4-2017

21st Annual Pectinid Workshop Abstracts and Program

Kevin Stokesbury

Jay Parsons

Sandy Shumway

21st International Pectinid Workshop

19th-25th April 2017 – Portland, Maine

ABSTRACTS & PROGRAM

WELCOME MESSAGE

On behalf of the IPW Organizing Committee, we are delighted to welcome you to Portland, Maine, USA for the 21st International Pectinid Workshop. Some may remember the 7th IPW held here in 1989 – the organizer is a little greyer, but the enthusiasm for scallops and the outstanding venue have not waned. This Workshop follows the example of the 20th IPW that was co-hosted by two countries, Ireland and Norway. Scallops are key to the coastal economies of Canada and the United States and joint sponsorship of the IPW by the Americans and Canadians was an obvious liaison.

In addition to nine keynote lectures and a special 'Industry Day', the scientific program includes the usual assemblage of topics including fisheries, aquaculture, genetics, disease, and management. We hope that bringing some new topics and scallop enthusiasts to the meeting will enhance your experience and perhaps bring new members to IPW extended family.

There are several social events planned, including a genuine all-American baseball game and a lobster bake with traditional music. Portland is a cornucopia of good food, good music, and activities – we hope you will take advantage of all it has to offer and enjoy your stay.

Meetings such as this can only succeed with the help and cooperation of many. We offer a grand thanks to our sponsors, please take a moment to thank any that you see. It is their support that made it possible to sponsor industry and student participation as well as many of the amenities. Much of the 'behind-the-scenes' effort was handled by Emily Keiley, Eric Heupel, and Noreen Blaschik, and it is safe to say we would not have the sponsorship, outstanding web page, or meeting materials without their collective talent and dedication.

We hope you have a great time in Portland!

Kevin Stokesbury   Jay Parsons   Sandy Shumway

Joint Chairs of the 21st International Pectinid Workshop

HISTORY OF THE INTERNATIONAL PECTINID WORKSHOPS

The first International Pectinid Workshop was held in 1976 in Ireland and has since moved throughout the world. The early Pectinid Workshops were small European meetings attended by some 30-40 people from half a dozen countries, but over a >40-year period the Workshop has grown to a large international group attracting well over 100 delegates from some 30 countries. Devoted Pectinid enthusiasts gather every second year to exchange the latest developments within a range of scientific fields, aquaculture, fisheries, and management, and to enjoy the company of fellow scallop fondlers. As the Workshop has moved between and across the continents, the scientific focus has changed, some disciplines have diminished, and new ones have emerged, but the Pectinid Workshop spirit has persisted. Plans are underway to publish a 'History of the IPW' – watch for it!

1st	1976	**Baltimore, Ireland**	Dan Minchin
2nd	1978	**Brest, France**	Jean Claude Dao
3rd	1980	**Port Erin, Isle of Man**	Andrew Brand
4th	1983	**Aberdeen, Scotland**	Jim Mason
5th	1985	**La Couña, Spain**	Guillermo Román
6th	1987	**Menai Bridges, Wales**	Andy Beaumont
7th	1989	**Portland, USA**	Sandra Shumway
8th	1991	**Cherbourg, France**	Pierre Lubet
9th	1993	**Nanaimo, Canada**	Neil Bourne
10th	1995	**Cork, Ireland**	Gavin Burnell
11th	1997	**La Paz, Mexico**	Estaban Felix-Pico
12th	1999	**Bergen, Norway**	Sissel Andersen / Thorolf Magnesen
13th	2001	**Coquimbo, Chile**	Elizabeth von Brand / Juan Enrique Illanes
14th	2003	**St. Petersburg, USA**	Norman Blake / Don Sweat
15th	2005	**Mooloolaba, Australia**	Michael Dredge / Peter Duncan
16th	2007	**Halifax, Canada**	Jay Parson
17th	2009	**Santiago de Compostela, Spain**	Luz Pérez-Parallé / José Luís Sánches
18th	2011	**Quindao, China**	Guofan Zahang
19th	2013	**Florianopólis, Brazil**	Guilherme S. Rupp
20th	2015	**Galway, Ireland**	Julie Maguire / Ellen-Sofie Grefsrud

21st International Pectinid Workshop
Portland, Maine
April 19th – 25th 2017

WEDNESDAY APRIL 19th 2017

4:30 PM	**Registration opens**
7:30 PM	**ICEBREAKER EVENT (CONNECTICUT/RHODE ISLAND ROOM)** **Welcome reception with nibbles and drinks**

THURSDAY APRIL 20th 2017

7:00 AM	**Registration**
8:30 AM	**WELCOME AND OFFICIAL OPENING**
8:45 – 9:00 AM	**KEYNOTE: Richard Bailey**
9:15 – 10:30 AM	**Fisheries Session**
10:30 – 11:00 AM	**MORNING BREAK**
11:00 – 12:45 PM	**Fisheries Session**
12:45 – 2:15 PM	**LUNCH BREAK**
2:15 – 2:45 PM	**KEYNOTE: Eric Foucher**
2:45 – 4:30 PM	**Spatial Management Session**
4:30 – 7:00 PM	**POSTER SESSION and HAPPY HOUR** **Scallop Taste Test (David Bethoney)**

FRIDAY APRIL 21st 2017 – INDUSTRY DAY (CHAIR, KEVIN STOKESBURY)

7:00 – 8:30 AM	**Registration**
8:30 – 9:30 AM	**KEYNOTE: Peter Auster**
9:30 – 10:30 AM	**Fisheries Session**
10:30 – 11:00 AM	**MORNING BREAK**
11:00 – 11:30 AM	**KEYNOTE: Bryce Stewart**
11:30 – 12:30 AM	**Gear Session**
12:30 – 2:00 PM	**LUNCH BREAK**
2:00 – 2:45 PM	**KEYNOTE: Brian Rothschild**
2:45 – 5:00 PM	**YOUNG CAPTAINS' HARVESTING TECHNOLOGY FORUM**
5:00 – 7:00 PM	**POSTER SESSION and HAPPY HOUR**

SATURDAY APRIL 22nd 2017

8:30 – 9:00 AM	**Registration**
9:00 – 9:30 AM	**KEYNOTE: Dan Speiser**
9:30 – 10:45 AM	**Disease Session**
11:30 AM	**PORTLAND SEADOGS BASEBALL GAME** **(all you can eat BBQ; beer / wine cash bar)** **First bus leaves at 11:30am**

SUNDAY APRIL 23rd 2017

7:00 AM – 8:00 PM	**BOSTON, FANEUIL HALL, AND NEW ENGLAND AQUARIUM** **Bus willdepart the hotel at 7:00am**

MONDAY APRIL 24th 2017

8:00 – 8:30 AM	**Registration**
9:00 – 9:30 AM	**KEYNOTE: Elisabeth von Brand**
9:30 – 10:30 AM	**Genetics Session**
10:30 – 11:00 AM	**MORNING BREAK**
11:00 – 12:30 AM	**General Session**
12:30 – 2:00 PM	**LUNCH BREAK**
2:00 – 2:30 PM	**KEYNOTE: Helga Guderly**
2:30 – 4:30 PM	**Aquaculture Session**
4:30 – 6:00 PM	**POSTER SESSION and HAPPY HOUR**
7:00 PM – late	**LOBSTER BAKE** **Music provided by Old Grey Goose**

TUESDAY APRIL 25th 2017

9:00 – 9:30 AM	**Registration**
9:00 – 9:30 AM	**KEYNOTE: Michael Tlusty**
9:30 – 10:30 AM	**Pectinid Bouillabaisse**
10:30 – 11:00 AM	**MORNING BREAK**
11:00 AM – 1:00 PM	**Pectinid Bouillabaisse**
1:00 PM	**CLOSING REMARKS**
	END OF IPW2017 WORKSHOP

THURSDAY APRIL 20TH

07:00am – 08:15am	**Registration**
08:30am – 08:45am	**WELCOME AND OFFICIAL OPENING**
08:45am – 09:15am	**KEYNOTE: *Neogene paleo-oceanography and fossil scallops of eastern North America* - Richard Bailey (USA)**
	FISHERIES SESSION - Chair: Allen Frazer (New Zealand)
09:15am – 09:30am	The Irish Sea queen scallop (*Aequipecten opercularis*) fishery: a cautionary tale – **Peter Duncan (Australia, UK)**
09:30am – 09:45am	Surveys and assessment of scallops in SCA 7, New Zealand - **James Williams (New Zealand)**
09:45am – 10:00am	Developing a new fishery for *Ylistrum balloti* in New Caledonia - **Mike Dredge (Australia)**
10:00am – 10:15am	Valuation of scallop beds along the Norwegian coast – what have we learned so far? - **Ellen Sofie Grefsrud (Norway)**
10:15am – 10:30am	A modified flounder sweep for flatfish by-catch reduction in the LAGC scallop fleet - **Ricky Alexander (USA)**
10:30am – 11:00am	**MORNING BREAK**
11:00am – 11:15am	Reduction of flounder by-catch in the sea scallop fishery on Georges Bank: the yellowtail versus windowpane problem **- Liese Siemann (USA)**
11:15am – 11:30am	Estimating Atlantic sea scallop (*Placopecten magellanicus*) incidental mortality through before-after-control-impact surveys - **Danielle Ferraro (USA)**
11:30am – 11:45am	The role of larval sources and population connectivity in rotating closures in the Atlantic sea scallop (*Placopecten magellanicus*) fishery - **Daphne Munroe (USA)**
11:45am – 12:00pm	Successful use of long-term monitoring data to predict and manage a recreational scallop fishery perturbation - **Steve Geiger (USA)**
12:00pm – 12:15pm	Rebuilding the stock: increasing social, economic, and biological capacity of the Maine sea scallop fishery - **Trisha Cheney (USA)**

THURSDAY APRIL 20TH

12:15pm - 12:30pm	Incorporating habitat metrics into the assessment and management of scallop fisheries: experiences from Atlantic Canada - **Jessica A. Sameoto (Canada)**
12:30pm – 12:45pm	Characterization and quantification of echinoderms on Georges Bank and their biological interactions with sea scallops - **Judith Rosellon-Druker (USA)**
12:45pm - 02:15pm	**LUNCH BREAK**
02:15pm – 02:45pm	**KEYNOTE: *COMANCHE Project: Ecosystem interactions and anthropogenic impacts on king scallop (*Pecten maximus*) populations in the English Channel* - Eric Foucher (France)**
	SPATIAL MANAGEMENT SESSION - Chair: Deborah Hart (USA)
02:45pm – 03:00pm	What has been learned from 22 years of closures and scallop area management in the northeastern US? - **Deborah R. Hart (USA)**
03:00pm - 03:15pm	Increased accuracy in landings data coinciding with rotational management help to rebuild the Maine sea scallop fishery - **Melissa Smith (USA)**
03:15pm – 03:30pm	Prices, quotas, and fishery management: the sea scallop market in the northeast United States - **Min-Yang Lee (USA)**
03:30pm – 03:45pm	Can rights-based management increase the economic and environmental efficiency of a scallop fishery? - **Isobel S.M. Bloor (USA)**
03:45pm – 04:00pm	An incentive-based, collaborative approach to reduce flatfish by-catch in the US sea scallop fishery - **Catherine O'Keefe (USA)**
04:00pm – 04:15pm	When too many scallops complicate spatial management: density-dependent mortality and its impact on rotational closed areas - **N. David Bethoney (USA)**
04:15pm – 04:30pm	Using vessel monitoring systems (VMS) to evaluate time-area closures: a case study from the Atlantic-Canada scallop fleet – **David M. Keith (Canada)**
04:30pm – 06:30pm	**POSTER SESSION & HAPPY HOUR** **Scallop Taste Test (Dave Bethoney)**

FRIDAY APRIL 21ST - INDUSTRY DAY (CHAIR, KEVIN STOKESBURY, USA)

07:00am – 08:30am	**Registration**
09:00am – 09:30am	**KEYNOTE:** ***Marine Protected Areas as a management tool: linking goals across fisheries*** **- Peter Auster (USA)**
	FISHERIES SESSION - Chair: Mike Dredge (Australia)
09:30am – 09:45am	The slow recovery of the Iceland scallop stock in Breiðafjörður, Iceland - **Jónas Páll Jónasson (Iceland)**
09:45am – 10:00am	The British fishery for scallops (*Pecten maximus*) in ICES Area VII. Industry strategies for contributing positively to the achievement of MSY and other targets by 2020: methods to deal with regulatory interventions and with environmental concerns - **Jim Portus (UK)**
10:00am – 10:15am	Dynamics and trends of king scallop (*Pecten maximus*) fisheries in the English Channel from 2000 to 2015 - **Eric Foucher (France)**
10:15am – 10:30am	Decline and stability in New Zealand scallop fisheries - **Allen Frazer (New Zealand)**
10:30am – 11:00am	**MORNING BREAK**
11:00am – 11:30am	**KEYNOTE:** ***Between a rock and a soft place: how bad really is the effect of scallop dredging on marine ecosystems?*** **– Bryce Stewart (UK)**
	GEAR SESSION – Chairs: Ronald Smolowitz (USA) & Cate O'Keefe (USA)
11:30am – 11:45am	A review of modifications made to the New Bedford-style dredge to achieve conservation goals - **Ronald Smolowitz (USA)**
11:45am – 12:00pm	Passing through: the effects of increasing the inter-ring spacing of a sea scallop dredge apron on by-catch - **Farrell Davis (USA)**
12:00pm- 12:15pm	Evaluating a by-catch avoidance program based on real-time communication in the US sea scallop fishery - **Brooke Wright (USA)**
12:15pm – 12:30pm	Stress and observations of mortality of the monkfish *Lophius americanus* in the scallop dredge fishery - **Amelia Weissman (USA)**
12:30pm - 02:00pm	**LUNCH BREAK**

FRIDAY APRIL 21ST- INDUSTRY DAY (CHAIR, KEVIN STOKESBURY)

02:00pm – 02:45pm	**KEYNOTE:** ***The "birth and death of ideas in marine science" and their impact on fisheries*** **- Brian Rothschild (USA)**
	YOUNG CAPTAINS' HARVESTING TECHNOLOGY FORUM - Chair: Kevin Stokesbury (USA)
02:45pm – 05:00pm	The Scallop Industry Looking Frward: A panel discussion with the emphasis on younger industry people addressing the question, "What are you looking for from science, management, and your industry in the upcoming years?" Each member will introduce themselves and their fishery/business. Then each will give their thoughts on the question followed by an open discussion. PANEL MEMBERS: Tad Miller – *F/V Julie Ann* Cassie Canastra – Whaling City Seafood Display Auction Derick Eilersten – Nordic Inc. Chris Wright, Jr. - *F/V Huntress*, Isaksen Fish Co. Harvey Matthews - Fundy North Fishermen's Association Matt Sarty – Clearwater Grant MacLeod – Clearwater **OPEN DISCUSSION**
05:00pm – 07:00pm	**POSTER SESSION & HAPPY HOUR**

