobster (*Homarus amricanus*) fed different lipid composition diets

Louise Gendron, Réjean Tremblay and Jean Côté

Institut Maurice-Lamontagne, Ministère des Pêches et des Océans, 850 route de la Mer, Mont-Joli, QC, Canada G5H 3V9, Louise Gendron <louise.gendron@dfo-mpo.gc.ca> (Department of Fisheries and Oceans)

Release of hatchery-reared lobster is seen by the Gaspé (Québec) fishermen as a possible tool to increase lobster stocks in depleted areas. To assist fishermen, experimental work was undertaken to try to increase and assess hatchery-reared lobster's competency to survive and grow in the wild when released. In 2009 and 2010, stage IV lobsters were produced at the Centre Aquacole Marin de Grande-Rivière (Québec) hatchery from larvae of ovigerous females captured in the wild in the surrounding area. Larvae (stages I-IV) were fed either live Artemia or natural zooplankton in 2009 and Artemia+algae in 2010. The objective was to determine if an increase in the level of essential fatty acids in the larval diet (zooplankton diet) could increase survival and growth during larval development and early benthic stages. The underlying hypothesis is that essential fatty acids increase osmoregulatory enzymatic activity favouring pelagic-benthic transition. Enclosures (61 cm x 91 cm x 15 cm) filled with cobbles as well as small cages (10 cm x 7.5 cm x 5 cm) were set in the wild and seeded with late stage IV and early stage V lobster fed the Artemia and the zooplankton diets (2009) and the Artemia+algae (2010) diet to assess survival, growth and physiological condition over a 3-month period. Activity of stage IV lobster fed the different diets was examined in tank experiments before their release in the wild. Results of the different experiments will be presented.

Aquaculture seminar: Culturing operations and growth

Preliminary assessment of the Tropical Spiny Lobster (*Panulirus* ornatus) aquaculture under pond conditions in Australia

Scott Shanks, Clive Jones and Le Anh Tuan

Matthew Johnston <matthewjohnston@lobsterharvest.com.au> (Lobster Harvest Ltd)

Successful spiny lobster aquaculture in Vietnam is based on sea cage growout of wild caught seed. In Australia there is interest in developing lobster aquaculture using a hatchery supply, as exploitation of wild seed is unacceptable. With hatchery technology well advanced, it is prudent to examine the production systems that might be used to growout lobsters to market size. In Australia environmental regulations preclude the use of sea cage systems, so alternative systems must be employed. Shrimp ponds were considered initially, because they are a relatively low cost production system and are readily available. An experiment was designed to grow lobsters (*P. ornatus*) in shrimp pond conditions and test the effect of providing shelter. The experiment was carried out in 4 raceways, each 35.2m x 2.2m x 1.5m, divided in half to provide 8 compartments. Each raceway contained one shelter and one non-shelter treatment and they were managed as per normal shrimp ponds. Over 197 days, survival averaged 77% and 85% without and with shelter respectively. The SGR was 0.07%/day for both treatments. There was no significant difference in growth or survival. This experiment was terminated due to reducing salinity brought on by the early onset of the wet season. Although the results of the trial suggest growth rates in such systems may be commercially acceptable the survival rates of such high value species at this size are not. This paper discusses the opportunity for and risks of pond and other land-based culture systems for lobster production in Australia.

Spiny lobster aquaculture in Vietnam: constraints and opportunities

Le Anh Tuan

Clive Jones <clive.jones@deedi.qld.gov.au> (Queensland Government)

With a coastline of 3260 km, along which there are more than 4000 islands and many lagoons giving protection against waves and wind, Vietnam has great potential for seacage-based spiny lobster aquaculture. Spiny lobster aquaculture started in the province of Khanh Hoa in 1992 and has expanded significantly around Southern Central Vietnam since 2000. Ornate spiny lobster (Panulirus ornatus) and scalloped spiny lobster (*P. homarus*) are the most important cultured species among others. In 2006, there were more than 49,000 cages producing approximately 1,900 metric tonnes of product and valued at more than US\$65 million. However, due to the milky disease that appeared in late 2006, lobster production declined and the production for 2007/2008 begin of the skype highlighting 2007/2008 end of the skype highlighting was less than 1,000 metric tonnes. The industry has recovered recently with the production for 2009/2010 begin of the skype highlighting 2009/2010 end of the skype highlighting about 1,500 metric tonnes worth more than US\$60 million. This paper reviews the current status of spiny lobster aquaculture industry in Vietnam, and identifies major technical and socio-economic constraints and opportunities for further development. KEYWORDS: spiny lobster, aquaculture, Vietnam.

Review of Spiny Lobster Aquaculture in Indonesia

Bayu Priyambodo¹, Clive Jones² and Scott Shanks²

1. Lombok Marine Aquaculture Development Center PO. BOX 1 Sekotong Lombok

Barat – West Nusa Tenggara bayu_lombokmadc@yahoo.com

2. Department of Employment, Economic Development and Innovation Northern Fisheries Centre Cairns Australia 4870

clive.jones@deedi.qld.gov.au

Spiny lobster (Palinuridae) aquaculture has great potential in Indonesia with 17,504 islands and some 81,000 km of coastline. This coastline is home to thousands of sheltered lagoons and bays that are suitable for seacage culture. There are six endemic species of spiny lobster commonly exported from Indonesia including: Panulirus homarus, P. ornatus, P. longipes, P. versicolor, P. polyphagus and P. penicillatus. Of the total lobster production in 2008, aquaculture supplied 3%; however, by 2009 aquaculture supplied over 5%. In Southern Lombok, West Nusa Tenggara province, lobster pueruli and juveniles were first found in 2004 attached to grouper cages and among seaweed culture rafts. As a result of the natural supply of puerulus, more than 2,500 small-scale farm units have been established which produce approximately 5 tonnes of lobster per month. Lobster aquaculture production in Lombok has increased by 10% a year since 2008. The strong market for spiny lobsters and the success of lobster grow-out by smallholder farmers suggests that lobster aquaculture will provide a profitable business opportunity to coastal communities where pueruli can be found. While lobster farming is now established in Indonesia, improvement in seed collection techniques, husbandry and nutrition will help the industry expand. This paper reviews the current status of the lobster aquaculture industry in Indonesia and identifies major technical and socioeconomic constraints to further development. This research and development project is being supported by the Australian Federal Government through the Australian Center for International Agricultural Research (ACIAR). Key word : lobster, aquaculture, puerulus, Indonesia.

Genetic mapping to improve growth performance, survival and feed conversion ratio (FCR) for on-growing of European lobster in Recirculating Aquaculture Systems (RAS)

Asbjørn Drengstig, Ann-Lisbeth Agnalt & Knut Jørstad Asbjørn Drengstig <ad@hobas.no> (Norwegian Lobster Farm)

Attempts to farm European lobster (Homarus gammarus) to plate size in land-based systems have in the past been difficult. Several attempts have been made to mass-produce these cannibalistic crustaceans, but none of the attempts proved to be successful in incorporating all important elements into one single design. Major constraints have been the need for individual rearing to avoid cannibalism, heated water, lack of high quality dry food, high labour costs, inadequate technological solutions and high investment costs. Today, Norwegian Lobster Farm operates the world's first landbased farm based on recirculating aquaculture systems, producing plate sized lobsters with an annual capacity of 1.5 -2.0 MT. The company operates its own brood-stock and a small scale hatchery with annual capacity of 60,000 IV-stage larvae. The company has patented a single cage technology in 23 countries world-wide. The company has developed a formulated feed diet which is commercially used in the production, from I-stage larvae to plate-sized lobster. In 2008, Norwegian Lobster Farm launched a genetic mapping programme in cooperation with Institute of Marine Research in Bergen. The overall aim is to develop a genetic databank to select best performing brood-stock by monitoring growth, survival and feed conversion ratio (FCR) in the surviving offspring. Screening of the juveniles is currently under evaluation. The company has started to manipulate the temperature of the broodstock to obtain hatching throughout the year. Moreover, the brood stock consists of males and females and successful matings were observed in 2010.

Ongrowing juvenile American lobsters (*Homarus americanus*) at sea using suspended polyculture methods in Nova Scotia, Canada

Michelle Theriault

Michelle Theriault <michelle.theriault@usainteanne.ca> (Université Sainte-Anne)

This project investigated the effectiveness of traditional aquaculture techniques for the production of juvenile American lobsters (*Homarus americanus*) at sea. Hatchery-reared stage IV lobsters were cultivated in a suspended culture system alongside sea scallop (*Placopecten magellanicus*) in Chedabucto Bay, Nova Scotia, Canada, from 2006 to 2010. Optimal lobster growth was obtained using two container sizes, with a cage transfer after the first five months to maximize growth and reduce cage fouling. Initial culture containers (177 cm2) yielded a growth rate of 0.055 mm CL per day and a mean lobster size of 12.3 \pm 0.14 mm CL after one growing season (June to October). Transfer to a larger cage size (1156 cm2) yielded growth rates of 0.086 mm CL per day and a mean lobster size of 24.1 \pm 0.64 mm CL after a second growing season. Maximum lobster size attained to date in at sea cages is 33.3mm CL (101.1 mm TL). Biological assessments of sea grown juveniles indicated they were in good nutritional condition and well acclimated to their natural conditions (high survival, high rate of claw differentiation, normal coloration, sex ratio (M:F) of 1.3, and mean total hemolymph protein of 54.8 \pm 2.0 mg/ml). In addition to producing a juvenile lobster suitable for release, the integration of lobster culture within an existing aquaculture operation would also reduce production costs while providing a supplementary source of income for farmers.

Lobster resource enhancement in Atlantic Canada through stage iv larvae seeding: The HOMARUS inc. experience

D. Daoud, M. Mallet, R. Haché and M. Comeau

au Michel <michel.comeau@dfo-mpo.gc.ca> (Department of Fisheries and Oceans)

Decline in American lobster (*Homarus americanus*) landings in some areas of Atlantic Canada induced the Maritime Fisherman's Union to create Homarus Inc., a non-profit organization comprised of several partners from the public and private sectors. Its mandate is to develop strategies for increasing lobster abundance through practical approaches of lobster enhancement and sea ranching, increasing scientific knowledge of lobster biology, and introduce educational tools to better explain ecological processes to the fishing industry. It is within this initiative that an experimental lobster hatchery project was created at the Coastal Zones Research Institute in Shippagan, New-Brunswick (Canada) in 2002. The aim of this project is to ensure the production of stage IV lobsters for stocking experiments supervised by the Department of Fisheries and Oceans Canada. Another project goal was to develop a simple and cost-effective hatchery technology which would enable community-based fishermen groups to pursue their own stocking efforts. One approach to reducing costs was to elaborate feed alternatives to the use of live *Artemia salina* nauplii in hatchery production. Results from several studies carried out to evaluate the survival, growth, metabolism, lipid composition, and behavior of lobster larvae in relation to different test diets will be presented.

Biological and Economic Benefits of an American Lobster (Homarus americanus) Enhancement Project in Atlantic Canada

Michel Comeau, Marcel LeBreton and Martin Mallet

Comeau Michel <michel.comeau@dfo-mpo.gc.ca> (Department of Fisheries and Oceans)

An experimental American lobster (*Homarus americanus*) hatchery project initiated by a harvesters' association has produced and released over 1.2 million stage IV lobsters since 2002 in the southern Gulf of St. Lawrence, Canada. Based on a Before-After-Control-Impact approach, the release of over 53,000 stage IV (age-0) in 2004 significantly increased the 2005 age-1 lobster density in seeded reefs compared to controls, indicative of a good survival over the 1st winter. Furthermore, a significantly higher density for the age-2 lobster in 2006 was also observed suggesting a good survival over several years for hatchery-reared animals released in the natural habitat. A bio-economic model has been developed to assess the biological and economic benefits associated with lobster stock enhancement initiatives. The model was used to calculate benefits generated by an investment of \$25,000 CDN to seed 100,000 stage IV lobsters. Results showed that this investment would increase landings in the Spring fishery by 16,290 kg and generate \$130,405 over 10 years in revenues for harvesters, i.e., equivalent to a ROI of 16.6 %. The Gross Domestic Product generated would amount to \$186,100 locally and \$274,800 nationally. Based on the simulations, there were significant economic benefits to the industry from the released of hatchery-reared stage IV larvae. Harvesters' associations can now make informed decisions about the profitability of lobster enhancement using hatchery.

Conditioning improves survival of hatchery-reared juvenile European lobster (*Homarus gammarus*)

Ann-Lisbeth Agnalt, Eva Farestveit, Ellen Sofie Grefsrud, Asbjørn Drengstig and Knut Eirik Jørstad Ann-Lisbeth Agnalt <ann-lisbeth.agnalt@imr.no> (Institute of Marine Research, Bergen Norway)

Predation immediately after release has been regarded a major limitation with releases of European lobster (Homarus gammarus), whether for sea-ranching or restocking. A series of experiments were conducted to test if enriched environment, i.e. conditioning, can improve survival. In the first experiments, the conditioning period lasted from stage IV until 4 months of age. Thereafter, 20 naïve and 20 conditioned juveniles of the same sizes were introduced into tanks (4 m2) with shell sand and 20 shelters (empty shells of scallop). The treatment groups were tagged with different colours of elastomer tags. After 12 days, all shelters were occupied by juveniles. Of those that had not found shelter, 80% were naïve juveniles. After 3 months, 88% of the lobsters in shelter were conditioned juveniles. In the second experiment, naïve juveniles were purchased from Norwegian Lobster Farm. One group was conditioned for shell sand and shelter for 6 1/2 week. The other group continued in single compartments for the same period. The juveniles were released in equal numbers into two enclosures (10 m2), placed on the bottom of a lobster holding park facility. The bottom of the enclosures consisted of shell sand and shelter. After 9 months, from 66 to 75% of the surviving lobsters were those that had been conditioned prior to release. These data are the first to demonstrate that hatchery-reared European lobster juveniles can be conditioned. We suggest that this may serve as a strategy to train hatchery-reared lobster prior to releases into the wild.

Can the rags to riches tale of spiny lobster live exports from NZ be applied to the king crab fishery in Norway?

Philip James, Sten Siikavuipio & Svein Ruud Nofima Marin, Tromsø, Norway Norway King Crab AS, Burgoynes, Norway Philip James <philip.james@nofima.no> (Nofima Marin)

The live export of spiny lobsters from New Zealand has been a remarkable tale of success. Twenty years ago 85% of the spiny lobsters fished in NZ were sold as a low value product that were frozen and exported to the USA. Today there has been an almost complete reversal with 97% of the lobsters landed in NZ being exported live to high value markets in Asia. Norway now finds itself in a similar position to the spiny lobster fishery in NZ twenty years ago. It has a developing king crab fishery based on the spread of this species from the Barrent Sea where they were introduced in the 1960's. Currently less than 10% of the catch is exported live, the remainder being sold as frozen product. However, there is now a rapidly developing live king crab export industry based in Burgoynes in northern Norway which is modeling itself on the NZ lobster industry. This talk compares these two industries and looks at the similarities and lessons than can be learnt from each to enhance live export of crustacean species around the world.

STREAM TWO

Ecology and ecosystems

Geography of top-down forcing in the Northwest Atlantic lobster-groundfish interaction: the role of predator diversity, identity and abundance

Richard A. Wahle¹, Curtis Brown², Kevin Hovel²

1. School of Marine Sciences, University of Maine, School of Marine

Sciences, Darling Marine Center, Walpole, Maine, USA

2. Gulf of Maine Research Institute, Portland, Maine, USA

3. Department of Biology, San Diego State University, San Diego, California, USA

Richard Wahle <richard.wahle@maine.edu> (University of Maine)

After widespread depletion of commercial groundfish, American lobster (Homarus americanus) abundance has increased dramatically since the 1980s in the Gulf of Maine. But in southern coastal New England the response to groundfish declines appears to have been weaker prior the onset of a devastating shell disease epizootic in the late 1990s. We evaluated the hypothesis that the apparent difference in lobster response to groundfish depletion could be attributed to the long-standing regional contrast the diversity and composition of the predator assemblage. Trawl survey data (1981-2004) indicate that despite harvesting, the collective biomass of predatory groundfish did not decline over the period in either region, whereas collective groundfish average body mass did, resulting in a statistical correlation between shrinking groundfish body mass and the increase in lobster abundance for northern New England. Recent stationary video surveillance, ROV surveys and tethering experiments in shallow rocky lobster nurseries confirm a persisting strong southward gradient in fish diversity and predation rates, and a corresponding gradient of increasing lobster shelter occupancy. Particular groundfish species attacked tethered lobsters at rates disproportionate to their abundance, underscoring the importance of species identity as well as abundance in assessing interaction strength. The combination of a more diverse predator assemblage with the recent onset of disease suggests a gradient of increasingly strong and diverse biotic interactions to the south.

Understanding the ecosystem impacts of fishing for western rock lobster; a progress report

L. M. Bellchambers, S. E Evans and J. J. Meeuwig Lynda Bellchambers <lynda.bellchambers@fish.wa.gov.au> (Western Australian Fisheries and Marine Research Laboratorie)

Western rock lobster, Panulirus cygnus is distributed along the west coast of Australia from North West Cape to Cape Leeuwin. As a major benthic consumer this species is ecologically important and the target of substantial commercial and recreational fisheries. The West Coast Rock Lobster Fishery is Australia's most valuable single-species fishery and was the first fishery to obtain accreditation by the Marine Stewardship Council (MSC) in 2001. Previous research has focused on the biology of the species with little known about its ecology. Recent declines in production coupled with low puerulus numbers have highlighted the importance of understanding the ecological impacts of removing lobster biomass from the environment, particularly in deep water. Here we discuss the progress that has been made in addressing this gap by quantifying the relationship between the abundance and size of lobster and the habitats where they are found. We discuss the approaches and outcomes of two studies to illustrate that incorporating a knowledge of the distribution and densities of preferred habitats is essential to assess the effects of fishing, improve stock assessments and to design long term monitoring programs to detect change.

Why spiny lobsters still exist in the Mediterranean? A metapopulation approach for *Palinurus elephas,* an ancient overexploited species

Díaz D., Goñi R., Zabala M., Stobart B., Reñones O., Linares C., Marí M., Abelló P. David Diaz <david.diaz@ba.ieo.es> (Insituto Español de Oceanografía)

Sustained high fishing pressure of marine species in the Western Mediterranean has led to overexploitation of many local populations. However, after centuries of exploitation, spiny lobster artisanal fisheries are still profitable in some regions. For a slow-growing, highly capturable species this suggests that population resilience is aforded by a metapopulation structure with large scale connectivity. To test this hypothesis, we built a series of settlement indices at 13 separate locations over 300 km for a period of 11 years. Spatial synchrony was measured as the correlation in the time series of pairs of sites as a function of the lag distance. The results of the study show a synchronous

settlement for *P. elephas*, although there is no correlation between local adult abundance (as measured by commercial landings) and settlement, implying that auto-recruitment is null or very low. Recent progress on the quantification of larval dispersal distance has motivated the relaxation of rules to define a marine metapopulation. The long larval dispersal stage for the species (4-5 mo), despite littoral environmental conditions that have a strong effect in the strength of local settlement, leads a common larval pool. This suggests that the dynamics of this species agrees with the metapopulation model with a common larval pool. Therefore one of the main implications for the species management must take into account not only the local catch trends but also the oscillations of the settlement indeces.

Environmental correlates of American lobster settlement at the sea surface as measured by satellites and oceanographic buoys

Mahima Jaini, Richard Wahle, Andrew Thomas (University of Maine) Mahima Jaini <mahima.jaini@umit.maine.edu> (University of Maine)

Diver-based surveys of American lobster (Homarus americanus) nurseries in New England, USA and Atlantic Canada have given rise to over 20 years of data on annual recruitment of young-of-year (YoY) lobsters. There is considerable interannual variability in the YoY time series, suggesting the role of environmental factors in regulating planktonic larval supply and transport. Here we evaluate statistical correlations between the YoY index and sea surface temperature anomalies (SSTa), wind stress, and river discharge, from satellites, data buoys and weather stations, for three oceanographically contrasting regions: southern New England, the Gulf of Maine and the Bay of Fundy. YoY indices were correlated with the environmental variables for the month of settlement sampling, as well as prior months when larvae are in the plankton. Significant relationships existed between the YoY index and SSTa for all three regions. In certain cases, spatial correlations of SSTa mapped to recognizable oceanographic features on the sea surface. Lobster settlement was strongly coupled with cross-shore stress in the Bay of Fundy and alongshore wind stress in southern New England and the Gulf of Maine. However, Local river discharge correlated significantly with Gulf of Maine YoY time series only. Our analysis revealed significant associations between YoY abundance and environmental variables for time lags relevant to larval transport and settlement (up to 2 months prior to settlement sampling). Our results help identify areas of the sea surface of Northwest Atlantic shelf waters that are of particular value in predicting year-to-year fluctuations in larval settlement.

Recruitment and management

Modelling Ocean circulation, Stokes drift and connectivity of western rock lobster population

Ming Feng¹, Nick Caputi², James Penn² (Presenter), Dirk Slawinski¹,

Simon de Lestang², Evan Weller¹ and Alan Pearce²

1. CSIRO Marine and Atmospheric Research, Floreat, WA 6014 Australia

2. Western Australian Fisheries and Marine Research Laboratories, Department of

Fisheries, Western Australia, PO Box 20 North Beach WA 6920, Australia

James Penn <jim.penn@fish.wa.gov.au> (Western Australian Fisheries and Marine Research Laboratorie)

An individual-based model (IBM) incorporating outputs from a data-assimilating hydrodynamic model was developed to investigate the recruitment processes of Western Australian rock-lobster (Panulirus cyanus), and investigate possible causes of the recent low puerulus settlements. The IBM simulations for the nine years 2000/1 to 2008/9 indicate that, strong northward winds and weak southward Leeuwin Current flows in summer aid the offshore movement of early-stage particles (phyllosoma) into the eastern Indian Ocean. Conversely, the eastward flows that feed the enhanced Leeuwin Current in winter, facilitate onshore movement of late-stage particles towards the nearshore settlement zone. These IBM outputs are strongly influenced by the diurnal movements and temperatures experienced by the 'phyllosoma', with particles hatched in late spring/early summer being more likely to successfully settle. The inclusion of Stokes drift induced by swells from the Southern Ocean in the IBM, significantly enhances onshore movement of the particles, and further increases the chance of settlement on the coast between latitudes 24° and 33°S, where puerulus regularly occur. The preliminary source-sink relationship developed, suggests that although the population was well mixed off the west coast, particles hatched closer to the shelf break are more likely to successfully settle. A general declining trend in the likelihood of successful particle settlement from hatchings north to south, most likely due to the temperature growth relationship, also occurred. The model further suggests that release locations along the central west coast, including the Abrolhos Is, are more likely to be significant to average successful puerulus settlement.

Preliminary assessment of the cause of the record low puerulus settlement in the West Australian Rock Lobster Fishery

Nick Caputi¹, Simon de Lestang¹, Ming Feng², James Penn¹, Evan Weller², Dirk Slawinski², Alan Pearce¹, Ainslie Denham¹ 1 Western Australian Fisheries and Marine Research Laboratories, Department of Fisheries, Western Australia, PO Box 20 North Beach WA 6920, Australia 2 CSIRO Marine and Atmospheric Research, Floreat, WA 6014 Australia Nick Caputi <nick.caputi@fish.wa.gov.au> (Department of Fisheries (Western Australia))

Puerulus settlement has been monitored for 40 years in the western rock lobster fishery and has accurately predicted catches 3-4 years later. Historically high settlement has been correlated with warm water La Nińa conditions, resulting in strong Leeuwin Current flows, and westerly winds in late winter/spring. In the last five years (2006/07 to 2010/11) settlement has been below average with a record low in 2008/09 when water temperature was conducive to good settlement. Some additional factors that may have negatively affected settlement include: three consecutive positive Indian Ocean Dipole events (2006-2008) associated with unusual winter/spring offshore winds during the shoreward phyllosoma movement phase and a reduced breeding stock in the far northern section of the fishery. This section of the breeding stock had declined partly through lower sub-adult lobster migration northward into the area, linked to above average strength southward currents in six of the last eight years. Oceanographic larval modelling suggests that larvae released in the northern part of fishery and from deeper hatching sites have higher chances of settlement. Management actions taken to influence future settlement, include increasing egg production, particularly in northern areas, by a 50-70% reduction in fishing effort, a lower maximum size limits for females, and an area closure to increase protection for animals in the far northern area. Strong La Nina conditions resulting in above average sea temperatures in early 2011 and improving breeding stock levels in the far northern sector of the fishery should both be conducive to improved settlement in 2011/12.

Use of a spatial population-dynamic assessment model in the assessment and management of the West Australian Rock Lobster Fishery during a period of low recruitment Simon de Lestang, Peter Stephenson, Nick Caputi and Rick Fletcher.

Simon de Lestang <simon.delestang@fish.wa.gov.au> (Department of Fisheries, Western Australia)

Puerulus recruitment is monitored throughout the Western Australia's Rock Lobster Fishery as it accurately represents legal recruitment 3-4 years later. The 2007/08 puerulus settlement was below the range expected given the environmental conditions. The following year water temperatures indicated that 2008/09 settlement should improve where in reality it was the lowest recorded, with the subsequent settlement being the second lowest. The impact of these low settlements on commercial catch rates and breeding stock levels (BS) were examined using a spatial populationdynamic assessment model that integrates a full range of data sources including puerulus settlement, survey and commercial catch rates, size compositions, tag-recaptures and environmental measures. The projected impact identified that significant management measures were required to achieve the fishery's decision rules: 1. Maintain BS above threshold levels over the subsequent five years with 75% certainty, and 2. Move towards Maximum Economic Yield. The model assessed a range of management measures with the chosen suite, which were implemented in 2008/09-2009/10 seasons prior to the low settlement recruiting to the fishery, resulting in a 44% and 72% nominal effort reduction from 2007/08 levels, respectively. This has enabled a significant carryover of an additional 4500 t, into the expected low catch years. The stock assessment model projected a short-term increase in catch rates and BS, followed by a subsequent decline in catch rates and a levelling off of BS in the years when the low recruitments were entering the fishery. To date the fishery has followed these predicted trends.

Sexual maturity in female American lobster – detecting major trends from the size of ovigerous females

Tremblay, M.J. Silva, M.A. Reeves, A.R. Pezzack, D.S. Denton, C.

M. John Tremblay <john.tremblay@dfo-mpo.gc.ca> (Fisheries and Oceans Canada)

Size at sexual maturity is a key parameter for the management regime of Canadian fisheries for *Homarus americanus*. Recent studies of female lobster sexual maturity along the coast of Nova Scotia using cement glands indicate that estimates are affected by the timing of the field sample (the week during the season), the area, and the year. At a larger geographic scale, it has been recognized for 75 years or more that lobsters in the southern Gulf of St. Lawrence bear eggs at smaller sizes than lobsters off southwest Nova Scotia and in the Bay of Fundy. Here we review historical trends in ovigerous female sizes to evaluate whether long-term trends are detectable. The data set begins with samples from 1916 and continues to the present but as might be expected sampling intensity has varied over the years.

The most intensive at-sea sampling for the Atlantic coast of Nova Scotia and the Bay of Fundy was for the years 2007-2010 (1185 samples). The historical data suggest that in spite of the many changes in the lobster fishery over the last century, geographic differences in the size of ovigerous females have been maintained. Evidence for decreasing size at maturity is examined.

Stock assessment and trends

The Norwegian fishery and management of the lobster Homarus gammarus Trond Ottemo

The Norwegian Nephrops fishery in Skagerrak and the Norwegian Deep – trends and monitoring

Guldborg Søvik, Sten Munch-Petersen, Mats Ulmestrand

Guldborg Søvik <guldborg.soevik@imr.no> (Norwegian Institute of Marine Research)

The Nephrops norvegicus stocks in Skagerrak and the Norwegian Deep are mainly exploited by Denmark and Sweden which together land between 5000 and 6000 tons per year from these areas. The Norwegian fishery is in comparison very small, with only 240-300 tons landed in 2007-2010. Nephrops is distributed in the whole Norwegian Deep except in the deepest parts of Skagerrak, and the Norwegian Nephrops fishery is evenly distributed over the area. The Danish and Swedish fisheries are in comparison concentrated to the southern and western parts of the trench. Norwegian offshore fishers use mainly Nephrops trawl, while catches from coastal areas are often caught in pots, or as bycatch in shrimp trawls. The present study gives an overview of the Norwegian fleet (length groups, landings per vessels). In recent years the Skagerrak stock has been monitored using LPUE (landingsper-unit-effort) figures from the Danish and Swedish fisheries as well as mean lengths in catches, but work is in progress to start monitoring using video surveys. Length measurements of Nephrops from an annual shrimp survey in Skagerrak and the Norwegian Deep and from Coast Guard inspections in the same areas are compared with Swedish and Danish length measurements. Nephrops in the Norwegian deep has been monitored using Danish LPUE data and length measurements. These data are compared with corresponding Norwegian data which also cover regions further north along the Norwegian coast. The largest animals are found in the north, which can be explained by these stocks being mostly unexploited.