SATURDAY APRIL 22ND

08:30am – 09:00am	**Registration**
09:00am – 09:30am	**KEYNOTE: *Holding mirrors up to nature: the structure, function, and evolution of the eyes of scallops* - Dan Speiser (USA)**
	DISEASE SESSION - Chair: M. Luz Pérez-Parallé (Spain)
09:30am – 09:45am	A new disease of the Atlantic sea scallop in the NW Atlantic caused by *Mycobacterium* sp. - **Roxanna Smolowitz (USA)**
09:45am – 10:00am	At-sea discard of gray meat tissue as a vector for apicomplexan transmission in the Atlantic sea scallop, *Placopecten magellanicus* - **Susan Inglis (USA)**
10:00am – 10:15am	Contaminants in scallops: seasonality and variability of heavy metals and polycyclic aromatic hydrocarbons in the great and queen scallops (*Pecten maximus* and *Aequipecten opercularis*): a case study from the Irish Sea – **Peter F. Duncan (Australia, UK)**
10:15am – 10:30am	Searching for scallop zero: observations on a re-emerging epizootic - **David B. Rudders (USA)**
10:30am – 10:45am	RNA-seq analysis of differential gene expression in response to domoic acid-producing *Pseudo-nitzschia* in the digestive gland of *Aequipecten opercularis* (L.) - **M. Luz Pérez-Parallé (Spain)**
11:30AM	**PORTLAND SEADOGS BASEBALL GAME** **(all you can eat BBQ; beer/wine cash bar)** **First bus leaves at 11:30am for the ballpark**

SUNDAY APRIL 23RD

07:00am – 08:00pm	**BOSTON, FANEUIL HALL, AND NEW ENGLAND AQUARIUM** **Bus will depart the hotel at 7:00am**

MONDAY APRIL 24TH

08:30am – 09:00am	**KEYNOTE: *Genetic tools and scallops* - Elisabeth von Brand (Chile)**
	GENETICS SESSION - Chair: Elisabeth von Brand (Chile)
09:00am – 09:15am	Genetic diversity of the giant lion´s paw scallop (*Nodipecten subnodosus*) from the Gulf of California - **Brenda P. Oviedo-Velázquez (Mexico)**
09:15am – 09:30am	The evolutionary trajectories of bilaterian animals: insights from the scallop genome – **Zhenmin Bao (China)**
09:30am – 09:45am	Development of genomic tools for the systematic study of the biology and evolution of the Pectinidae - **Shi Wang (China)**
09:45am – 10:00am	Genetic differentiation between natural and cultivated *Argopecten purpuratus* populations and its association with their physiological performance and stress response - **Claudia Cárcamo (Chile)**
10:00am – 10:15am	Molecular characterization and transcript expression of the antimicrobial peptide *big defensin* from the scallop *Argopecten purpuratus*: first insight into the role of ROI and *IκB* on its transcriptional regulation – **Katherina Brokordt (Chile)**
10:15am – 10:30am	Screening of candidate genes involved in orange shell coloration in bay scallops – **Huayong Que (China)**
10:30am – 11:00am	**MORNING BREAK**
	GENERAL SESSION - Chair: Guilherme Rupp (Brazil)
11:00am – 11:15am	Non-toxic photoactive release coatings for biofouling control - **Alex Walsh (USA)**
11:15am – 11:30am	Developing a genetic toolkit to detect and quantify sea scallop spawning events - **Skylar R. Bayer (USA)**
11:30am – 11:45am	Examination into a vessel effect for a multi-vessel, industry-based sea scallop dredge survey - **Sally Roman (USA)**
11:45am – 12:00pm	Comparing sea scallop density and shell height distributions with advancing drop camera survey technology - **Kyle Cassidy (USA)**

MONDAY APRIL 24TH

12:00pm – 12:15pm	Investigating the "rust tide" (*Cochlodinium polykrikoides*) harmful algal bloom on a commercial shellfish farm and potential mitigation strategies to reduce future impacts - **Daniel Ward (USA)**
12:15pm – 12:30pm	Inimical effects of *Dinophysis caudata* on Japanese and noble scallops: a comparative study – **Leila Basti (Japan)**
12:30pm - 02:00pm	**LUNCH BREAK**
02:00pm- 02:30pm	**KEYNOTE:** ***Scallop muscle physiology: past achievements and future directions*** **- Helga Guderley (Canada)**
	AQUACULTURE SESSION - Chairs: Dana Morse (USA) & Thorolf Magnesen (Norway)
02:30pm – 03:00pm	Global overview of scallop aquaculture
03:00pm – 03:15pm	Opportunities for developing purple-hinge rock scallop aquaculture on the U.S. west coast - **Jonathan Davis (USA)**
03:15pm – 03:30pm	What are the future options for scallop production in the Bay of Fundy? - **Shawn M.C. Robinson (Canada)**
03:30pm – 03:45pm	Bay scallop (*Argopecten irradians*) nursery and grow-out strategies - **Daniel Ward (USA)**
03:45pm – 04:00pm	A brief history and an update of sea scallop aquaculture in Maine - **Dana L. Morse (USA)**
04:00pm – 04:30pm	Adoption of Japanese scallop culture technologies in the development of an Atlantic sea scallop (*Placopecten magellanicus*) aquaculture industry in Maine, USA - **Christopher V. Davis & Hugh Cowperthwaite (USA)**
04:00pm – 06:00pm	**POSTER SESSION & HAPPY HOUR**
07:00pm – until late	**LOBSTER BAKE** **Music provided by Old Grey Goose**

TUESDAY APRIL 25TH

09:30am – 10:00am	**KEYNOTE:** ***The fisheries – aquaculture – certification – ranking seascape*** **- Michael Tlusty (USA)**
	PECTINID BOUILLABAISSE – Chair: Sandy Shumway (USA)
09:30am – 10:00am	Media and public outreach on behalf of the seafood industry – **Robert Vanasse, Executive Director – Saving Seafood (USA)**
10:00am – 10:30am	SCUBA tanks, ROVs, and yellow submarines: diving for scallops - **Jeff Godfrey (USA)**
10:30am – 11:00am	**MORNING BREAK**
11:00am – 11:30am	*Gyotaku* Artistry Explained - **Bruce Koike (USA)**
11:30am – 12:00pm	Scallop Working Group Summary – **Kevin Stokesbury (USA)**
12:00pm –12:30pm	IPW History – **Andy Brand (Isle of Man)**
12:30pm – 1:00pm	Spain: IPW 2019 - **M. Luz Pérez-Parallé (Spain)**
01:00pm – 01:15pm	**CLOSING REMARKS**
END OF IPW2017 WORKSHOP	

ORAL PRESENTATIONS

(indicates student)*

A modified flounder sweep for flatfish by-catch reduction in the LAGC scallop fleet

Ricky Alexander

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Limited-Access General Category (LAGC) scallop vessels in Northeast region are generally small (< 60 feet), and therefore more spatially and temporally restricted than the Limited-Access fleet. Due to this limitation, the LAGC fishing season is typically a function of fishing conditions, rather than management restrictions. Further, there may be an increase in by-catch due to temporal and spatial overlap of nearshore fish migrations. Interactions by the LAGC fleet with managed flatfish species could result in the implementation of Accountability Measures (AM), potentially jeopardizing the profitability of the fleet. One approach to avoid exceeding Annual Catch Limits (ACL) and triggering an AM is to develop gear-based solutions for mitigating by-catch. To that end, a cookie sweep was attached to the outer bale bars of a scallop dredge forward of the cutting bar to drag the bottom, creating a sand cloud that initiates a herding (escape) response from flatfish, which, in turn, should result in a lower catch rate of flatfish. If effective, the flounder sweep could prevent the need for seasonal closures of nearshore fishing grounds that could have severe impacts for the LAGC fleet. In the fall 2016, testing of the flounder sweep began aboard an active LAGC scallop vessel. Preliminary results are promising with an 11.35% decrease in total by-catch of all finfish species and a 14.66% decrease in flatfish by-catch. These results indicate that the flounder sweep may be effective in reducing finfish by-catch, without impacting gear handling or target species catch, sea scallop (*Placopecten magellanicus*).

Prices, quotas, and fishery management: the sea scallop market in the northeast United States

Greg Ardini[1] and **Min-Yang Lee*[2]**

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During the first five years of the General Category Individual Fishing Quota (IFQ) program, the IFQ fleet received prices that averaged $0.67 per pound (6%) higher than the non-IFQ fleet. A hedonic model to understand the effects of fishery management, individual size, gear, trip length, fishing location, landing locations, and daily landings on prices was estimated. Because the dataset is relatively large (over 204,000 sales spanning 12 years), a relatively flexible hedonic price model was estimated. Prices and quantities could be simultaneously determined in this market; in particular, there is likely to be a positive relationship between price shocks and landings of scallops. This is addressed using the first lag of daily landings as an instrument for the endogenous daily landings.

The econometric model reveals three causes for higher prices for the IFQ fleet. First, the largest scallops (unsurprisingly) receive higher prices than small scallops (Figure 1), and these large scallops make up a larger share of the IFQ fleet landings. Second, the IFQ fleet receives slightly higher prices for these large scallops than the non-IFQ fleet; this could be related to a combination of unmeasured product quality, segmented downstream markets, and random chance. Third, the IFQ fleet lands on days that have lower landings and buyers are willing to pay slightly more for scallops on those days. It was also shown that prices received by the IFQ-transition fleet were lower; this may be due to derby-style fishing that occurred during the transition period. Understanding the effects of individual size on prices can inform managers about the benefits of alternative fisheries policies, specifically policies that involve delaying harvest to allow individuals to grow.

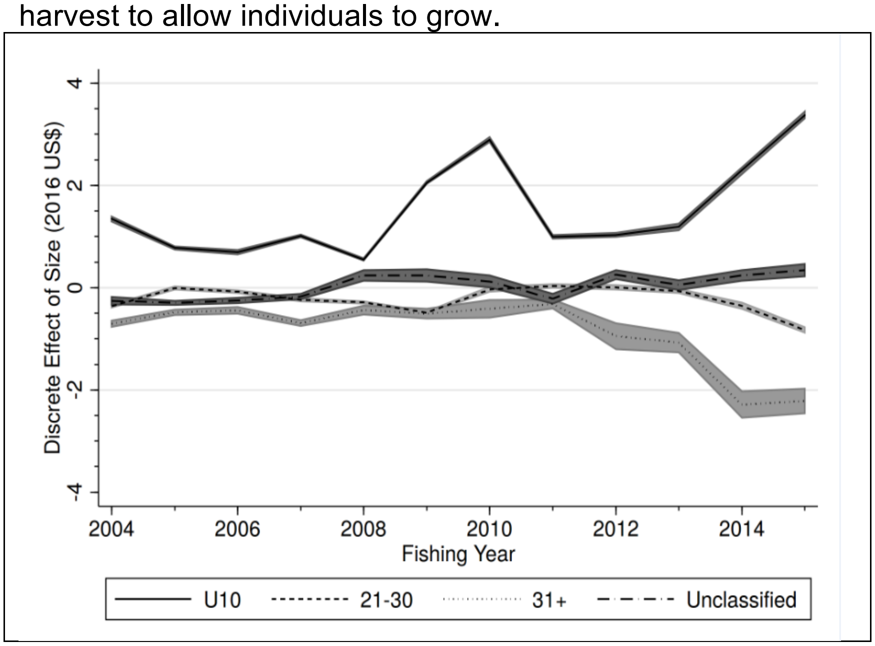

Figure 1: Price premia (lines) and 95% confidence intervals (ranges) relative to the 11-20 scallop size category over the twelve year study period

Marine Protected Areas as a management tool: linking goals across fisheries

Peter J. Auster

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Spatial management approaches have been used in multiple fisheries to enhance survival and growth as well as minimize mortality of targeted species. This presentation will review and synthesize the scope of MPA benefits and link elements of species interactions – that mediate productivity of fished species – with fisheries goals. Our current understanding based on empirical studies will identify information needs that could improve predictions of MPA risk-benefit trade-offs. I propose a route forward to engage in approaches to harmonize fisheries and conservation goals. The Northeast US Large Marine Ecosystem will serve as a model ecosystem.

Neogene paleo-oceanography and fossil scallops of eastern North America

Richard H. Bailey

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Marine paleoclimates and North Atlantic circulation patterns of the Pliocene (c. 5.3 to 2.6 Ma) were markedly different from those that exist today. Closing of the Central American Seaway in the mid-Pliocene (c. 3.5 Ma) deflected the North Equatorial Current northward strengthened the Florida Current and Gulf Stream, and shifted sub-tropical and warm-temperate faunal provinces northward along the eastern North American continental shelf. During the Mid Pliocene Warm Interval (MPWI) (c. 3.3 to 3.0 Ma), a period of ice free conditions in Greenland and Antarctic deglaciation, sea level stood approximately 25m to 35m higher than at present. At the maximum extent of the MPWI transgression the mid and shallow shelf habitat was greatly expanded and the shoreline extended approximately to or somewhat beyond the current western boundary the present Atlantic Coastal Plain. A significant portion of this history of dramatic climatic and oceanic change is recorded in sedimentary strata of the Chesapeake Group of the mid-Atlantic Coastal Plain of Maryland, Delaware, Virginia and North Carolina and correlative (age equivalent) strata extending to northwestern and south Florida. In Virginia and North Carolina the Yorktown and Chowan River Formations, (c. 4.2 to 1.8 Ma) contain diverse and exceptionally well preserved mid to shallow shelf molluscan assemblages. The Yorktown-Chowan River sequence is comprised of shoaling upward cycles deposited during transgressive and subsequent high stand intervals followed by a low stand unconformity. Pectinids, representing both extinct and extant lineages, have distribution patterns that reflect changing oceanic conditions, are extremely common, and were important members of the paleocommunities, often comprising a dominant portion of the molluscan biomass.

The robustly ribbed genus *Chesapecten* (*C. jeffersonius*) not only represents the first fossil described and illustrated from America, but is also the most useful index fossil in the Chesapeake Group. Species of *Chesapecten*, ranging from Delaware to south Florida, are only known from the western Atlantic and the genus did not survive the regional molluscan mass extinction at the end of Yorktown deposition. Species of *Argopecten* and the morphologically similar and related(?) genus *Carolinapecten* are abundant in shallower shelf assemblages. The lineage *C. eboreus* – *C. bertiensis* is found in the Yorktown and Chowan River Formations, respectively. *Carolinapecten* did survive the lowstand at the end of Chowan River deposition but became extinct later in the Pleistocene. Deeper mid-shelf to outer shelf strata of the latest Miocene Eastover Formation and the Sunken Meadow Member of the lower Yorktown Formation were deposited in cool temperate conditions and contain the *Placopecten principoides* – *P. clintonius* lineage. These are the oldest known species of *Placopecten*, a taxon that does not occur in any other exposed Pliocene deposits. *Placopecten clintonius* is certainly the direct ancestor of *P. magellanicus* as they are morphologically very similar so the lack of a fossil record is most likely due to non-preservation of strata in northern parts of its range. A less common thin-shelled pectinid, *Chlamys* (or *Placopecten*?) *decemnaria* co-occurs with *Chesapecten madisonius* and both species become extinct during the lowstand after Yorktown deposition.

Inimical effects of *Dinophysis caudata* on Japanese and noble scallops: a comparative study

Leila Basti[1], Riyoji Matsushima[2], Toshiyuki Suzuki[2], Satoshi Nagai[2]

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Several species of the genus *Dinophysis* are responsible for the widespread contamination of shellfish with diarrhetic shellfish toxins (DST), oakdaic acid (OA) and dinophysistoxins (DTX) responsible for the diarrhetic shellfish poisoning (DSP) in humans. Mollusc bivalves are known to accumulate DST at differential rates and are not known to be affected by DST toxins; however, there are practically no studies that have explored the potential subtle effects of *Dinophysis* spp. on bivalve molluscs. In the present study, adult Japanese scallops, *Patinopecten* (*Mizuhopecten*) *yessoensis* from the northern island of Hokkaido, and noble scallops, *Mimachlamys nobilis* from the western Prefecture of Mie, were fed a daily ration of a clonal culture of a strain of *Dinophysis caudata* isolated from western Japan and producing only the lipophilic toxin PTX-2.

The dinoflagellate *Dinophysis caudata* induced several behavioral alterations (hypersecretion of mucus and pseudofeces, retraction of the mantle and tentacles, reduced response to physical stimuli, reduced to suppressed escape response), paralysis then death in both Japanese and noble scallops, with higher sensitivity and mortalities observed for *P*. *yessoensis*. Scallops that have survived the one-week feeding experiments showed several pathological alterations, ranging from inflammatory responses to hemorrhage. In Noble scallops, the gills, hepatopancreas, stomach and intestines were affected. In Japanese scallops, in addition to the same organs affected in noble scallops, the labial palps and mantle showed pathologies. The most severe pathologies were observed in the intestines of both Japanese and noble scallops, and included necrosis and epithelial desquamation. In the intestine of Japanese scallops, neoplasia was also observed. Alterations in the oxidative enzymes in the hepatopancreas of both noble and Japanese scallops, with increased activity of the glutathione-*S*-transferase (GST) and glutathione peroxidase (GPx) showed that *D*. *caudata* induced oxidative stress in the scallops. These results are the first report of lethal effects of a *Dinophysis* species on bivalve molluscs, independent from conventional DST. Further research is being conducted to better understand the mechanism of toxicity of *D*. *caudata* in scallops.

Genetic differentiation between natural and cultivated *Argopecten purpuratus* populations and its association with their physiological performance and stress response

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The scallop, *Argopecten purpuratus*, is a resource of economic importance for fisheries in Peru and for aquaculture in Chile. This species is distributed from Piura, Peru to Coquimbo, Chile. Because *A. purpuratus* live preferably in semi-closed bays, their populations present discontinuous distributions and thus they are exposed to environmental factors of different magnitudes and frequency of variation. There are few natural populations of *A. purpuratus* in Chile, most of them located in the extreme north of the country (e.g., Arica) and its exploitation has been prohibited for 30 years. On the other hand, the main *A. purpuratus* population in Chile (located at Tongoy Bay, Coquimbo) has been cultivated intensely during the last 30 years without adequate genetic management. Over recent years, this population has experienced several massive mortalities, presumably associated with increasing temperature and hypoxia events. In this study, genetic differentiation between the cultivated *A. purpuratus* population from Coquimbo and a natural population from Arica were evaluated. Although the Arica population is the most northern *A. purpuratus* population in Chile, it is located near the center of distribution of this species. In order to evaluate genetic differentiation between both populations, 12 microsatellites were analyzed for their allele frequencies, number of alleles, and allelic richness per locus. Moreover, the effect of environmental stressors (hypoxia and hyperthermia) on metabolic rates [standard metabolic rate (SMR) and aerobic scope] and transcriptional levels of genes associated with cellular stress (*Cu/Zn-SOD* and *HSP70*) were also evaluated in *A. purpuratus* individuals from Arica and Coquimbo grown in a common garden in Tongoy Bay. The factorial stress experiment consisted of a partially nested design with temperature levels (14 °C and 20 °C) as blocks and conditions of oxygen availability (normoxia and hypoxia) crossed with the population factor (Arica and Coquimbo) within each block ($n = 20$). Results showed a strong genetic differentiation between *A. purpuratus* populations of Arica and Coquimbo (F statistics, $P < 0.01$). Scallops from Arica showed higher SMR than scallops from Coquimbo. Furthermore, the former were capable of maintaining their aerobic scope in face of the temperature increasing at both normoxia and hypoxia. Meanwhile, scallops from Coquimbo had a strong decrease in their aerobic scope under the same conditions. Interestingly, under high stress conditions (i.e., hypoxia + 20 °C), only Arica scallops over-expressed *Cu/Zn-SOD*, whereas Coquimbo scallops over-expressed just *HSP70.* This suggests that *A. purpuratus* from Arica may be better suited for decreasing oxidative damage, and together with their aerobic scope, this population could be better adapted to respond to stress conditions than the Coquimbo population. These would support the central distribution hypothesis that proposes a better biological performance of populations located in the center of the species distribution. These results also could partially explain massive mortalities of Coquimbo scallops when faced to high stress conditions.

Developing a genetic toolkit to detect and quantify sea scallop spawning events

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The sea scallop (*Placopecten magellanicus*) is one of the most valuable commercial species harvested in the northwest Atlantic. As a broadcast spawner, the sea scallop releases gametes into the water column where fertilization occurs. Previously, spawning events have only been detected in retrospect by evaluating changes in gonad mass over weeks. Detecting daily spawning activity by sampling for gametes is extremely difficult, and even then it is nearly impossible to visually distinguish scallop gametes from those of other bivalves. Here we describe a proof of concept study demonstrating the use of a molecular probe we have developed to detect and quantify scallop DNA in near real time from field samples.

The main objective of this project was to develop a quantitative real-time PCR (qPCR) survey technique as a quick and reliable way to detect scallop sperm in plankton samples. The method included: (1) selecting and sequencing a region of the scallop genome, (2) developing a probe and primer set to detect this region, and (3) testing the developed probe and primer set on a dilution series of scallop sperm and eggs to quantify the relationship between number of cells and DNA copy number.

To develop the probe and primer set, the transcribed spacer (ITS) region, a non-coding segment of DNA located between the genes coding for the small and large subunit ribosomal RNA was targeted. The probe and primer set worked successfully, and to our knowledge this is the first time this segment of the *P. magellanicus* genome has been sequenced.

Dilution series revealed a clear relationship between DNA copy number and independent sperm cell counts, indicating potential for this method detect and quantify male spawning events *in situ*. Pending future field tests, this method might be used to map and quantify population-level scallop reproductive activity at considerably higher temporal and spatial scales than have been achieved to date.

When too many scallops complicate spatial management: density-dependent mortality and its impact on rotational closed areas

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Extremely high recruitment events of the Atlantic sea scallop (*Placopecten magellanicus*) have resulted in an unprecedented number of areas with exceptionally high scallop densities. There is no comprehensive understanding of how these densities will alter scallop growth or mortality, complicating the rotational management strategies employed in the in the U.S. and Canadian fisheries. This is exemplified on Browns Bank where two temporality closed areas, approximately 7 km apart, with extremely high densities of scallops exhibited different patterns of population change based on drop camera survey results from 2013-2016. In one area, as expected, density decreased as scallops grew and exploitable biomass increased. In the other area density and exploitable biomass sharply decreased and growth was not observed, indicating a mass mortality event. The primary difference between these two areas was much higher initial densities of scallops in quadrat samples (≈ 3 m^2 areas) from the area with the dramatic loss. Paired comparison revealed that these quadrats were contained in the survey stations that had the largest declines in scallop densities. Visual examination of images from these quadrats also indicated high mortality (Figure 1). This appears to be an example of density-dependent or carrying capacity related mortality in a wild scallop population, suggesting this area could have been opened to fishing earlier. Further studies to better understand the growth and mortality rates of scallops in high density areas could help adapt spatial management strategies to optimize harvest.

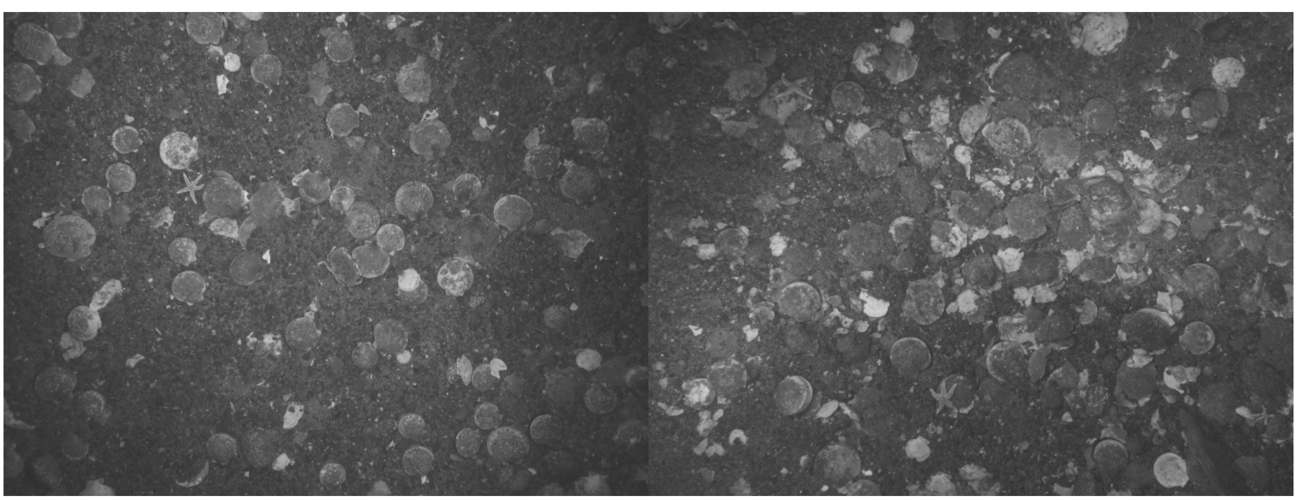

Figure 1. Images from Browns Bank taken in 2015 (left) and in 2016 (right). The image locations are about 20 m apart and in 2016 clappers and much more shell debris is present, indicating scallop morality.

Can rights-based management increase the economic and environmental efficiency of a scallop fishery?

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Ramsey Bay is a small, but important, traditional fishing area for king scallops (*Pecten maximus*) that is located on the north-east coast of the Isle of Man. In December 2009, the Bay was closed to scallop fishing following concerns raised by the local Manx Fish Producers Organisation (MFPO) about overfishing and the future economic viability of the Bay. The area was subsequently designated as a Marine Nature Reserve (MNR) integrating five discrete zones (1. Conservation Zone, 2. Horse Mussel Zone, 3. Eelgrass Zone, 4. Fisheries Management Zone (FMZ), 5. Rocky Shore Zone) each with its own level of protection and management. In 2013 the MFPO was issued a statutory five year licence (2013 – 2017) for harvesting king scallops from within the FMZ. This provided a novel situation where local industry, supported by scientific advice, was given a level of exclusivity and security of tenure to fish the area for king scallops. As part of this, the responsibility for strategic decisions on when, where and how much to fish within the FMZ was transferred to the MFPO, with support from government. In Year 1, following scientific advice the MFPO adopted a cooperative harvest strategy with 3 vessels fishing the Total Allowable Catch (TAC) and a dividend paid to each active MFPO member. In Years 2 and 3, the MFPO decided to adopt a rights based approach where each member was given a proportion of the TAC to catch directly or to fish cooperatively with another vessel.

Although it is too early to ascertain the long-term effects of the rights based management regime implemented in Ramsey Bay FMZ, there have already been significant short-term benefits. As the resources in the Bay have recovered, the TAC (and associated profit share) has increased annually with the overall fleet gross profit increasing from £63,144 to £104,356. The secure tenure of the lease to fish has allowed local industry the flexibility to alter the timing of the harvest to best optimise financial returns with an additional £4.00 kg/meat from harvesting in December rather than May which equates to an average of approximately £23,000 a year in additional gross profit. In terms of environmental efficiency, the results of annual resource surveys enable industry to target high density areas of scallops and leave areas with low scallop density or sensitive habitat unfished, while still contributing to reproductive output. This results in an efficient harvest strategy with an average of only 2.7% of the area of the FMZ impacted by fishing activity in a given fishing season, and appears to have maintained recruitment. Other indicators of environmental efficiency such as fuel use intensity, greenhouse gas emissions and edible protein energy return on investment also compare very favourably to values calculated for the island-wide king scallop fishery.

Initial results from Ramsey Bay indicate fisheries and conservation benefits from providing clear ownership and security of rights to local industry for a defined fishery and fishing areas. The secure tenure (licence) affords industry the security and flexibility to implement management measures that provide significant increases in both economic and ecological efficiency when compared to open access scallop fisheries.