The french lobster fishery for 10 years

Martial Laurans

Laurans Martial <martial.laurans@ifremer.fr> (IFREMER)

The establishment of fishing form for all vessels not supplying logbooks and development of a calendar fishing activity of all fishing vessels has greatly improved knowledge of the vessel fleets with size less than 10 meters in France. Among these boats, we find the majority of the lobster potters. In 2010, the data set now covers 10 years. This data is used here to monitor the abundance of lobsters along the coast of Brittany and Normandy. The estimate of an abundance index is achieved by fitting a GLM model and considering four major fishing areas and seasonal factors. It appears that trends in these four areas are very close even if the size structure of catches are distinct. Meanwhile, an analysis of the proportion of ovigerous females of these various indications of strong homogeneity of the population.

Recent large-scale shifts in the spatial distribution of West

Coast Rock lobster (Jasus lalandii) in South Africa

A.C. Cockcroft

Andrew Cockcroft <andrewc@daff.gov.za> (Dept Agriculture, Forestry and Fisheries South Africa)

A major shift in resource availability in the West Coast rock lobster *Jasus lalandii* from the traditional grounds on the West Coast to the more southern fishing grounds was observed between the late 1980s/early 1990s and the turn of the century. The contribution of the West Coast region to total lobster landings declined from about 60% to <10%, whereas that of the southern region increased from around 18% to around 60% over that period. The early 1990s was also the start of a major influx of lobster abundance. The movement of lobster has been restricted to the nearshore zone (<50 m depth) with few lobster found in summer and winter trap surveys in deeper water (50 – 200m) EOCH. The ecological, fisheries and resource management implications of these shifts in the nearshore zone have

been severe and are likely to cause further major challenges in the future management of both the rock lobster and abalone resources. The temporal coincidence of the shifts in lobster distribution with events such as the onset of reduced somatic growth and increased lobster walkouts suggests a linkage in the underlying environmental causes or forcing factors. Despite a number of recent studies on the variability of the physical environment, the underlying cause of these events remains unknown.

Fisheries technology

Assessing and managing unaccounted fishing mortalities in the fishery for Sagmariasus verreauxi in New South Wales, Australia

Geoffrey W. Liggins

Geoffrey Liggins <geoff.liggins@industry.nsw.gov.au> (Cronulla Fisheries Research Centre, Industry & Investment NS)

The reported landed catch of eastern rock lobster (Sagmariasus verreauxi) from the commercial fishery in New South Wales (NSW), Australia, has been known precisely from 1994-95 onwards, when a mandatory logbook and individually-numbered management tags on lobsters were introduced. However, as is the case for many fisheries, there are multiple components of fishing mortality (F) that remain unaccounted for, or at best, poorly known. Unified models of components of F (e.g. ICES, 1995; Chopin et al., 1996) recognise specific sources of F, including those attributable to: reported landed catch (by multiple sectors); illegal, misreported and unreported landings; discarding; escape and drop-out from gears; and ghost-fishing. Unaccounted components of fishing mortality, if of significant magnitude, introduce serious sources of error in stock assessments. Moreover, they represent a waste of valuable fisheries resources. Management actions to remove or reduce such mortalities provide the opportunity to increase fishery production. A review of the information available for the NSW lobster fishery derived from the commercial fishery logbook, observer surveys, questionnaires to fishers and pilot experiments indicates that (i) landed catch from the recreational sector; (ii) illegal, misreported and unreported landings from the commercial and recreational sectors; (iii) discard mortality; and (iv) ghost-fishing mortality may be significant components of F. This paper provides an overview of the evidence for the significance of these components of F, the imprecision and potential bias of existing estimates and strategic options for estimating and mitigating these unaccounted fishing mortalities.

Finding the unreported catch in the Norwegian lobster (Homarus gammarus) fishery

Alf Ring Kleiven, Esben Moland Olsen, Jon Helge Vølstad

Alf Ring Kleiven <alf.ring.kleiven@imr.no> (Institute of Marine Research)

Official landing statistics do not always reflect the total catch in a fishery. Here we present a case study to estimate total landings in the Norwegian fishery for European lobster (*Homarus gammarus*). This fishery is conducted by both recreational and commercial fishers, but reliable information on total fishing effort and total catch is lacking. In 2008, we conducted a probability-based strip transect sampling survey throughout the lobster fishing season along the Agder counties in southern Norway to estimate the number of deployed lobster traps over time. Surface buoys marking lobster traps were counted along strip transects placed representatively in the survey area in 5 different weeks from start to end of the lobstering season. Catch Per Unit Effort (CPUE) data was obtained independently from volunteer catch diaries, phone interviews and questionnaires. We estimated that recreational catch account for 65 % of the total catch in the study area. Moreover, our study show that only a small proportion (23 %) of the commercial lobster is found to be nearly 14 times higher than the officially reported landings. Our study highlights the need for appropriate data collection of catch in coastal areas and is a warning sign to management authorities of the consequences of ignoring coastal illegal, unreported and unregulated (IUU) fisheries and the potential impact of recreational fisheries.

Trap efficiency comparisons between two trap designs used in the fishery for the American lobster, *Homarus americanus*

John Garland, Stacey Frame

John Garland <jgarland@clearwater.ca> (University of Hull)

Single and double parlour lobster traps used in the Atlantic Canadian lobster (*Homarus americanus*) fishery were evaluated during a 10 month survey period on three offshore lobster fishing vessels. Double parlour traps had an overall increased catch rate of 11.7% with a range of increases between fishing

vessels of 4.9% to 17.2%. Modifications to the trap entry mechanism also improved trap performance. There were no significant size-specific differences observed within the landed catch from both trap designs. Increased catch rates, based on trap designs within the constraints of fisheries regulations, may have implications on the fishing effort assumptions of an input control-based fishery such as the inshore Atlantic Canada lobster fishery.

Fishery and ecological indices for assessing alternative fishing methods: trap versus trammel nets in Mediterranean spiny lobster fishery

Sandra Mallol

Sandra Mallol <sandra@ba.ieo.es> (Instituto Español de Oceanografía-Baleares)

Palinurus elephas is the most commercially important spiny lobster species in the Mediterranean and North-eastern Atlantic. Traditionally, the spiny lobster was captured by means of traps/pots but a major change in the exploitation strategy took place during the 1970s with the progressive introduction of trammel net and the totally replacement of traps by early 2000s. In our study, fishing and ecological impacts of traps and trammel net are compared by using a set of simple efficiency indicators developed with the aim to facilitate managers the comprehension of the ecological and socio-economic consequences of each fishing method. A total of 746 hauls (408 from trammel netters and 338 from trappers) were analyzed on board during the annual fishing season from 1998 to 2002. Target (lobster) and by-catch specimens were sampled. The species composition, individual size and the fate of all macro-benthic species was registered. The catch of each species was expressed as the number and weight of individuals per set. A set of indicators were developed: Lobster Stock Use efficiency, Ecological Use Efficiency, Vulnerable Use Efficiency, Waste Use Efficiency and Labour Efficiency, for both the lobster and total retained catch. In number, lobster made a greater proportion of the commercial catch of trammel nets than of traps, as did the proportion of lobster damaged that could not be marketed. The proportion of the commercialized catch of traps was twice that of trammel-nets. The efficiency indices are presented in standardized, comparable form and are intended to provide a basis for assessing the relative merits of different fishing methods targetting the same species.

The Implementation of Electronic Logbook Technology for Different Crustacean Fisheries in Australia, USA and South Africa

Amos Barkai, Fatima Felaar, Guy Meredith, Zahrah Dantie, Dave du Buys Amos Barkai <amos@olrac.com> (Olrac)

This paper discusses the features and implementation of electronic logbook (eLog) solutions for three different crustacean fisheries, in South Africa (Palinurus gilchristi), the USA (Chaceon quinquedens) and Australia (Portunus Pelagicus). It describes three varying technical approaches to the same need: the transition from paper-based to digital data logging and reporting. The technology presented is based on the Olfish eLog, customized for the reporting needs of these specific crustacean fisheries. Olfish was developed by OLRAC, a South African company, as a generic solution for the collection and reporting of commercial and recreational fishing data. Olfish can collect, analyze, plot, map, report, trace and transmit all data related to fishing operations. Olfish works with all commonly-used satellite communication providers for near real-time data transmission. Data can be compressed, encrypted and digitally authenticated before transmission. Olfish includes a dynamic report generator, eliminating the need for paper-logbooks. Olfish includes an onboard version (Olfish Dynamic Data Logger: Olfish-DDL), a shore component which can import data from numerous vessel units, and a web-based reports management hub (Olfish Reports Management System: Olfish-RMS). Olfish-DDL captures data in real-time and/or post-event mode, reads GPS input and incorporates GIS capabilities for viewing vessel movements and operational data. Users can collect any type of data in any form, (images, video-clips, numerical and alphanumeric fields, free-text, date, time, location, etc). Olfish is currently installed on hundreds of vessels worldwide, including Europe, Australia, the USA and Africa and can be updated to match the reporting requirements of any nation, fishery or fishing method.

Tuesday 21 June 2011

PLENARY SPEAKERS

Adaptations of Lobsters to Predators: A Review

Kari L. Lavali & Ehud Spanier

Ehud Spanier <spanier@research.haifa.ac.il> (Maritime Studies, University of Haifa, Israel)

Juvenile and adult mobile, surface dwelling decapods (reptantians) roam across all benthic substrates (e.g., algal surfaces, rock substrates, corals, and soft bottom) in search of food and mates, to find thermal regimes that are beneficial to egg and larval development, to locate circulation patterns that are conducive to distributing larvae to settlement habitats, or to escape near shore wave action in various seasons. This mobile existence leaves them exposed to a variety of predators that are both diurnally and nocturnally active. Many decapods respond to predation threats with predator avoidance mechanisms that prevent their detection (e.g., diurnal sheltering, having coloration patterns that match their backgrounds, or freezing in place) or, if detected, respond with antipredator mechanisms that block a predatory action from being completed. Lobsters are a highly diverse group of decapods with hundreds of species comprising the families Palinura and Nephropida. Within those families, the body forms, sculpturing, spination, and thickness of the calcified cuticle vary considerably. Some forms also possess weaponry. However, compared to other decapods, lobsters use only a small suite of morphological adaptations to combat predators and, instead, rely on additional behaviors (escape swimming, coordinated defense, sound production) that are not as common in other decapods. This presentation will compare the adaptations of lobsters to those of other decapods and provide a theoretical framework for why differences amongst decapod groups exist.

Managing Lobster Resources under Stress (or what happens when the host,

the pathogens and the environment team up to create a natural disaster)

K. Castro, M. Tlusty, J.S. Cobb, M.Gomez-Chiarri

In 1997, the fishery for American lobster in Southern New England, USA was booming. Landings of 9,935 mt produced a value of over \$52 million. A subsequent decrease in landings to a low of 2,600 mt between 2002-2007 has produced severe biological, economic and social concerns for the industry.



The ASMFC has declared the SNE stock to be in recruitment failure. Managers are struggling with decisions that will have severe consequences for the fishery. What happened to this stock? This change in abundance is concurrent with the appearance of several diseases (or syndromes) including paramoebiosis, limp lobster syndrome, calcinosis, idiopathic blindness and epizootic shell disease (ESD). As a result of the Southern New England Lobster Health Initiative, there is a wealth of new information on the American lobster and its interaction with pathogens in the marine environment. Detailed information on the emergence of ESD (when, where, what lobsters and changes over time) laid the groundwork for an in-depth exploration of possible causes and consequences of ESD on American lobster in Southern New England waters. The host-pathogen-environment model offers an opportunity to explore these multiple issues and examine the proximate and ultimate mechanisms of the disease on the population in the larger context of global climate change. Management of a stock under these types of changing scenarios must be able to be adaptive and allow for changing biological reference points.

STREAM ONE

Competition and predation

Geographic variation in the outcome of agonistic interactions between adult invasive green crabs *Carcinus maenas* and juvenile American lobsters *Homarus americanus* in Atlantic Canada Mathe Largen Llears, Dému Deshette

Marthe Larsen Haarr, Rémy Rochette

Marthe Larsen Haarr <mhaarr@hotmail.com> (University of New Brunswick, Saint John)

The European green crab *Carcinus maenas* is an invasive species in the Maritimes, which has the potential to compete and prey upon endemics such as the American lobster Homarus americanus. Recent research in this area has reached opposite conclusions regarding which species will dominate the other. Interestingly, these contradicting results involved crabs from different regions, the Northumberland Strait and the Bay of Fundy, which have recently been shown to be genetically distinct and the result of different invasive events. In this study I housed juvenile lobsters (20-45 mm CL) and green crabs (50-80 mm CW) together in 3-m diameter flow-through tanks, and monitored mortality, growth and behaviour from September through December 2009. The experiment involved two control treatments with lobsters stocked to 2.5 and 5 individuals/m2, respectively, and three experimental treatments with 2.5 lobsters/m2 and 2.5 green crabs/m2 from Passamaquoddy Bay (Bay of Fundy), St. George's Bay (Northumberland Strait) and Chedabucto Bay (the Scotian Shelf). Lobster mortality was significantly higher for lobsters paired with St. George's Bay and Chedabucto Bay crabs compared to lobsters paired with Passamaquoddy Bay crabs. These results are consistent with the previous published studies and the hypothesis that differences in interspecific dominance patterns are due to genetic differences between green crab populations. The mechanisms responsible for this pattern of crab predation remains elusive, however, as no differences in crab behaviour or morphology were found that correlated with the pattern of lobster mortality.

Is there Evidence for starvation in Nephrops norvegicus in the field?

Andrew Watts (University of Glasgow, UK), Amaya Albalat (University of Glasgow, UK), Rona McGill (Scottish Universities Environmental Research Centre, UK), Phil Smith (Marine Biological Station Millport, UK) Jim Atkinson (Marine Biological Station Millport, UK), Douglas Neil (University of Glasgow, UK) a.watts.1@research.gla.ac.uk

Nephrops norvegicus (the Norway lobster) feeds in a predatory and scavenging manner. They appear to be non-selective feeders, since the species composition of foregut contents closely matches the species diversity of available prey, such as crustaceans, echinoderms, polychaetes and molluscs. This study looks at whether or not starvation occurs in *N. norvegicus* at different times of year, due to food availability or some life history strategy (e.g. avoiding predators when females are brooding eggs within burrows). A range of biomarkers of starvation were developed and tested and their appropriate time scales determined. Then these biomarkers were measured in *N. norvegicus* collected from the Clyde Sea Area and the North Minch (both off the west coast of Scotland). The findings provide an initial insight into annual feeding behaviours of both male and female N. norvegicus and whether brooding females undergo starvation.
Reproduction and reproductive behaviour

Increased reproductive opportunity: a potential benefit of seasonal aggregation for a little-gregarious spiny lobster

Enrique Lozano-Álvarez*, Erika Magallón-Gayón, Patricia Briones-Fourzán Enrique Lozano-Alvarez <elozano@cmarl.unam.mx> (Universidad Nacional Autonoma de Mexico)

Panulirus guttatus reproduces year-round, exhibits a rather low degree of gregariousness, and does not express group defense behavior. Yet in the laboratory, individuals of P. guttatus were more attracted to dens emanating conspecific scents during a 'high reproductive activity season' (HRAS, >70% of ovigerous females in the population) than during a 'low reproductive activity season' (LRAS, <40%), suggesting that seasonal aggregation may increase reproductive opportunities for these lobsters. To test this hypothesis in the field, we marked, over 6 consecutive times (3 during a LRAS and 3 during a HRAS), all crevice dens harboring P. guttatus lobsters on two adjacent reef patches, counted all occupants in each den, and determined their sex and size. Dens marked at a given time were considered as having zero occupants at previous times. All observed lobsters were adults. Lobster distribution was examined by time (sample) using data from all marked dens (n = 89). The negative binomial distribution fitted data from each sample well. Using parameters m (mean density/den) and k (dispersion index), we constructed Lloyd's 'mean crowding' and patchiness indices, both of which were higher (but less precise) during all HRAS samples than during LRAS samples. We then used a model selection approach to contrast four competing models regarding m and k. Results showed that m was similar through time but k was considerably lower (indicating more aggregation) during all HRAS samples than during LRAS samples. These results support the hypothesis that increasing aggregation during the HRAS increases reproductive opportunities for these lobsters.

Female mate choice and sperm allocation by males in a highly sedentary, habitat-specialist spiny lobster

Erica Magallón-Gayón, Patricia Briones-Fourzán, Enrique Lozano-Álvarez

Patricia Briones-Fourzan <briones@cmarl.unam.mx> (Universidad Nacional Autonoma de Mexico

Populations of *Panulirus guttatus* –a small, obligate reef- dweller– are rather fragmented because these lobsters are highly sedentary and probably remain on the same reef patch since settlement. In some Caribbean locations, P. guttatus reproduces year-round with mature females producing and brooding several clutches in succession. However, mating windows are rather narrow, increasing the potential for female mate choice and male-male competition for mates. Through choice/no-choice laboratory experiments that controlled for effects of male-male competition, quality of shelter, and mere social attraction, we found that large females, but not small mature females, expressed preference for larger males relative to their own size. As clutch size increases non-linearly with female size and females can mate only once before laying each clutch, this result suggests that large females prefer large males to secure sufficient sperm to fertilize their clutches, whereas small females are less selective because even small males would produce sufficient sperm to fertilize their clutches. However, unlike other palinurids wherein spermatophore area was found to increase with size of both partners, spermatophore area in *P. guttatus* increased with size of males irrespective of size of their female partners. We propose two potential explanations for this result: (1) as females produce and brood eggs throughout the year, mate availability for males is permanently low increasing selection for making the most of any current mating attempt and/or (2) as these males produce very small and thin spermatophores, they have a fast sperm recovery. This study suggests variability in mating strategies among palinurid species.

The importance of conserving recruitment pulses in southern rock lobster (*Jasus edwardsii*) fisheries where puerulus settlement is low or highly sporadic

Adrian Linnane, Peter Hawthorne and Matthew Hoare

Adrian Linnane <adrian.linnane@sa.gov.au> (SARDI Aquatic Sciences)

The commercial fishery for southern rock lobster (*Jasus edwardsii*) is South Australia's most valuable fishery resource worth in excess of AUS\$100 million annually. Over the past decade, there has been a significant decrease in recruitment to the fishable biomass, which has translated to declines in commercial catch rates. For example, in the Northern Zone rock lobster fishery, catch per unit effort declined from 1.42 kg/potlift in 1999 to 0.67 kg/potlift in 2008, a decrease of 52%. Puerulus monitoring has been undertaken in the zone the since 1996, with the period from settlement to recruitment estimated at ~4 years. In 2002, 2005 and 2006, spikes in settlement were recorded, which were predicted to enter the fishery as recruitment pulses in 2006, 2009 and 2010

respectively. Management decisions failed to conserve the 2006 recruitment pulse by allowing total allowable commercial catches (TACCs) to remain above commercial catch levels. However, in 2008, a conservative management approach was adopted with the TACC reduced from 470 to 310 tonnes despite the fact that 403 tonnes had been landed in the 2008 season. In 2009, commercial catch rates increased by 31% while fishing effort decreased by 42%. Catch rates continued to increase during the 2010 season. The study highlights the importance of management decisions that conserve recruitment pulses in order to sustain lobster resources on which fisheries depend.

Maternal influences on offspring size variation and viability in wild European lobster (*Homarus gammarus*)

Even Moland, Esben Moland Olsen, Nils Chr. Stenseth

Even Moland <even.moland@imr.no> (Institute of Marine Research)

In many marine species, large females tend to produce more robust offspring than small females. However, knowledge on maternal influences in decapod crustaceans is limited. This is unfortunate since many decapod populations are being intensively harvested and show signs of 'juvenescence', i.e. the loss of large (and presumably old) individuals. In this study, we quantified maternal influences in European *lobster Homarus gammarus* from Skagerrak, southern Norway. Historical lobster catches in Skagerrak were substantial but the stock has suffered a major decline over the past 30 to 40 yr and is currently red listed as near threatened according to the IUCN (International Union for Conservation of Nature) criteria. We studied eggs and larvae from wild-caught ovigerous females ranging in carapace length from 79 to 152 mm (n = 45). Mean egg size increased while sibling size variation decreased significantly with increasing maternal size. Mean larval size at hatching was closely linked to both maternal size and mean egg size. A laboratory experiment showed a weak but significant nonlinear increase in pelagic larval survival with increasing mean egg size in the absence of food. These findings suggest that maternal influences on offspring quality could be a significant source of variation in lobster recruitment. Consequently, maternal influences could be an important source of error in fisheries science and management if they are assumed to be absent or unimportant.

Comparative analysis of gene expression profiles from the

Iarval American Lobster, Homarus americanus D.Hines K.FraserClark, A.Acorn, S.J. Greenwood

dhines@upei.ca

The American lobster, *Homarus americanus*, is a decapod crustacean endemic to the Western North Atlantic Ocean, occurring in high densities in waters surrounding Atlantic Canada. Various studies have been conducted to gain an understanding of the biochemical and hormonal processes that regulate development and metamorphosis of the lobster. The larval stage of the American lobster is characterized by rapid growth, development and ultimate metamorphosis. During this time period,

there are a variety of physiological, morphological and behaviour changes that occur. This is the first study to characterize the transcriptomic differences between developmental stages of American lobster larvae. A spotted oligo-nucleotide microarray was constructed using 14,592 unique expressed sequence tags (ESTs). Potential function was determined for 40% of EST sequences when compared to GenBank. Total RNA was extracted from individual larvae, from each stage. Using a reference design, the gene expression profiles of larvae from the 4 stages were compared to each other. A total of 550 genes were determined to be differentially expressed between larval stages. Among the differentially expressed genes, several immune, stress and cuticle related genes were activated at different stages of development. With increasing interest in the sustainability of the American lobster fishery, this information will provide an important basis for directed investigations of particular developmental events. Understanding the mechanisms regulating larval development may give insight into factors such as larval fitness and survivorship; two important characteristics when considering larvae in the wild and hatchery settings.

Optimising temperature for the larval culture of Panulirus ornatus

N.G. Sachlikidis and C.M. Jones Nikolas.Sachlikidis@deedi.qld.gov.au

Hormonal control of decapod reproduction: facts and perspectives

Giulianini PG, Mosco A, Guarnaccia C, Edomi P Piero G. Giulianini <giuliani@units.it> (Department of Life Sciences)

In crustaceans the gonad function and development are under the control of the neuroendocrine axes and of a complex network of interrelationships between target tissues and nervous system. More than 65 years ago Panouse reported that evestalk ablated shrimps showed an evident increase of gonadosomatic index, the ovaries reaching a weight about 13 times bigger compared to the controls. The hormones involved in the current scenario of endocrine control of reproduction are: 1) the family of evestalk neuropeptides that includes the crustacean hyperglycaemic hormone (CHH), the moult inhibiting hormone (MIH), the mandibular organ inhibiting hormone (MOIH) and the gonad (or vitellogenesis) inhibiting hormone (GIH or VIH); 2) the biogenic amines (serotonine and dopamine); 3) the sesquiterpene methyl farnesoate. The pleiotropic effects of the different isoforms of CHHs in decapods play a central role in the reproductive physiology. The function as gonadotropin of CHH B isoforms in Homarus americanus was demonstrated, by a heterologous in vivo and by homologous in vitro bioassays. These data were further corroborated by a study describing the levels of CHHs mRNA in the MTXO, their storage in the SG and their concentration in the haemolymph throughout the female reproductive cycle. Surprisingly, in penaeid shrimps the CHHs seem to exert an inhibitory action on vitellogenesis. Understanding the functional key roles of the CHHs, for their use in reproduction modulation, needs adequate quantities of neuropeptides impossible to obtain by classic biochemical purification therefore very promising techniques like molecular biology and chemical synthesis are now overcoming such limitations.

Metapopulation dynamics, management areas and biological units of American lobster *Homarus americanus* in eastern Canada

Marthe Larsen Haarr, Brady Quinn, Gudjon Sigurdsson, Kristin Dinning, Bryan Morse, Rémy Rochette Marthe Larsen Haarr <mhaarr@hotmail.com> (University of New Brunswick, Saint John)

The "lobster node" within the Canadian Capture Fisheries Research Network is a 5-year collaboration between industry, government and academia, which aims to elucidate metapopulation dynamics and stock structure of the American lobster, Homarus americanus, in Atlantic Canada. It proposes to achieve this goal by undertaking 5 integrated research activities: (1) assessing the input of larvae into the system by quantifying the abundance and size of gravid females collected by fishermen at 50-75 km intervals along the coastline, and determining whether all larvae can be "treated equal" by quantifying non-genetic maternal effects and population-level genetic effects; (2)using an individual-based bio-physical model to predict the dispersal and settlement of these larvae, and comparing these values to the abundance of postlarvae (passive collectors and quadrats), juveniles (research surveys) and adults (fisheries landings); (3)studying the effect of substrate characteristics on settlement behaviour, and investigating the patterns and processes (e.g., larval supply, wind-driven currents) underlying patchiness of settlement at different spatial scales, to further parameterize our dispersal-settlement model; (4) using ultrasonic telemetry to quantify the movements (e.g., seasonal migrations) of different size/age lobsters from different regions, and determining the importance of these movements to connectivity among subpopulations; (5)developing non-neutral genetic markers to refine our understanding of lobster populations genetics and patterns of local adaptation. This research is expected to inform best management practices, particularly where these depend on the connectivity between lobster management areas. But perhaps more importantly, it is hoped that this project will constitute the foundation of a lasting partnership between lobster fishermen and scientists.

Early life stages: Dispersal, retention and behaviour

Behavior of scyllarid phyllosoma larvae asociated with medusae as revealed using in-situ video recording

Hideo Sekiguchi and Tomoji Tanaka

Hideo Sekiguchi <sekiguch@bio.mie-u.ac.jp> (Graduate School of Bioresources of Mie University)

Behavior of a final stage phyllosoma of scyllarid lobster *Ibacus ciliatus* riding on the dorsal bell surface of the scyphozoan *Pelagia noctiluca* of Pelagiidae was examined using in-situ video recording while SCUBA diving in Oomi-jima along the Japan Sea coast of Honshu, Japan. Pereiopod endopodites of the phyllosoma were firmly stuck into the bell surface while the endopodites repeatedly beat up and down to pull the scyphozoan through the water. The phyllosoma did not detached from the bell even after repeated disturbances due to sporadic bursts of water movement by strong waves for the scyphozoan to rapidly turn in rotation. The scyphozoan was most probably being used for food, possibly also for protection, and perhaps for a combination of both, so the phyllosoma might even use the scyphozoan as weapons to catch prey and to ward off predators.

Stock separation in American Lobster is maintained by selection, genetic adaptation and behavior

Jana Deppermann¹, Jelle Atema^{2,3,4}, Julia Halverson⁴, Kristin Radcliffe⁴, Ann M. Tarrant³, Gabriele Gerlach^{1,2}

- 1. Carl von Ossietzky University, Oldenburg, Germany
- 2. Marine Biological Laboratory, Woods Hole, MA, USA
- 3. Woods Hole Oceanographic Institution, Woods Hole, MA, USA 4. Boston University Marine Program, Boston, MA, USA
- Jana Deppermann <jana.deppermann@uni-oldenburg.de> (University Oldenburg)

The American Lobster (*Homarus americanus*) inhabits the American East Coast up to Labrador, Canada. Lobster larvae spent approx. 3-4 weeks in the pelagic before they become benthic and settle. The distribution of lobsters is determined by larval dispersal as well as by mobile adults, which can migrate over hundreds of kilometers. We show that this widespread potential for gene flow is not realized in lobsters. Using microsatellite markers we demonstrated the existence of lobster population structure at both large (400km) and small (30km) scale. We found genetic as well as phenotypic differences between populations using a morphometric approach. In addition to this clear stock separation, we identified a behavioral-olfactory recognition mechanism by which lobsters prefer their own population. Next to behavioral mechanisms, pre-settlement selection might be a key to establish population structure in this dynamic environment. Results of behavioral experiments and gene expression analyses (HSP70, HSP90, CHH) indicate that larvae from different areas (Maine versus Rhode Island) respond differently to varying temperature regimes. We suggest that social segregation mechanisms, in addition to physiological and genetic adaptation to habitat features can shape population structure and micro evolutionary processes.

American lobster benthic recruitment from New England to Newfoundland as measured by diver-based suction sampling and passive postlarval collectors

Richard A. Wahle¹, Charlene Bergeron¹, John Tremblay², Carl Wilson³, Victoria Burdett-

- Coutts⁴, Michel Comeau⁵, Rémy Rochette⁶, Peter Lawton⁷, Robert Glenn⁸, Mark Gibson⁹
- 1. University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, Maine, USA
- 2. Department of Fisheries and Oceans Canada, Halifax, Nova Scotia, Canada
- 3. Maine Department of Marine Resources, Boothbay Harbor, Maine, USA
- 4. Memorial University, St. Johns, Newfoundland, Canada
- 5. Department of Fisheries and Oceans Canada, Moncton, New Brunswick, Canada
- 6. University of New Brunswick, St. John, New Brunswick, Canada
- 7. Department of Fisheries and Oceans Canada, St. Andrews, New Brunswick, Canada
- 8. Massachusetts Division of Marine Fisheries, New Bedford, Massachusetts, USA
- 9. Rhode Island Division of Fish and Wildlife, Jamestown, Rhode Island, USA
- Richard Wahle <richard.wahle@maine.edu> (University of Maine)

Our understanding of postlarval settlement patterns for the American lobster, Homarus americanus, has long depended on diver-based suction sampling. Recently developed passive postlarval collectors, however, have enabled us to explore and quantify settlement and early juvenile densities in locations that are either unsafe or impractical for divers, thereby considerably expanding our capacity to monitor settlement throughout the species range. Here we describe geographic patterns of young-of-year and older juvenile lobster abundance that have emerged at an unprecedented geographic scale by virtue of an international collaboration using the two methods under a standardized sampling protocol. Passive collectors have been particularly valuable in elucidating lobster settlement at previously inaccessible depths. We describe bathymetric patterns of young-of-year recruitment in three oceanographically contrasting regions, helping us to further evaluate hypotheses regarding the response of settlers to thermoclines. We also evaluate the comparability of data generated by the two methods, and identify subtle differences in size selectivity of the two samplers and ways to calibrate for those differences. Spatial correlations between young-of-year and older juvenile abundance have further served to identify consistent settlement "hot spots" that are likely determined by ocean circulation. Finally, in another correlation analysis, we infer the strength of interactions between young-of-year recruitment and suspected predators or competitors such as fishes and crabs also quantified in collectors.

Recruitment of west coast rock lobster (*Jasus lalandii*) puerulus in relation to the upwelling environment at Lüderitz Bay, Namibia

F.J. Keulder , A.J. Booth , C.A.F. Grobler, and P.J. Britz Felicia Keulder <fkeulder@yahoo.com> (Institute of Marine Research)

We hypothesised that high puerulus recruitment was coincident with a high abundance of nutritionally fit late stage larvae one week earlier at the shelf-beak and weather conditions, which promoted the transport of pueruli inshore. Peak puerulus settlement during spring (August-September) in *J. lalandii* at Lüderitz Bay during the present study was related to strong upwelling and high productivity, which may have facilitated high food availability to the feeding late stage larvae. The environmental conditions experienced during the strong upwelling seasons in August-September at Lüderitz during the study were characterised by low SST, strong southerly winds and moderate sea swell conditions. Wind stress and SST are the most important of the three environmental factors associated with upwelling. A good year of puerulus settlement in 2000 was associated with very strong upwelling conditions with lower than average SST and stronger than average southerly winds. The intensity of these environmental factors was less pronounced during "poor years" of puerulus settlement in 2001 and 2002.

Settlement of the American lobster *Homarus americanus* in the southwest Bay of Fundy: patterns and patchiness at different spatial scales

Gudjon Mar Sigurdsson Rémy Rochette

Gudjon Mar Sigurdsson <gudjon.mar@unb.ca> (University of New Brunswick)

The spatial and temporal patterns and dynamics of marine invertebrate settlement are generally poorly understood. That is the case for the American lobster, Homarus americanus, for which spatial and temporal patterns of settlement have only been investigated in a handful of studies and localities. The objective of this study was to identify areas of lobster settlement in the southwest Bay of Fundy (swBoF), New Brunswick, Canada, and estimate patchiness of settlement at three different spatial scales: between collectors within sites (from a few meters to tens of meters apart), between sites (1000-2000 meters apart) and between areas (5-100 kilometres apart). To estimate settlement, standardized settlement collectors (0.55 m2) were deployed in shallow rocky habitats of the swBoF in 2009 (240 collectors across 12 sites and 4 areas) and 2010 (220 collectors across 15 sites and 7 areas). All lobsters captured were measured and classified as settlers (<13 mm CL, 1-4 months old) or juveniles (>14 mm, 1 year old and above). In order to assess patchiness, we compared variance in settlement observed at different spatial scales to variance obtained by Monte Carlo randomization of settlement values assuming spatially uniform settlement. Preliminary analyses indicate that lobster settlement varies markedly between areas and sites, and in some case is even patchy within sites. Spatial patterns of settlement also showed surprising inter-annual consistency. This study, first of its kind in Canadian waters, has identified some lobster settlement "hotspots" in the swBoF, and has provided insight into the spatial scale of lobster settlement patchiness.

Local lobster subpopulations from limited adult migration and high larval retention

Vidar Øresland and Mats Ulmestrand

Vidar Öresland <vidar.oresland@fiskeriverket.se> (Inst Mar Res, Lysekil, Sweden)

Detecting the extent of adult migration and marine larval dispersal is crucial to our understanding of connectivity between, and detection of, marine subpopulations. Here we show, through tagging of 4016 adult European lobster, *Homarus gammarus*, over 16 yrs within the Kåvra Lobster Reserve on the Swedish west coast, that lobsters have limited migration in that area. By using light traps, we show a tenfold annual variability of stage 1 larvae concentration. These larvae have a short peak period of abundance < ten days, and the vertical distribution of larvae can be detected at a 1 m scale. By daily tracking the currents in real time during the larval period, using GPS current drifters at mean larval depth of 16 m (below the halocline), we could infer two potential local subpopulations. The combination of these two methods greatly simplifies detection of local marine subpopulations. In 2011 we plan to track surface currents and trawl for stage 3 and 4 larvae above and below the halocline in order to improve our estimates of subpopulations.

Large dispersal potential yet restricted distribution: phyllosomas of the two lobster species (Decapoda, Achelata) present in Robinson Crusoe Island in the Juan Fernández archipelago

Palma AT, Cáceres-Montenegro I, Bennett RS, Magnolfi S, Henríquez LA, Guerra JF, & Manríquez K. Palma RE Alvaro Palma <apalma@bio.puc.cl> (Universidad Católica de Chile)

Two lobster species coexist in the Juan Fernández archipelago, the spiny Jasus frontalis and the slipper Acantharctus delfini. Like many lobsters they undergo a prolonged larval period. Although

typical of spiny lobsters, this is usually not thought to be conducive to local recruitment. We know their recruitment is confined to this unique island system, but we know little about how local larval supply, through settlement and recruitment, allows such geographic distribution pattern. The general question we intend to address is whether our evidence on larval distribution and abundance supports the hypothesis suggesting locally produced and retained larvae around the island of Robinson Crusoe. More specifically we: (1) registered the spatial (sites, depths) and temporal (day, night) distribution pattern of phyllosoma larvae around the island since October 2008, (2) unequivocally identified phyllosomas of these two species by means of morphological features corroborated through molecular analysis and (3) analysed the distribution and abundance patterns of larvae alongside information on water column characterization. Based on our results on spatial and temporal larval distribution it is likely to propose the occurrence of some nearshore larval retention mechanisms for these species. Phyllosomas of both species were never too abundant at the surface and they tended to approach the surface strata of the water column during the night. These results, although preliminary, when it comes to understand the mechanisms behind these species endemism, represent a pioneering effort into this direction.

First record of the early benthic juvenile stage of the Mediterranean slipper lobster, Scyllarides latus

Ehud Spanier and Kari L. Lavalli

Ehud Spanier <spanier@research.haifa.ac.il> (Maritime Studies, University of Haifa, Israel)

Postlarvae (nistos) and/or live juveniles of the commercial Mediterranean slipper lobster, *Scyllarides latus*, have not been found despite continuous sampling efforts. Recently a preserved tiny specimen of this species (CL = 11.7 mm) that was sampled in Reggio Calabria, southern Italy at the beginning of the 20th century was located in the zoological museum of Turin. This early juvenile *S. latus*, probably recently settled, varied considerably from adults, having a carapace width much greater than the carapace length, which is proportionally reversed from that of adults. It is similar in morphology to the nistos known from a few other Scyllarides species and especially to early juveniles of *S. nodifer*. Although the collection information on this rare specimen was partial, additional data on habitats of some other sub-adult *S. latus* sampled in the Mediterranean enable the formulation of a hypothetical recruitment scenario for this species. It is assumed that *S. latus* larvae drift large distances for many months in pelagic waters before settling as nistos in deeper waters where they are possibly more protected against predators. They develop there to small juveniles and then return to the shallower adult grounds as migrating juveniles.

Morphology

Morphometric differences between lobster (Homarus americanus) populations at large and small spatial scales

Kristin Radcliffe, Jelle Atema, Julia Halverson

Kristin Radcliffe <krad@bu.edu> (Boston University)

Lobsters are sexually dimorphic with differences that gradually appear more distinctly at and after sexual maturity. Individual morphology seems dependent on sex, size, maturity and location. We are interested in the latter as it may relate to genetic population structure at small spatial scales. For this study we sampled lobsters at 22 sites over a wide area at site distances ranging from 30-500 km. To eliminate the influence of sex we analyzed males and females separately. To reduce size effects we limited the size range as measured by Carapace Length (CL). The relationship between size, age and maturity varies over large geographic scales; this variation is not quantitatively established. Sample sizes were typically around 20 males and 20 females from each site, but in some (off-shore) sites most animals were well beyond the standard size (85-95 mm CL). We took 63 measurements of each individual and subjected these to Discriminant Analysis, both as absolute values and as standardized (divided by CL) values. All sites were discriminated with a total of only 26 misclassified males and 30 females. The misclassified animals were assigned to other sites in interesting ways. There was little difference between absolute and standardized measurements. We are comparing the morphometric results to those obtained by genetic analysis of the same individuals and sites (Deppermann et al.). In addition, we have seen behavioral evidence for odor discrimination among lobsters from genetically and morphologically distinct sites: females prefer to associate with males from their own site.

Are the shield fan slipper lobster, *Evibacus princeps*, and the Horseshoe crab *Limulus polyphemus* a case of convergence evolution?

Ehud Spanier and Kari L. Lavalli

Ehud Spanier <spanier@research.haifa.ac.il> (Maritime Studies, University of Haifa, Israel)

The shield fan slipper lobster, Evibacus princeps, and the horseshoe crab, Limulus polyphemus, seem very similar in their external morphology. Is this the result of convergence evolution? Ecological characteristics of these two species were reviewed and external morphological traits were examined in preserved specimens of the subject species in zoological collections in order to reveal the answer to this question. Evibacus princeps belongs to the subfamily Ibacinae of the lobster family Scyllaridae, infraorder Palinura (Achelata), suborder Reptantia, order Decapoda of the subphylum Crustacea and Phylum Arthropoda. Limulus polyphemus belong to another subphylum of Arthropoda, Chelicerata, class Merostomata, subclass Xiphosura and family Limulidae. Thus, taxonomically the two species are extremely unrelated organisms, sharing only a common phylum. The two species are found in separate oceans: E. princeps is located in the eastern Pacific while L. polyphemus is found along the Northwestern Atlantic coasts. Yet they share a similar depth range and shallow soft substrates habitat types. They share also some similar morphological proportions such as that of the anterior and posterior carapace width/body thickness, total carapace length/width of body, anterior and posterior carapace width /total length. These similar morphological relationships derive from the existence of a very large dorsal shield that protects the sensitive parts of the body underneath. It is assumed that these are antipredator adaptations developed as a result of similar ecological conditions of living in shallow water soft substrates.

STREAM TWO

Diseases

Shell disease in American lobster (Homarus americanus) from Norwegian waters

Egil Karlsbakk, Ann Cathrine B. Einen, Nina Sandlund, Ingrid U. Fiksdal, Eva Farestveit, Knut E. Jørstad, Ann-Lisbeth Agnalt Egil Karlsbakk <egil.karlsbakk@imr.no> (IMR)

Through DNA analysis, 24 lobsters captured in Norwegian waters have been verified as American lobster (Homarus americanus; 1999-2010). Additional lobsters verified as American have been captured off Sweden (5) and off Denmark (1). Lobster is a valued seafood, and importation of live American lobster to Europe has increased the last decades. The release or escape of live American lobster in European waters may introduce exotic parasites and other disease agents, and hence represent a threat to European lobster populations as well as to other decapods. Five of the American lobsters captured in Norway in 2009-2010 had symptoms of being infected with shell disease, similar to Epizootic Shell-Disease (ESD). ESD is of great concern in American lobster stocks, particularly in USA. Histology suggests the lesions are due to bacteria degrading the exoskeletal matrix. Several of the bacteria species typically found in affected American lobster in USA were also found in lesions in Norway. Follow-up studies of European lobsters (Homarus gammarus) in an area where several diseased American lobsters were caught have not revealed similar lesions in those. However, during the commercial fishery in autumn 2010, several European lobsters from this area were found with a different type of lesions. Most were below legal size and released back into the sea, but samples were secured from two (analyses ongoing). The presence of live American lobster in Norwegian waters has raised concerns about disease transfer, ecological interactions and hybridisation with the European lobster.

A brief history of American lobsters (*Homarus americanus*) and gaffkaemia (*Aerococcus viridian*s var. homari) in the UK

Paul Stebbing

Paul Stebbing <paul.stebbing@cefas.co.uk> (Cefas)

Live American lobsters became a viable import commodity for the UK with the development of high speed trans-Atlantic flights. Mortalities were observed in imported American lobsters and in European lobsters (*Homarus gammarus*) being held in facilities. It was found that these mortalities were caused by gaffkaemia, a disease caused by the bacterium *Aerococcus viridians* var. homari. Gaffkaemia is

recognised as one of the most damaging diseases known to the clawed lobster industry, and was introduced into the UK with the importation of American lobsters. The potential effects of gaffkaemia on the UK lobster industry promoted the implementation of control measures to attempt to prevent the spread and control gaffkaemia. Subsequent to these events, American lobsters started to be found off the UK coast. Initially this was in relatively low number, but in 2010 a total of 13 animals were found from a number of locations. A survey carried out in 2009 also found gaffkaemia present in wild populations of European lobsters at a number of geographically separate locations around the UK. Gene sequencing demonstrated that the strains of gaffkaemia found in the UK matched with isolates from America and those associated with mortality events in holding facilities. This paper presents a brief history of American lobsters and gaffkaemia in the UK, highlighting the potential issues relating to the introduction of the non-native American lobsters and associated pathogens.

Distinguishing disease impacts from larval supply effects in

southern New England's lobster fishery collapse

Richard A. Wahle¹, Mark Gibson², Michael Fogarty³

1, University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, Maine 04573, USA

2. Rhode Island Division of Fish and Wildlife, Jamestown, Rhode Island 02835, USA

3. Northeast Fisheries Science Center, National Marine Fisheries Service, Woods Hole, Massachusetts 02835, USA

Richard Wahle <richard.wahle@maine.edu> (University of Maine)

Over the past two decades shell disease and variable larval supply have interacted as key determinants of cohort size in coastal populations of the American lobster, Homarus americanus, in southern New England, USA. We recently described a time series analysis that differentiates the effects of variable larval supply from the mortality impact of shell disease on cohort abundance. Prior to the onset of a shell disease in 1997, larval settlement alone fully explained 82% of the variability in the numbers of pre-recruit lobsters about to enter the lobster fishery, as measured by annual nearshore trawl surveys. With the onset of shell disease, however, the model required an additional term for disease prevalence to provide a sufficient statistical fit to the observed data. Neither time trends in bottom temperature nor predatory fish provided significant additional explanatory power for variability in pre-recruit abundance. To our knowledge, this analysis constitutes the first demonstration in which cohorts of a benthic marine invertebrate have been successfully tracked from settlement to the threshold of a fishery by accounting for the joint effects of variable supply of new recruits and subsequent disease during post-settlement years. As such, it illustrates how factors altering the rate of post-settlement mortality over time can obscure predictive relationships between settlement and subsequent recruitment. We further examine the implications of the collapse in adult populations for subsequent fishery recruitment. The analysis underscores the value of maintaining parallel time series of different life stages, as well as the need to better quantify both pre- and post-settlement mechanisms that influence cohort success in marine populations.

Myopspora metanephrops: the first description of a

microsporidian parasite infection in clawed lobsters

Stentiford, G.D., Bateman, K.S., Small, H.J., Moss, J., Shields, J.D., Reece, K.S., Tuck, I.

Grant Stentiford <grant.stentiford@cefas.co.uk> (EU Reference Laboratory for Crustacean Diseases)

Microsporidians are significant pathogens of aquatic crustaceans. Historically, their classification has been based upon morphological features, but recent evidence using phylogenetic data has demonstrated the potential for relatively high morphological plasticity in genetically similar species. This contradiction has led to significant confusion in the taxonomy of the phylum – a problem when attempting to classify newly discovered species for which both morphological and genetic data are available. We have recently described the first microsporidian parasite from Nephropid lobsters. Infected lobsters, displaying hyperpigmentation and lethargy, contained muscles that were largely replaced by merogonic and sporogonic stages of the parasite. Transmission electron microscopy revealed diplokaryotic meronts, sporohasts and spore stages, all in direct contact with the host sarcoplasm. Analysis of the SSU rDNA gene sequence from the parasite suggested close affinity with Thelohania butleri (from marine shrimp). Morphological features were however more consistent with members of the family Nosematidae. The contradiction between morphological and molecular taxonomic data supported the erection of a new genus in which the lobster parasite is the type species (Muospora metanephrops). Furthermore, utilising the genetic-ecological classification system recently proposed by Vossbrinck and Debrunner-Vossbrinck (2005), we have also erected a new family (Myosporidae) and order (Crustaceacida) to contain this genus, and other muscle infecting forms from marine crustaceans. The taxonomic framework could be further applied for reclassification of existing members of the Phylum Microsporidia for which appropriate morphological and molecular data are available and, for novel microsporidian parasites discovered in host phyla from marine, freshwater and terrestrial habitats.

Mineral Fine Structure Defense of the American Lobster (Homarus americanus) Cuticle

Joseph G. Kunkel, Wolfram Nagel and Michael Jercinovic Joseph Kunkel <joe@bio.umass.edu> (UMass Amherst)

While calcite and amorphous calcium carbonate are the most abundant minerals in the American lobster cuticle, carbonate apatite is suggested to play a strategic role in microbial defense by lobster integument. Carbonate apatite exhibits a flexible composition using its least soluble form to protect the environmentally most exposed surfaces of critical gland canal and neuronal canal linings. Hardened canal linings insulate the cuticle's more soluble calcium carbonate from attacks by microorganisms which could produce acid in the canal lumens that pass critical secretions and neurites from the epidermis to the cuticle surface. Trabecular-like structure similar to spongy bone is utilized in the inner exocuticle demonstrating an efficient use of environmentally scarce phosphate to provide a hardness layer of the cuticle. Strength is derived from the trabecular bone structure embedded in the phenolicly hardened exocuticle layer. A schematic model of the cuticle emphasizes the advantage of regional diversity of the composite cuticle. An outer calcite crystalline layer provides a thin dense barrier that dissolves slowly providing an external alkaline unstirred layer inhibitory to bacterial invasion. Superficial injury to the epicuticle and calcite layer in this model would provide a stronger flush of alkalinity from the deeper more rapidly dissolving amorphous calcium carbonate layers, generating a general immune response by adding to the alkalinity of the antimicrobial unstirred layer. This model may provide a heretofore under-appreciated general role for both calcite and bone in Decapod Crustaceans. (Supported by RI SeaGrant).

Diseases of rock lobsters and slipper lobsters in Australia and New Zealand

Brian Jones and Nick Caputi

Nick Caputi <nick.caputi@fish.wa.gov.au> (Department of Fisheries (Western Australia))

In Australia and New Zealand, lobster fisheries are based on potting for panulirid lobsters, Jasus spp. and Panulirus spp. with small incidental catches of Bay lobsters or "Morton Bay Bugs (Thenus spp.) and nephrops lobsters. Though rock lobsters form a significant commercial catch in Australia and New Zealand (2008-09 exports for Australia and New Zealand combined were worth about US\$450 000 000), there have been relatively few studies undertaken on lobster diseases. This is due, in part, to: the absence of significant aquaculture or long term live holding that provides an opportunity to see diseased animals; the lack of disease diagnostic expertise generally and finally to the difficulty in sampling sick animals from wild fisheries using methods that catch only animals exhibiting foodseeking behaviour. Such a fishery is unlikely to discover non-feeding individuals. Disease has resulted in significant economic damage in wild lobster fisheries in the northern hemisphere, including mortalities of clawed lobsters along the Atlantic seaboard of the USA, protozoan infections in the Norway lobster industry in Scotland, the emergence of a virus in Caribbean spiny lobsters, and a rickettsia in farmed lobsters in Vietnam. In every case the causative agents were unknown until the outbreaks occurred. This paper will summarise the known diseases of lobsters in Australia and New Zealand from published and unpublished sources. So far, the identified diseases do not appear to pose a threat to the wild capture fisheries.

New Approaches to Understanding Emerging Marine Diseases: The New England Shell Disease Research Initiative for American Lobster

Barbara Somers, Dr. Kathleen M. Castro, Dr. J. Stanley Cobb Barbara Somers <bsomers@mail.uri.edu> (University of Rhode Island)

The New England Lobster Research Initiative (NELRI) is a 5-year project created to address the problem of lobster shell disease. The goal of the project was to describe the disease agent, determine how it affected lobsters, and understand their susceptibility to it. This coast-wide initiative was funded with a Congressional appropriation obtained by Sen. Jack Reed (D-RI) and Sen. Olympia Snowe (R-ME) and allocated \$2.3 million to support research involving two state agencies and over 35 scientists and graduate students from 16 institutions. This collaboration of some of the world's most prominent lobster experts shattered the old model of researchers working in isolation and allowed for groundbreaking analysis of a complex problem. Each project of the NELRI expanded upon scientists' fundamental understanding of lobster biology and disease and provided insights for fishery managers to improve the health of one of New England's most valuable resources. Experts in fields including

crustacean endocrinology, genetics, veterinary medicine, behavior, microbiology, lobster biology, chemistry, environmental science, and epidemiology worked together with fishermen and fisheries managers to find answers. The 100 lobster project was created as part of the NELRI. This project was designed to make use of the expertise of each researcher and included a new approach of studying the entire animal. Approximately 100 lobsters were captured from the same location, cataloged into a database, and then dissected with pieces being sent to the appropriate researcher. This database will become available as a resource to further understanding of the complex effects of a marine disease.

Caribbean Spiny Lobster Connectivity and the Role of Larval Dispersal in the Spread of an Emergent Disease

Andrew Kough, Claire Paris, Mark Butler

Andrew Kough <akough@rsmas.miami.edu> (University of Miami, RSMAS)

The spiny lobster (Panulirus argus) commands the most valuable fishery in the Caribbean, vet its management is an extraordinary challenge due to complex dispersion during early life history and the threat of emergent disease. Spiny lobster have highly mobile larvae with an extended pelagic larval duration of 5 – 8 months, theoretically enhancing dispersal potential, hindering local recruitment, and increasing the reliance on subsidies from distant sources. The lobster virus PAv1 could be harnessing long range larval fluxes around the Caribbean. We simulated lobster reproduction, larval transport, and recruitment in the Caribbean using a coupled biophysical model to examine the connectivity of larvae as a proxy for the spread of marine disease. The connectivity modeling system used here is a Lagrangian individual-based model that combines physical oceanographic models with biological and habitat submodels. Oceanographic data from multiple sources were nested to ensure the highest resolution possible and effectively capture smaller scale hydrodynamic features that may influence larval dispersal. Ontogenetic vertical migration behavior based on laboratory and field studies was included. Surveys distributed to fisheries managers around the Caribbean helped determine lobster abundance and fecundity. These data were used to scale the magnitude and seasonality of the simulated spawning pattern in the model. We present the results from 4 years of larval exchange simulations from monthly spawning production of Wider Caribbean lobster populations. The distinct connectivity pathways are evaluated to investigate the potential of larvae as agents of disease transmission.

Do casitas increase transmission of Panulirus argus Virus 1 (PaV1)? I. Variability in disease prevalence in Caribbean spiny lobsters occupying commercial casitas over a large bay

Rebeca Candia-Zulbarán, Patricia Briones-Fourzán*, Fernando Negrete-

Soto, Cecilia Barradas-Ortiz, Enrique Lozano-Álvarez

Patricia Briones-Fourzan <briones@cmarl.unam.mx> (Universidad Nacional Autonoma de Mexico)

In certain Caribbean locations, casitas (artificial shelters) are used to harvest Panulirus argus. Due to their large refuge area (~2 m²) and the gregarious behavior of P. argus, commercial casitas typically harbor a mixture of juvenile-subadult-adult lobsters. Since emergence of the Panulirus argus Virus 1 (PaV1) disease, which mostly affects juveniles, there is concern about a gradual increase in prevalence of disease in casita-based fisheries. We estimated prevalence (percentage) of diseased lobsters (exhibiting diagnostic signs of infection) in Bahía de la Ascensión, Mexico, a large bay where fishermen extensively use casitas. We sampled 530 casitas (harboring 4,860 lobsters) over three distant fishing zones within the bay denoted as PA, VC, and LC, in four different periods spanning two years. Overall prevalence in the population was not affected by period (4.1-5.1%) but was always significantly lower in VC (0-2.9%)than in LC (5.3–7.3%) and PA (5.4–11.0%). No apparent relationship emerged between local disease prevalence and mean size of lobsters suggesting that, in this bay, local environmental factors probably affect the dynamics of the disease more than casitas per se. A model selection approach comparing parameters of the negative binomial distribution of lobsters in casitas occupied by visibly healthy lobsters only versus casitas harboring mixed healthy and diseased lobsters, provided weak evidence for avoidance of disease by healthy lobsters, probably because lobsters colonizing commercial casitas are relatively large. However, large lobsters may be asymptomatic carriers of PaV1 but move more, warranting further research into the local disease dynamics.

Do casitas increase transmission of Panulirus argus Virus 1 (PaV1)? III. Preliminary results of a controlled field experiment in progress

Enrique Lozano-Álvarez*, Patricia Briones-Fourzán, Rebeca Candia Zulbarán, Fernando Negrete-Soto, Cecilia Barradas-Ortiz, Juan Pablo Huchin-Mian

Between 1997 and 2002, a controlled field experiment showed that casitas deployed on experimental sites over a shallow reef lagoon significantly enhanced survival, density, and biomass of juveniles of

Panulirus argus relative to control sites. This led to the suggestion that casitas could be used to enhance juvenile populations of *P. argus* elsewhere. Unfortunately, the recent emergence of the pathogenic Panulirus argus Virus 1 (PaV1), which mostly affects juvenile lobsters and can be transmitted by contact, could result in casitas potentially increasing local disease prevalence. To address this issue, a new field experiment began in June 2009 by re-establishing five 1-ha control sites (without casitas) and five 1-ha casita sites (with 10 casitas each) across two different zones over the same reef lagoon. On each site, lobster density and mean size, and disease prevalence (% of lobsters with overt clinical signs) have been recorded every few months. Up to February 2011 (N = 6 surveys), density has been affected only by Treatment (casita/control sites) and Time (repeated measure), and mean size by Treatment X Zone and Time, but prevalence (14% on average) has not been affected by any factor or interaction term. Thus, casitas would not appear to significantly affect disease prevalence over the short term. However, a multiple regression confirmed no effect of mean size but revealed a marginally significant effect of density (p = 0.04) on local prevalence. Therefore, data collection will continue for several years to examine prevalence dynamics with and without casitas over the long term.

Physiological characterization of juveniles of spiny lobster,

Panulirus argus, infected naturally by virus (PaV1)

Herrera-Salvatierra N, Huchin-Mian JP, Briones-Fourzán P, Lozano-Álvarez E, Rodríguez-Canul R, Pascual Jiménez C. Nancy Herrera Salvatierra <salvarierran@gmail.com> (Universidad Autónoma de México (UNAM))

The spiny lobster *Panulirus argus*, has been affected by a highly pathogenic virus known as Panulirus argus Virus 1 (PaV1). PaV1 appears to be widespread throughout the Caribbean region. Macroscopic signs of PaV1 infection are milky hemolymph that lacks the ability to clot, reddish carapace and lethargy. Despite the important information obtained through experimental infections, little is known about the physiological responses in naturally infected P. argus. The aim of this study was to evaluate with immunological parameters and plasmatic metabolites the effect of Pav1 on natural infections. Sixty-seven lobsters; 36 healthy and 31 with signs of PaV1 infection were caught by scuba diving in Puerto Morelos, Mexico (20°51' N, 86°53' W) and transported alive to the laboratory. PaV1 infection was confirmed through histological observations and PCR. The variables: total hemocyte count, hemagglutination, phenoloxidase activity, respiratory burst and plasmatic metabolites (proteins, glucose, cholesterol and acylglycerol) were analyzed with an ANOVA to identify differences between healthy and infected lobsters (grades of infection: lightly (1), moderately (2) and heavily infected (3) were assessed by histology). Significant alterations (p < 0.05) of total hemocytes counts, phenoloxidase activity, hemaglutination, and respiratory burst, and high levels of cholesterol, glucose and acylglycerols were among the most reliable effects observed in the infected lobsters suggesting metabolic alterations and presumed immunosuppression. Understanding the process of infection is extremely important to understand the development of infection in natural conditions and also to assess epidemiological studies of PaV1.