Comparing sea scallop density and shell height distributions with advancing drop camera survey technology

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Recently there has been a push to implement high-resolution imagery in scallop surveys to improve detection of Atlantic sea scallops, *Placopecten magellanicus*, in the wild. While various surveying techniques have been implemented in stock assessments, high resolution cameras have been successful in accurately identifying recruits in areas with low visibility. Using high-resolution images from two surveys in the Nantucket Lightship Closed Area on Georges Bank we will compare the mean density of scallops per meter square in 10 mm shell height bins for three different cameras of varying resolutions (1) Kongsberg OE14-408, (2) Imperx Bobcat B6620, and (3) DeepSea Multi-SeaCam MSC 2060 (Figure 1). Images for each camera will be analyzed in the lab by technicians using specialized software to digitize the video footage and high resolution pictures. A dot will be placed over each identified scallop to gain an accurate count per quadrat. Once the images are processed and have undergone a quality assurance check, visible scallops will be measured from the hinge to the top of the shell using software correctly calibrated for each of the three cameras. Measurements from each camera will be used to determine counts of juvenile (<70 mm) and adult (>70 mm) scallops. Estimates for density and standard error will be calculated using a 2-stage sampling design in which each station contains 4 quadrats. The estimates for each of the camera will be compared only for the stations where the survey footprint had overlapping coverage. The results from this research will show if the addition of a high resolution camera will (1) increase our ability to detect new recruits. Having a better understanding of scallop mortality and growth throughout their entire life will provide better insight into scallop biology throughout a wider range of size distributions (2) provide more accurate estimates for biomass, growth, and mortality; (3) enhance our understanding of scallop population dynamics.

Figure 1. The image on the left depicts a high density of scallops taken with a 6K resolution camera while the image on the right shows a high density of scallops taken with a standard definition camera.

Rebuilding the stock: increasing social, economic, and biological capacity o Maine sea scallop fishery

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The Maine sea scallop (*Placopecten magellanicus*) fishery was formerly a valuable fishery providing a substantial source of income to fishing businesses and coastal communities during winter months. At its peak, the fishery landed over 3.8 million pounds of scallop meats in 1981 valued at $15.2 million. Since that time, the fishery has experienced decline, reaching an all-time low in 2005 with 33,141 meat pounds being landed, prompting the Maine Department of Marine Resources (ME DMR) to initiate a forward-thinking management approach to rebuild this once robust fishery.

Working closely with the industry-based Scallop Advisory Council through a co-management approach, ME DMR set out to rebuild a sustainable resource that would provide stable economic opportunities to coastal communities. Increasing the social capacity amongst diverse industry members across the State was critical to ensure that harvester knowledge and input were incorporated into the rebuilding strategy.

Since 2005, the ME DMR, the management framework has evolved to include a 4" minimum shell and ring size, daily limits, limited fishing days, a prohibition on nighttime fishing, a requirement for the immediate liberation of sublegal scallops, and spatial management. The combination of these conservation measures appear to be effective as demonstrated by 452,672 meat pounds being landed. At a historical high of $12.70/lb., the overall value of the fishery has increased to $5,749,209, primarily due to the increase in Yield Per Recruit (YPR). Larger, older scallops produce highly valuable under-10 (U10) meats per pound, a market category product which is keenly sought after by white tablecloth restaurants and markets (Figure 1).

Figure 1: A U10 scallop, landed from the Lower Blue Hill Rotational Area. This area had two full years of rebuilding prior to re-opening for harvest in the 2016-17 fishing season.

Maine scallop aquaculture development initiative, community development through international tech-transfer

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Maine based Coastal Enterprises, Inc. (CEI) a private, nonprofit Community Development Corporation (CDC) and Community Development Financial Institution (CDFI) recently organized and led a group of Maine commercial fishermen and aquaculturists on a trip to Aomori, Japan to learn about their scallop aquaculture industry. Japanese scallop enhancement and culture dates back to the 1930s. Japan produces ~500,000 metric tons of scallops per year with Aomori ranking 2nd (to Hokkaido) in scallop production for all of Japan producing ~90,000 metric tons of scallops annually. The recent exchange between Maine and Aomori was conducted over a two week period in October of 2016. Photos from the trip will be shown during the session to highlight the annual Japanese scallop aquaculture production cycle, various grow out techniques including spat collection, pearl nets, lantern nets and ear-hanging. Long line system setup, equipment, vessels, fishing cooperative structure and scallop products will also be discussed. In recent years CEI has built a relationship with a manufacturer of specialized equipment located in Aomori to handle high volume aquaculture production. CEI is in the process of purchasing equipment to test the feasibility of the ear-hanging technique for growing Atlantic sea scallop (*Placopecten magellanicus*). Commercial production trials are set to begin in Maine during the summer and fall of 2017. The goal of the project is to test Japanese machinery on Atlantic sea scallops, determine financial feasibility and ultimately begin growing Atlantic sea scallops commercially in Maine waters.

Adoption of Japanese scallop culture technologies in the development of an Atlantic sea scallop (*Placopecten magellanicus*) aquaculture industry in Maine, USA

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Over the past fifteen years, there has been growing interest in culturing Atlantic sea scallops (*Placopecten magellanicus*) in Maine. While early efforts have focused on wild spat collection methodologies, in recent years, researchers and entrepreneurs have developed suspension culture methods adaptable to Maine environmental conditions including net, cage and ear-hanging technologies. Concurrent with these efforts has been a burgeoning relationship with members of the scallop industry in Maine's Japanese sister-state of Aomori Prefecture. Since 1999, three delegations of Maine seafarmers have visited scallop farms, processing and research facilities, and equipment manufacturers in the Mutsu Bay region to better understand and adapt the technology for net and ear-hung culture of Japanese scallops (*Patinopecten yessoensis*). Key to the successful development of this industry has been the mechanization of labor-intensive handling processes. Through a series of short video clips, this presentation will highlight the machinery and processes being adapted to the Maine scallop farming industry including size grading, removal of biofouling organisms, pearl nets and ear-hanging growout systems.

Passing through: the effects of increasing the inter-ring spacing of a sea scallop dredge apron on by-catch

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Large sea scallop (*Placopecten magellanicus*) recruitment events in scallop rotational access areas can create a situation where high densities of pre-recruit scallops are found amongst commercially viable densities of harvestable scallops. Under these circumstances there is a real likelihood that recruitment overfishing could occur as a result of high discard mortality associated with thermal shock and desiccation. Modifications to the scallop dredge bag configuration to increase the selectivity could reduce the impact of fishing effort on pre-recruit scallops while allowing for the harvest of commercial sized scallops. By using two links rather than a single link to connect the rings of the apron together, the inter-ring spacing can be increased both vertically and horizontally altering the selective properties of the dredge bag. Preliminary analysis of the data collected during four research trips, one of which utilized a non-selective dredge bag, indicates that this configuration has the potential to reduce the by-catch of pre-recruit scallops as well as elasmobranchs and finfish. Development of methodologies like the use of a dredge cover net to better determine the efficacy of this and other modifications will be also discussed.

Opportunities for developing purple-hinge rock scallop aquaculture on the U.S. west coast

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Many shellfish farms on the US west coast cultivate a diverse assemblage of species. Oysters and clams, including geoducks, are commonly grown together in order to stabilize annual revenues. Opportunities to economically cultivate a new species for aquaculture require a good understanding of critical bio-economic parameters. A viable shellfish industry in the United States is important to help maintain rural economies that are dependent on marine resource development, and diversification in shellfish aquaculture can assist significantly with maintaining working waterfronts.

The purple hinge rock scallop, *Crassadoma gigantea,* offers an emerging opportunity for shellfish farmers on the North American west coast. Rock scallops are large (up to 25 cm in SL), cementing scallops that are native from southeast Alaska to Baja, Mexico. The large size of the adductor muscle at maturity, relatively rapid growth, and wide natural distribution make it an excellent candidate for aquaculture development, especially in mid to southerly latitudes within its range. Larval rearing techniques are relatively well established. Larval scallops thrive on a standard larval rearing method that includes diatoms (*Chaetoceros* spp.), flagellates (esp. *Pavlova* spp.) and the red algae, (*Rodomonas salina*) in the diet. The major bottleneck to commercial viability lies in reliable production of seed 4-6 weeks past the settlement stage. Rock scallops have a protracted period of metamorphosis where feeding on suspended material does not commence for 2-3 weeks post settlement. Juveniles remain very sensitive to disturbance with most mortalities occurring during this phase of culture. Once 3-4mm SL, scallops grow rapidly but remain sensitive to density. Growout of juveniles in pearl nets is optimized at densities of 400 scallops per M^2 until about 30mm SL. Scallops initiate cementation at this size, and juveniles must be regularly handled to prevent significant cementation into the gear until approximately 50mm SL. Growout to a marketable size (120mm SL) is projected to take 36-40 months based on research on size at age for scallops currently maintained in several Puget Sound locations (Figure 1).

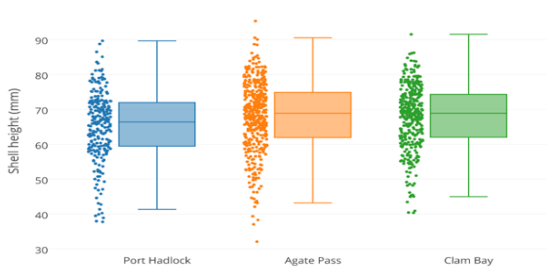

Figure 1. Size at age after 24 months in rock scallops for three Puget Sound locations.

Critical research to assess biotoxin uptake, retention and detoxification in rock scallops is underway. Triploid development for the rock scallop is also in development with the intent to assess relative sterility on production characteristics. Technologies to accommodate the behavior associated with the cementation stage for rock scallops will be discussed, as well as general prospects for developing rock scallop aquaculture on the US west coast.

Developing a new fishery for *Ylistrum balloti* in New Caledonia

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A resource of saucer scallops, *Ylistrum* (*Amusium*) *balloti* was first identified by divers in the New Caledonia Grande Lagoon in the late 1970s. The distribution and extent of the resource was established in a series of trawl surveys in the period 1987-1991. These surveys indicated that a population varying between 1200 and 3000 tonnes (whole animal weight) existed in the area between 19°20'S and 20°05'S within the waters of the Grande Lagoon. This area covers almost all of the water depths in the Lagon between 35 – 55 m, which is the normal depth range for this species.

A partnership between a Queensland-based consortium, the New Caledonia Northern Province government and the people of Belep, an island community from northern New Caledonia, developed a short-lived fishery for the species between 1995 and 1998. The fishery collapsed when a manager absconded with the joint venture's operating funds.

The resource remained untouched until February 2016, when a second consortium which included an investment arm of the Northern Province government, the Belep community and a Western Australian fishing company supported a detailed survey of the resource and examined by-catch that may have been taken in a fishery. The survey established that a resource of approximately 3000 tonnes existed in the area area bounded by 19°25'S 163°20E - 163°50E and 19°58'S 163°42E – 19°49'S 164°02'E. By-catch to scallop ratios in areas where commercially viable concentrations of scallops existed averaged 0.135:1, which is much lower than seen on equivalent grounds in Australia. The by-catch was dominated by fish, with one species (*Nemipterus peronii*) making up about 70% of the entire by-catch.

A 6 week fishery took place after the survey, and is being developed for a February 2017 re-opening. The fishery is remarkable both for the level of *a priori* information about the resource and for the nature and detail of management arrangements. It is subject to an annual pre-season survey, a quota (no more than 50% of B_0), limited entry (a single boat), mandatory use of TEDs and by-catch reduction systems and on-going catch reporting. A skill transfer / training program for the young people of Belep is an integral component of the development. The fishery has the potential to be a valuable source of employment and training for a remote community with little other access to local employment.

The most obvious threat to the future of the fishery is the impact of increased water temperatures. There has already been one well recorded case of a population collapse in the Western Australian distribution of the species triggered by a warm water event, and suggestion that the Queensland population is under stress, possibly through warming water.

The Irish Sea queen scallop (*Aequipecten opercularis*) fishery: a cautionary tale

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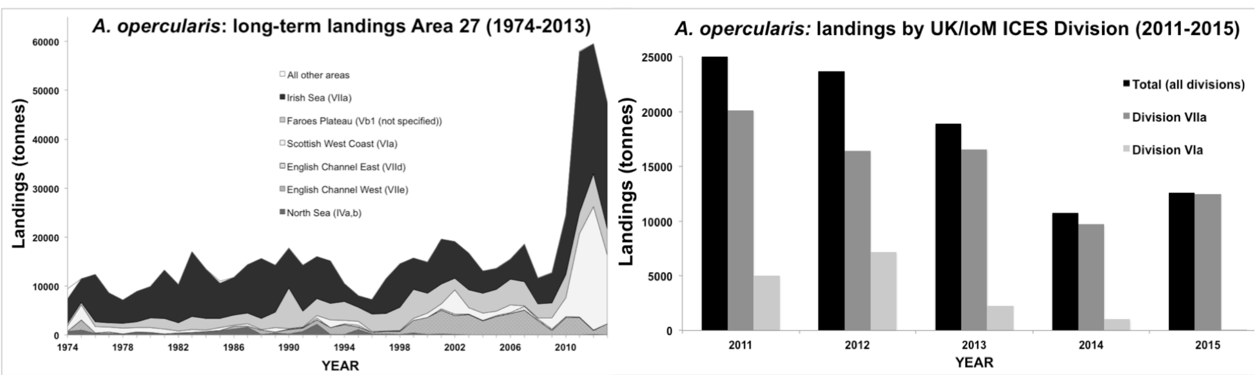
The queen scallop, *Aequipecten opercularis* is distributed from Norway to North Africa and the Mediterranean, supporting a £6m UK fishery centred on ICES divisions VIIa (Irish Sea) and south-eastern VIa (Northern Ireland/West Scotland) (within UN fisheries area 27). Between 2010 and 2012 total landings were significantly above long-term averages, but have since declined. The Isle of Man territorial sea has been particularly important for this fishery, but a well-documented stock biomass decrease, demonstrated since 2010 (Bloor 2016; Duncan *et al*. 2016), has subsequently resulted in reduced fishery revenue, significant and restrictive management measures and, to date, very little evidence of stock recovery.



Since mid-2013 the main UK scallop fishing industry organisation has requested improved management in Areas VIa and VIIa, and the UK and Isle of Man fisheries administrations have undertaken an extended process of evidence gathering and established a multi-stakeholder working group to develop options and processes.

In May 2016 a voluntary fishery closure was introduced by industry, broadly coinciding with the main spawning and settlement period. This was observed successfully, but temporary displacement to other grounds and no mechanism to reduce subsequent effort suggests limited actual benefit to Irish Sea stocks. However, the introduction of some regulation initiated by fishermen themselves may be seen as a positive step. In October 2016 a two-month public consultation process was launched, seeking views on a range of potential management options including: increasing MLS, closed seasons, limiting vessel numbers, effort reduction, quotas, closed areas and gear-specific management. Activity in 2017 will likely focus on progressing some of these options.