PaV1 infection in the Florida Spiny Lobster Fishery and its Effects on Trap Function and Disease Transmission

Donald C. Behringer Jessica Moss Jeffrey D. Shields Mark J. Butler IV Donald Behringer <behringer@ufl.edu> (University of Florida)

The Caribbean spiny lobster (*Panulirus argus*) is one of the most economically valuable fisheries in Florida (USA) and the Caribbean, although many fisheries in the region have experienced major declines in landings over the past decade. In Florida, the commercial trap fishery is permitted to "bait" traps with live, subadult lobsters to attract larger legal-sized lobsters. However, subadult lobsters are particularly susceptible to the lethal, pathogenic virus Panulirus argus Virus 1 (PaV1), thus creating the potential for interplay between fishery practices and host-pathogen disease dynamics. Here we describe the first PCR-based assessment of PaV1 within the commercial trap fishery segment of the *P. argus* population in the Florida Keys. We also tested the effect of the presence of diseased lobsters within traps on trap attractiveness and the transmission of PaV1 to other trapped, but healthy lobsters. We found a mean PaV1 prevalence of 11% in the fished lobster population with PCR+ lobsters as large as 95 mm carapace length (76 mm is legal). We also found that traps harboring an infected lobster caught significantly fewer lobsters than traps containing healthy lobsters. Furthermore, healthy lobsters confined in traps with diseased lobsters became infected with PaV1 more frequently than those confined with other healthy lobsters. This study demonstrates the indirect and subtle effects that pathogens can have on fishery function through altered animal behavior and the unintended consequences of fishery practices on pathogen epidemiology.

Ecological Effects of Panulirus argus Virus 1 (PaV1) on Caribbean Spiny Lobster Condition, Behavior, and Survival

Donald C. Behringer Mark J. Butler IV Jeffrey D. Shields Donald Behringer
sehringer@ufl.edu> (University of Florida)

Pathogens can profoundly impact the ecology of the organisms they infect through changes in host behavior that influence demographic processes. Juvenile Caribbean spiny lobsters infected with PaV1 (Panulirus argus Virus 1) are avoided by their normally social conspecifics, which alters local spatial distributions and rates of transmission. Infections are typically lethal, but prior to succumbing to the disease, infection may impact other host dynamics that effect transmission. We used a suite of experiments to determine the impact of PaV1 infection on lobster ecology, including: movement, physiological condition, shelter use, and survival. Lobsters with early-stage infections moved at an equivalent rate to healthy lobsters, but as infection progressed infected lobsters moved less and ultimately remained sedentary. However, during the early stages of infection they remained active and capable of dispersing the virus throughout the population. However, heavily infected lobsters in mark-recapture studies were recaptured less frequently than healthy lobsters, indicating either greater emigration from the area or greater mortality. Infected individuals were lethargic and had lower blood protein levels, indicating poor physiological condition, which supported the probability of increased mortality from predation. Tethering experiments revealed that predation was indeed higher on infected individuals and on all lobsters deprived of shelter. Moreover, in shelter competition experiments, neither healthy nor diseased lobsters dominated access to shelters, but lobsters shared shelter less often when diseased lobsters were present. These results offer striking evidence of how diseases shape not only the behavior of social animals, but also their use of shelters and risk of predation.

Disease workshop

Some Interesting Non-Infectious Ways to Kill American Lobsters

Jean Lavallée AVC Lobster Science Centre, Charlottetown, PE, Canada Jean Lavallée <jlavallee@upei.ca> (AVC Lobster Science Centre)

Ongoing or sporadic mortality events have been occurring in some lobster holding facilities located in Atlantic Canada. These disease occurrences are rarely investigated as no provincial or federal authorities are mandated to conduct such investigations. However, it is not unusual for commercial facilities to suffer over commutative mortality rates over the duration of the holding season of more than 20 %. Traditionally, outbreaks of gaffkemia (caused by *Aeroccocus viridans*) have been one of the most common reasons for increased mortalities post-harvest. However, very few cases of this bacterial infection have been documented in recent years, while infections with Photobacterium indicum among weak/stressed lobsters kept in communal holding facilities could be increasing. This presentation will focus on two cases from Atlantic Canada, including a sudden mass lobster mortality event in a natural pound and a recurring decreased productivity in a lobster processing plant where bacterial agents were not identified although the disease outbreak curves were suggestive of the presence of an infectious agent.

A European Union Reference Laboratory for Crustacean Diseases: why now?

G.D. Stentiford

Wednesday 22 June 2011

"Managing our own Ship": How collective action can add value to New Zealand rock lobster fisheries

Nici Gibbs

Nici Gibbs <nici.gibbs@seafood.co.nz> (New Zealand Seafood Industry Council)

New Zealand's Quota Management System (QMS) has ensured the sustainability of fish stocks and provided a secure basis for individual quota owners to reap the rewards of their investments in harvesting, processing, retail and export operations. The economic benefits that can be generated from the actions of individual quota owners are becoming constrained as the seafood industry increasingly faces issues, risks and opportunities that are beyond the power of individual businesses to manage. The rights-based framework of the QMS has also provided commercial stakeholder organisations, including those in the rock lobster industry, with the confidence to voluntarily embark on numerous collective initiatives to improve fisheries management and stock abundance. However, there are also limits to the gains that can be made from voluntary collective management initiatives because the benefits of these actions are enjoyed even by those who choose not to participate. The New Zealand fishing industry is therefore now looking to the "next big step" in the evolution of the OMS – that is, a statutory framework to enable quota owners to act collectively in a structured and binding way to manage commercial harvesting activity and enhance the value of fisheries. The logic of this proposal is that it brings together the collective management rights associated with the individual ownership of quota shares within the sustainability limits of the QMS and relevant environmental standards. The development of a more secure legislative framework for collective industry management initiatives will enable the rock lobster industry to further consolidate stock abundance and economic performance.

Lobster Research and Management in South and Southeast Asia

Vijayakumaran M

Vijayakumaran Manambrakat <vijay@niot.res.in> (national Institute of Ocean Technology, Chennai, India)

Though the annual lobster production in South and Southeast Asian countries is only around 10000MT, the region has taken a lead in the aquaculture of spiny lobsters in sea cages using naturally settling



post larval and small juvenile lobsters. Vietnam leads in the aquaculture of lobsters producing over 2000 MT of Panulirus ornatus per year. The lobster fishery is a multispecies one consisting of tropical palinurids such as *P. homarus*, *P. ornatus*, *P. polyphagus*, *P. versicolor*, *P. penicillatus*, *P. longipes* and the scyllarid lobsters *Thenus oriebtalis*, *Scyllarides squamosus* and *Paribacus antarticus*. Most of the countries in the region do not have any specific management measures to regulate the lobster fishery, apart from those widely applied across all exploited fish species. Few management measures, though rarely implemented effectively, are gear, area and temporal restrictions; input control; delimitation of fishing zones; minimum size for export, and establishment of Marine Protected Areas. Lobster research in these countries is carried out primarily by government research institutions and recently many inter governmental projects have been initiated in Southeast Asia especially to study lobster aquaculture. The emphasis of research is on aquaculture-related areas such as breeding, larval rearing and juvenile grow out. Very little data is available on stock assessment; phyllosoma abundance, and distribution; habitat, and ecology; fishing pressure and sustainability of lobsters in the region. This paper deals with the status and future requirements of lobster research and management in South and Southeast Asian countries.

STREAM ONE

Fisheries Management

Spiny lobster fishery in Brittany (France), how the lack of management led to the quasicollapse of the stock. Nevertheless, positive changes in management are putting in place

Laurans Martial, Jérémie Habasque, Nicolas Caroff Laurans Martial <martial.laurans@ifremer.fr> (IFREMER)

The aim of the presentation is to show the evolution of the Spiny lobster fishery in Brittany which exist since the middle of the XIX century. Landing data exist for the XX century with a good time series since 1950. These data permit to observe the huge decrease of the landings characterizing the bad evolution of the stock status. On a shorter and more recent period, the data of effort and catch from the netter fleet (which represents 90 % of the landings) are used to estimate an abundance index from a fitted GLM model. The results confirm the serious declining situation of the stock. In parallel, the fishing effort is analysed to well understand the evolution of the situation. In front of this situation, the fishermen have recently reacted and put in place new management fishing rules. One of the decisions has been to develop a closed fishing area as a laboratory area. The first results from fishing surveys seems to confirm the positive evolution of the abundance in this area. Today the discussions are concentrated on the way to use these results in order to develop some new management rules for spiny lobster. The future works to improve the knowledge of the biology and ecology of these species will be presented and discussed.

Management of the CRA8 (Southern New Zealand) Rock Lobster Fisher – The change from historical reactive government measures to industry led proactive strategies

Malcolm Lawson

Malcolm Lawson <lawson_otatara@xtra.co.nz> (NZ Rock Lobster Industry Council)

The CRA8 fishery has been the highest producing area since the development of the New Zealand spiny red rock lobster (*Jasus edwardsii*) industry during the 1940's. This fishery was typical of many in that it experienced the "boom" period of exploitation of a virgin fishery where annual catches exceeded 3000 tonnes, and a subsequent "bust" period where annual catches dropped to less than 600 tonnes. This presentation describes the range of historical reactive management measures implemented by various governments and their effects. We then describe the change to current proactive management strategies led by the commercial industry. There is particular focus on the development and implementation of an operational management procedure that generated Total Allowable Catch (TAC) decisions between 1997 and 2007 and the successful rebuild of the fishery. We then describe the development of a subsequent "maintenance" operational management procedure and the motivations behind the harvest control rules embedded in this. Where an important focus has been to maintain abundance well above statutory stock reference points and as a result provide certainty for business planning and the opportunity for the maximisation of financial returns through selective fishing to meet market demands. Finally we compare the number of participants, the economic value and profitability of the

industry in 2002 - when the TAC was at its lowest point - and the present day where the CRA8 area now produces 36% of New Zealand's rock lobster exports and is the most valuable of all inshore quota management areas in New Zealand across all species.

With rights comes responsiblities

Larnce Wichman

Larnce Wichman <larnce@burkhart-fish.co.nz> (NZ Rock Lobster Industry Council)

Fisheries Management Theme With rights come responsibilities and the role of rights holders acting collectively can ensure the responsible stewardship of fish stocks. Examples from the Canterbury/ Marlborough (CRA 5) rock lobster fishery in New Zealand. Larnce Wichman Executive Officer CRA 5 Rock Lobster Industry Association Inc. (CRAMAC 5) The role of commercial rights holders in managing the stocks in which they have some ownership is generally expressed in terms of industry generated data programmes which inform stock assessments and guide decisions on sustainable catch limits. That is an important dimension of the management role but there are equally important demands on rights holders who operate in "shared fisheries" where the interests of non-commercial extractive and nonextractive users are influential in guiding Government decisions which affect the quality and quantity of commercial access and utilisation. The CRA 5 rock lobster industry since 1996 has implemented a range of internal processes and procedures which enable the commercial sector to maintain a productive working relationship with other sectors in support of agreed biological and environmental standards. CRAMAC 5 has led the implementation of a formal disputes resolution process, drafted a marine mammal Code of Practice; enhanced the efficiency of enforcement and compliance; and enabled a greater understanding of the manner in which the community can have effective input and participation to rock lobster fishery research and management processes. The CRA 5 fishery is currently operating well about reference levels and the quality of fishing success for all sectors is high.

Growth models of European lobster and identification of critical management options for rebuilding local Norwegian populations

Einar Mjølhus¹, Tore Kristiansen², Ann-Lisbeth Agnalt², Eva Farestveit²,

Knut E. Jørstad² Korresponding author: Einar Mjølhus

1. Institute of Mathematics and Statistics, University of Tromsø, Norway

2. Institute of Marine Research, Postboks 1870 Nordnes, 5817 Bergen, Norway

Einar Mjølhus <emj000@uit.no> (University of Tromsø)

Lobster populations in Norway have supported local fisheries for several centuries. However, the landings declined dramatically from 1960 and onwards. This led to increased interest in stock enhancement, i.e., production and releases of hatchery produced juveniles. A large-scale enhancement program was initiated at the Kvitsøy Island in southwestern Norway in 1990, and during a period of 10-15 years biological investigations were conducted. Basic biological information such as size distribution, sex ratio, maturation, fecundity, individual growth and movement were recorded for a large number of individuals, including wild lobster. This accumulated data collection was used as basic information for developing a model to generate understanding of how different management actions and strategies will influence restoration of the local lobster populations. The main model describes the lobster population in terms of length distributions instead of the more common age distributions. In addition, we have studied simpler models, in order to understand the effect of the gross parameters on growth and re-establishment of the population. The time of recruitment to maturation turns out to be crucial. This has earlier been poorly known, but Kvitsøy data indicate that 5 years appear typical. The models were used to identify the efficiency of various management approaches such as total ban of fishing, legal size options, berried females ban, establishment of marine protected areas (MPA). In all cases the time needed for rebuilding lobster populations were substantial (20 - 40 years), clearly demonstrating the need for longtime approaches in developing realistic rebuilding strategies.

POTBot: A cost effective approach to mapping habitats.

Matthew Barrett Pember, Simon de Lestang, and Dirk Slawinski Simon de Lestang <simon.delestang@fish.wa.gov.au> (Department of Fisheries, Western Australia)

Knowledge of the relationships between exploited species and the habitats that support them is critical to effective fisheries management. However, the acquisition of the spatially explicit habitat information required is expensive. POTBot combines open source software with inexpensive and readily available hardware in a system capable of providing high resolution, geo-referenced habitat information. POTBots can be deployed by fishers, with no added cost or interruption to their fishing operation, and the collated data can provide a map of the benthic habitats fishers operate in across the extent of a fishery. In addition to mapping habitat, these systems are capable of collecting a range of other important data including spatially specific environmental data (salinity, water temperature and depth) and the relative abundance / species composition of fauna in that area. This increased understanding of the way habitats influence the demographics of exploited species and continuous system of monitoring habitat changes will enhance the capacity of fisheries management to adapt to issues such as climate change. These technologies have far reaching applications across other areas of marine science.

The Norwegian Nephrops fishery on Møre – trap fishery and live handling.

Astrid K. Woll¹; Gulborg Søvik²; Wenche E. Larssen¹

1. Møreforsking Marin, Ålesund, Norway

2. IMR, Bergen, Norway

Astrid Kari Woll <astrid@mfaa.no> (Møreforsk Mariun)

Norwegian landings of *Nephrops norwegicus* (250-300 tons annual) are mainly from Skagerrak and the Norwegian Deep, where the largest part is taken with trawl. North of 62 °N, a coastal trap fishery for Nephrops has developed and landings increased to 49 tons in 2009. This study focuses on the region Møre, where a small trap fishery for Nephrops has been carried out for more than 30 years. Effort and landings have been increasing in this fishery the last years, both for professional and recreational fishers. Most of the catches in the region are sold alive or cooked fresh attaining high prices compared to frozen products. The aim of the study was to obtain an overview of the fishery and compare it with the fishery in Skagerrak and Norwegian Deep, identify bottlenecks regarding live handling of the commodity, and doing trials to improve quality and survival. In Møre Nephrops is fished all year round, making live handling difficult during summer due to high temperatures with subsequent high mortality. Effort to avoid this is described. The size of the Nephrops is large compared to trawl catches further south. Individual measurements in 2009 showed that 45% was in the size-class 4 -9 pieces/kg. Large size together with good quality due to improve dhandling will give these lobsters an advantage on the live market.

Going live: a science-industry collaboration to develop an Icelandic live lobster product

Heather Philp and Gudrun Marteinsdottir

Heather Philp <heather_philp@yahoo.co.uk> ()

During the last two decades, improved transport links combined with greater knowledge and understanding of lobster biology has facilitated the expansion of trade in live langoustines (Nephrops norvegicus) in most of Europe. Live products consistently achieve a higher sales price than their processed counterparts and are increasingly sought after by consumers due to the high quality. In Iceland, the fishery is prosecuted exclusively by large trawlers with products being sold either as frozen whole, tails or fresh. There is a collective ambition amongst producers to diversify into the live market but they face unique challenges including the unpredictable climate which precludes regular fishing trips and logistical limitations on transport. Research was commissioned as part of a doctoral study to determine the best method for capture, storage and transport of live langoustines from Iceland. A range of biological parameters including haemolymph chemistry and tissue composition were assessed to measure the lobster's health and capacity to recover from physiological stress. Our study found that despite the low-stress method of trap fishing, an immune response was triggered very quickly after capture. Recovery was expedited if the lobsters were placed to tanks containing filtered rather than flow-through water at the holding facility. Storage in filtered, recirculating water was important for both survival and maintenance of vigour during simulated transportation, and recovery from the emersion period. The results of the study were used to develop an optimised approach to creating a live lobster product from Iceland. The first shipments were dispatched earlier this year.

STREAM TWO

Behaviour

Does the behavior of lobsters in, and around, ventless and standard lobster traps influence catch?

Winsor H. Watson III, Steven Jury, Abigail Clark, Tracy Pugh, Tom Langley and Jason Goldstein. Win Watson <win@unh.edu> (UNH)

Effective management of the American lobster (*Homarus americanus*) fishery is dependent on accurate estimates of lobster abundance. While several methods are used to obtain these estimates, catch from lobster traps remains a very useful and cost effective approach. Furthermore, vent disabled or 'ventless' traps have become increasingly important in some monitoring programs. The first goal of this project was to understand the relationship between catch in traps and the size structure and density of lobsters on the bottom. We fished traps with and without video cameras mounted on them, while simultaneously conducting SCUBA surveys to quantify lobster density in the same study area. At this study site we found that catch in traditional commercial lobster traps correlated to the density, as long as the abundance was low. This was due, in part, to the fact that traps saturated in 24 hrs, or less. Our second goal was to compare the dynamics of ventless traps, identical to those used for surveys by many New England State agencies, with standard commercial traps. In general, ventless traps captured far more lobsters, took longer to saturate, and the mean size of lobsters captured was smaller. Data will also be presented, based on analysis of videos obtained from both types of traps, that illustrate the differences in how each type of trap fishes and how this can be applied to the use of ventless traps as a management tool.

Egg-bearing lobster movements in coastal Gulf of Maine USA waters – Influence on egg development, larval hatch, and relevance in connectivity models

Jason S. Goldstein and Winsor H. Watson III

Jason Goldstein <jsh5@unh.edu> (University of New Hampshire)

American lobster (Homarus americanus) supports one of the most economically important fisheries in the Northwest Atlantic and Gulf of Maine (GoM), and this success is attributed, in-part, to a high degree of broodstock conservation. Studies of ovigerous lobster movements indicate that some, if not most, display seasonal inshore-to-offshore patterns, and it is generally accepted that these movements serve to expose eggs to warmer offshore water temperatures which should accelerate development. We set out to test the potential adaptive significance of such patterns and attempt to more fully elucidate the processes involved in seasonal lobster movements as well as the timing and location of hatching events. In the field, we used ultrasonic telemetry to track both ovigerous (n=24) and non-ovigerous lobsters (n=26) while concurrent lab studies examined the impact of naturally fluctuating simulated thermal regimes for both inshore and offshore locations on egg development and time to hatch. Finally, experimental ocean drifters were deployed in temporally- and spatially-relevant areas in the vicinity of hatching lobsters to determine where these larvae might initially drift to and settle. Some data indicate that offshore movements of lobsters in GoM waters actually delay egg development and hatch by more than two weeks. Based on time and location of hatch, most of the larvae that hatch in coastal waters are likely to settle in southern waters while other data show a potential source of larval recruitment to offshore locales. Our results suggest the importance of temporal and spatial data for larval hatch and the ensuing implications for population connectivity and management of this important fishery.

Home range and activity patterns of wild European lobster (*Homarus* gammarus) studied by acoustic telemetry and archival tagging

Even Moland, Esben Moland Olsen, Halvor Knutsen, Kristian Andvord, Jan Atle Knutsen, Carl André, Svein Erik Enersen, Nils Chr. Stenseth Even Moland <even.moland@imr.no> (Institute of Marine Research)

We investigated movement and activity patterns in European lobster by combining ultrasonic tracking and archival tagging in lobster reserves on the Skagerrak coast, Southern Norway from September 2006–August 2007. Home ranges were estimated for 19 individuals (mean carapace length: 95 mm, range: 74-117 mm). Home range estimates based on a kernel density estimator of the 95 % utilisation distribution ranged from 5 728–41 548 m², with no significant difference between males, non-ovigerous females and ovigerous females for an overlapping observation period of 242 d. Logistic

regression predicted average time to reach 50 and 95 % of minimum convex polygon home range area at 98 and 259 days, respectively. Lobsters equipped with archival tags recording in situ depth and temperature used habitats within a depth-range of 1 - 57 m, and experienced sea temperatures ranging from 2 °C during late winter (February – March) to 18 °C during late summer (August – September). Activity levels declined from September, reaching a minimum during February and March. From April activity levels resumed. Seasonal variation in activity was correlated to water temperature (R2 = 0.55). Lobsters were more active during nighttime than during daytime, and there was a tendency for lobsters to reside in more shallow water during nighttime versus daytime. These results show that European lobsters can be resident with limited home ranges. Small coastal reserves can be designed to afford complete or partial protection by letting boundaries engulf or intersect patches of habitat preferred by this species.

Environmental effects on recruitment

Increase in the period of closure of lobster (panulirus spp.) fishery and its effects on the catch of puerulos and juveniles in collectors of algae of the genus *gracilaria*, *flecheiras* beach, state of ceara, northeastern brazil.

Masayoshi Ogawa - Federal University of Ceara – ogawa@ufc.br Toivi Mashi Neto - Federal Institute of Ceara toivi@ifce.edu.br Roberto Carvalho - Federal University of Ceara – rcac@ufc.br Diego Weskley Student, Federal University of Ceara Masayochi Ogawa <ogawa@ufc.br> (Universidade Federal do Ceara)

Lobsters of the genus Panulirus are the most important commercial fishery resource in the state of Ceara. Due to overfishing, production has fallen significantly: from 2001 to 2007, it fell 50%. Through studies of collections of puerulos, one can determine the volume of sustainable catch of lobsters during commercial fishery operations. A research aiming to capture puerulos and juveniles of Panulirus spp using collectors with marine algae was conducted at Fleicheiras Beach, Municipality of Trairi, Ceara. The collectors consisted of a nylon rope 50m long, with branches of algae trapped in the structure. The collectors were installed at approximately 500m from shore, at a depth of about 5m. Individuals were collected once per month in the new moon phase, and then counted and given back to the sea. The experiment was conducted in the following yeara: 2005, 2006, 2008 and 2009. Through the analysis of the results obtained, it was observed an average of 60± 30, 44, 72±37, 11, 96,4± 41,48 and 161,17 ±179 individuals per month for each year, respectively. In 2009, the average of individuals was significantly above those observed in the other years of the research. This increase may be related to the longer period of closure applied to lobster fishery since 2007. More studies are needed to confirm this hypothesis. The increase in the number of collectors along the coast of Ceara is very important to obtain more representative information that could be used in the study of population dynamics and alternative management strategies of this marine fishery resource. Key words: Puerulos, prediction, lobster

Effect of temperature on the time budget of stage IV larvae of the American lobster (*Homarus americanus*)

Melanie Chiasson, Gilles Miron, Dounia Daoud and Martin Mallet Melanie Chiasson <mani08@hotmail.com> (Université de Moncton)

The American Lobster (*Homarus americanus*) is an important economic species in Atlantic Canada. The low recruitment observed in certain areas combined with an important commercial fishery contributed to the decline of the populations. In response to this decline, the lobster industry initiated a lobster seeding program to increase the stock abundances. The stage IV larva was targeted because it is at this particular stage that the larvae go from a pelagic to a benthic lifestyle. Several environmental parameters can influence the behaviour and survival of the larva during enhancement including water temperature. The aim of this study is to document, in laboratory, the behaviour of the larvae under various water temperatures. Three temperatures were used (10°C, 15°C and 20°C). The effect of acclimation at a given temperature, prior to the treatment, was also studied. Two acclimation temperatures were used (15°C and 20°C). Preliminary results showed that water temperature influences the general behaviour of the larvae including their cryptic behaviour. Larvae tend to hide more quickly in high water temperature than in low water temperature. The time necessary to reach the substrate however varies according to the acclimation. For instance, larvae acclimatized to 15 °C

take less time to reach the substrate than those acclimatized to 20°C, except for the 20°C treatment. Information resulting from this study will be useful to improve the effectiveness of the enhancement program carried out by industry.

Impacts of seaweed bed dynamics on early benthic stages of the Japanese spiny lobster, *Panulirus japonicus*, and possible connections with sea warming

Taku Yoshimura, Kousuke Yatsuya, Setsuo Kiyomoto & Shogo Arai

Taku Yoshimura <yoshimura.taku@affrc.go.jp> (Seikai National Fisheries Research Institute)

The pace of sea warming in the northern East China Sea adjacent to western Kyusyu, Japan, is estimated at +1.3 °C per 100 years, which is 2.6 times the global average. Recently, we found unusula perennial seaweed beds along western Kyusyu that form dense stands for a relatively short period (March to July) and lose most thalli after maturing in August. Thus, in mid-summer the landscape dramatically changes from being lush to nearly bare. Researchers have suggested that the seaweed loses most branches and leaves because of high grazing/browsing pressures by herbivorous fishes that probably increase with sea warming. We refer to this condition as "spring seaweed bed" (SSB), based on the main formation season of the seaweed beds, as opposed to a "four-season seaweed bed" (FSB). Post-larvae of the Japanese spiny lobster (Panulirus japonicus) settle in seaweed beds from May to November, and these beds are important nursery grounds for early benthic stages of the lobster. However, 3 years of field research in SSBs indicated that settlement occurs mainly from May to July, when the beds are vegetated, and does not occur after August. Field experiments using artificial habitats of Sargasso seaweeds and cages to exclude herbivorous fishes showed that P. japonicus postlarvae settlement continued from May to October even in SSBs. These results indicate that post-larval lobsters can detect seaweeds keenly and sea warming should adversely affect the recruitment and survival of early benthic stages of the Japanese spiny lobster.

A Summary of Hemolymph Plasma Biochemistry Profile Results from American Lobsters (Homarus americanus) in Atlantic Canada (2007-2010)

Andrea Battison & Jean Lavallée Atlantic Veterinary College Lobster Science Centre, University of Prince Edward Island, PE, Canada Andrea Battison <abattison@upei.ca> (AVC Lobster Science Centre)

Hemolymph biochemistry analysis is a tool that can assess lobsters as they experience normal physiologic events (e.g., moult) and pathologic events related to disease or changes in their environment. Any such studies first require the establishment of 'normal' values (reference intervals) for a specific population. Between 2007 and 2010, a total of 1,675 (n= 786 F; n = 889 M) hemolymph samples were collected at sea from freshly-hauled lobsters in four Lobster Fishing Areas (LFAs 33, 34, 25, and 26A) in Atlantic Canada. Carapace length, pleopod moult stage, shell hardness, and hemolymph total solids (Brix index) were recorded. Plasma biochemistry profiles were run on the Cobas c501, an automated biochemistry analyser, by Diagnostic Services at the Atlantic Veterinary College, University of Prince Edward Island, Canada. Biochemistry profile parameters included mineral, electrolyte (sodium, chloride, potassium, calcium, magnesium, phosphorus) and metabolite concentrations (glucose, lactate, triglycerides, cholesterol, total protein, 'albumin', urea, uric acid) and enzyme activities (alanine aminotransferase, aspartate aminotransferase, glutamate dehydrogenase, alkaline phosphatase, lipase). Seasonal patterns with slight year-to-year shifts associated with the moult were noted for many variables. Regionally, triglycerides and cholesterol reached higher levels in lobsters from LFAs 25 and 26A. Gender variation was evident for triglycerides with females reaching higher values in all regions June-August which is suspected to be related to oocyte development. As we increase our understanding of the normal fluctuations in many of these parameters, plasma biochemistry analysis becomes an increasingly useful tool for health assessment in H. americanus.