For the fishery, the central problems include; uncontrolled capacity and effort, lack of stock assessments and fishery-independent data and lack of management leadership, complicated by multi-jurisdictional issues. From initial request to the introduction of any formal fisheries management action may well be more than 4 years. 'Boom and bust' scallop fisheries are still a distinct possibility, despite local and international precedents.

Estimating Atlantic sea scallop (*Placopecten magellanicus*) incidental mortality through before-after-control-impact surveys

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After several decades of stock decline, the Atlantic sea scallop (*Placopecten magellanicus*) fishery is one of the most valuable in the United States due in part to the implementation of new management measures in 1994. The continued sustainability of the fishery is dependent on catch limits determined by yearly stock projection models. Incidental mortality is an important term in sea scallop stock projection models, but is historically difficult to measure. Current estimates are derived from experiments that relied heavily on qualitative observations and as a result lack precision. To better estimate incidental mortality, a Multiple-Before-After-Control-Impact (MBACI) experimental design was used to measure the effect of scallop dredging on the disposition of sea scallops that remain on the seafloor following dredging. An autonomous underwater vehicle (AUV) was employed to collect color photos and side-scan sonar images of the seafloor before and after controlled dredge treatments in the Mid-Atlantic and Georges Bank regions. Approximately 170,000 photos were annotated for instances of dredge-induced mortality. It was found that 2.5% and 8% incidental mortality for the Mid-Atlantic Bight and Georges Bank sites, respectively, a difference that is likely attributable to the relatively harder substrate of the scallop habitat on Georges Bank resulting in greater physical trauma. This study provides a quantitative estimate of incidental mortality using a precise and noninvasive platform. The spatial scale and distribution of the study sites are broader relative to past studies and represent the two principal stocks of the sea scallop resource. These results are lower than the incidental mortality values currently used in fishery stock models and suggest the existing values are conservative, but appropriate estimates.

COMANCHE Project: Ecosystem interactions and anthropogenic impacts on king scallop (*Pecten maximus*) populations in the English Channel

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The king scallop, *Pecten maximus,* constitutes the first landed species in terms of tonnage and the second or third one in terms of value for the French fisheries. More than 90% of these landings come from the English Channel indicating that its exploitation is essential to local fleets. The COMANCHE project (Ecosystem Interactions and anthropogenic impacts on king scallops populations in the English Channel) proposed to improve the knowledge of the scallop within the Channel, through an ecosystem-based approach for fisheries, appealing to a wide range of scientific disciplines (physics, chemistry, genetics, ecology, geostatistics, modeling, economics). Research on spatial location of scallop beds, connectivity by larval dispersal between beds, life history and recruitment variability, dynamics of plankton communities and determinism of toxic algal blooms, position in the food web, development of invasive species like the American slipperlimpet, impact of dredging on seabed and analysis of the main market supplies for this species have been conducted. The project goal was to contribute to a sustainable development of a fishery, supported by government, local authorities and stakeholder associations.

According to the research activities, different conceptual approaches and tools, as numerical modeling methods, mapping, molecular biology techniques, use of genetic markers, laboratory cultivations of algae have been used. For this, the COMANCHE project was built on the use of *in situ* data, but also on biological data time-series collected during scientific sea surveys conducted for more than 30 years by IFREMER or on data collected during the project. Data coming from the declarative flow (fisheries statistics) of fishing vessels have also been used.

A connectivity map between the different scallop populations has been proposed, highlighting three major functional units (Bay of Seine, Normand-Breton Gulf and Southwestern coast of England). It was shown that the influence of the sea surface temperature and related climatic indexes could explain inter-annual fluctuations of recruitment for the stock in the Bay of Seine, probably because of the role of temperature on gametogenesis and early life stages. Significant progress has been made in understanding the emergence of harmful algal blooms which affect the scallop fisheries. Over 70 strains of 4 species of *Pseudo-nitzschia* were isolated from samples taken in the Bay of Seine and kept in culture. A biochip for rapid identification of different species of *Pseudo-nitzschia* was developed and could be used for biomonitoring of toxic phytoplankton. An ecosystem model coupled with a biogeochemical model and a population dynamics model were developed for English Channel scallop populations. The economic analysis of fisheries raises the question of the adequacy of management measures and the operation of the market in a global context.

The project shows a strong scientific production (28 papers/books and 52 communications) and a positive media coverage (38 requests in press or broadcasting, from local to international).

Dynamics and trends of king scallop (*Pecten maximus*) fisheries in the English Channel from 2000 to 2015

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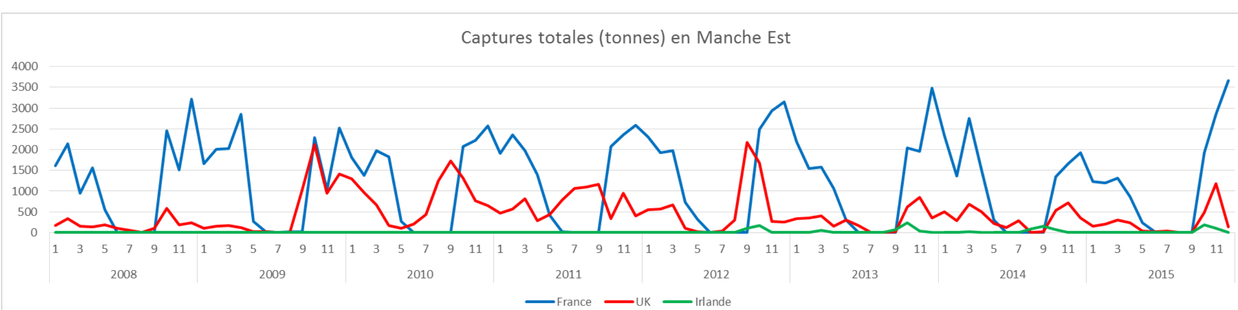
King scallops (*Pecten maximus*) fisheries in Western Europe were considered as inshore fisheries for some time, only relevant from the UE Member States concerned. Thus, these fisheries are not managed under UE regulations, but only under local regulations. It is clearly the case for French fisheries, which are managed by a mix of national, regional, and local regulations. Some of them have really constraining measures, such the global fishing closure during breeding period for scallops, from the 15th of May to the 1st of October, for all fishermen targeting king scallop all over the French coasts. Technical measures, as the 92mm inside diameter for dredge rings or limitation of number, length and power of boats, complements the French management system. But this management system driven by French laws is not applicable to fishing boats from other UE countries. In UK, apart from the European minimum landing size (11cm in ICES VIId division), no management rules are applied.

On the French side of the Eastern English Channel, this management system works as long as most of the king scallop fishers were French boats. Recently, opportunistic UK fishing boats coming from Scotland started fishing king scallops in inshore waters, just outside the 12 miles French territorial waters limit at the end of summer (August and September) when the fishing season is still closed for French fishers. Socially, this situation caused and continues to cause conflicts between fishermen and is leading to an overfishing situation.

After reviewing the French management system, the economic dependence on king scallop for the French fishermen based all along the Eastern English Channel coast will be shown. The history of the fishery from 2000 to today, the recent trends of landings (France, UK and Ireland) and effort, the main fishing areas concerned, and the seasonality of the fisheries will be presented and potential solutions proposed for the future.



Total landings in the Eastern Channel from 2008 to 2015.

Decline and stability in New Zealand scallop fisheries

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New Zealand scallop fisheries are important to some fishing communities, but are relatively small on a world scale. Annual commercial landings of scallops have averaged around 100 tonnes meat weight per year over the past 5 years, with non-commercial (recreational and customary Maori) catches of around 180 tonnes green weight per year. Most catch is of the fan scallop (*Pecten novaezelandiae*), with only minimal catches of queen scallops (*Zygochlamys delicatula*).

All of the New Zealand scallop fisheries are managed within a commercial quota system, however, and for historical and other reasons the rules and strategies that apply to each fishery are different.

The historically largest fishery at the top of the New Zealand South Island has been notable for innovative industry-led management and an intensive enhancement programme since the late 1980s. A high, non-constraining, commercial quota limit applies, with many roles in the annual decision-making process led by industry; however, the fishery has declined dramatically over the last 15 years from a catch of around 540 tonnes meat weight to the point where it was closed last year by the government to all fishing sectors to protect the remaining scallop beds.

Work is underway to better understand and address the drivers of this decline (discussed by Willams et al at the 20th International Pectinid Workshop), and fisheries managers, scientists, industry and other stakeholders are working on a long-term package of management changes for the fishery.

Other main scallop fisheries are at the top of the North Island of New Zealand. A constraining commercial quota limit applies to these fisheries, and they have generally been fished at lower exploitation rates. A greater spatial area has also been set aside for non-commercial use in these fisheries. Possibly as a result of these factors, catches have generally been more stable in these fisheries.

Successful use of long-term monitoring data to predict and manage a recreational scallop fishery perturbation

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The adult abundance of bay scallops (*Argopecten irradians*) in Florida estuarine and coastal Gulf of Mexico waters have been monitored continuously since closure of the commercial fishery in 1994 (adult surveys). Juvenile settlement rates have been monitored since 1997-98. The data are used to inform management of the recreational fishery.

The Florida population consists of fragmented subpopulations in approximately 16 discreet locations with varying levels of interaction through larval transfer. The westernmost Florida panhandle bays appear to only be populated sporadically, and are not likely self-sufficient at current densities. St. Joseph Bay, a semi-enclosed basin located at the mid-point of the panhandle, has traditionally been one of the most stable and resilient subpopulations. There is a weak, but positive, relationship between the number of juveniles settling to spat traps (primarily November – January) and the number of adult scallops observed in pre-season abundance estimates (June).

In the Fall of 2015, a red tide consisting of *Karenia brevis* impacted the bay for the entirety of the spawning season, resulting in a severe decline of the 2015-2016 recruit class. The recruit-stock model predicted very low adult abundance, so biologists informed management that sustainable levels would be unlikely during the summer 2017 season, resulting in a poor harvest and carrying the potential for collapse of the sub-population. Loss of the summer scallop industry could have profound economic effects on the local economy. The agency conducted a series of public workshops to a) inform the local government and public of our concern and b) allow the tourism industry time to prepare and adjust their marketing strategy. Subsequent surveys confirmed the concerns and management actions were recommended: a drastically reduced season and catch limit. The public was overwhelming supportive, including collection of 2700 broodstock with the assistance from volunteers. The scallops were placed in a legally protected spawner sanctuary within the bay. Survival of those scallops was excellent, and preliminary fall data suggest at least a modest rebound in settlement has occurred in 2016-2017.

Valuation of scallop beds along the Norwegian coast – what have we learned so far?

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A national program mapping marine habitats along the Norwegian coast has been ongoing since 2007, and will finish in 2019. The Institute of Marine Research, Norwegian Institute of Water Research and Geological Survey of Norway are responsible for the mapping and valuation of ten different marine habitats regarded as important in the coastal zone. The habitats are as varied as large kelp forests, ice marginal deposits and soft sediments in the littoral zone. In addition, some species in key habitats are included like the great scallop *Pecten maximus*, Iceland scallop *Chlamys islandica,* and European flat oyster *Ostrea edulis*. Large scallop beds with high abundances have a value, not only as fishing grounds but also in their ecological function of coupling the benthic and pelagic zone. Both *Pecten maximus* and *Chlamys islandica* have a patchy distribution and while the presence of the great scallop is strongly associated with shell-sand deposits the Iceland scallop is associated with sloped hard bottom (a combination of rock, pebble and coarse sand) in high current areas.

Methods of mapping the habitats are diverse, such as aerial photo, grab samples, video records, plankton collectors, bathymetry analysis and school projects. The combination of a long coast line (100 000 km including the mainland coast and islands) with highly heterogenous bottom topography and sediment types over short distances, makes habitat mapping a challenge.

The scallop beds are mapped using a vessel-towed camera platform collecting real-time video along survey lines. The scallop beds are given a value based on the density, age distribution and size of area. The value is categorized as A, B and C, where the A and B areas are the largest areas with high densities and are considered important on a national and regional scale, while the C areas are smaller and are considered important on a local scale. The information is registered in a data base, “Naturbase”, where the local authorities can use the habitat maps for coastal management. Only the A and B areas are mandatory to register.

As there is a growing pressure on coastal ecosystems from human activities, managers and policy makers need information to make sound management decisions and protect important habitats; however, giving value to an area also creates a dilemma for both scientists and authorities – what is most important when for instance considering an application for a new harbor or a new aquaculture facility? Our experience is that C areas get very low protection by local planners compared to A and B areas. This raises a question about the need for additional classes in order to visualise different levels of local importance. It must be kept in mind that the maps represent a static view of a dynamic reality Abundance and distribution may change with time and seasons, thus the maps cannot replace field surveys before a decision of coastal development is taken.

Scallop muscle physiology: past achievements and future directions

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Scallops have advanced the knowledge of muscle molecular structure, muscle performance, of the metabolic underpinnings of jet propulsion, of mechanisms underlying trade-offs between reproductive investment and muscle performance. Scallops are suited for research in muscle physiology given that the basic actions of scallop swimming are achieved with few structural elements: two valves, one adductor muscle and a rubbery hinge ligament. The phasic adductor powers swimming whereas the tonic adductor maintains constant openings during filtration. The metabolic underpinnings of scallop swimming were established in the early 1980s. Scallop muscle differs from vertebrate muscle in using arginine phosphate to buffer ATP levels during contractile activity and in producing octopine as the end product of anaerobic glycolysis. In all scallop species examined, arginine phosphate powers most phasic contractions, while anaerobic glycolysis with octopine production intervenes primarily during anaerobic recuperation. Aerobic metabolism is required for full recuperation of escape response capacity. Reproductive investment reduces performance and slows recuperation after burst swimming. This trade-off is based in part on reduced metabolic capacities and in a loss of aerobic power during reproductive maturation.

Comparisons of scallops with different shell morphologies show that the intensity of phasic contractions, muscle metabolic capacities and patterns of muscle use vary with valve morphology. Smooth, hydrodynamic valves such as those of *Amusium balloti* allow swimming with continual, spaced phasic contractions that can carry the scallop up to 30 m in one bout. In contrast, heavier plano-convex valves such as those of *Pecten* species require rapid fire contractions to lift the animal off the bottom reducing the distance that can be covered during an escape response. These differing escape response strategies in turn rely upon different muscle metabolic capacities and morphological arrangements.