Effect of photoperiod manipulation on the biochemical composition of the spiny lobster, *Panulirus homarus*

Vijayakumaran, M, J.T. Mary Leema, R.Kirubagaran, M.C.Remany, D. Magesh Peter

Vijayakumaran Manambrakat <vijay@niot.res.in> (national Institute of Ocean Technology,Chennai, India)

Photoperiod has distinct influence on the physiology of many organisms, especially the invertebrates such as crustaceans. This study reports the effect of photoperiod regimes on the biochemical composition of lobsters. Juveniles (75–125 g) of the spiny lobster, *Panulirus homarus*, were exposed to five photoperiod regimes [OL(light): 24D(dark); 6L: 18D; 12L: 12D; 18L: 6D; 24L: 0D] during a 45-day trial, and the changes in the levels of total protein, total lipid, total free amino acid, total free sugars, glucose and glycogen contents in muscle and hepatopancreas were estimated. Lobsters grown

under the 6L: 18D and 24L: oD photoperiods had significantly higher (P < 0.05) total protein content in muscle and hepatopancreas than the other treatments. However, photoperiod did not significantly affect the free amino acid content of the different groups. Lobsters grown under 24L: oD and 6L: 18D photoperiods had significantly (P < 0.05) higher total free sugars and glucose than the other treatment groups. Nevertheless, there was no significant difference in the glycogen content of the lobsters maintained under different photoperiod regimes. The total lipid content of the hepatopancreas of lobsters grown under the 6L: 18D and 24L: oD photoperiods was also significantly higher (P < 0.05) than other treatment groups. The significance of the results are discussed in the paper. Keywords: Lobster, Photoperiod, *Pamulirus homarus*, biochemical composition

Thursday 23 June 2011

STREAM ONE

Keynote MPA:

Responses of the spiny lobster *Palinurus elephas* to 20 years of protection in a temperate marine reserve

Raquel Goñi, David Díaz and Sandra Mallol

Raquel Goñi <raquel.goni@ba.ieo.es> (Instituto Español de Oceanografía)

The European spiny lobster *Palinurus elephas* has been unfished in the Columbretes Islands MPA (Western Mediterranean) since its creation in 1990. The MPA harbours 44 km² of lobster coraligenous and maërl grounds, largely closed to all extractive activities. Monitoring started 7 years after MPA creation and its first aim was to assess the status of P. elephas in the MPA relative to areas continued to be fished. This intitial spatial comparison indicated that lobster density and relative egg production was 5–20 times greater in the MPA than in fished areas. Continued monitoring up to year 20 of protection (2010) provided a unique oportunity to assess the evolution of abundance and demography in the unfished population for a period close to the life span of the species. Tag-recapture experiments allowed to document and measure the amount of spillover from the MPA being harvested by the adjacent commercial fishery. We estimated a net benefit of spillover from the Columbretes MPA to the regional lobster fishery of 11% of the annual catch, which compared to a 6 times greater egg production supports the contention that egg and larval export have far greater potential than spillover to benefit exploited populations. Marine protected areas that effectively rebuild biomass of exploited species within their boundaries are expected to benefit local fisheries through biomass spillover and export of eggs and larvae. The Columbretes MPA lobster study is unique in that has evaluated both of these effects.

Keynote Neurobiology:

Basic structure and function of the nervous system in lobsters and their decapod relatives: a review

Steffen Harzsch Steffen Harzsch <steffen.harzsch@uni-greifswald.de> (University of Greifswald, Zoological Institute, Dept. Cytol)

This contribution will summarize recent progress in our understanding of how the nervous system orchestrates the behavior in decapod crustaceans. I will provide a brief overview over the architecture



of the central nervous system and the associated sensory systems. I will then go on to point out active research areas in which decapods today serve as models for analysing the interplay of nervous system structure and behavior. These areas include (but are not limited to) circadian aspects of behavior, chemosensory systems and chemical communication, vision research, adult neurogenesis, feeding behavior and food digestion. My contribution hopefully will raise questions for which the workshop on Neurobiology, Sensory biology and Behaviour that is associated with this session and that is organized by Thomas Breithaupt can serve a as a platform for further discussion.

MPA

Marine protected areas for lobsters - why bother?

Andreas Sundelöf

Andreas Sundelöf <andreas.sundelof@bio.uib.no>

Local management is a promising tool in the management of natural resources. The growth and revenue of local stocks becomes the interest of the exploiters and not the managers. In many areas this comes down to a scale issue and identifying the biological scales of species may be very difficult. Apart from reserve size there is a set of variables that the functioning of a reserve will be sensitive to, individual growth rate, mortality rates, recruitment functions etc. I have used an IBM of lobster, parameterized with a large set of data, to assess the possibility of local management options. Lobster adults are predominantly resident to a habitat patch and larvae are pelagic for no more than 14 days, such that they do not disperse over vast areas. This small scale migration and dispersion makes lobster a good model species for testing assumptions and behavior of no-take reserves (MPA) as a local management option. Model simulations show that the proportion of closed habitat need not be large in order to protect a fraction of the population as a larval pump with extensive reproductive subsidies. However, the contribution of larvae produced locally (retention) relative to the total larval pool will be important for the effect of small scale reserves. I conclude that small scale reserves can function well for the conservation of lobster size distribution and may render high revenue in archipelago type areas, however, only when the ambient population is badly managed.

Lobster reserves in coastal Skagerrak: a field laboratory for science and management

Even Moland, Esben Moland Olsen, Halvor Knutsen, Alf Ring Kleiven, Jan Atle Knutsen Even Moland <even.moland@imr.no> (Institute of Marine Research)

Scientific documentation of marine reserves as a means to conserve species and ecological processes has reached a level where this management tool is considered a critical component of ecosystem based management and successful rebuilding efforts. However, because there are opportunity costs to conservation, there is a continuing need for science based assessment of marine reserves whenever this measure is introduced to new areas, species or systems. Experimental lobster reserves were implemented along the Norwegian Skagerrak coastline in 2006 as a collaborative effort between the Norwegian Institute of Marine Research and the Directorate of Fisheries, with support from commercial fishers. The primary aim was to provide a science based evaluation of small-scale reserve effects on local lobster populations, with potential to improve management of this iconic species. In addition to long term monitoring inside reserve and control areas, launched in 2004 (two years prior to protection), complementary studies were conducted within the framework of three research projects. These incorporated socio-economics, lobster ecology and -demography, and lobster population genetics in marine reserves context. Results from this multidisciplinary approach suggested rapid rebound of lobster within reserves, strong stakeholder support for the reserves, high site-fidelity and increased survival of protected lobsters, and weakly structured lobster populations along the Skagerrak coast. Here, we highlight some of the most important findings and discuss their implications for lobster management in particular, and more broadly, for introduction of marine reserves as a management tool in northern temperate coastal waters.

Population age structure of the Caribbean spiny lobster, *Panulirus argus*, in a marine protected area in Florida Keys, USA

Kerry E. Maxwell, Thomas R. Matthews, Rodney D. Bertelsen, and Charles D. Derby Thomas Matthews <tom.matthews@fwc.state.fl.us> (Florida Fish and Wildlife Conservation Commission)

Fishery managers are increasingly using marine protected areas (MPAs) to ensure continued sustainability of fisheries throughout the world. Within the Florida Keys National Marine Sanctuary, Western Sambos Ecological Reserve (WSER) was created to provide a natural area for spawning and a permanent residence area for marine life. To evaluate if WSER met these design criteria, we assessed the population age structure and reproductive capacity for the Caribbean spiny lobster (Panulirus argus). We used histological methods to quantify the amount of the age-based pigment, neurolipofuscin, from eve stalks. We compared Monte Carlo simulations of the age of lobster populations in the open fishing area to those inside WSER. The age structure of the lobster populations indicated that lobsters within WSER were older than in the unprotected-fished area. The age distribution suggested that lobsters outside of WSER were predominately 1-2 years old whereas most lobsters in WSER comprised 3 year classes and a few lobsters were the same age (5-6 years old) as the MPA at the time of the survey. Also evident in this age-based study was the protection of females, as confirmed by the presence of older females, which was not obvious in size-based surveys. Additionally, these older female lobsters produce more egg clutches per year, which results in increased reproductive output in WSER compared to the unprotected-fished area. Research funded by the National Oceanic and Atmospheric Administration's (NOAA) Marine Fisheries Initiative Program, the National Fish and Wildlife Foundation, and NOAA's Coral Reef Conservation Program.

Movement patterns and exploitation rates of Caribbean lobsters in fishing zones within MPA's in Mexico

Ley-Cooper, K., De-Lestang S, Phillips B

Kim Ley-Cooper <kim.ley.cooper@gmail.com> (Curtin University)

Caribbean spiny lobsters (*Panulirus argus*) are the major commercial fishery in Bahía del Espíritu Santo, the southern bay of Sian Ka'an Mexico, a marine protected area where fishing for spiny lobsters is allowed with restrictions. Commercial catch rates were examined and a wide size range of lobsters were tagged throughout the 2010/11 fishing season in order to examine fishing mortality rates and movement patterns. Recaptured individuals were re-released when below legal size (<76 mm carapace length), or harvested with associated tag-recapture information reported by the fishers when legal. Tag recovery data was aggregated into 2 week periods and analysed using a modified Brownie model that was parameterized to account for tag-reporting (λ), and the tag-retention (φ) rates to estimate instananeous rates of fishing (F) and natural (M) mortality with F being comprised of lobster catchability and fishing effort. Aquaria trails were conducted to better estimate (φ) and interviews with fishers were conducted to better estimate (λ). The bays fishery is mainly based on legal size early adults with fast growing rates, where the stock subject to fishing is limited to a 20m maximum depth due to diving and trap restrictions. The Brownie model indicated that exploitation rates within the fishing area is >90%. The movement patterns of lobsters combined with changes in CPUE indicate an important influx of lobsters into the bay in early winter, as well as the off season.

Physiology

Examination of protein expression during ovary maturation in American lobsters (*Homarus americanus*).

Rachael Summerfield and Andrea Battison

Rachael Summerfield <rsummerfield@upei.ca> (AVC Lobster Science Centre, UPEI)

American lobster is the most lucrative fishery in Atlantic Canada and effective conservation measures are essential for its long-term sustainability. The ability to accurately determine when a female lobster reaches sexual maturity is vital in the development of fishery management policies. At present, female reproductive status can only be determined by lethal sampling methods and subjective assessment. The objective of this study is to identify and isolate proteins whose expression level is unique to mature ovaries and which are detectable in lobster hemolymph. Ovaries were collected from 140 lobsters in spring 2008 and 2009 and staged by visual examination (colour, oocyte diameter, ovary factor). Three ovaries from each of the seven stages of ovary development [1–3, 4a, 4b, 5–6, as defined by Waddy and Aiken (2005)] were compared by 2-dimensional electrophoresis, following optimisation of protein extraction.

As expected, different protein expression patterns were observed for immature, developing and mature ovaries. Both the relative expression and number of proteins decreased with increasing ovary maturity. Protein spots that are differentially expressed in mature ovaries will be sequenced by mass spectrometry. Based on sequence data, candidate proteins will be chosen for the development of an enzyme-linked immunosorbant assay (ELISA) that can measure their concentration in hemolymph. This non-lethal means of determining female reproductive status could provide an invaluable tool for size at maturity studies.

Effect of temperature and body size on long-term emersion and reimmersion responses of the American lobster, *Homarus americanus*

John Garland, Dr. Roger Uglow

John Garland <jgarland@clearwater.ca> (University of Hull)

Commercial exports of the live lobster (*Homarus americanus*) from Canada comprise 26.6 million kg p.a. and are worth approximately \$379 million dollars (CAD). Long-haul commercial air transport options have been declining in recent years, resulting in airline cargo route options that require increased transit time and consequently longer emersion times for live lobster consignments. This study compares the physiological responses of two lobster sizes, two immersion temperatures and two emersion durations used typically in the Canadian live lobster shipping industry. Additionally, the affects of 3 re-immersion durations were examined. A suite of haemolymph constituents, known to be related to emersion-induced hypoxia, has been assayed using groups of n=8 lobsters at each sampling occasion to comprise an overall total of 256 individual lobsters. The physiological and commercial implications of the findings are discussed.

Physiological Assessment of American Lobsters (Homarus americanus) held in a specialized Live Seafood Transport System

Melanie Burton, Andrea Battison & Jean Lavallée

Melanie Burton <mburton@upei.ca> (AVC Lobster Science Centre)

North American lobsters (Homarus americanus) are shipped live to local markets (via ground transport) and worldwide markets (via air freight). Physiological and biological parameters were assessed before and after a 7 day trial using a novel Live Seafood Transport System (LSTS) designed for ocean freight in which lobsters are shipped in re-circulating sea water. The study evaluated the survival of 3 groups of lobsters initially sorted by total solids content (Brix index: Low <8, Medium 8-11 and High >11). Lobsters were kept in the system for 7 days at 0 -2°C in 6 LSTS tanks (250kg lobster/ tank). Lobster condition (sex, carapace length, vigour, Brix index, shell hardness, eyestalk withdrawal reflex, defensive posture, pleopod moult stage and recent wounds) was assessed on all lobsters pretrial. Hemolymph for plasma biochemistry profile evaluation was collected from 10 lobster/tank. Profiles were run on a Cobas c501 automated biochemistry analyser, Diagnostic Services, Atlantic Veterinary College. Baseline data showed correlations among Brix groups and biochemical profile parameters related to energy reserves. The Low Brix group responded differently in the system than the medium and high groups failing to maintain hemolymph glucose concentrations. Mortality was also significantly higher in the low group compared to the other two groups; 9.7% vs. O% and 0.9% (p<0.001). These results suggest that the LSTS could be a good alternative to air freight for shipping live lobsters with initial Brix index above 8.

Sex-specific differences in *Nephrops norvegicus* haemolymph total protein during the moult cycle

Ameya Anil Gudekar, Chris Burke and Arthur Ritar

Ameya Gudekar <ameyagudekar@live.com.au> (University of Tasmania)

The ability of the putative probionts Phenon 8, Phenon 52, *Vibrio cyclitrophicus* and *V. orientalis* to prevent or reduce mortality in newly hatched *Jasus (Sagmariasus) verreauxi* phyllosoma infected with *V. chagasii* and *V. penaecida* was examined. Phyllosoma were preemptively colonized with the probionts and then challenged with pathogens. All the isolates were introduced via Artemia to reproduce natural disease transmission. Survivals at the conclusion of the trials on Day 9 after hatch in the treatments receiving pathogens from hatch were significantly lower in all cases, while survival in the treatments receiving the putative probionts from hatch and Control treatments were highest. Survivals in the probiont-pathogen treatments, which received the probiont exclusively until Day 4 and a combination of probiont and pathogen after Day 4, were higher than the pathogen-only treatments. Highest survival (88%) among the probiont-pathogen treatments, the survival was 75-86%. The

total heterotrophic and Vibrio bacteria on Day 9 were significantly higher in the pathogen treatments. Sucrose positive bacteria were highest in the probiont treatments and high in probiont-pathogen treatments while sucrose negative Vibrio bacteria were highest in pathogen treatments. The survivals in all trials were negatively correlated to the heterotrophic and Vibrio bacterial abundances. The magnitude of the linear regression relationship between the survival and sucrose positive Vibrio was less than that of the survival and the sucrose negative Vibrio bacteria.

Growth-related physiology

Protein synthesis in wild-caught Norway lobster (Nephrops norvegicus L.)

Mente E., Carter C.G., (Katersky)Barnes, R.S. and Karapanagiotidis, I.T. Elena Mente <emente@uth.gr> (University of Thessaly, Greece)

In recent years, the need to understand and control growth mechanisms in crustaceans has been stimulated by increasing interest in the aquaculture of shrimps, lobsters and crabs. Commercial culture of the Norway lobster *Nephrops norvegicus* appears to be feasible although there is lack of detailed information on their protein metabolism and nutritional requirements. This research aimed to assess the nutritional status of wild caught Nephrops by measuring tissue rates of protein synthesis and comparing these with rates from fed and unfed Nephrops maintained in aquaria. Rates of protein synthesis were measured in the tail muscle, hepatopancreas and gill tissue. A time-course validated the use of a flooding-dose of 3H phenylalanine to measure protein synthesis in Nephrops. The time course of incorporation of [3H]phenylalanine showed that the flooding-dose technique is suitable for the study of protein turnover in Nephrops. The relationship between mean capacity for protein synthesis (Cs) and the measured rate of protein synthesis showed differences between tissues and between the starving, fed and wild-caught animals. The tail muscle Cs values showed higher capacity in the fed and wild-caught animals. For fed animals the Cs and protein synthesis rates were high in the hepatopancreas, whereas in the starved and wild-caught Cs was also high but protein synthesis was low. Knowledge of the dynamics of muscle protein deposition and the relationship between fed and starved protein synthesis and muscle protein deposition is required to understand Nephrops ability to adapt to environmental variations and provides baseline information for developing aquaculture

Impact of endosulfan on growth, histology and metabolic rates in juveniles of American lobster (*Homarus americanus*)

D. Daoud, W. Fairchild, P. Jackman, K. Benhalima, M. Comeau, B. Bruneau, D. Chabot, M. Mallet Dounia Daoud <dounia.daoud@gmail.com> (Homarus inc.)

In recent years, several studies have been initiated to gather information on the decline of the American lobster (*Homarus americanus*) landings in some areas of Atlantic Canada. One of these studies, carried out by Environment Canada and Fisheries and Oceans Canada, has looked at the effect of anthropogenic environmental contaminants on lobster. The presence of some chemicals in the environment during critical developmental periods could potentially affect lobster growth and survival. Endosulfan, sold under trade names such as Thiodan, is a broad-spectrum organochlorine insecticide, widely used in agricultural areas within the Gulf of St. Lawrence, Canada. It has already been shown that an acute exposure to endosulfan has significant effects on survival and growth of stages I to IV larvae. In order to detect more subtle physiological impacts to endosulfan exposure, we investigated if metabolic rate, measured by oxygen consumption, changes for juvenile lobsters (stages 5 and 6) exposed to sub-lethal levels of this contaminant. Long-term measurements of oxygen consumption with an intermittent-flow system allowed the calculation of standard (SMR), active (AMR) and routine (RMR) metabolic rates. Histological observations of controlled and exposed animals will also be presented.

Nutritional Condition of the American lobster, *Homarus americanus*, at different stages of the moult cycle

Michael Ciaramella, Andrea Battison, Barbara Horney, and Rachael Summerfield Michael Ciaramella <mciaramella@upei.ca> (University of Prince Edward Island)

In May through September of 2009 and 2010, 86 lobsters (50 male and 36 Female, *Homarus americanus*) representing five distinct moult categories were collected from the Northumberland Strait off Prince Edward Island, Canada. The nutritional condition, in the form of energy reserves,

was examined to identify natural physiological fluctuations in the lobster as it progresses through its moult. Tissue samples (hepatopancreas, abdominal, pincher, and crusher claw muscles) were removed and stored at -80 °C for determination of lipid and glycogen concentrations. Lipid concentrations were determined gravimetrically through the chloroform: methanol extraction techniques of Folch et al. (1957). Glycogen concentrations were measured indirectly by a colorimetric hexokinase based glucose assay following digestion of glycogen to glucose with amyloglucosidase. Glycogen equivalents were established with a similarly digested oyster glycogen reference curve. Significant changes in nutritional condition were observed in both lipid and glycogen reserves. There was a drop in total lipid content of the hepatopancreas in the post-moult stage with little variation in the late inter-moult and pre-moult stages. There was very little change in lipid concentrations of muscle in the different moult categories. Variations in stored glycogen at different stages of the moult were observed in all tissues. The prominent trend was a significant decrease in the post-moult with tissue dependent variations in the inter-moult and pre-moult stages. This data offers insight into the natural fluctuations in nutritional condition during the moult. These observations are important for interpreting data used for the monitoring, management, and conservation of lobster populations.

Temperature matters: moving toward a degree-day model for the growth of the American lobster

Charlene Bergeron, Richard Wahle, Yong Chen, Peter Lawton Charlene Bergeron <charlene.bergeron@maine.edu> (University of Maine)

Thermal variability adds extra complexity to an already challenging task of modeling growth in crustaceans. For the American lobster, a species whose geographic range spans the steepest latitudinal gradient in sea surface temperature on earth, a growth model incorporating temperature effects would be especially valuable to modeling population dynamics. We present a probabilistic stepwise growth model, modified to include variable temperature, for three thermally distinct regions of the species range, from the cool, well-mixed Bay of Fundy, to the warmer, summer stratified, central Gulf of Maine, to the even warmer, summer-stratified, southern New England shelf, USA. The model has the added novel feature of merging estimates of size-at-age from modal analysis of length-frequency data for the youngest lobsters with molt process information from tagging data for older lobsters. Temperature is incorporated by determining the probability of molting as a function of growing degree-days. Average daily temperature predicts the molt process through time. If temperature were the major determinant of regional differences in growth, we would expect the molt probability curves plotted against degree-day to remove differences that are apparent when they are plotted simply over time. We found, however, that "correcting for" thermal effects by the degree-day method does not entirely explain regional differences in growth, suggesting other environmental or heritable influences may be at work. Understanding the influence of temperature and other factors on growth would provide more biological realism and generality to population dynamic models, and will be especially relevant in the context of a changing climate.

STREAM TWO

Neurobiology, Sensory Biology and Behaviour

How predator kairomones and substrate quality affect and influence the behaviour response of the European lobster (*Homarus* gammarus).

Kjerstin Longva Nilsen, Gro Van Der Meeren, Per Jakobsen kjerstin Nilsen <kjerstin@nni.no>

In this study, the influence on changes in the behavioural pattern of the European lobster (*Homarus gammarus*) dependant on given parameters was examined. The parameters investigated were predator odour (kairomones), substrate and the interaction effect of kairomones and substrate. My hypothesis predicted that the parameters used would result in a measurable change in behavioural patterns. By using the parameters as treatments on different experiments, several behaviour patterns useful to release programs were tested to determine which of the parameters would influence behaviour. The behaviour patterns chosen to examine in my experiment were walking distance when introduced to a new habitat, accepting new shelter, digging behaviour, freezing and foraging behaviour. The main influence on the juvenile lobsters in my experiment turned out to be predator kairomones. With this I can document that the juvenile European lobster can sense and react to kairomones, and that predator

pressure is a strong influence in accepting shelter, manipulation of shelter and foraging behaviour. My hypothesis was also about the amount of influence the substrate played in behavioural patterns. In the case of substrate we could not find that it alone influenced the behaviour, but the interaction effect between the two parameters influenced the freezing behaviour. Hopefully this information will help understand more of the basic knowledge concerning the European lobster. And by this helping local population of lobsters recover by adding recourses to sea ranching projects.

Crushing Defeat Remembered

Jelle Atema, Dorothy Shi, Hillary Braverman Jelle Atema <atema@bu.edu> ()

In American lobsters, male dominance is directly related to mating success, which has led to sexual dimorphism with males growing very large claws. In dominance fights, size-matched lobsters often escalate their interaction to claw-crushing and ripping levels. While lethal wounds can be inflicted, most fights do not result in serious damage. As the fight escalates more urine is released; the urine odor is detected by the aesthetasc sensilla of the antennules and remembered by the loser. Evidence for memory is that the loser avoids subsequent fights with the familiar individual winner, but not with unfamiliar winners from other fights. This individual memory lasts about a week. Here, we investigated the role of claw crushing in memory consolidation. Four treatment groups of 10 male lobster pairs were tested for memory as measured by fight duration. The normal, no-band control group showed the known decline of fight duration after one day and a small increase in duration a week later. Pairs with both claws banded shut had significantly longer fights and showed no decline in duration on day 2 or day 7. This result was similar in pairs where only the crusher claw was banded shut. When only the seizer claw was shut, fight duration declined, significantly after one week. We conclude that the crusher claw provides information critical for memory consolidation. It is difficult to know if this is due to crushing strength or to crush receptors in that claw.

Chemosensory behaviour of Norway lobsters Nephrops norvegicus

Emi Katoh and Thomas Breithaupt

Thomas Breithaupt <t.breithaupt@hull.ac.uk> (University of Hull)

The Norway lobster *Nephrops norvegicus* is one of the most important commercial crustacean species in Europe. Despite its increased exploitation little is known about the social behaviour of this species. Knowledge about the significance of chemical communication in particular could facilitate further commercial exploitation. For example, the use of pheromones could enhance fishing as well as aquaculture. Hence, we need a better understanding of the chemosensory behaviour of *N. norvegicus*. Previous studies have reported that Norway lobsters fight over burrows. Our detailed analysis of dyadic aggressive interactions revealed that they establish dominance in the initial fight. In repeated fights dominance is maintained through urine-borne chemical signals. Blocking of urine increases fight duration, whereas artificial introduction of dominant male odour significantly shortens a fight between two size-matched males. In contrast to the well investigated American lobsters (*Homarus americanus*), *N. norvegicus* appears to respond to a general dominance odour rather than the individual smell of familiar dominants. Mating generally occurs after the female has moulted. Our experiments show that males would also mate with an intermoult female if the water was conditioned by a freshly moulted female rather than by an intermoult female. Together, these studies show that in Norway lobsters, chemical signals are crucial for mediating agonistic interactions as well as mating.

Empty inside: are 'large' female lobsters (*Homarus americanus*) in Southern New England failing to mate?

Tracy L. Pugh, Jason S. Goldstein, Kari L. Lavalli, Michael Clancy, and Winsor H. Watson, III. Tracy Pugh <tracy.pugh@state.ma.us> (University of New Hampshire)

The Southern New England stock of the U.S. lobster (*Homarus americanus*) population is depleted and the ASMFC Lobster Technical Committee has recently declared the stock to be in a state of recruitment failure. The potential for rebuilding this stock depends, in part, on larval production and recruitment, one aspect of which is mating success. However, low abundance, coupled with femaleskewed sex ratios in some areas, could set the stage for sperm limitation in Southern New England. We sampled female lobsters captured in the coastal waters of Rhode Island and southern Massachusetts and tested for the presence of a sperm plug or sperm in their seminal receptacles, as an indicator of mating success. Data (% with sperm) were compared to local size-at-maturity indices (% mature) to determine if all the potentially mature females were actually mating. Preliminary results indicate that while many smaller-than-expected females mated, some larger lobsters that should have mated did not. There are several possibilities to explain why these females failed to mate, including reduced encounter rates, an over-reliance on small males, and depleted males due to a combination of low abundance and female mate choice. Current management practices make the assumption that mature females reproduce on a predictable cycle, based on regional growth rate information. This assumption may not hold true if there are portions of the population where sperm limitation is a factor, and lobster management may need to shift its perspective from female-centric biological controls to a broader, more inclusive perspective to conserve reproductive potential.

Class-level vs. true individual recognition in the American lobster (Homarus americanus)

Francesca Gherardi, Federica Cenni & Laura Aquiloni Francesca Gherardi <francesca.gherardi@unifi.it> (University of Florence)

The increased theoretical interest in individual recognition in non-human vertebrates and the recent flowering of studies showing that this ability is widespread even in invertebrates have led, since the 1980s', to several attempts to provide an unambiguous definition of the phenomenon. Recently, Tibbetts and Dale (2007) distinguished between two forms of individual recognition, i.e. "class-level recognition" (CLR) and "true individual recognition" (TIR). CLR consists in the animal's ability to assign a conspecific to an appropriate class based on the distinction between a few -often only twoalternatives (e.g. "familiar" vs. "unfamiliar"). On the contrary, TIR requires that both identification (i.e. the emission by the sender of "signature" cues that label its identity) and recognition (the ability by the recognizer to decode these cues) are individual-specific. Herein, TIR is likely to be a much more complex task than CLR: the signatures emitted by the senders should show a wide inter-individual variability and the recognizer should have specific discrimination abilities, along with refined cognitive adaptations. Based on the previous literature and on original data, we will discuss here the potential ability of TIR by the American lobster, Homarus americanus, the possible advantages of being "different" in this species, and the sensory channels likely adopted in this task. We will show that clawed lobsters are an ideal taxon in which complex cognitive mechanisms associated with TIR are expected to be disclosed. Tibbetts EA, Dale J (2007) Individual recognition: it is good to be different. Trends Ecol Evol 22:529–537

Spiny lobster sound production: Antipredator behaviour helps lobsters survive variable environments

Peter E. Bouwma, Michael J. Childress

Peter Bouwma <pbouwma@gmail.com> (Friedrich Schiller University Jena)

Anthropogenic stresses on marine systems have sent many populations of corals and sponges into decline. Animals that rely on the shelter created by these sessile invertebrates as refuge from predators may be especially vulnerable to such losses. Consequently, when shelter is scarce, an individual's survival will likely depend on other defensive mechanisms. Spiny lobsters are highly likely to encounter habitats of varying quality due to a far-ranging oceanic larval stage, migratory behavior, or both. Spiny lobsters also exhibit a wide variety of mechanical and behavioral defenses in addition to sheltering, including sharp spines, tailflipping, retaliatory defense, cooperative defense, and sound production. In Caribbean spiny lobster Panulirus argus, sound production in particular (commonly called stridulation) reduces predation risk significantly against fish and octopus when used alongside other defensive actions. In this study, we examined the putative benefits of stridulation for P. argus lobsters residing in habitats where shelter is scarce. Using a new, spatially-explicit, agent-based simulation model in NetLogo, called SLAPS (Spiny Lobster And Predator Simulation), we simulated lobster interactions with predators in habitats with varying shelter availability and distribution. Stridulation decreased lobster mortality uniformly in all habitat types compared to non-stridulating lobsters. In non-stridulating lobsters, mortality rates depended on shelter availability; individuals were most likely to be killed in habitats with the fewest shelters. These data suggest that stridulation may serve to reduce both the variability and severity of predation risk for lobsters settling or moving into an everincreasing number of degraded and sub-optimal habitats.