Since the heyday of comparative physiology has given way to an age of “omics”, it is important to consider the directions physiological studies of scallops will take. The omics age started with the genome. The need for functional understanding moved us into higher “omes”: the transcriptome, proteome, methylome and brought us to the metabolome. These impressive data collection mechanisms allow a new level of exploratory analysis, using statistical analysis to identify previously unknown target genes, RNAs, proteins or metabolites. Some of these techniques are being used to study the genetics of traits of interest for aquaculture, particularly in China but also in Chile. Molecular phylogenies have helped establish how swimming behavior and visual capacities arose in the scallop lineage, allowing scallops to become model organisms for assessing patterns of evolution of complex traits. Metabolomics are being used to study responses of scallops to ocean warming and acidification to evaluate whether such reactions can explain extinction events in geological time. Studies of scallop activity on the sea floor have become possible due to advances in video tracking. Past studies of physiological mechanisms in scallops have made strong contributions, but perhaps the best is yet to come.

What has been learned from 22 years of closures and scallop area management in the northeastern US?

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Rotational and long-term closures have been a part of the management system for the US sea scallop (*Placopecten magellanicus*) fishery since 1994. In that year, three areas on or near Georges Bank were closed to scallop and groundfish fishing. Scallop biomass in these areas tripled between 1994 and 1996, increased over 10-fold from 1994 to 1998, and over 20-fold from 1994 to 2004. Biomass in the closed areas has declined somewhat since 2004 as portions of these areas were reopened to fishing. A system of rotationally closed areas was developed in the Mid-Atlantic Bight, starting in 1998. Large increases in biomass were also observed in some of these areas during the periods they were closed. There is also evidence that these closures may have increased recruitment in “downstream” areas.

Closures can also be used to help understand the life history of scallops in the absence of fishing, and to infer the effects of fishing on scallops. Scallops in closed areas grow larger, with greater meat and gonad weights at size, compared to fished areas, likely due to selective removal of fast growing individuals by the fishery. Monitoring in closed areas indicates that the natural mortality of sea scallops remains low until about age 11 or 12, after which the natural mortality rate increases substantially.

Closed areas may not only be useful for fishery and “ecosystem-based” management, but also to help improve the scientific understanding of scallops and their benthic habitat.

At-sea discard of gray meat tissue as a vector for apicomplexan transmission in the Atlantic sea scallop, *Placopecten magellanicus*

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Scallops with small, darkened and stringy adductor muscle (gray meat) occur episodically along the eastern Atlantic seaboard, and is linked to a highly pathogenic apicomplexan parasite. This infection, which targets muscle and connective tissue, and is lethal to the scallop in severe infections is persistant on Georges Bank and has been confirmed in areas of the Mid-Atlantic region. Direct transmission of this parasite between hosts is suspected but not confirmed. Gray meat scallops are often discarded at sea and effects of returning infected tissue on the spread of the parasite is unknown.

An eight month infection trial was conducted to test if discarded gray meat tissue is a reservoir for parasitic infection. Live Atlantic sea scallops from a population not showing clinical signs of gray meat disease were collected and transported to a saltwater laboratory. Histological and molecular analysis was conducted on a subset of the population to confirm naïvety to this parasite. Scallops (n=40) were randomly assigned to one of three experimental groups; infected (exposed to tissue directly dissected from infected gray meat scallops), fresh water treatment (tissue dissected from infected gray meat scallops and treated in a fresh water bath for four hours prior to exposure) and control (no exposure to infected or treated gray meat tissue). Scallops were maintained on a live algae culture and each experimental group was monitored for number of mortalities, clinical signs of infection (meat color and weight/gonad condition) and the presence and intensity of apicomplexan infection through molecular and histological analysis.

Preliminary results from this experiment suggest that gray meat tissue can act as a vector for parasite transmission and the freshwater treatment appeared to reduce virulence. Significant differences ($p \leq 0.05$) were observed between the three treatment groups in number of mortalities, clinical signs of the disease, and presence and intensity of parasitic infection. At the end of the experiment, scallops in the control group did not display clinical, histological or molecular presence of the apicomplexan. Scallops exposed to infected tissue were severely to moderately infected with the apicomplexan, exhibiting brown/gray meat color and poor gonad condition. The group exposed to tissue treated in a fresh water bath exhibited an intermediate response, with all scallops only lightly to moderately infected. Although the exposed groups tested positive for the apicomplexan, clinical signs (discolored meat) were not observed until six months post exposure. When considering the significance of these laboratory results on scallop populations in the wild, it is important that these results be interpreted in context to ocean conditions such as depth and flow, as well as fishing practices.

The slow recovery of the Iceland scallop stock in Breiðafjörður, Iceland

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The largest fishery for the Iceland scallop (*Chlamys islandica*) in Icelandic waters was conducted in the bay of Breiðafjörður from 1970 until 2004 when a fishing moratorium was put in place due to collapse of the stock. Annual harvest was around 8 500 t and the stock had remained rather stable in the years prior to the collapse, which was first noticed in the late 1990s. Poor recruitment combined with intensified fishing and high natural mortality caused by protozoan infestation in adult scallops seems to have caused the decline of the stock. Survey indices declined drastically between 2001–2006, to a historical minimum in 2013. Recruitment has remained poor but year-classes from 2010 and especially 2012 are emerging in areas where old scallops are present. The recovery of this stock has been lagging as expected in a slow growing long lived subarctic species. Some smaller grounds where scallops had vanished already in 1985 – 1995 have not recovered yet.

In 2014, with initiatives from the industry, the traditional dredge survey was replaced with a camera survey and was stretched to new areas within the bay. Scallops were found in fishable quantities in the new areas with more year-classes present than on the conventional grounds. A small scale fishing trials on defined areas started with variable fishing pressure. The catch increased from around 300 t in 2014 - 2015 to 750 t in 2016, with more areas defined. The coming years will be used to evaluate the outcome from those trials on the stock status and to propose a new management scheme, which is more spatially explicit than the former advice.

Contaminants in scallops: seasonality and variability of heavy metals and polycyclic aromatic hydrocarbons in the great and queen scallops (*Pecten maximus* and *Aequipecten opercularis*): a case study from the Irish Sea

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Isle of Man fisheries are dominated by two species of scallop: the great scallop (*Pecten maximus*) and the queen scallop (*Aequipecten opercularis*). The combined value of these two fisheries is around £5-7 million /annum at first sale. The island has a long history of fisheries and marine environmental monitoring and management and was recently recognised by UNESCO after the island became the first entire jurisdiction to be awarded World Biosphere status.

This paper reports results obtained from a two-year monitoring programme of heavy metals (Pb, Cd, Cu, Zn, As, Cr & Ni) and polycyclic aromatic hydrocarbons (PAH) in the great and queen scallop populations of the Manx territorial sea. Such contaminants can enter coastal waters via a number of pathways and heavy metal contamination has been attributed to sources including anthropogenic (e.g. industrial, mining, sewage-sludge disposal and coastal/harbour dredging operations) and natural processes (e.g. weathering of metal-bearing rocks, volcanic inputs etc.), PAH contamination is primarily through anthropogenic sources and are a consequence of the incomplete combustion of fossil fuels. PAHs can also find their way into coastal waters through a number of pathways including riverine and urban run-off and port dredging operations.

Results suggest that there are differences between the two species in relation to uptake and storage of these contaminants. Great scallops show a greater tendency to cadmium uptake than queen scallops, while queen scallops appear to accumulate lead. Data suggests a possible seasonal pattern, with metal concentrations being generally highest during the winter months and lowest during the summer.

Polycyclic aromatic hydrocarbons are lipophilic compounds. Analysis shows that in both species PAH concentrations are highest during winter months (December to April) and are closely associated with spawning activity cycles. Analysis of separate tissues show that it is the gonad that preferentially stores PAH compounds and that concentrations fall immediately after spawning suggesting a possible depuration route.

The use of scallops as biomonitors for these compounds and routes of contamination are discussed, in addition to how vectors such as plankton blooms can be important in transferring contaminants from inshore areas to offshore fishing grounds.

A brief history and an update of sea scallop aquaculture in Maine

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The development of aquaculture of the sea scallop (*Placopecten magellanicus*) in Maine has mostly been a tale of fits and starts, yet one leading to a sustained effort in recent years. Since the 1970's and beyond, suspension and bottom culture have yielded mixed results, but a more recent combination of changes within the state's commercial fishing industry, combined with regulatory modifications, positive developments in the marketplace, and technical advancements have all contributed to an optimistic outlook for the commercialization of scallop aquaculture. In general, the species grows well in culture, but requires low density, which has implications for equipment and labor costs, and leasing. An earlier assumption - that the extra value of roe-on or live products were needed for profitability, instead of simply harvesting adductor muscles (meats) - is now being challenged because of high value for dayboat quality product, and the early indications from trials of the Japanese ear-hanging technique. Some of the principal efforts contributing to the present understanding of both the promises and pitfalls for sea scallop aquaculture in Maine will be reviewed,

The role of larval sources and population connectivity in rotating closures in the Atlantic sea scallop (*Placopecten magellanicus*) fishery

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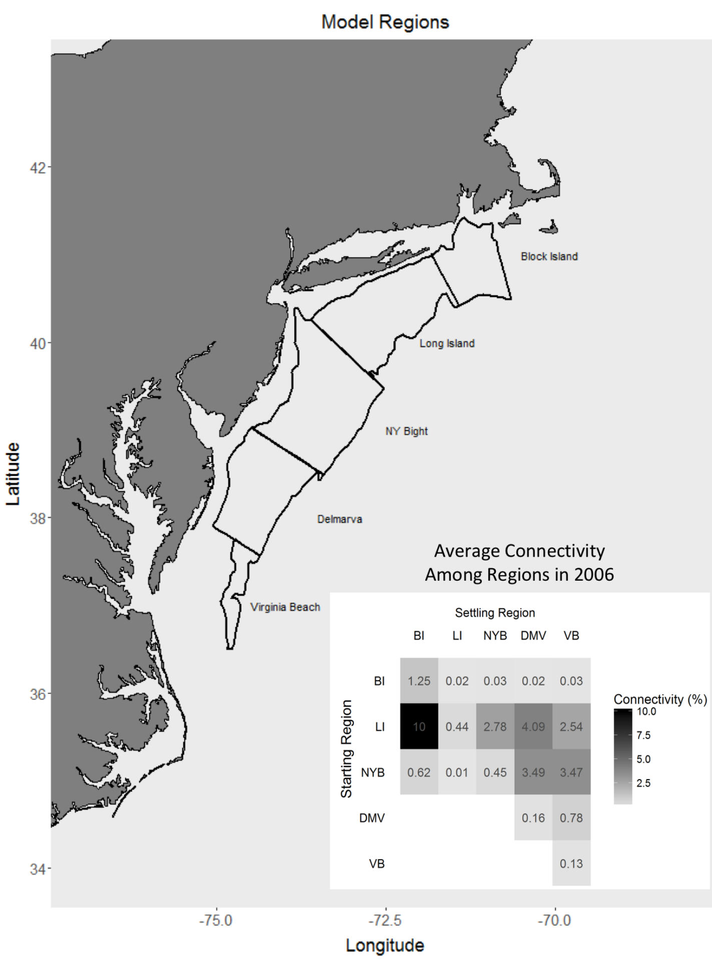
The Atlantic sea scallop (*Placopecten magellanicus*) fishery is among the most valuable fisheries in the U.S., and has shown remarkable recovery from a severely overfished state in the early 1990s. One probable contributor to the recovery is the system of rotational fishery closures that have enhanced broodstock biomass and may have led to elevated downstream recruitment. Additionally, enhanced fertilization success due to high density of broodstock in closed areas may be contributing even more to larval production than would be inferred by simply increases in biomass. We examined the linkage between increased broodstock abundance and potential for amplified recruitment downstream using a circulation model (ROMS) coupled to an individual-based scallop larval model to simulate larval dispersal dynamics and connectivity among the stock. Simulations focus on the trajectories of larval dispersal from areas of increased scallop biomass, allowing examination of whether broodstock in closed areas are likely to supply high recruitment events elsewhere in the stock following closures. Estimates of dispersal encompass years 2006 through 2012 inclusive, and cover multiple spawn timing scenarios. In general, patterns of larval connectivity are ‘downcoast’, with interannual and seasonal variation in these general patterns. The understanding of sea scallop connectivity in the Mid-Atlantic will greatly assist developing metapopulation stock-recruit models, rather than a simple whole stock dynamic pool relationship.



An incentive-based, collaborative approach to reduce flatfish by-catch in the US sea scallop fishery

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By-catch of flatfish has been a constraint to achieving optimum yield in the US sea scallop fishery. Since 1999, the scallop fishery has been allocated catch limits of flounder stocks, and exceeding the limits results in costly time/area closures. Between 2004 and 2009, by-catch closures resulted in economic losses of over USD $100 million. To address this constraint, collaborating with the scallop fishing industry was established to initiate a by-catch avoidance program in 2010. A system was designed to collect information on flatfish by-catch that expands the use of Vessel Monitoring System technology and relies upon the fishing fleet to provide data on catch rates and locations during fishing activities. Participating vessels provided spatially and temporally-specific data on catch rates of flatfish and scallops. The information was compiled and provided near real-time by-catch advisories to the fleet. Vessels gain valuable information from all participants, which they can use to avoid by-catch "hotspots". The program has grown to include over 250 participants that voluntarily share information throughout the fishing year. In response to recent regulatory changes and reduced by-catch limits, the objectives of the by-catch avoidance program have shifted towards a focus on maintaining long-term access to historic fishing grounds. The development, implementation, and expansion of the program from 2010 through 2017 will be described, and how management measures can influence incentives and fishing behavior will be highlighted.

Genetic diversity of the giant lion´s paw scallop (*Nodipecten subnodosus*) from the Gulf of California

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The giant lion´s paw scallop, *Nodipecten subnodosus,* the largest species within the Family Pectinidae, is considered a species with great aquaculture potential in Mexico due to its rapid growth rate and high commercial value. Its economic importance has led to an overexploitation in different bodies of water of the Peninsula of Baja California, Mexico causing such a reduction in their natural populations that its fishery has been restricted.

The evaluation of genetic parameters in natural and cultured populations of aquatic resources constitutes basic information relevant to aquaculture and fisheries management. For aquaculture proposes, inbreeding and loss of genetic variability can generate negative effects on the progenies produced, such as decrease in growth and survival rates, among others. Nowadays, there are several useful molecular markers to evaluate population genetic diversity and structure; these include microsatellite markers that, being co-dominant, represent a good option to identify genetic relations between the individuals of a population and among the subpopulations existing in the range of distribution of the target species.

To evaluate the genetic diversity of wild populations of *N. subnodosus*, samples were obtained at five locations in the Gulf of California: Bahía de los Angeles (BLA, n=30), Bahía de Las Animas (BA, n=37), Punta Soldado (PS, n=9), San Francisquito (SF, n=4) and Bahía de La Paz (LP, n=30). Twenty microsatellite markers were selected from literature, fifteen were standardized and ten of them show successful amplification in four locations, but not in all samples. Successful amplification was obtained in BLA (n=9), BA (n=9), PS (n=3) and SF (n=3) using the microsatellite markers: *NsubA004, NsubA208, NsubC205, NsubC261, NsubA249, NsubA245, NsubA235, NsubA005, NsubA1G09* and *NsubA1F03.*

Samples from Bahía de La Paz, B.C.S. failed to amplify for all markers. Genotyping was done by fragment analysis using high resolution electrophoresis (QIAxcel, Qiagen). Genetic parameters, such as number of alleles (*Na*), observed and expected heterozygosity (*Ho, He*), Hardy-Weinberg Equilibrium (*HWE*) and the inbreeding coefficient (*Fis*) were calculated with GenALEx 6.5 and FSTAT 2.9.3 software. Wild populations showed low genetic diversity, probably related to the low number of samples with successful amplification and its reproductive strategy (hermaphrodite) with a high potential for self-fertilization. These results were unexpected, taking into account that these markers have been used before to characterize eleven natural populations (four from the Gulf of California and the rest from the Pacific Coast) and five batches of hatchery-reared scallops, with samples taken from 2004 to 2008. Implications of over-exploitation overtime of this socio-economically important aquatic resource will be presented. New genomic tools (RAD-Seq) will be used to describe the genetic architecture of these natural populations.

The British fishery for scallops (*Pecten maximus*) in ICES Area VII. Industry strategies for contributing positively to the achievement of MSY and other targets by 2020: methods to deal with regulatory interventions and with environmental concerns

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In 2016 I was elected Chairman of the Scallop Industry Consultation Group (SICG), an industry-led, government supported body established in 2012 for the purpose of taking responsibility for the future wellbeing of the fishery and ensuring it is managed sustainably.

The UK dredge fishery for Scallops developed slowly from the 1970s. From 1986, the only control on scallop dredge fishing in the UK was firstly the 10% by-catch limit of “protected species” in the EU Technical Conservation Regulation, subsequently revised to 5% by-catch limit of non-bivalve molluscs. For conservation purposes, the MLS for scallops in ICES 7d and 7a is 110mm and 100mm elsewhere. Since 1996 there have been other constraints in the fishery.

The EU Western Waters Effort management regime (WWEMR) was established in 1995 to avoid an increase in scallop and other sector fishing effort. The 1995 Regulation was subsequently replaced by Regulation (EC) No 1954/2003.

The UK complied with the provisions of the WWEMR by restrictive licensing of scallop dredging and crab potting, based on historic involvement in the fisheries. A Member State can request more effort for non-TAC fishing should the available limits be reached. For many years there was tacit encouragement for fishermen to abandon fishing for quota species in favour of fishing for non-TAC scallops and crabs.

The UK scallop effort limits were reached in 2009 and exceeded in 2010 and 2011. Penalties were incurred and effort “swaps” involving fish quotas had to be negotiated. Requests from industry for the UK to obtain more effort from the EU were met with rejection, evidently because of the lack of scientific endorsement of the fishery’s sustainability.

Since 2012, the UK industry has been determined to prove the sustainable exploitation of this valuable fishery. My presentation aims to explain the industry strategies for contributing positively to the achievement of MSY and “Good Environmental Status” required by the Marine Strategy Framework directive by 2020. I will outline industry methods to deal with regulatory interventions and with environmental concerns.

What are the future options for scallop production in the Bay of Fundy?

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Scallop production on the east coast of Canada is dominated by the Georges Bank region fishery which produced over 55,000 tonnes in 2015. In comparison, scallop production over the last 20 years in the Bay of Fundy has averaged less than 5% of the offshore landings with the bulk of those on the Nova Scotia side of the Bay. Although there have been some initiatives to boost the production of scallops through aquaculture since the late 1980s, aquaculture-based initiatives on scallop aquaculture have languished over the last 30 years and annually produce 0.01% product in comparison of the fishery. In the inshore areas, landings have fluctuated between 2,000-3,500 tons annually based on sporadic recruitment pulses while demand for scallops has continued to increase as reflected in both the import and export of scallops in Canada.

So, if the production of more scallops is desired to support coastal communities, what are the options available? Enhancement of natural stocks using ranching techniques is a possibility and has been successful in some countries. Experimental and pilot scale projects have been conducted in eastern Canada and show that there is potential in this approach. While technically challenging at times, some of the major hurdles for further development of this are social in nature. Another option would be direct farming of scallops through either monoculture or multi-species integrated multi-trophic aquaculture approaches. A basic economic model suggests that $15-$20 million gross profit could be grown in coastal areas at the mouth of the Bay of Fundy. However, there are a number of technical, bureaucratic and social issues that also limit this development.

As coastal communities continue to grow and look for methods to boost their local economies, new approaches to seafood production will have to be considered to meet the continuing demand. If changes to natural production and subsequent harvest are affected by factors associated with climate change, then some aggressive and proactive alternative strategies may be needed. The purpose of this talk will be to try to put some of these in perspective for the Bay of Fundy region.

Examination into a vessel effect for a multi-vessel, industry-based sea scallop dredge survey

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Fishery-independent surveys of the northwest Atlantic sea scallop (*Placopecten magellanicus*) resource inform stock assessments and provide guidance for setting annual fishery specifications. The Virginia Institute of Marine Science (VIMS) conducts a cooperative dredge survey of the Mid-Atlantic (MA) resource unit of the sea scallop resource, where commercial fishing vessels are chartered as research platforms and where multiple vessels are typically used during a survey year. Quantifying the effect of vessel will assist in understanding the impact of using multiple vessels within a cooperative survey framework and can provide useful information relative to the scaling of absolute abundance estimates. Understanding this effect with respect to biomass estimates will aid in quantifying any directional bias as a function of vessel and provide a more robust estimate for fishery managers during the annual specification process.

A generalized linear model (GLM), Bayesian statistical framework and a generalized linear mixed model (GLMM) were developed to test for differences in fishing power (vessel effect) between three commercial fishing vessels chartered as research platforms to conduct the VIMS dredge survey during the summer of 2015. The GLM and Bayesian framework were used to test for a vessel effect on the pooled catch of sea scallops (number of animals) captured with survey strata, vessel, commercial effort (hours fished), latitude and average depth (m) as potential covariates. A GLMM was used to examine for a vessel effect on scallop catch-at-length with strata, vessel, length (mm), and a second order polynomial length term as fixed effects and station as a random effect. All models used a negative binomial error distribution.

The optimal GLM and Bayesian models returned similar results, indicating that vessel was not a significant predictor of scallop catch. The optimal GLM had one covariate, stratum, as a significant predictor. The optimal GLMM model had vessel, stratum and the second order polynomial length term as significant predictors and indicated a significant vessel effect for the third vessel that completed the survey. The GLMM result may be attributed to sea scallop growth for smaller length classes over the course of the survey. Results from this study are consistent with previous calibration studies suggesting that scallop catch is robust to the effect of vessel and provide an empirical basis for the use of a suite of industry vessels to participate in annual sea scallop resource assessment surveys.

Characterization and quantification of echinoderms on Georges Bank and their biological interactions with sea scallops

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Echinoderms constitute the bulk of the biomass of the macrobenthos of Georges Bank. They are predator, prey, and competitors for some commercially targeted species including sea scallops, so the detailed information on abundance and distribution of echinoderm populations is important for understanding the ecology of other species.

The population structure and spatio-temporal variation of the distribution of echinoderms in this ecosystem from 2005 to 2012 was examined. Using video survey techniques, estimated abundance, biomass and density of four groups of echinoderms (brittle stars, sand dollars, sea stars, and sea urchins) were examined. Using local spatial statistics, zones of high (hotspot) and low (coldspot) density of echinoderms were determined. Hotspots varied significantly by echinoderm group; brittle stars were confined to the northern edge, sand dollars were mainly located in the central and south-western areas, sea star were limited to the southern edge, and sea urchin were randomly located throughout the entire region.

Echinoderm beds, with hundred of individuals per meter square, may directly affect other species due to intensification of biological interactions. For example, sand dollars were the most abundant echinoderm on Georges Bank and share essential habitats with sea scallops, thus competitive exclusion for space may be occurring. Sand dollar abundance (1.1E+11 individuals) was two orders of magnitude greater than scallops (4.0E+9), biomass (510,255 mt) was at least six-fold greater than scallops (84,840 mt), and density (35.1 ind/m^2) was thirty-fold greater than scallops (0.14 ind/m^2). Sea stars are main predators for scallops and influence their distribution. Sea star abundance (3.3E+10 individuals) was one order of magnitude greater than scallops, biomass (120,607 mt) was almost two-fold greater than scallops, and density (6.11 ind/m^2) was six times greater than scallops. These comparisons are remarkable when analyzing scallop recruitment patterns. For instance, scallop extreme recruitment events like the one observed by Bethoney et al. in 2014, may be partially explained by a decrease of sea star predation pressure on scallops. A sharp decrease of sea stars abundance occurred from 2009 to 2014 inside the same area where most of sea scallop recruits were observed in 2014. This study enhances biological information on echinoderms and on echinoderm-scallop interactions, having valuable implications towards implementation of multi-species models.

The “birth and death of ideas in marine science” and their impact on fisheries

Brain J. Rothschild

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The organizers of the Pectinid Workshop have invited me to discuss my “Food For Thought” paper published in 2015 in the ICES *Journal of Marine Science* at the invitation of its editor, Howard Browman. The paper reviewed six decades of my scientific, educational, and academic contributions to marine science. It has become one of the most widely read papers published by the *Journal of Marine Science*. Here, at the Pectinid Workshop, I bring together how the ebb and flow of ideas in marine science, as I see it, affect those who harvest the resource. What are the big questions? What do we know? What do we need to learn? Topics discussed include REX, the recruitment experiment, and the dynamics of marine fish populations; theories on biological physical interactions in the sea; GLOBEC; plankton dynamics and turbulence; fisheries management; and the “overfishing” metaphor. My objective is to show how these topics impact the day-to-day quality of fisheries management including pectinids.

Rothschild, B.J. 2015. On the birth and death of ideas in marine science. ICES Journal of Marine Science, 72: 1237–1244.

Searching for scallop zero: observations on a re-emerging epizootic

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The sea scallop, *Placopecten magellanicus,* supports a fishery that during the 2015 fishing year, landed over 35 million pounds of meats with an ex-vessel value of over U.S. $439 million. These landings resulted in the sea scallop resource supporting the second most valuable single species fishery along the east coast of the United States. While the fishery has enjoyed a protracted period of prosperity, systemic risk does exist with one possible source originating from an epizootic disease. Examples of diseases that result in extensive, negative economic impacts are common in the marine environment and can impact a wide range of taxa. While in the extreme, such an occurrence can result in greatly elevated natural mortality rates, sub-lethal effects can potentially cause significant impacts both biologically and economically.

During the spring of 2015, sea scallops were landed exhibiting lesions on the exterior of the adductor muscle with reports centering on the recently opened access area in the mid-Atlantic (DelMarVa and Elephant Trunk Closed Areas). This occurrence was not unprecedented, with similar lesions reported during May 2003. In that instance, the incidence of affected scallops waned over time with no further reports in subsequent years until reports resurfaced during May of 2015.

Morphological and molecular evidence suggest an ascarid nematode worm (*Sulcascaris sulcata*) as the likely cause of the observed lesions. This species exhibit a complex life cycle with *S. sulcata* larval stages typically utilizing a range of benthic molluscs, including bivalves (clams, scallops) and gastropods (whelks, snails) as intermediate hosts. While a suite of benthic molluscs have been documented as intermediate hosts, two species of marine turtles (Loggerhead (*Carretta caretta* and Green (*Chelonia mydas*)) have been reported as the definitive host.

Utilizing a region-wide resource assessment survey as a platform for further investigations, the basic biology of the parasite and its interactions with host species, spatio-temporal distribution of the larval form and fishery impacts were investigated. Results to date support the life cycle reported in the literature and over the two year study period, the parasite continues to be observed with a moderate spatial expansion. While many questions remain unanswered, it was hypothesized that both biological and environmental conditions have created a situation that appear to support the persistence of the parasitic nematode on the continental shelf of the mid-Atlantic Bight.

Incorporating habitat metrics into the assessment and management of scallop fisheries: experiences from Atlantic Canada

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The importance of incorporating spatial information into the assessment and management of scallop populations has long been recognized. Due to the strong association between scallops and substrate type, scallop distributions can be relatively well represented by seafloor habitat maps. These maps, combined with geospatial fishery data, have tremendous potential to improve our understanding of the spatial patterns and complexities of scallop populations and their dynamics in response to fishing. Further, marine habitat maps provide spatial classification of patterns which can be used to understand ecosystem dynamics and support ecosystem-based fisheries management.

Traditionally, habitat maps were derived from conventional *in-situ* sampling of the sea floor such as cores, grabs, and imagery surveys (stills/video); however these methods sample relatively small areas (m's) making it difficult to use these data alone to derive accurate maps at broader spatial scales. More recently, acoustic survey techniques such as multibeam echo sounders (MBES) are increasingly being used for benthic habitat mapping since they provide full coverage bathymetry and backscatter data that when combined with *in-situ* sampling can result in high resolution (m's) thematic maps.

In the Maritimes Region of Atlantic Canada, the majority of commercial scallop fishing areas (SFA) have had been surveyed with MBES. In 2010, a detailed underwater imagery survey was conducted in SFA 29W off south-west Nova Scotia and these data were subsequently modelled with MBES bathymetry, backscatter, and associated metrics to derived both a species-specific habitat map for the sea scallop, *Placopecten magellanicus*, and a benthoscape map of broad bio-physical characteristics of the seafloor. The scallop habitat map has been used to improve the understanding of scallop population dynamics, develop a habitat based population model, and set biological reference points for fisheries management that incorporates habitat associations. This talk will present an overview of the experience and approach of applying habitat metrics to the assessment and management of scallop fisheries and discuss the future role of habitat mapping towards improved fisheries management in the Maritimes.