Neurobiology, sensory biology and behaviour workshop

Lobsters as model systems in Sensory- and Neurobiology: research challenges for the Twenty-First Century

Thomas Breithaupt

Thomas Breithaupt <t.breithaupt@hull.ac.uk> (University of Hull)

The study of decapod crustaceans has provided crucial insight into our understanding of the general functioning of the nervous system. Important hallmarks of research on crustacean nervous systems include the analysis of the neural mechanisms underlying rhythmic behaviours such as walking, swimmeret movement, mouthpart and gut movement, the deciphering of the neural control of the tailflip escape behaviour, the comparative analysis of the architecture of the crustacean brain, and the unravelling of sensory transduction processes in chemo- receptor cells. Recently, the discovery of lifelong neuro-genesis in crab and lobster brains has spurred interest into the possibility that animals use this neuronal plasticity to adapt to environmental changes and to enhance learning and memory throughout life. The social behaviour and the role of different sensory modalities has been analysed in much detail in lobsters. However, despite these major advances, our understanding of how the nervous systems of lobsters and other decapods crustaceans extract information from the environment and how they produce complex behaviours such as aggressive, courtship, or predatory behaviour is still in its infancies. The workshop will review important achievements in crustacean neuro- and sensory biology and discuss the research potentials and challenges offered by lobsters and other decapods crustaceans in these fields.



Poster Presentations Abstracts



Aquaculture

Carrying capacity in juvenile stages of European lobster (*Homarus* gammarus; essential knowledge for restocking and sea ranching

Ann-Lisbeth Agnalt, Eva Farestveit and Knut E. Jørstad

Ann-Lisbeth Agnalt <ann-lisbeth.agnalt@imr.no> (Institute of Marine Research, Bergen Norway)

Juvenile European lobster (Homarus gammarus) smaller than 40 mm carapace length have rarely been captured in the wild, hence we have no knowledge of neither preferred substrate the juveniles live on/in nor carrying capacity. Previous experimental studies indicated preference to settle in a complex substrate of sand/cobble. The sheltering behaviour in these early-life stages can be considered an antipredator response. Knowledge of the early benthic stage of European lobster is considered crucial for restocking and sea ranching endeavours. Carrying capacity in aquaculture refers to potential maximum production maintained within an area, relative to available food and environmental resources. Carrying capacity can eventually reach a limit and thus reduce the production, either due to perturbations of the environment or to overexploitation of the food source. A series of experiments were run aiming to estimate juvenile density under controlled conditions. Pelagic stage IV larvae were released at densities from 10 to 40 per m2 into tanks stocked with shell sand and shelter. After 8 months, the various experiments yielded from 8 to 20 juveniles per m2. Highest mortalities were found in the experiments with highest release density (82%). There were indications that the carrying capacity had not been reached in the experiments with lowest release density. This was also the experiments with lowest mortality (32%). Perspectives of possibilities to further increase the carrying capacity will be discussed.

Assessment of the spiny lobster (Panulirus spp.) puerulus resources in Vietnam used for aquaculture

Nguyen Van Long, Dao Tan Hoc and Clive Jones

Clive Jones <clive.jones@deedi.qld.gov.au> (Queensland Government)

Aquaculture of spiny lobsters in Vietnam has grown rapidly over the past 15 years, based on the collection of lobster puerulus. An flourishing fishing industry now exists comprising fishers and dealers whose livelihoods are entirely based on catching and sales of pueruli. Although a number of species are available, the bulk of the catch is *Panulirus ornatus* and *Panulirus homarus*. An annual census of captured wild lobster puerulus has been carried out in eight coastal south-central provinces

of Vietnam from Da Nang in the north to Binh Thuan in the south, for the past five years. A structured interview and questionnaire/logbook process was used, which targeted both the fishing villages where the seed were captured and the dealers distributing the captured seed. Some 72 to 102 local dealers from 29 to 34 fishing communes/villages in 19 cities/districts were surveyed. Lobster puerulus settlement in Vietnam occurs within the period August through to June. Total catch of *P. ornatus* for 5 years from 2005 to 2010 was 8,081,446 pueruli and has ranged from 2,280,288 to 900,566. Total catch of *P. homarus* was 3,774,842 pueruli, and ranged from 1,329,000 to 1,329,000. The price of seed annually ranged between \$US2.90 and \$US9.20 per puerulus for *P. ornatus* and \$US0.60 and \$US2.00 for *P. homarus*. Total income from fishing of P. ornatus pueruli has been approximately \$US46,478,952 over the five year period. Variability in catch rate, location and pricing are discussed.

Culture of temperate spiny lobsters (*Jasus edwardsii* and *Sagmariasus verreauxi*) phyllosoma in Tasmania: recent developments and the prophylactic use of chemical disinfectants

Q. P. Fitzgibbon and S. Battaglene

Quinn Fitzgibbon <quinn.fitzgibbon@utas.edu.au> (Institute for Marine & Antarctic Studies)

Spiny lobster propagation research has been undertaken for more than ten years on two temperate planurid species endemic to southeastern Australia; southern rock lobster, Jasus edwardsii and eastern rock lobster, Sagmariasus verreauxi. Australia's first successful culture of J. edwardsii from egg to juvenile was in our laboratory in 2004 and for S. verreauxi in 2006. Excellent progress in culture has been made based on improved understanding of health management, abiotic requirements and larval behaviour and physiology. Background information on propagation research is presented focusing on microbial control and the use of chemical disinfectants for larval health management. In a series of experiments the prophylactic use of benzalkonium chloride, sodium hypochlorite and hydrogen peroxide were examined on the survival, growth and bacteriology of early-stage phyllosoma. High concentrations of all chemicals disinfectants were acutely toxic. Lower doses of some chemicals improved survival. However, it was often associated with a chronic suppression of growth. The use of some chemical disinfectants appears beneficial for controlling bacterial disease in phyllosoma culture. Sustained use of chemical disinfectants can also negatively affect phyllosoma culture performance through chronic toxicity, disruption of beneficial bacterial flora and facilitation of resistant bacterial strains. The benefits and disadvantages of chemical disinfectants will be discussed in relation to other control methods to minimize bacterial disease in phyllosoma culture.

Developments in upwelling stacked holding systems for early stage juvenile larvae of *H. gammarus* using the 'Aquahive' (patent applied for) and innovations in seabed deployment using fishing boats.

Dennis Gowland & Richard Land

Dennis Gowland <dennis@researchrelay.com> (Shellfish Hatchery Systems Ltd)

In 2007 Northbay Shellfish Ltd (www.northbayshellfish.co.uk) worked in conjunction with Orkney Fisheries Association to test a prototype based on an upwelling stacking system. The work was carried out at the Orkney Lobster Hatchery and was assisted by a small grant from Seafish UK (www.seafish. co.uk). Scientific trials were carried out during August to October 2007 and a report prepared for publication through Seafish. The prototype was then handed over to the Orkney Lobster Hatchery where it became the centre of production at the hatchery for juvenile stages IV – VII. Production immediately doubled from 50,000 to 100,000 stage VI-VII released to sea in the first year using the same number of brood females and larval holding as available in 2007. In 2010 the Orkney Lobster Hatchery used 1 of the chambers of the Aquahive to grow juveniles to stage (range) VIII – X and Dennis Gowland carried out further scientific trials in another chamber looking at holding earlier stage larvae from hatch to stage IV. The company has designed a novel and safe method of deploying juveniles from the hatchery to the seabed in the fishery. The system enables the hatchery holding trays to be adapted to minimise handling and to be effectively used by fishers in the course of their normal workday. This followed testing during 2010.

Behaviour in hatchery reared European lobster (Homarus gammarus) juveniles

Ellen Sofie Grefsrud, Eva Farestveit, Ann-Lisbeth Agnalt Ellen Sofie Grefsrud <ellens@imr.no> (Institute of Marine Research)

Lobster juveniles (*Homarus gammarus*) reared under hatchery conditions (i.e. in single cell compartments) construct burrows and seek shelter when given the opportunity. However, in situ observations have shown that predators like crabs and wrasse prey upon recently released hatchery-reared lobster juveniles. Reduced ability to find and seek shelter may explain why they are highly

susceptible to predation when released. Recent studies have shown that conditioning (i.e. exposing the juveniles to a habitat consisting of shell-sand and shelter for a period of several weeks) lead to increased survival rate upon release. A pilot study was conducted to study shelter-seeking behaviour and social interactions in lobster juveniles of 10-12 mm carapace length. There was a clear tendency for the hatchery-reared juveniles to crawl on the side of the experimental tank, thus spending less time searching for shelter. Such behaviour is not optimal in a release situation, exposing the juveniles to a number of potential predators. When competing for shelter, in 54 % of the trials the conditioned juveniles were established under shelter within 30 minutes after release. In 12.5 % of the trials the single-compartment juveniles clearly indicate that conditioning seems to change behaviour in lobster juveniles, increasing the ability to compete for shelter. More experiments are needed to look not only into shelter-seeking behaviour but also predator-prey interactions as an attempt to avoid the situation of feeding frenzies at the release site.

Application of a gelatinous zooplankton tank for the mass production of larval Caribbean spiny lobster, *Panulirus argus*

Jason S. Goldstein and Brian Nelson

Jason Goldstein <jsh5@unh.edu> (University of New Hampshire)

Culture tank designs for larval production are a critical step to facilitating the most favorable combinations of water flow, food contact, and larval survivorship over the course of development. The evolution of new plankton-kreisels that are used by aquariums to culture and exhibit gelatinous zooplankton (e.g., jellyfish) provide a unique opportunity for testing the feasibility for spiny lobster larval culture, particularly with tropical species such as Caribbean spiny lobster (*Panulirus argus*) whose larval duration, although complex, is comparatively shorter than other spiny lobsters. Here, we report on the initial feasibility of culturing *P. argus* larvae (i.e., phyllosomas) from hatch to Stage VI using large, (180 L), modified acrylic plankton-kreisels. We compared overall growth and survival of phyllosomas at starting densities of 5,000 (~ 27.8 larvae L-1) and 2,500 individuals (~ 13.8 larvae L-1) and found no significant difference with respect to survival through to 65 days (p = 0.2066) resulting in mean survival rates of 60.7% (se = ± 3.7) and 54.5% (se = ± 3.2), respectively. Comparable growth was also achieved between both densities to Stages V and VI (mean body lengths of 7.5 and 10.2 mm, respectively) at 25.1 ± 0.41 °C (pH = 8.1). Phyllosoma utilized the entire tank volume, and they displayed minimal entanglement. The application of such tank designs for larval spiny lobster culture not only contributes to future designs for aquaculture production, but also provides a useful platform for conducting behavioral studies for this complex larval phase.

LobsterPlant – an FP7 Project Development of automated technology for large scale land based production of lobster juveniles and lobster to market size, including development of robotic feeding and imaging control system

Lene Beadle

Lene Beadle <lene.beadle@teknologisk.no> (Teknologisk Institutt AS)

Are we any closer to having an economical commercial land based, large scale production site for European lobster? The European Lobster, *Homarus gammarus*, is cannibalistic and must therefore be kept in separate living quarters during rearing to avoid losses. Manual feeding and control of viability in a large scale facility is therefore very time consuming and costly. The LobsterPlant project has focused on objectives which will contribute to making land based production of lobster on a large scale attractive, both with respects to economy and practical issues during rearing. In our project we have the objective to solve three main technological challenges; automated feeding and feed consistency, automated monitoring and cleaning of raceways. The project is partly funded through EU's FP7 Research for SMEs, where SMEs and RTDs form the Consortium, with the RTDs performing the majority of the RTD work for the SMEs. The three year project will finish in September 2011. Results to date include a prototype of a robot housing the imaging and feeding system, with hardware and software for movement and control. In addition, the Consortium has obtained results from feed and feeding trials, disinfection of larvae trials, and biological raceway cleaning trials. During the summer of 2011, the last work will be completed, which includes validation testing of the integrated prototype and meat evaluation tests comparing farmed lobster with wild lobster.

Molecular methods to determine the natural diet of larval spiny lobsters

S. Chow 1, S. Suzuki 2, T. Matsunaga 2, S. Lavery 3, A. Jeffs 3*, H. Takeyama 4 a.jeffs@auckland.ac.nz

Despite their economic and ecological importance, the natural diet of the larvae of spiny lobsters has not been confirmed. This has become a bottleneck in improving our understanding of the larval processes driving variation in recruitment to fisheries and for the development of larval aquaculture techniques for spiny lobsters. A variety of techniques have been attempted for identifying the natural prey of spiny lobster larvae with relatively little success. However, recent work using molecular genetics techniques has made some significant progress by identifying prey species from very small amounts of gut contents from wild caught larvae. Nucleotide sequence analysis using polymerase chain reaction (PCR) may be a promising tool, but the large quantity of the larval (host) DNA may mask subtle signals from the prey genome. We used a peptide nucleic acid (PNA)-directed PCR clamping to selectively inhibit amplification of host DNA for this purpose. The Japanese spiny lobster (*Panulirus japonicus*) and eel (*Anguilla japonica*) were firstly used as model host and prey organisms, respectively to demonstrate the veracity of this approach for gut content analyses. The method was then applied to wild-caught lobster larvae of *P. japonicus* and *P. longipes bispinosus* collected around Ryukyu Archipelago, Japan, and ITS1 sequences of wide variety of animals (Ctenophora, Cnidaria, Crustacea, Teleostei, Mollusca and Chaetognatha) were detected suggesting a highly diverse planktonic diet.

Feeding strategy for early life stages of red king crab *Paralithodes camtschaticus* (Tilesius, 1815) under artificial conditions

Kovatcheva* N.P., Kryachova N.V., Borisov R.R.

Nikolina Kovatcheva <nikolinak@mail.ru> (Russian Federal Research Institute of Fisheries &Oceanograph)

A feeding strategy for the early stages of development of the red king crab was generated. The material taken for the strategy included the results of effort to establish a technique for reproduction of the red king crab made since 2001, and the experiments to find out the rate of the passage of feed through the gastrointestinal tract, diet preference, and testing of various feeds. The work was done on red king crab larvae and juveniles. Advice for optimal feeds, regime of feeding, and methods of introducing feeds to the larval stages of zoea 1-IV and to juveniles are given. It is noted that the prezoea and glaucotoe are the non-feeding stages in the life cycle of the red king crab. Key words: Red king crab, nutrition, crustacean cultivation

Artificial reproduction of the red king crab (*Paralithodes camtschaticus*) in Russia. Progress and perspectives

N.P. Kovatcheva, R.O. Lebedev, A.V. Parshin-Chudin, R.R. Borisov, N.V. Kryahova, I.A. Zagorsky Nikolina Kovatcheva <nikolinak@mail.ru> (Russian Federal Research Institute of Fisheries &Oceanograph)

The red king crab is the most important object of crab fishery both in the Far East and in the northern fishing area (Barents Sea) in Russia. The interest to the red king crab as a potential species for mariculture became logical in recent years because of the invariably great demand for this product, especially live. That is why in 2002 VNIRO scientists began research under the Program Elaboration of normative and methodical bases for artificial reproduction of the red king crab in order to restore its natural populations. First steps were taken in the aquarium module of the laboratory of crustacean reproduction (VNIRO). Numerous studies on crab ontogenesis, early life history, morphology, behavior, development and growth were undertaken. Different culture systems and conditions were tested and upgraded. As a result in 2006 an effective technology of artificial reproduction of the red king crab was worked out, published and presented at different conferences and workshops. In 2009 all the knowledge and experience in this field found an application for building an experimental land based hatchery for the red king crab artificial reproduction (Dalniye Zelentsy, Barents sea). In June 2010 nearly 200 000 juveniles were released into the sea in specially designed collectors. The same year similar hatchery was built in the Far East region (Primorie). In 2011 we plan to start there artificial reproduction and releasing juveniles into the sea, as in the Far East the problem of rehabilitation of red king crab stock is extremely actual.



Fisheries, Management and Aquaculture

Performance of baited underwater video for estimating abundance of spiny lobsters

Ben Stobart, Cristina Alonso, David Díaz and Raquel Goñi*

Raquel Goñi <raquel.goni@ba.ieo.es> (Instituto Español de Oceanografía)

Baited underwater video (BUV) is increasingly been used to sample fish species but lobsters are potentially good candidates for sampling with BUV as they are attracted to bait due to their scavenging habits. We built a cost effective BUV system to sample Palinurus elephas, a Mediterranean deep-water lobster. Camera deployments were performed at the Columbretes Islands MPA. We compared the standard method of estimating abundance with BUV, by recording the maximum number (Nmax) of individuals at any one point on the tape, with the estimated true number of lobsters having attended the bait (Ntot). We found it possible to use images of unique body patterns for identifying individuals over time. The highest Nmax - 6 lobsters in the field of view - was lower than the total number of lobsters estimated by identifying individuals in all three recordings - total of 7 to 11 individual lobsters. This highlights the extent of underestimation of abundance derived from Nmax estimates (Mean Nmax = 4 as opposed to Ntot= 8.6 by tracking individuals). Measurement of lobster size was trouble free with the coefficient of variation of all measurements being low. However, all measurements were biassed due to calibration problems related to lobster height above the bait bag. Taking into account the relatively low cost of the units, coupled with the ability of this system to work to depths impractical for visual surveys, we propose that this non-intrusive method will be useful for sampling deep water lobsters.

Study of the connectivity of *Palinurus elephas* among different no-take areas of Sardinian sea (cw Mediterranean) integrating biological, genetic and mark-recapture data

Cannas R., Follesa MC. Cau Al., Gastoni A., Marcias S., Mulas A., Pedoni C., Porcu C., Usai G., Deiana AM., Cau A. Maria Cristina Follesa <follesac@unica.it>

The continuous market demand of spiny lobster *Palinurus elephas* and the consequent impoverishment of resources made indispensable the research of innovative managerial approaches. In this context, since 2009 we have carried out a restocking experiments in 19 central western Mediterranean areas that extends over surface ranging between 3 and 11 hectares, at depth of between 50 and 100 m. In these areas, from 2010 to 2011 about 1000 tagged lobsters were released. All these lobsters of TL<26
cm were caught by fishermen in commercial neighboring areas. The biometric and sex parameters of all specimens were recorded. All of these data will allow to study the population dynamics, growth pattern and movements of the lobsters in the different areas and over the years. Furthermore, the connectivity of spiny lobsters, *P. elephas*, among and within the restocking areas have been also investigated using genetic markers. Microsatellite loci revealed significant differentiation among the three areas (Northern coast, Southern coast and central Western coast), in particular as concerns gene diversity and allelic richness, with the lowest genetic diversity recorded in the most exploited area. Furthermore, the comparison of samples of the "Su Pallosu reserve" collected in 1998 and in 2010 (12 year after its establishment) permitted to record an increased genetic diversity, supporting the effectiveness of no-take areas for preserving the genetic variability and hence the long term persistence of populations.

Role of artificial structure as fishing gear in the Florida Keys lobster fishery, USA

Chris R. McHan, Thomas R. Matthews, and John H. Hunt Thomas Matthews <tom.matthews@fwc.state.fl.us> (Florida Fish and Wildlife Conservation Commission)

Artificial shelters used to attract and aggregate lobsters are utilized in lobster fisheries throughout the Caribbean. These shelters, also known as casitas, became prevalent in the Florida spiny lobster (Panulirus araus) fishery in the late 1990's. Although the harvest of lobsters from casitas was banned in 2003, commercial divers continue to utilize the structures and there remains intense interest to legalize their use. The discussion of additional fishing gear in an already overcapitalized fishery underscores the need to fully understand the potential use of casitas. Gear efficiency, gear conflicts, and potential displacement of traditional traps must all be considered when making adaptive management decisions in today's ever changing fishery. We examined the potential performance of casitas in the lobster fishing grounds north of the lower Florida Keys using historic landings reports, deployed casitas, and traditional slat traps. Landings records indicated that during the era of casita proliferation (1998/1999-2002/2003) a higher proportion of annual catch from this region was harvested earlier in the season as compared to time periods before and after. Lobster catch rates from experimental casitas indicated that casitas were productive early in the season with catch rates declining rapidly; 90% of total casita catch occurred during the first 4 weeks. Traps, by comparison, required four to five months to catch 88% of their total trap landings. Comparisons of size selectivity between gear types indicated that both casitas and traps captured the same size range of the lobster population.

Hatchery-reared lobsters (*Homarus gammarus*) released around the rocky island of Helgoland (German Bight, North Sea)

Isabel Schmalenbach, Folke Mehrtens, Michael Janke & Friedrich Buchholz Friedrich Buchholz <friedrich.buchholz@awi.de> (AWI)

At Helgoland waters, the local population of the ecologically and economically important lobster (Homarus gammarus) has declined dramatically since the 1960s and catch rates reached a minimum of a few hundred individuals per year. When a mandatory logbook was established for fishermen to report lobster landings in 2006, the commercial landings varied between 0.01 to 0.02 lobsters per pot lift. Legislative regulations may have prevented a complete extinction of the local population, but till today did not result in the population's recovery. A research programme served as a pilot project for restocking and to decide if a successful settlement of hatchery-reared juvenile lobsters at Helgoland were feasible. From 2000 to 2005 about 5,400 one-year-old lobsters were tagged and released around the rocky island of Helgoland. The recaptured lobsters showed no evidence of the "Black Spot" shell disease or other visible diseases and about 95% of lobsters had developed a crusher claw also indicating normal development. To date, up to 19% of single year-class cultured lobsters were recaptured and the smallest berried females caught were 83 mm in carapace length and 4 years old. Furthermore, the minimum landing size (85 mm CL) of cultured lobsters was reached after 4-7 years. Cultured lobsters showed strong fidelity to their release sites, and thus remained around the island of Helgoland. A basis has been laid to enhance this endangered lobster population by means of a large scale restocking programme and which may be helpful to establish further fishery and management regulations.

Influence of natural inshore and offshore thermal regimes on egg development and time of hatch in the American lobster *Homarus americanus*

Jason S. Goldstein and Winsor H. Watson III Jason Goldstein <jsh5@unh.edu> (University of New Hampshire)

Studies of ovigerous lobster (*Homarus americanus*) movements indicate that many display seasonal inshore-to-offshore movement patterns that serve to expose eggs to developmentally-optimal thermal

regimes. The overall aim for this study was to determine the impact of naturally fluctuating temperature regimes on egg development and time to hatch in lobsters exposed to natural inshore or offshore bottom temperatures over the full course of their development. We subjected ovigerous lobsters to natural inshore or offshore seasonal fluctuations in water temperature, either in the laboratory (n = 14 inshore, 8 offshore) or in the field (n = 8/each inshore/offshore). Temperatures averaged 7.08 ± 0.19 °C for inshore laboratory simulations (total degree days = 922) compared with offshore 6.40 ± 0.17 °C (total degree days = 798) ones. There were no significant differences with natural or simulated inshore thermal regimes or natural vs. simulated offshore temperatures. Although the rate of egg development between inshore and offshore animals did not differ significantly in the fall, inshore eggs developed significantly faster in the spring compared with eggs exposed to offshore temperature (p < 0.001). Eggs exposed to inshore thermal regimes hatched ~ 15-20 days earlier (mean = June 26) compared with offshore eggs (mean = July 27), and their time of development, from extrusion to hatch was significantly shorter (inshore = 287 ± 11 days vs. offshore: 311.5 ± 7.5 days). These results suggest that seasonal movements of ovigerous lobsters have a strong influence on both the location where larvae originate and their time of hatch.

A non-invasive method for determining mating success in female American lobsters (*Homarus americanus*)

Jason S. Goldstein, Tracy L. Pugh, Kari L. Lavalli, Michael Clancy, and Winsor H. Watson III Kari Lavalli <klavalli@bu.edu> (Boston University)

Despite being one of the most productive fisheries in the Northwest Atlantic, much remains unknown about the natural reproductive dynamics of American lobster, particularly regarding how exploitation impacts reproductive potential. Recent work in exploited crustacean populations suggests there are circumstances where mature females are unable to achieve their full reproductive potential due to sperm limitation. To examine this possibility in different regions of the American lobster fishery, we developed a reliable and non-invasive method for sampling large numbers of female lobsters at sea. We inserted a blunt-tipped needle into the seminal receptacle of females to both determine the presence or absence of a sperm plug and to detect sperm. In order to confirm that the method was reliable before applying it under field conditions, we conducted a series of control studies in the laboratory. We sampled a total of 294 female lobsters and dissected those seminal receptacles that yielded negative results to confirm the absence of sperm (assuring against false negatives). A total of 93% of females had a sperm plug, while the remainder did not (n = 20). We concluded that most observations of females with sperm plugs but no sperm cells in the sample were the result of the sampler not inserting the needle to a sufficient depth to collect the sperm. Hence, the presence of a sperm plug is a reliable indicator of a female bearing sperm supplies.

Online Lobster Inventory System; how live American lobster (*Homarus americanus*) inventories are monitored and estimated in North America

Jean Lavallée & Natasha MacDonald AVC Lobster Science Centre, Charlottetown, PE, Canada Jean Lavallée <jlavallee@upei.ca> (AVC Lobster Science Centre)

Since November 2006, the Atlantic Veterinary College Lobster Science Centre (AVCLSC) has offered a unique reporting system to the North American live lobster (*Homarus americanus*) industry. This system allows for real time knowledge of live lobster inventory from a representative group of companies in the lobster industry both in Canada and the USA. The more companies participating, the more effective this vehicle becomes at tracking overall inventory levels in any given week and therefore, estimating what the total live lobster inventory is in North America. Weighted averages according to holding facility capacities are used to generate weekly estimated total inventory levels. North American Industry currently has a combined holding capacity estimated at approximately 27.8M lbs, while the combined capacity of our participants represents approximately 27 % of this total live lobster holding capacity. This third party arm's length position of the AVCLSC is critical to the success of the project and it guarantees professional data collection, assures confidentiality and provides the highest level of data accuracy.

The Atlantic Lobster Moult & Quality Monitoring Project: Could such a project be used for Fishery Management?

Jean Lavallée AVC Lobster Science Centre, Charlottetown, PE, Canada Ross Claytor Youyu Lu Stefan Leslie Fisheries and Oceans Canada, Dartmouth, NS, Canada Jean Lavallée <jlavallee@upei.ca> (AVC Lobster Science Centre)

The lobster fishery in southwest Nova Scotia (SWNS), Canada accounts for approximately 40 % of Canadian lobster landings and contributes annually 20,000 mt. Since 2002, there have been several years where soft-shell and low meat-yield lobsters have disrupted the industry in SWNS, resulting in an economic challenge. The Atlantic Lobster Moult & Quality Monitoring project was established to monitor lobster hemolymph protein levels, shell hardness and moult stage, and has been ongoing since June 2004 with sampling occurring throughout the year in several SWNS sites. This project is a collaborative effort among the AVC Lobster Science Centre, the federal department of Fisheries and Oceans Canada, the Fishermen & Scientists Research Society, and industry stakeholders in Nova Scotia Canada, and has resulted in more than 95,000 lobsters sampled to date. Timing of the moult is important in its effects on lobster quality as a certain period after moulting is required before lobsters harden and of premium marketability and is affected by water temperature and depth, lobsters size and sex, nutrition, density and other factors. Using the data generated via the monitoring project in conjunction with oceanography data such as ocean forecasting modelling, it is likely that novel models could be developed that could have fishery management applications. Such implications could include dynamic fishing season opening/closing dates, sub-area and smaller-scale management, atsea management procedures, and the establishment of grading/quality standards with appropriate labeling on Canadian lobster harvests.

Will we see you again? Population monitoring of Palinurus elephas

inside a marine reserve from capture-mark-recapture data

L. González-Vicente, R. Goñi, S.D. Frusher, D. Díaz, and S. Mallol Raquel Goñi <raquel.goni@ba.ieo.es> (Instituto Español de Oceanografía)

To achieve an effective management of the marine exploited populations it is necessary to understand their dynamics and the processes driving short- and long-term changes. Key population parameters such as survival and movement can be estimated by means of capture-mark-recapture studies, based on the capture, tagging and re-encounter of the individuals at later times. The Cormack-Jolly-Seber model, which assesses the apparent survival \Box i and the recapture rate pi of a population conditional on first capture, was applied to European spiny lobster *Palinurus elephas* data from the Columbretes islands marine reserve to evaluate the evolution of this population after closure to fishing over. Particularly strong winter conditions were reported for some years during the period of study which were reflected as an increase in the estimate of the encounter probability and a decrease in their survival rate. *P. elephas* showed a relatively high plasticity against short-term environmental effects, with the apparent survival quickly returning to pre-storm levels. Also a slight increase in survival was identified for this protected population over time. These preliminary results are discussed in terms of the factors affecting the dynamics of this population and the implications for the management of this exploited stock.

Use of artificial shelters ("Casitas") as an alternative tool for management and stock evaluation of Caribbean spiny lobsters in Banco Chinchorro (México)

Ley-Cooper K*, Lozano-Álvarez E, Briones-Fourzán P, Sosa-Cordero E, García Rivas, M Kim Ley-Cooper <kim.ley.cooper@gmail.com> (Curtin University)

In metapopulations of Caribbean spiny lobsters (*Panulirus argus*) over the Mesoamerican Reef, large reproductive adults are being depleted. In Banco Chinchorro (Mexico), an oceanic coralline atoll and Biosphere Reserve (BR) where fishing for *P. argus* is allowed, fishing pressure on reproductive adults is high. Although catch rates have been relative stable for the last decade, catch rates were previously much higher and current lobster production is low. An inter-institutional steering committee was established to propose a series of actions in order to create alternative fishing practices and new management ideas, as a strategy for repopulating and analysing local lobster stock of P. argus in this BR. Based on knowledge obtained in previous studies carried out further north and in other Latin American countries, preventive measures for reducing fishing effort and pressure on reproductive adults in this BR include a controlled deployment of "casitas" (large artificial shelters) as an innovative tool for local stock assessment that will provide useful data to examine juvenile growth rates, local migrations, and the potential for repopulation. Responsible use of casitas within a well regulated BR, incorporated in a cooperative based socio-economic scheme, is hereby perceived as a useful initiative for defining future management action plans in this area.

Eggs development and captive breeding of the spiny lobsters Panulirus inflatus and P. gracilis

Raúl Pérez-González and Dagoberto Puga-López

Raúl Pérez-González <raulp@ola.icmyl.unam.mx> (Universidad Autónoma de Sinaloa)

The Mexican tropical Pacific Ocean and Gulf of California spiny lobster fishery is based on *P. inflatus* and *P. gracilis*. Their combined catch averaged 132 t annually over the past 14 years, but with considerable year-to-year variation. Despite the importance of this fishery on the Pacific coast of Mexico, there haven been few published studies of this reproductive biology. Therefore, laboratory experiments were used to study the eggs development and incubation periods of these tropical spiny lobsters. *P. inflatus* is a species endemic to Mexico and *P. gracilis* is distributed from southwest coast of Baja California peninsula to Peru. The longest incubation periods observed for *P. inflatus* and *P. gracilis* under experimental conditions were 24 and 36 days during spring and winter and 20 and 44 days during autumn and winter, respectively. Considering females that has newly oviposited eggs and redeveloping ovaries, the minimum period of avarian maturation should approximate the duration of incubation. Thus, the entire reproductive cycle would be approximately 7 to 9 weeks. Embrionic development was allocated into six stages.

Assessing Bycatch in a Nephrops Trawl Fishery

Rosanna Milligan, Andrew Watts and Douglas Neil Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow, Scotland, UK Andrew Watts <a.watts.1@research.gla.ac.uk> (University of Glasgow)

An assessment of the bycatch composition from the Stornoway-based Nephrops trawl fishery was carried out between December 2008 and June 2010 to identify and quantify the animal bycatch occurring in this fishery. A total of 57 two-hour survey trawls were carried out aboard the MV Comrade, and in each case, the entire catch was sorted into 'target' and 'bycatch' animals. Every by catch species was identified and counted, and the weights of the major taxa and the target catch were recorded. Subsamples of Nephrops and important bycatch species (cod, spurdog, whiting and haddock) were collected from each sampling trip and all data were compared against environmental measures recorded for each trawl. Overall, a total of 94 species were captured during the study, of which the pouts (Trisopterus spp.), whiting, lesser-spotted dogfish and crustaceans were typically the most dominant by number and weight, and a significant temporal effect was evident in the data. The occurrence of cod and spurdog was relatively low, with only 99 and 110 respectively being captured over the entire period (representing 0.8% and 0.1% of the average catch biomass respectively). This work establishes a baseline data set for bycatch composition within this Nephrops fishery, from which investigations across the rest of the fleet can be made, with a view to decreasing the occurrence of bycatch animals within the catches. This work was supported by a grant from the European Fisheries Fund (EFF) through Marine Scotland, and by Young's Seafood Ltd.

Impacts of V-notching the spiny lobster Palinurus elephas: Results of experiments

Sandra Mallol*, Francisco Sobrado, Cristina Alonso, David Díaz and Raquel Goñi Sandra Mallol <sandra@ba.ieo.es> (Instituto Español de Oceanografía-Baleares)

V-notching tagging has been practiced for decades in juveniles and ovigerous females of the clawed lobsters *Homarus americanus* and *H. gammarus* as an effective conservation strategy in several European and US fisheries. For the first time a V-notch experimental study was conducted with the spiny lobster *Palinurus elephas* with the aims of: 1) assess survival of notched versus unnotched lobsters, 2) assess differences in the incidence of shell disease of notched and unnotched lobsters, and 3) assess the rate of notch loss (tag retention) with respect to molt frequency. A total of 36 wild young adults were housed in a tank of 10000 litres separated in three replicates of 12 lobsters each one. Half of individuals of each replicate were marked with a v-notch (side 1 cm long). Tank environmental conditions (temperature, salinity and dissolved oxygen) were controlled to mimic conditions in the wild. The experiment lasted 20 months. There were no significant differences in survival or health conditions of notched and unnotched specimens. After 15 months, all the indivudals had completed two molts and five of them have undergone the third one. After the second molt on average 25% of the notched area has been overgrown and lobsters with the third molt have overgrown 45% of the notched area. The performance of area, width and height of the V-notch tab for regulatory purposes are discussed.

Habitat enhancement for early benthic juvenile stages of the Japanese spiny lobster, *Panulirus japonicus*

Taku Yoshimura, Norimasa Takagi, Jun-ya Fukushima Taku Yoshimura <yoshimura.taku@affrc.go.jp> (Seikai National Fisheries Research Institute)

The early benthic stages of the Japanese spiny lobster (*Panulirus japonicus*) are den dwellers that hide in small solitary holes in the surface of rock reefs. The juvenile lobsters move to larger holes as they grow and continue to live in the nursery ground of seaweed beds for at least 1 year after settlement. Most small holes used by lobsters were bored by pholads, and the number of these holes available for small lobsters is regionally limited by hard-bottom substrate. The results of field research investigating the settlement requirements of post-larvae of P. japonicus suggest that both suitable small holes and seaweeds are important for settlement and survival of the lobster. Therefore, we developed an artificial concrete habitat that has many holes of 10 increasingly larger sizes on the wall. The habitat was installed in a natural seaweed bed, and Sargasso seaweeds grew naturally on the habitat after 1 year. The results of a field experiment using the artificial habitat that began the following year indicate that juvenile lobsters can live in the artificial habitat for about 1 year after settlement, and lobster density in the artificial habitat was several times the natural density in rocky reefs. Because it is not easy to grow seaweeds in barren areas, installation of the artificial habitat into and around natural seaweed beds should enhance the amount of suitable habitat available for juvenile lobsters.

Evaluation of ecological impacts of a proposed lobster fishing gear, casitas, in the Florida Keys, USA

Thomas R. Matthews and Chris McHan

Thomas Matthews <tom.matthews@fwc.state.fl.us> (Florida Fish and Wildlife Conservation Commission)

The use of artificial structures, commonly called casitas, to facilitate the capture of spiny lobsters, *Panulirus argus*, is common throughout much of the Caribbean. The evaluation of the proposed use of casitas in portions of the Florida Keys National Marine Sanctuary must consider the ecological effects of these structures. We examined the sessile flora and fauna, fish community, and motile invertebrate community on and near casitas in the lobster fishing grounds north of the lower Florida Keys. We observed 39 casitas whose size averaged 3.55m2 and ranged from 1.32 to 6.86m2. There was an average of 50.3 lobsters at each casita and only one lobster at all 39 control sites. The percent cover of benthic fauna, defined as stony corals, sponges, octocorals, tunicates, sessile bivalves, and bryozoans was higher on casitas (8.7%) than next to casitas (0.9%) or at control sites (38.6%). There were 2.5 times more fish species (49 total) and 13.6 times more fish (average 201 per casita) associated with casitas than at control sites. There were no differences in the abundance of motile invertebrates over 2.5 cm at casitas and control sites. Resource managers will ultimately evaluate the implications of casita use in a broad context which includes ecological, fishery, economic and sociological issues.

Volunteered self-reporting catch diaries as a means to increase legitimacy and mutual understanding of stock development

Alf Ring Kleiven

Alf Ring Kleiven <alf.ring.kleiven@imr.no> (Institute of Marine Research)

Communication between researchers, managers and fishers can be a challenging task. Fishers may often doubt the legitimacy of data collected by scientists, leading to disagreement regarding stock status and management needs. This was also the case in the fishery for European lobster (*Homarus gammarus*) in Norway when new regulations were introduced in 2008. To increase the level of cooperation between researchers and recreational fishers, a collaborative monitoring program was initiated in 2007 where recreational fishers volunteered to keep a detailed catch diary throughout the lobstering season. This monitoring program resulted in the most precise data on lobster stock development in Norway and has been growing from 15 volunteers in 2007 to 277 in 2010. In this presentation we discuss the potential of such collaborative monitoring program increases the legitimacy of the data on which management decisions are based. Two-way communication and long term individual trust and commitment are considered important factors to succeed.

The scale, structures and resources involved in exploiting and managing crustacean fisheries in Norway: correspondence between staus of fisheries, the value and investments in the management

G.I. van der Meeren, G. Søvik & T. Thangstad grom@imr.no

In 2005 the concept of ecosystem-based management of marine resources was introduced in Norway. Preparations for implication are in progress and will involve decapod crustacean fisheries. Fisheries for crustaceans in Norway goes back to the mid-1650's, when fisheries for European lobster (Homarus *gammarus*, Linneus, 1758) was initiated. It has since developed to coastal and off-coast fisheries from the North Sea to the Barent Sea, for lobsters, edible crabs (*Cancer pagurus*, Linneus, 1758), shrimps (Pandalus borealis, Krøver, 1838), Norway lobsters (Nephrops norvegicus, Linneus, 1758), and lately, the introduced red king crabs (Paralithodes camtschaticus, Tilesius, 1815). The wide geographical scale of the fishing grounds, traditions, and often weak databases has led to separate management regimes of and highly variable sustainability for these fisheries. An overview over the present-day fisheries and management are presented; the size and quality of the fishing fleet, landings, the social impact and value of the fisheries, compared to investments in research, stock assessment, and management efforts. How culture, tradition, and research have led to the present status of these fisheries is discussed and compared to international crustaceans and finfish fisheries. There is little correspondence between the values of these biological resources (both ecologically and economically) and the efforts and investments put into the management. The new management approach must be founded on appreciation of biological and ecological data, insight in the ecosystem each species is part of, and a true understanding of the value of these fisheries and the social implications they make along the Norwegian coast.

Stock assessment of lobster (*Panulirua argus*) in different fishing zones of the coast from Yucatan and Quintana, Roo Mexico

Veronica Rios-Lara, Aurora Ramirez-Estevez y Carlos Aguilar-Cardozo Veronica Rios <g_veronicar@yahoo.com> (Instituto Nacional de Pesca)

The exploitation of lobster *P. argus* in the Yucatan Peninsula takes place in a large area which there are differences in resource distribution, effort distribution, techniques capture, organizational level of fishing communities, local and federal management policies and demand in local and abroad market. For management purposes, proposed to divide the area, analyze fishery and to obtain reference points in each fishing zone, based on existing information in each of them. This document presents results of lobster assessments for the Yucatan shelf, and north (Holbox) and northeast (Isla Mujeres) from Quintana Roo coast. For population assessment in Yucatán shelf was used a dynamic model, nonlinear, and structured by age and to north and northeast of Quintana Roo, were built biomass dynamics models. The estimated initial biomass for Yucatan shelf was BO = 1, 636 t with standard deviation of 52.5 t and F = 0.49. To north of Quintana Roo was obtained a carrying capacity K = 1695 t, intrinsic growth rate r = 0.186 and RMS = 78 t. To northeast of Quintana Roo, were obtained values of K = 2500 t, r = 0.154, and RMS = 100 t. These results may be useful in management in framing rules, but are sensitive to model choice, this kind of stock assessment should be reviewed constantly.

Biologic and socioeconomic optimum harvesting strategies of the Caribbean lobster fisheries

Ernesto A. Chavez

Ernesto A. Chavez Dr. <echavez@ipn.mx> (CICIMAR, IPN)

Spiny lobster fisheries of the 25 Caribbean countries are subject to heterogeneous harvesting practices, with recurrent socioeconomic crisis in some of them. Therefore, a meta data analysis was conducted with the purpose of evaluating the performance of the five main Caribbean lobster fisheries as well as the total production of the region aiming to provide general management recommendations. It was based on 25 years of catch data and the population parameter values. The associated costs, benefits and social values of a small fishery of the north western Caribbean were taken as reference. The stocks were assessed reconstructing the age structure of each population for the whole period, then the catch, the profits, direct jobs, and the profits per fisher were estimated under different ages of first catch (tc). From here, values related to the maximum sustainable yield (FMSY) and the maximum economic yield (FMEY) were selected as optimum harvesting options. Results show that the yield increases with tc and in three cases, at the FMSY level are higher than at the FMEY. The profits are higher at high tc values in three fisheries, being more profitable under the FMEY levels. One fishery is not profitable under the FMSY level at any age. The social value, as profits/fisher, is the highest at a tc = 2, and again, is higher on applying the FMEY strategy. In one of the fisheries the social value at FMSY is negative at any tc.

Tag shedding estimation in Palinurus elephas (Fabricius, 1787)

L. González-Vicente, D. Díaz, S. Mallol and Raquel Goñi Raquel Goñi <raquel.goni@ba.ieo.es> (Instituto Español de Oceanografía)

In this paper a numerical method for tag shedding calculation from double tagging data was used to estimate the tag loss rate in *Palinurus elephas* from capture-mark-recapture experiments. Four consecutive experimental surveys during years 1999-2002 inside the Columbretes islands marine reserve (CIMR) were carried out and the captured spiny lobsters were dorso-laterally double-tagged with T-bar anchor tags on both sides between the first and second abdominal segments. The recaptures during the following years (2000-2008) were recorded and the evolution of the proportion of single-and double-tagged specimens was analysed. The immediate tag loss produced after tagging could not be accurately modelled, but in view of the results is believed to be low. The probability of tag loss per year was estimated in 6% (sexes combined). The factors causing this tag loss and the repercussion of this rates of shedding on further studies are examined.

Testing a multi-generational artificial reef for the American lobster (*Homarus americanus*) in the Magdalen Islands (Québec).

Louise Gendron, Pascal Tremblay, François Hazel, Selma Pereira, Linda Roberge and Yves Gingras, *Institut Maurice-Lamontagne, Ministère des Pêches et des Océans. 850 route de la Mer, Mont-Joli, QC, Canada G5H 3V9 Louise Gendron <louise.gendron@dfo-mpo.gc.ca> (Department of Fisheries and Oceans)

In October 2009, eight 120 m² artificial reefs (10 m x 12 m) were installed in the Magdalen Islands (Québec), on a sandy bottom, at 7 m depth, near a lobster nursery ground. The installation of the reefs was part of a mitigation project to compensate for a loss of fish habitat caused by the refection of a nearby wharf. The reefs were designed to provide habitat for different phases in the life cycle of the lobster, from early benthic to adult. The concept of a multi-generational reef was borrowed from the artificial reef project in the Boston Harbour (MA, USA). Each reef was composed of five sections. A central section of 10 m x 5 m was filled with rocks 10–20 cm in diameter to mimic a nursery habitat. On each side of the central section, a 10m x 4 m area was filled with rocks 20-40 cm diameter to provide habitat for young vagile lobster. Finally, at each of the two extremities, an area of 10m x 3.5 m was filled with boulders 40–75 in diameter, to benefit the larger lobsters. Results of diving surveys of the area before installation of the reefs (October 2008) and on the reefs one year after their installation (September 2010) will be presented. In September 2010, lobsters were observed in all sections of the reefs, among a number of motile and sessile species. The middle section of the reefs appeared to mimic the nearby nursery area. Density of young-of-the-year lobsters in the two areas was similar.



Ecology and behaviour

Factors affecting differences in feeding and feeding-based measurements on *Nephrops norvegicus* across two fishing grounds off the west coast of Scotland, UK

Andrew Watts (University of Glasgow, UK), Rona McGill (Scottish Universities Environmental Research Centre, UK), Amaya Albalat (University of Glasgow, UK), Phil Smith (Marine Biological Station Millport, UK) Jim Atkinson (Marine Biological Station Millport, UK), Douglas Neil (University of Glasgow, UK) email: a.watts.1@research.gla.ac.uk

The Norway lobster *Nephrops norvegicus* is a benthic decapod crustacean that is both a scavenger and an active predator. This project studies the trophic dynamics and nutritional status of *N. norvegicus* populations in relation to environmental variables, both spatially and seasonally within two West of Scotland Nephrops fishing grounds. Stable isotope analysis and fatty acid analysis have been used alongside other techniques such as nutritional indicators for this species. These results are considered in relation to the food sources available in different sites and seasons. Results indicate that there are differences in both $\delta_{15}N$ and $\delta_{13}C$ and also in certain fatty acid concentrations between the two fishing grounds (the Clyde Sea Area and the North Minch) throughout the year, indicating N. norvegicus could be feeding differently at each site. Certain biotic and abiotic factors are considered to explain these differences.

Temporal dynamics and the role of benthic habitat for the slipper lobster Scyllarides latus in a National Park

Díaz D., Reñones O., Coll J., Stobart B., Morey G., Navarro O., Deudero S., Grau A.M., Goñi R. David Diaz <david.diaz@ba.ieo.es> (Insituto Español de Oceanografía)

Populations of large large decapods have diminished due to intense fishing pressure and habitat modification along the widely inhabited coast. During the last decade some of the well established marine protected areas (MPAs) in the Western Mediterranean have led to growing densities of one of the most sought after large decapods, the slipper lobster *Scyllarides latus* (Latreille, 1803). A four year monitoring study was conducted to assess seasonal dynamics and habitat preference of *S. latus* in the Cabrera Archipelago National Park. Sampling was carried out through underwater visual census on rocky habitats at 0 - 50 m depth. The species may be found in caves, under boulders, and on walls

and slopes at depths of up to 35 m, showing a preference for caves at 5 to 20 m depth. These habitats provide diverse shelter types that are used during the daily period of trophic inactivity. *S latus* has a marked seasonality with highest densities occurring in late spring, and they disappear almost entirely from rocky coastal habitats in mid-summer. Knowledge of the preferred habitats and spatial pattern of the species is needed for implementing appropriate management schemes to stimulate their recovery.

Genetic structure of different Norway lobster (*Nephrops norvegicus*) populations using restriction fragment length polymorphism technique (RFLP)

Hasnita che Harun and Douglas M. Neil Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, University Of Glasgow, Scotland, UK. Douglas Neil <douglas.neil@glasgow.ac.uk> (University of Glasgow)

Nephrops norvegicus (Linnaeus, 1758) is one of the most commercially-valuable marine decapods in the Europe. This species has been exploited throughout its geographic range from the Mediterranean Sea to Icelandic waters, with the UK being the largest fishing country. The present study aimed to identify the genetic structure of N. norvegicus, and to gain information regarding the differentiation of Scottish from Iceland populations. This information is crucial for conservation and future stock management of the species. The PCR-RFLP technique has been used to characterize a 1.4kb segment of the Cytochrome Oxidase subunit I (COI) gene. A total of 78 individuals, from three sites in Scotland and one from Icelandic waters, were amplified and used for restriction analysis. Each of the variations found in the study was then confirmed by sequencing. A total of 14 haplotypes, constructed from the banding pattern, were designed, although 2 were excluded as inconsistent. No significant differences were found among the populations (FST = 0.018), with 75% of the haplotypes being unique to one population and only 8% being found in all populations. The present study has thus confirmed the low variability in N. norvegicus populations reported from previous studies on Scottish, Iceland as well as other populations. However a larger sample size is needed to confirm the finding. HCH would like to acknowledge her support from The Ministry of Higher Education, Malaysia and University of Malaysia, Kelantan.

Metabolomics of different tissues from the Norway lobster, *Nephrops norvegicus*: A first approach to determine uses for fishery waste and biomarkers of environmental health in a crustacean

Lauren Nadler¹, Amaya Albalat¹, RuAngelie Edrada-Ebel² and Douglas Neil¹ 1. Institute of Biodiversity, Animal Health & Comparative Medicine, College of Medical,Veterinary and Life Sciences, University of Glasgow, Scotland, UK. 2. Strathclyde Institute of Pharmacy and Biomedical Sciences, University of Strathclyde, Scotland, UK Douglas Neil <douglas.neil@glasgow.ac.uk> (University of Glasgow)

In this study, metabolomics technology was applied to the tissues of the Norway lobster, Nephrops norvegicus, a macrobenthic decapod crustacean. This study aimed to find harvestable resources within the cephalothorax (head) waste product from the Norway lobster fishery as well as determine if biomarkers within the tissues could be used for environmental monitoring. Environmental metabolomics measures the composition of low-molecular-weight metabolites, which incorporate both genetic and environmental cues during expression. Specimens were captured in 2009 from two Scottish sites, the Clyde Sea and the Minch. Lipid was extracted from homogenized head pastes and individual organs, the hepatopancreas and gonads. These extracts were analyzed using 1D and 2D NMR spectroscopy. These analyses found that the valuable resources Nephrops oil, chitin, and astaxanthin were found within the head waste. Low concentration compounds, which could provide more reliable biomarkers, were not detected by the NMR spectroscopy so HPLC with full scan HRFTESIMS was employed, detecting significant differences in composition between sites and seasons in the head paste, and between seasons in the hepatopancreas. No significant differences were detected between the male and female hepatopancreas or between seasons in the female gonads. Identification of the compounds found was, however, very limited as few metabolite identifications for marine organisms have been recorded. Statistical analysis was completed by principal components analysis (PCA) and hierarchical cluster analysis (HCA) with approximately unbiased (AU) p-values. Future research would be necessary to identify the compounds found, which could be used to determine biomarkers for N. norvegicus health within an ecosystem.

A cannibal by night? In situ infra-red video monitoring reveals diel shifts in inter- and intra-specific predation on tethered American lobster

Noah G.Oppenheim and Richard A. Wahle University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, Maine, USA Richard Wahle <richard.wahle@maine.edu> (University of Maine)

The American lobster, *Homarus americanus*, is a conspicuous and ecologically important member of the coastal benthic community in the Gulf of Maine. Trophically, it is a mid-level consumer, as both predator and prey. Over that past two decades lobster population densities in coastal Maine have increased to historic highs while most predatory groundfish have been reduced to historic lows by overharvesting. Previous davtime observations indicate that juvenile lobsters are vulnerable to visually-foraging predators, mostly fishes and crabs, that are active during the day, whereas lobsters tend to emerge from shelter to forage at night. But observations of predation at night, when lobsters would likely be most exposed, remain unreported. Using infrared time-lapse video monitoring and tethering experiments, we observed significant day-night differences in predator species composition and predation rates on tethered juvenile lobsters. Predation rates were unexpectedly significantly higher at night, and over 90% of the observed predation at that time was by larger lobsters. To our knowledge this is the first quantitative field evidence of cannibalism in the American lobster, potential artifacts inherent to tethering experiments notwithstanding, and at least indicates heightened levels of intraspecific interaction at night. Because of the implication that cannibalism could be an important density-dependent process operating when and where lobster population densities are high, nocturnal activity warrants further investigation.

A new beginning on the benthos? No effect of larval or postlarval experiences on settlement and shelter-seeking behaviors of the lobster *Homarus americanus*

Jacobs MW, Bayer SB, N Shuttari N, Christmas AF, Gallager S

Skylar Bayer <skylarrb@gmail.com> (Woods Hole Oceanographic Institution)

The lobster *Homarus americanus* releases swimming larvae that feed and grow through three molt stages in the plankton before metamorphosing into a postlarval settlement stage. During the settlement stage, postlarvae gradually transition from planktonic to benthic life, and from a roving, exploratory lifestyle to a very cryptic benthic one. This behavioral transition may be affected by a wide variety of environmental factors. We present an overview of experiments with larval and postlarval lobsters that have examined (1) variation in swimming behavior of larvae and postlarvae in response to physical barriers such as a thermocline or sharp change in light level; (2) variation in settlement terrain and (3) variation in shelter-seeking behavior of juveniles as a function of exposure to settlement terrain and flexible processes, strongly influenced by environmental factors such as shelter availability and food level that would affect the survival of juveniles, and relatively unaffected by larval and post-larval experience, the length of the larval period prior to metamorphosis, or the presence of a thermocline. Settlement appears to involve two separate transitions: a transition from planktonic to benthic living, and a transition from exploratory to cryptic behaviors.

Impact of mass sponge mortality and juvenile density on Caribbean spiny lobster recruitment in Florida Bay, FL, USA

Michael J. Childress, Peter E. Bouwma

Peter Bouwma <pbouwma@gmail.com> (Friedrich Schiller University Jena)

Caribbean spiny lobsters utilize the shallow waters of Florida Bay as their primary nursery in the Florida Keys, USA. However, recent mass sponge mortalities due to cyanobacteria blooms have reduced the availability of crevice shelters thought to be essential to early juvenile survival. In this study, we investigated the role of conspecific settlement cues and sponge shelter loss by conducting a mark-recapture field experiment of newly settled juvenile lobsters on experimental plots with high and low juvenile lobster density before and after mass sponge mortality. Prior to the mass sponge mortality, recapture rate of marked recruits was similar on high and low density sites, but settlement of unmarked recruits was significantly increased with increased juvenile density. After the mass sponge mortality, recapture rate of marked recruits increased on impacted sites over non-impacted sites regardless of lobster density. Impacted sites also experienced increased lobster densities due to the presence of artificial shelter blocks that served as alternative shelters in the absence of sponges. This effect was present for all sizes of juveniles including those that had recently recruited to the site. These results suggest that sponge shelters play two additional roles in regulating juvenile lobster settlement in the Florida Bay nursery. First, they provide shelters to larger juveniles that potential signal the suitability of the habitat for new recruits, and second, they provide a corridor for dispersal when juveniles begin to migrate from the nursery.

Findings of phyllosoma larvae and nistos of the family Scyllaridae (Crustacea, Decapoda) in the southern Mediterranean Sea

M.L. Bianchini 1a, D. Massi 2, A. Fortunati 1a, E. Canali 3, E. Pagliarino 1b
1a IBAF-CNR, Via Salaria km 29.300, 00015 Monterotondo Scalo RM, Italy – bradipo50@yahoo.com
1b IBAF-CNR, Villa Paolina, 05010 Porano TR, Italy
2 IAMC-CNR, Via L. Vaccara 61, 91026 Mazara del Vallo TP, Italy
3 CRA-ING, Via della Pascolare 16, 00015 Monterotondo Scalo RM, Italy
Marco L. Bianchini
bradipo50@yahoo.com> (IBAF-CNR)

Specimens in larval (phyllosoma) and post larval (nisto/early juvenile) stages belonging to the family Scyllaridae, are reported for the waters around Sicily. Some were stranded in different winter occasions near the Strait of Messina (north eastern Sicily), while others were collected in deep waters (up to 300 m) during autumn trawl surveys carried out in the Strait of Sicily. All phyllosoma larvae were in advanced stages of development; still, the absence of complete morphological references on the larval characteristics of the family Scyllaridae, necessary for distinguishing the different genera (Scyllarus and Scyllarides, small or large slipper lobsters, or the extremely rare Acantharctus) and species inhabiting the Mediterranean, did not allow to attribute the phyllosomas to a specific taxon. On the contrary, nistos have been classified, on the basis of similarities with the morphology of adult antennae, as pertaining to the genus Scyllarus, but the examined morphological characters were ineffective to discriminate between Scyllarus arctus and Scyllarus pygmaeus (the only two known Central Mediterranean species). The small size and the depth at which they settled suggested that some may belong to the smaller, deeper species Scyllarus pygmaeus. To settle the questions, total genomic DNA extraction was performed on some specimens, and a region of about 500bp of the 28S gene was amplified by PCR; this fragment was sequenced and the obtained sequences were compared by phylogenetic analysis (cladograms) and with genetic databank records. The genetic results allowed to discriminate the species and to verify the ecological assumptions on the larval settlement.



Reproduction

Variability in size and contents of spermatophores produced by male lobsters (*Homarus americanus*)

Tracy L. Pugh and Winsor H. Watson, III

Tracy Pugh <tracy.pugh@state.ma.us> (University of New Hampshire)

The quantity (and quality) of sperm produced by a male lobster may affect the fecundity of his female partner. Additionally, spermatophores transferred by the male also contain seminal fluids, which may aid in preserving the spermatozoa and, when hardened into a sperm plug, block mating attempts by other males. Previous studies that examined spermatophores extruded by male *H. americanus* documented variability in the size and contents of those spermatophores, and that some contained no spermatozoa. Our goal was to extend upon this work and determine whether male lobsters of different sizes differ in the quantity or content of ejaculate produced, as this variability may impact the realized fecundity of their mates. Spermatophore extrusion was stimulated by applying an electrical current near the gonopores of male lobsters, at the base of the male's 5th periopods. If spermatophores were extruded they were weighed and photographed, and the images were analyzed to calculate the ratio of seminal fluid (plug material) to spermatozoa. We will review the successes and failures of a pilot study utilizing these techniques on more than 70 males, and will present preliminary results along with a summary of an improved methodology.

Tracking cohorts of American lobster (*Homarus americanus*) in the Magdalen Islands (Québec) from settlement to recruitment to the fishery from a diving and a trawl survey.

Louise Gendron, Stéphanie Delayat and Gilles Savard, Institut Maurice-Lamontagne, Department of Fisheries and Ocean, 850, route de la Mer, Mont-Joli, QC Canada G5H 3V9 Louise Gendron <louise.gendron@dfo-mpo.gc.ca> (Department of Fisheries and Oceans)

American lobsters (5-160 mm carapace length, CL) are quantitatively surveyed by SCUBA diving at a nursery ground and with a Nephrops trawl in the southeast part of the Magdalen Islands (Québec) since 1995. The 17-year time series offers the opportunity to examine the growth trajectory and track cohorts from settlement up to their entry into the fishery, laying the foundation for the development of a settler-recruit relationship, and for forecasting trends in lobster landings. For each year, modal analysis was performed on SFDs to characterize instars, based on growth data. The analysis reveals that up to 11 instars are present on the nursery ground (V-XVI) and at least 7 instars are captured during the trawl survey (XVI to XXII). In their year of benthic settlement, lobsters reach instar VII or VIII before winter. Most lobsters leave the nursery at instar XIV or XV (circa 40 mm CL). Lobsters reach commercial size (83 mm CL) at instar XX and the commercial catch of a given year is mainly composed of three instars (XX to XXII). Instars identified in the SFDs were then assigned to year-classes (cohorts), visually for the first three years, and based on data on moulting frequency for the following years. It was estimated that landings in a given year could easily be composed of four cohorts, and that lobsters would recruit to the fishery between 7 and 10 years old. Knowledge of commercial catch composition in terms of instars and cohorts and a better understanding of growth trajectories allow for the development of more precise forecasting tools.

Spatial and temporal coherence of settlement, juvenile, and adult American lobster, *Homarus americanus*, in the coastal Gulf of Maine

Jui-Han Chang, Yong Chen, Richard Wahle, and Carl Wilson Jui-Han Chang <jui-han.chang@umit.maine.edu> (University of Maine)

Two surveys have been conducted by Maine Department of Marine Resources in the inshore waters of Gulf of Maine (GOM) to monitor the abundance and spatial distribution of lobster in different life history stages. Diver-based suction sampling survey is designed to mainly sample recently settled young-of-year (< 10.5 to 13 mm carapace length [CL]) and older juvenile lobsters up to nearly 50 mm hidden in rocky nurseries. Inshore trawl surveys, by contrast, capture lobsters that are mostly larger than 40 mm CL available to trawls sweeping level bottom habitats. Spatial overlap between the two survey programs provides opportunities to evaluate the coherence of the lobster at different life history stages. With models based on the inshore trawl survey data, we estimated the spatial distribution of juvenile and adult American lobster for spring and fall from 2002 to 2007 in the coastal GOM. Lobster settlement density at dive sites was correlated with the older juvenile and adult lobster density estimated at the nearest trawl survey sites. Juveniles in trawl surveys had stronger positive correlations with the settlement indices than adults. Moreover, settlement indices were more strongly correlated with juvenile densities in the spring than in the fall. The highest correlation appeared with a lag of one-half year for most years. Adults had weaker correlations with settlement indices compared with juveniles. This analysis suggests variability in spatial and temporal coherence of the American lobster distribution in different life history stages, likely driven by specific habitat requirement.

Hemolymph plasma triglyceride and cholesterol concentrations as potential aids to determine of ovary maturity in the american lobster (*Homarus americanus*)

Andrea Battison, Melanie Burton, & Rachael Summerfield Atlantic Veterinary College Lobster Science Centre, University of Prince Edward Island, PE, Canada Andrea Battison <abattison@upei.ca> (AVC Lobster Science Centre)

Size at Maturity (SAM) is used for determination of the minimum legal size limits for each Lobster Fishing Area (LFA) in Atlantic Canada. SAM estimates currently use lethal sampling in order to directly visualise the ovaries for maturity staging. Development of non-lethal methods to determine SAM would be beneficial to fishery managers as higher numbers of animals could be sampled more frequently. Hemolymph plasma biochemistry profiles were examined as a non-lethal alternate for SAM. One hundred and forty female lobsters from LFA 24, June 2008 (n=70) and LFA 31, June 2009 (n=70) were collected for measurement of hemolymph plasma triglyceride (TG) and cholesterol (CH) concentrations, ovary staging, cement gland and pleopod staging, and carapace length. Plasma TG and CH were measured on a Cobas c501 biochemistry analyser, Diagnostic Services, Atlantic Veterinary College, University of Prince Edward Island, Canada. A subset of ovaries representing different stages of maturation were used for tissue homogenisation studies including TG and CH content. Data analysis showed that TG and CH levels increase as ovaries mature. Plasma TG and CH levels also increased as ovaries matured; however, the pattern in each LFA was slightly different. Hemolymph plasma TG and CH levels may assist with non-lethal assessment of ovary maturation in American lobsters.

Occurrence of partial molting in Nephrops norvegicus

Margarida Castro Margarida Castro <mcastro@ualg.pt> (CCMAR - U Algarve)

The occurrence of partial molting in a Norway lobster kept in captivity is described. A male *Nephrops norvegicus* with 33 mm carapace length, caught 28 October 2009, has been kept in captivity in an individual aquarium, up to the present. It arrived without lesions and had a behavior considered normal, with aggressive posture when disturbed and finding and eating quickly all the food made

available (regular feeding with pellets, once a week live food). In April 2010, 178 days after arriving at the lab, it molted only the claws (dactylus, propodus and carpus of the first pair of periopods). In November 2010, 210 days after the partial molt and 388 days after arrival it when through a normal complete molt. The claws of both molts and the carapace of the second molt were kept and measured. The claws were differentiated (crusher on the left side) and there was an increase in the total length of the claw. No signs of abnormalities could be observed.

Tissue isotopic fractionation in captive and wild European spiny lobster Palinurus elephas

Salud Deudero, Ariadna Tor, David Díaz, Sandra Mallol and Raquel Goñi Raquel Goñi <raquel.goni@ba.ieo.es> (Instituto Español de Oceanografía)

Isotopic fractionation δ_{13} C and for δ_{15} N of the spiny lobster *Palinurus elephas* has been tested in four tissues: tail and leg muscle, telson and hemolymph. Comparison of tissue fractionation factors among tissues in two groups of lobsters, captive (controlled diet) and wild, show lower intra-individual variability in captive than in wild individuals. Statistical analysis (PERMANOVA) was performed to check for significant differences in δ_{13} C and δ_{15} N isotopic signatures between tissues and treatments. Results show significant differences in the δ_{13} C and δ_{15} N isotopic composition among the four tissues analyzed. Legs are the most enriched tissue in δ_{15} N, followed by muscle, hemolymph and telson in both captive and wild specimens. For δ_{13} C the sequence is muscle > legs> hemolymph ~ telson. The fractionation or enrichment factor for δ_{13} C is 0.87‰ and 1.17‰ and for δ_{15} N 1.99‰ and 2.38‰, in captive and wild lobsters respectively. Leg muscle presents the lowest variability at isotopic level for N and telson for C. Telson presents differences for N and C in both captive and wild lobsters (Mann-U Whitney p<0.05). Hemolymph and leg only present statistical differences for N between captive and wild individuals. In the first study of tissue isotopic fractioning of a spiny lobster species we conclude that leg muscle is the best tissue for studying P. elephas trophic dynamics applying non-invasive techniques.

Female Choice and Sperm Limitation in the Spotted Spiny Lobster, Panulirus guttatus

Denice Robertson and Mark Butler

Mark Butler <mbutler@odu.edu> (Old Dominion University)

Unequal investment in gametes or parental care results in females generally being more selective than males when choosing mates. Female mate choice is influenced by male size, male resource provisioning, and other proxies for male genetic quality that tend to maximize fertilization success and offspring survival. In decapod crustaceans, mating dynamics are further complicated by sizedependent sperm limitation associated with low sperm:egg ratios. We explored how mate size influences mating dynamics in the spotted spiny lobster (Panulirus guttatus), a philopatric species that dwells on shallow and often isolated coral reefs in the Caribbean where their choice of mates can be limited. In a series of laboratory experiments we varied the availability and size of male and female P. guttatus mates, then quantified courtship behavior, determined mate choice, and measured the fertilization success of each mating. Large males initiated most interactions with other males, won 99% of those encounters, and were more successful in garnering mates, although males of all sizes courted and attempted to mate with all sizes of females. Females nearly always (92% of trials) chose males larger than themselves, but if large males were unavailable, females mated with smaller males. However, the mating of large females by small males resulted in reduced fertilization success. Thus, for species like *P. guttatus* that dwell in patchy habitats where mate availability can be temporally and spatially variable, the optimal strategy for mate choice may be context-dependent, although not without cost to the largest females.

Workshop: Neurobiology, Sensory Biology and Behaviour

Phototaxis and geotaxis in the early ontogenesis of the red king crab *Paralithodes camtschaticus*

Rostislav R. Borisov*, Nikolina P. Kovatcheva, Elena S. Chertoprud, Alexandra G. Tertitskaya Roman Vasilyev <vasilyevrm@gmail.com> ()

Photo- and geotaxis in the red king crab *Paralithodes camtschaticus* was studied in all early stages of ontogeny. It was found that planktonic larvae zoea (I-IV stages) and prezoea of the red king crab are photopositive and geonegative. During glaucothoe stage larvae switch from planktonic to bentic mode of life, which defines change of geotaxis from negative to positive. In glaucothoe phototaxis remains

positive. It seems that glaucothoe use phototaxis to choose sites for sedimentation, which are located in well-illuminated coastal areas. Benthic juveniles, on stages I-II demonstrated positive phototaxis at all tested ranges of light intensity but while growing, at stages IV-V, start to be photonegative at high light intensity, remaining photopositive at low light intensity. Taxis variations in the red king crab are associated with the change of lifestyle in ontogenesis of the species.

The lobster mandibular common inhibitor motorneuron revisited: distribution, neuronal mapping and descending control

Enrico A. FERRERO, Piero G. GIULIANINI, Gabriella STOCCA, William WALES Ferrero Enrico A. <ferrero@units.it> (University of Trieste)

Common inhibitor (CI) motoneurons are defined as those acting by hyperpolarizing postsynaptically a high number of muscles involved in a common function and both agonist and antagonist. They are widespread in arthropods and in crustaceans are involved in bilateral movements e.g. in walking and swimming control. They tend to fire tonically with simultaneous spikes in all motor nerves innervating slow, tonic muscle fibers. Lobster mandibles chew both in phase and out of phase and sensory monitored overload or overstretch of the mandible increases the firing mainly of the homolateral CI. This neuron is peculiar because its tonic firing is strongly bilaterally coupled, occurring simultaneously in all the appropriate motor nerves (and muscles) on both sides. Evidence of the same pattern of neuronal activity was found in the homologous muscles in Norway lobster. Bilateral differential mapping of motoneurons in the foremost sub-oesophageal ganglion shows 4 clusters of cell bodies and a couple of large ones (> 200 um in diameter) with bilateral dendritic arborizations, likely CI candidates due to their large field of innervation. Electrical stimulation of selected, isolated bundles of the circumoesophageal connectives elicited both homolateral and contralateral responses in mandibular motor nerves. Depending on the bundle and voltage/frequency threshold, CI bilateral firing rate was accelerated (uncoupled at higher frequencies) or depressed or even abolished, while ordinary motorneurons were also recruited. This evidence speaks in favour of an as yet undescribed modulation and descending control by the cerebral ganglion on the mandibular motor pattern generator.

Olfactory orientation and imprinting in European lobster larvae, Homarus gammarus (L.)

Hilke Alberts-Hubatsch[1], Gabriele Gerlach[1], Isabel Schmalenbach[2], Heinz-Dieter Franke[2] [1] Carl von Ossietzky University, Oldenburg, Germany [2] Alfred Wegner Institute, BAH, Helgoland, Germany Hilke Alberts-Hubatsch <hilke.alberts.hubatsch@uni-oldenburg.de> (University of Oldenburg)

For European lobster larvae (Homarus gammarus) it is crucial to find suitable habitat for settlement after spending weeks in the pelagic. Because the isolated rocky island Helgoland is the only site within a distance of 300 km colonized by lobster, we hypothesized self-recruitment of larvae. To understand how the dispersing larvae could find this area at settlement, we tested larvae of different stage for their reactions towards different natural odour stimuli. The postlarvae expressed very strong preferences for their home water (tank water), when tested against offshore water. They also showed this affinity when they were tested for other stimuli from the shore (macroalgae, cobble substratum) and so did stage I and III larvae. Since all larval stages expressed significant attraction towards water in which they were raised, we investigated whether imprinting is the underlying mechanism or habituation. We used phytoplankton enriched water as the stimulus. Lobster larvae were exposed to this stimulus at different times (1) from hatching through all larval stages, (2) only for 30 hours after hatching or (3) as a control: no exposure. In olfactory choice tests larvae of group 1 expressed strong significant preferences for the stimulus whereas the 3rd group did not show any preferences. Since group 2 also preferred the stimulus we conclude that European lobster larvae undergo an imprinting phase during their first hours after hatching and they could use such permanent memory for later olfactory guided homing.

Terrestrial adaptations of olfactory systems – A comparative neuroanatomical study of terrestrial versus marine decapoda

J. Krieger, F. Seefluth, R. E. Sandeman, D. C. Sandeman, B. S. Hansson and S. Harzsch Steffen Harzsch <steffen.harzsch@uni-greifswald.de> (University of gGreifswald, Zoological Institute, Dept. Cytol)

The conquest of land probably has occurred five times convergently within malacostracan crustacea. In this context, we are interested in terrestrial adaptations of the sensory organs and the nervous system of different crustacean taxa in comparison to their nearest marine relatives. Our aim is to analyse the central olfactory pathway of crustaceans in order to gain a better understanding of the different adaptation strategies for conquering land within the Meiura. To that end, we examined

histological sections of the brains of the marine *Carcinus maenas* (Brachyura), *Pagurus bernhardus* (Anomura) and the terrestrial *Gecarcoidea natalis* (Brachyura) and *Birgus latro* (Anomura) with immunohistochemistry against synaptic proteins and allatostatin. In addition, we reconstructed a three dimensional model of the brain and selected brain structures of *B. latro*. Our results provide evidence for an extensive elaboration of the first antennae (antennules) and olfactory lobes in terrestrial anomurans in comparison to their marine relatives. In contrast, in terrestrial Brachyura the first antennae and olfactory lobes are highly reduced in size as compared to marine brachyurans. In conclusion, our data suggest that terrestrial anomurans evolved an elaborated sense of aerial olfaction whereas in terrestrial brachyurans the deutocerebral olfactory pathway eroded away to a great extent.

The production of sounds by American lobsters and the response of fish to these sounds

Winsor H. Watson III* and Daniel Ward Win Watson <win@unh.edu> (UNH)

American lobsters (*Homarus americanus*) will, on rare occasions, produce sounds by vibrating their dorsal carapace. Although this behavior can be elicited in the laboratory by handling lobsters, the stimuli that trigger the production of sounds in the lobster's natural habitat is not known. We investigated the influence of two fish that are known to prey on lobsters, cod (*Gadus morhua*) and striped bass (*Morone saxatilis*), on the production of sounds by American lobsters. In addition, we examined the response of these fish to the sounds the lobsters produced. Although solitary lobsters spontaneously produced sounds at a low rate of 1.2 ± 0.23 sound events /30 min, the presence of fish greatly increased the rate of sound production (cod: 51.1 ± 13.1 per 30 min; striped bass: 17.0 ± 7.0 per 30 min). Most (74.6 ± 6.6%) of the 292 sound events recorded occurred when fish came within 0.5 m of the lobsters, but fish did not have to come in contact with lobsters to elicit sounds. Immediately following the production of a sound by a lobster, fish turned and swam away at a significantly faster speed than when they encountered a lobster that did not make a sound. Moreover, after striped bass (but not cod) experienced a number of these sound events, they subsequently tended to avoid swimming close to the lobsters. These data, taken together, suggest that sound production by American lobsters may serve to deter potential fish predators.

Workshop: Diseases

Do casitas increase transmission of *Panulirus argus* Virus 1 (PaV1)? II. Clinical and subclinical infection in Caribbean spiny lobsters from a casita-based fishery in Mexico

Juan Pablo Huchin-Mian, Patricia Briones-Fourzán, Fernando Negrete-Soto, Cecilia Barradas-Ortiz, Rossanna Rodríguez-Canul, Enrique Lozano-Álvarez

Juan Pablo Huchin-Mian < langostaespinosa@gmail.com > (CINVESTAV Unidad-Mérida)

Populations of Panulirus argus throughout the Caribbean are being attacked by the highly pathogenic Panulirus argus Virus 1 (PaV1). Lobsters may carry the virus well before developing clinical signs of infection (milky hemolymph and a reddish discoloration over the exocuticle) or without developing clinical signs at all. PaV1 can be transmitted by contact, raising concern about a potential increase in transmission with the use of "casitas"-large artificial shelters that harbor multiple lobsters over a wide size range— in some local fisheries. Using molecular techniques, we evaluated infection by PaV1 in lobsters (with and without clinical signs of infection) from Bahía de la Ascensión, Mexico, where casitas are extensively used. We randomly sampled lobsters from the commercial catch in August 2009 and July 2010. In these relatively large lobsters, prevalence of infection was 4% (n = 30/723) and did not differ between years, but 33% of infected individuals (10/30) were asymptomatic. We also sampled individuals of all sizes from multiple casitas on two distant fishing zones within the bay, Punta Allen (PA) and Vigía Chico (VC), during winter and summer of 2010. Prevalence of infection was not affected by season but differed significantly between zones, with 28% of individuals carrying PaV1 in PA (118/420) and only 3% in VC (8/263). In PA, 47% of infected lobsters were asymptomatic (55/118), as were 75% in VC (6/8). Our results suggest that local environmental factors may have a greater influence on transmission rates of PaV1 than lobster cohabitation in casitas.

Subcuticular uric acid accumulation in an American lobster (Homarus americanus)

Andrea Battison <abattison@upei.ca> (AVC Lobster Science Centre)

The AVC Lobster Science Centre was presented with an unusual 'lumpy' lobster. Physical examination revealed a weak animal with numerous pale raised and flat (3 - 10 mm) areas on the shell, some

of which were ulcerated. On necropsy, the pale areas corresponded to an accumulation of a pasty white, free-flowing material in the subcuticular connective tissue. No internal organs were affected. Wright-Giemsa stained imprints of the white material contained numerous fine, rounded, non-staining granules free in the background and within individual round cells (macrophages). Direct light examination of non-stained impression smears showed abundant crystalline material resembling uric acid, amorphous urates, and sodium urate. The polarizable crystals were readily soluble in 1 M KOH. Crystallography confirmed the presence of urates or mixed urate salts. Significant abnormalities on hemolymph plasma biochemistry included detectable creatinine (14 umol/L, generally 0 umol/L) and elevated urea (1.7 mmol/L, usually < 1.0 mmol/L) and lactate (36.6 mmol/L, usually < 1.0 mmol/L) concentrations likely related to the dehydration. Hemolymph uric acid was also increased at 287 umol/L (usually < 200 umol/L). Histology showed aggregates of vacuolated mononuclear cells in the loose, subcuticular connective tissue occasionally infiltrating into muscle fibres. Possible considerations include increased urate production or decreased excretion or solubility and will require further investigation. Anecdotal reports of similarly affected lobsters in this area have been received but are intermittent and undocumented.

Insight into the molecular diversity of the Caribbean spiny lobster virus, Panulirus argus virus 1

Jessica Moss, Donald C. Behringer, Mark J. Butler and Jeffrey D. Shields Jessica Moss <jamoss@vims.edu> (Virginia Institute of Marine Science)

Panulirus argus virus 1 (PaV1) is the first pathogenic virus described in lobsters and occurs in the Caribbean spiny lobster throughout most of its range. Prevalence of the virus differs with ontogony; it is pathogenic and lethal in juveniles but less so in adults, which are asymptomatic when infected but may be potential carriers. During optimization and validation of a PCR assay for PaV1, sequence analysis of one DNA locus showed significant nucleotide variation. We have since investigated the molecular diversity of PaV1 infecting various P. argus life stages in the Florida Keys (USA) and the potential mechanisms explaining this viral genotypic diversity. We confirmed the tremendous genetic diversity of PaV1 at the locus analyzed not only in juvenile P. argus, but also within puerulus postlarvae, documenting at least 20 different viral genotypes. PaV1 has never before been reported from pueruli; this finding has important ramifications regarding the dispersal of the pathogen. Oceanographic modeling indicates that the Florida Keys receives larvae from throughout the Caribbean so possible explanations for this viral variation include the presence of strains endemic to different geographic locations and dispersal, or local viral hypermutation within the Keys. Infection trials, wherein the potential for viral hypermutation was evaluated, demonstrates that the observed strain variation is not due to hypermutation. We are now exploring the molecular diversity of PaV1 throughout the Caribbean Sea and the potential for disease connectivity via larval and postlarval vectors.

A re-evaluation of the prevalence and seasonality of Hematodinium sp. infection in Norway lobsters (*Nephrops norvegicus*) in the Clyde Sea area, Scotland

Nicholas Beevers(1), Elizabeth Kilbride(1), Jim Atkinson(2) & Douglas Neil(1) 1. Institute of Biodiversity, Comparative Medicine and Animal Health, University of Glasgow, Scotland, UK. 2. University Biological Marine Station Millport, Isle of Cumbrae, Scotland, UK Douglas Neil <douglas.neil@glasgow.ac.uk> (University of Glasgow)

For the past 20 years an annual mortality of Norway lobsters (Nephrops norvegicus) due to infection by the dinoflagellate parasite Hematodinium has been reported from the Clyde Sea area (CSA), Scotland. The number of patently-infected animals reaches a peak in the spring, but they are not detectable by visual methods at other times of the year. This study aimed to establish the existence of sub-patent infection between the annual peaks of patency, and to estimate its prevalence, using a combination of immunoassay (ELISA) and molecular (PCR) techniques. Two hypotheses were tested: (1) that infection develops over the months between the peaks of infection, and (2) that sub-patent levels of prevalence matching those at peak patency occur throughout the year. Sub-patent levels of infection were detectable throughout the year which were comparable to those at the patent infection peaks in the spring. Logistic regression analysis of these data predicts that size and month of sampling significantly affect the probability of finding infected hosts (p<0.01 and p<0.05 respectively), but that sex does not. It is therefore proposed that the Hematodinium sp. infection of N. norvegicus in the CSA should no longer be described as a 'seasonal infection', but rather that the patent infection be described as 'seasonally apparent'. The new prevalence data have been added to the existing published and unpublished data available for the Hematodinium in the CSA, forming an 18 year data series. NB was supported by a BBSRC CASE Studentship with Young's Seafood Ltd

Effects of shell disease on female choice and male dominance in the American lobster (*Homarus americanus*)

Rycroft, N.; McDougal, E.; Radcliffe, K.; Halverson, J.; Atema, J. Nathan Rycroft <nrycroft@bu.edu> (Boston University)

Epizootic shell disease in the American lobster, *Homarus americanus*, is a serious issue facing inshore populations. The disease has been found to affect the biochemical profile of lobsters which may alter chemical cues released by individuals. We hypothesized that changes in chemical cues could affect mate choice and the establishment of dominance, critical factors in mating success. We used an odor choice flume to examine female preference when presented with the odor of a healthy and diseased male caged in separate upstream channels. In addition, we investigated the effect of shell disease on male dominance through staged fights. We discovered no significant difference between the time females spent near healthy versus diseased males, however healthy males established dominance over shell diseased males in 11 of 12 fights (p=0.006). Our results indicate that females do not avoid the odor and nearby presence of diseased males, however shell disease reduces male dominance and therefore could affect female mate preference. We suggest that *H. americanus* may not have evolved avoidance mechanisms since shell disease has only recently become prevalent in the wild. In related studies we found morphometric and some genetic differences between populations on a local scale where females preferred to associate with males of their own tribe. This tribal preference may provide a mechanism to reduce disease transmission between local populations.

Modeling the effects of behavior and habitat structure on disease dynamics in Caribbean spiny lobster

Thomas W. Dolan III, Mark J. Butler IV, and Jeffrey D. Shields Mark Butler <mbutler@odu.edu> (Old Dominion University)

We developed a spatially-explicit, agent-based simulation to examine the trade-off between risk of predation and disease transmission that occurs when susceptible hosts avoid diseased conspecifics, a behavior exhibited by juvenile Panulirus argus in response to conspecifics infected with Panulirus argus Virus 1 (PaV1). Because the virus also infects asocial, early benthic phase juveniles (EBJs) through an unknown mechanism, we included a density-independent infection mechanism, representative of environmental exposure. We also simulated the arrival of PaV1 in infected postlarvae, which we have documented in the field. Last, we examined the effect of the loss of sponges used by juvenile spiny lobster due to harmful algal blooms, which changes the pattern of lobster cohabitation. We found that without disease avoidance, outbreaks occurred rapidly, growing in intensity and duration until, by the end of 10 simulated years, PaV1 was maintained continuously at unrealistically high levels. Disease avoidance reduced simulated outbreak intensities and durations, and in the absence of other transmission pathways, resulted in extinction of the disease within five years. However, both EBJ infection mechanisms were capable of maintaining the disease, even at the highest level of disease avoidance, due to the long period between exposure and death. Loss of shelter did not significantly increase PaV1 transmission or persistence because increased predation and large-scale movement of lobsters quickly reduced local lobster populations. Thus, avoidance of diseased conspecifics may select against high virulence and promote alternative transmission modes, resulting in a more resilient hostpathogen system.

Genetic mediators of the American lobster's (Homarus americanus) immunological response to bacterial infection

K. Fraser Clark, Adam R. Acorn and Spencer J. Greenwood Fraser Clark <fclark@upei.ca> (Lobster Science Centre at UPEI)

The Canadian lobster (*Homarus americanus*) fishery adds approximately \$1 billion to the Atlantic Canadian economy annually, and represents the most economically significant commercial fishery in Canada. Adult lobsters live approximately 6-8 years in the wild before they are eligible for recruitment into the lobster fishery and have developed complex mechanisms to survive numerous environmental and pathogenic pressures. Although resistant to a diverse array of microbial pathogens present in their environment, the immune system of an adult H. americanus is particularly susceptible to infection by the gram-positive bacterium Aerococcus viridans var. homari. This pathogen causes lethal disease in *H. americanus* and represents a significant pathogenic cause of post-harvest loss. This study is examined the genetic mediators of the immune response using a novel lobster microarray. We have found ~850 genes which are differentially expressed during A. viridans infection including many traditionally associated with immune response including several lectins, crustins, anti-lipopolysaccharide binding proteins, alpha-2 macroglobulins, proteases and a variety of unannotated genes.

Genetic mediators of stress response in the American Lobster (*Homarus americanus*) under live holding and shipping conditions

Adam R. Acorn, K. Fraser Clark, John Garland, Spencer J. Greenwood Adam Acorn <aacorn@upei.ca> (Lobster Science Centre at UPEI)

The American lobster (*Homarus americanus*) fishery in Atlantic Canada and Quebec is the most economically important commercial fishery in Canada. This fishery lands over 50 metric tonnes of live lobsters every year at a value of approximately \$600 million. Lobsters are graded as either a premium product likely to survive live storage, or sold to processors for immediate processing. A live lobster demands a premium price as it is in good health and of top quality, but a lobster will face many stressors during its journey from ocean to plate. While in live storage, it is routine for companies to suffer losses of 5-15% due to mortality. In some cases, the mortality can be as high as 40% for lobsters stored during the late summer/early fall fishery. With a fishery worth ~\$600 million, and mortalities of 5-15% representing losses of \$30-\$90 million, there is significant room for improvement. It is the goal of this research project to begin to examine the types of physiological stress that a lobster faces while in storage, with the goal of improving the efficiency of storage and increasing the value to all levels of the fishery including: fishers, buyers, shippers and ultimately the consumer. This project uses a novel lobster microarray to monitor gene expression as a means of determine the genetic mediators of a lobster's stress response.