Molecular characterization and transcript expression of the antimicrobial peptide *big defensin* from the scallop *Argopecten purpuratus*: first insight into the role of ROI and *IκB* on its transcriptional regulation

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Because the development of infectious diseases is a constraint to scallop aquaculture sustainability, the knowledge of their immune response is relevant. Characterization of molecular components and a systemic notion of the interaction among them are required for a functional understanding of scallop immune response. Big defensins are antimicrobial peptides and important effectors of the immune response in molluscs; however, only one member of the big defensin family has been identified in scallop to date. Herein the cDNA sequence encoding a new big defensin (*ApBD1*) was characterized from the scallop *Argopecten purpuratus*. *ApBD1* cDNA sequence comprised 585 nucleotides, with an ORF of 375 bp that encodes a deduced protein of 124 amino acids that showed characteristic motifs of the big defensin family. The transcript levels of *ApBD1* were significantly higher in scallop at 24 and 48 h post injection with the bacteria *Vibrio splendidus*. These results suggest an important role of *ApBD1* in the immune response of *A. purpuratus*. Reactive oxygen intermediates (ROI) are metabolites produced by aerobic cells which have been linked to oxidative stress. Evidence reported in vertebrates indicates that ROI can also act as messengers in a variety of cellular signaling pathways, including those involved in innate immunity. In order to give new insights into the messenger role of ROI in the immune response of scallops, the effect of ROI production over the gene transcription of *ApBD1* was assessed on *A. purpuratus.* Results showed that 48 h-cultured hemocytes were able to display phagocytic activity and ROI production in response to the β-glucan zymosan. The immune stimulation also induced the transcription of *ApBD1*, which was up-regulated in cultured hemocytes. After neutralizing the ROI produced by stimulated hemocytes with the antioxidant trolox, the transcription of *ApBD1* was reduced near to basal levels. Results suggest a potential messenger role of intracellular ROI on the regulation of *ApBD1* transcription during the immune response of *A. purpuratus*. Inhibitors of nuclear factor kappa B (IκBs) are major control components of the Rel/NF-κB signaling pathway, a key regulator in the modulation of the expression of immune-related genes. Extracellular stimuli activate cell surface receptors, which induce the activation of signal pathways that allow the phosphorylation of IκB proteins trigging its degradation, then the activation the Rel/NF-κB signaling pathway; and transcriptional promotion of target genes. In order to understand the mechanisms underlying the immune regulation in scallops, the RNA interference technology was used for silencing *ApIκB* (an *IκB* that we previously characterize for *A. purpuratus*) expression to assess its regulation on *ApBD1* expression. Results showed that the silencing of *ApIκB* expression by RNAi caused the upregulation of *ApBD1* which suggest a role of *ApIκB* in regulating Rel/NF-kB in *A. purpuratus*.

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Reduction of flounder by-catch in the sea scallop fishery on Georges Bank: the yellowtail versus windowpane problem

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Coonamessett Farm Foundation has been conducting seasonal scallop dredge surveys on Georges Bank since 2010. The surveys provided the data needed to develop effective seasonal access area closures to mitigate yellowtail flounder by-catch. Beginning in 1999, the scallop fleet was granted seasonal access to fishing grounds in Closed Area II south (CAII S) from mid-June through the end of January. Yet by 2011, because the yellowtail flounder stock on Georges Bank was overfished and not recovering, yellowtail accountability measures were added to the scallop fishery management plan. Based on data from the by-catch survey, seasonal access to CAII S was shifted to mid-November through mid-August beginning in 2013. This change reduced yellowtail by-catch, without limiting fishing trips, while giving the scallop fleet access to CAII S when scallop meat weights were highest. Yet there is a downside to this apparent win-win adjustment to the scallop management plan. Windowpane and yellowtail flounder occupy CAII S during different seasons, and windowpane flounder abundance and by-catch rate peaks in CAII S in January through April (Figure 1). Since scallop fishing has been permitted in CAII S during these peak windowpane flounder months, windowpane by-catch in the scallop fishery has increased and northern windowpane accountability measures are being considered for the scallop fleet. Solutions for reducing by-catch of both flounder species include new adjustments to seasonal closures and scallop gear modifications.

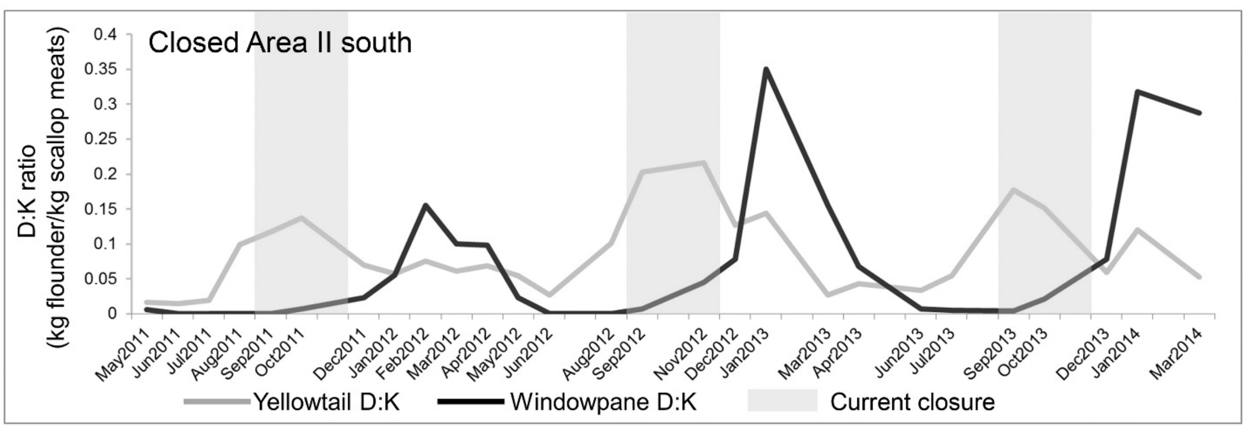

Figure 1. By-catch rates per trip for yellowtail and windowpane flounder (kg flounder/kg scallop meats) in Closed Area II south from May 2011 to March 2014.

Increased accuracy in landings data coinciding with rotational management help to rebuild the Maine sea scallop fishery

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Historical landings for sea scallops (*Placopecten magellanicus*) in Maine extend back to 1950. Landings have ranged widely; a record setting peak in 1981 of 3,813,685 pounds (meat weight) to a low of 33,141 pounds (meat weight) in 2005 (Figure 1).

Inadequate conservation measures and reported landings data had contributed to overharvesting of the inshore scallop fishery in past decades, prior to 2008. The evolution of new management strategies, such as increases in ring size, daily limits and rotational closures, within the Maine scallop fishery have coincided with changes in the reporting of landings, at both the harvester and dealer level. These new measures have turned the tides on the scallop fishery and initiated a rebuilding process.

After eleven years of employing an aggressive and forward-thinking management approach, the fishery has been trending upwards in both landings and value (Figure 1). The addition of a swipe card reporting system for individual harvesters will increase landings accuracy and timeliness. Utilizing real-time data to monitor harvest rates from a manager's perspective encourages proactive actions to support targeted harvest levels, ensuring appropriate retention of biomass to allow for long-term sustainability within the fishery.

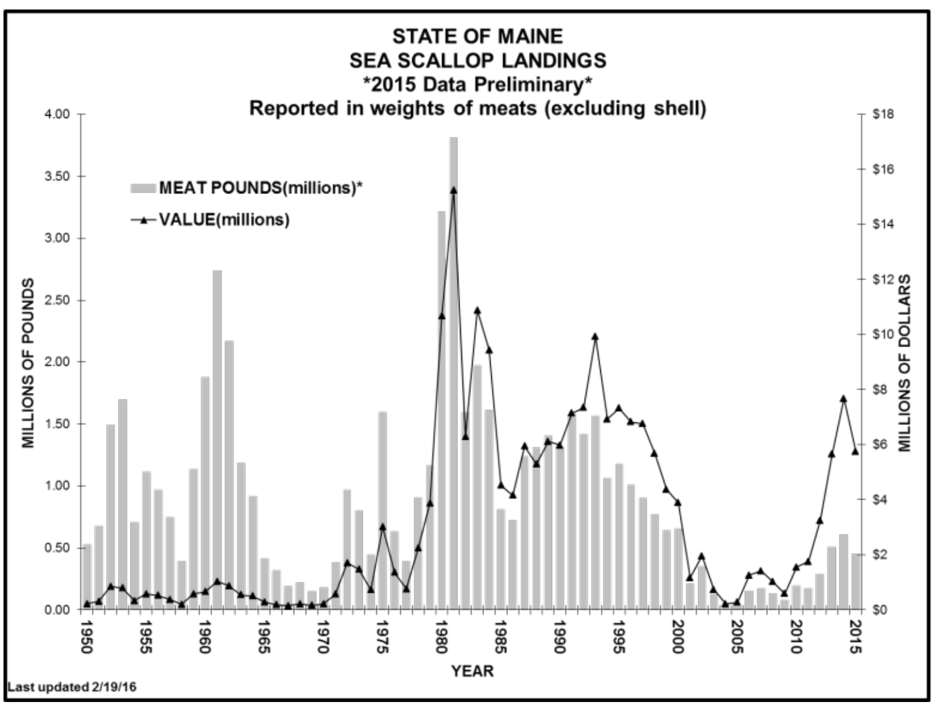

Figure 2: Scallop landings (meat pounds, millions) in Maine dating back to 1950 from 2015, along with value ($, millions).

A review of modifications made to the New Bedford-style dredge to achieve conservation goals

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This review compiles recent information from published and grey literature on modifications to the New Bedford style scallop dredge. This style of scallop dredge is the most widely used dredge by the US east coast sea scallop (*Placopecten magellanicus)* fishery. Due to effective fisheries management and continued improvements to fishing gear, the sea scallop industry has been and continues to remain the world's largest wild-capture scallop fishery and one of the most profitable fisheries along the east coast of the United States. The successful collaboration of industry, management and research under the Sea Scallop Research Set-Aside (RSA) program has allowed for a progressive approach to the design and implementation of modifications to the New Bedford style scallop dredge.

In recent years, awareness of the impacts associated with commercial fishing gear has increased resulting in the need for fisheries technologists to develop Environmentally Responsible Fishing (ERF) gear. The need to reduce by-catch, incidental mortality of juvenile scallops and protected species interactions are some of the important ERF objectives driving modifications to the New Bedford style dredge. Some regulations established to help meet these objectives include a minimum twine top mesh size and chain bag ring size, the mandated use of a turtle deflector dredge frame rigged with turtle chain mats, and controls on apron length. Past and on-going development of gear modifications has included the investigation of light use, electricity, and sound to further the achievement ERF objectives.

This review will present a summary of successful gear modifications that led to the development of current dredge design requirements used in the US sea scallop fishery, as well as discuss modifications that were ultimately deemed unsuccessful in achieving the ERF objectives. This information is useful for fishery technologists developing modifications for scallop dredge fisheries around the world.

A new disease of the Atlantic sea scallop in the NW Atlantic caused by *Mycobacterium* sp.

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With the establishment of rotational fishing using the Georges Bank Controlled Access Areas, the Atlantic sea scallop populations are again supporting a high value and important commercial fishing industry. Unfortunately, disease problems continue to plaque the sea scallop populations creating problems in abundance and meat quality. A new disease identified in Atlantic sea scallops produces orange/pink nodules in the adductor muscle and other areas in the scallop soft tissues.

Sea scallop samples were collected during the 2014 and 2015 seasonal by-catch surveys conducted by Coonamessett Farm Foundation (East Falmouth, MA) from fixed fishing stations within the scallop access areas on Georges Bank. Percentage of infected animals (determined by examining subsamples of the catch at each station) ranged from 0 to 16%. Grossly, variable sized 0.1 to 1 cm oblong/round, orange/pink caseous nodules were noted primarily identified in the adductor muscles in infected animals (Fig. 1). Histologically, small to large granulomas (encapsulations) were characterized by heavy infiltrations of live and dead hemocytes admixed with abundant acid fast +, Gram +, rod-shaped bacteria. The wall of the nodules were composed of layers of intact hemoctyes forming the outer boarders of the granulomas. Using primers for the 16s-23S internal transcribed spacer region and fragment of the 16s genes, we were able to identify that the cause of these lesions was indeed *Mycobacterium* sp. At this time it appears to be a new species of Mycobacterium.

Mycobacterium sp. is a potential pathogen for humans. It is most likely that meats with visible orange/pink nodules are discarded and not included in the catch on the fishing boats. But small nodules may escape the notice of the shuckers. Because this disease effects the quality of the catch and is a potential human health problem, the industry should continue to monitor sea scallop catches to determine if increases in the incidence of this infection occur. (Funded by the Sea Scallop Research Set Aside)

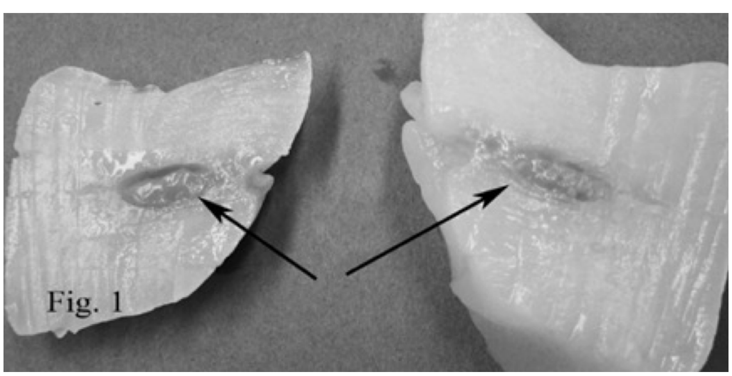

Figure 1. Nodules resulting from mycobacterial infections (arrows) in the adductor muscle of a sea scallop.

Holding mirrors up to nature: the structure, function, and evolution of the eyes of scallops

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The eyes of animals come in a variety of forms and some of the most unusual designs are found in certain types of molluscs. Scallops, for example, have dozens of eyes arrayed along the edges of their valves. These eyes provide scallops with visual acuity that far exceeds that which is observed in other bivalves. The eyes of scallops are among the only eyes known to use a concave mirror to focus light for image-formation and they are one of the very types of eyes to contain two separate retinas. Here, I will present several lines of research demonstrating that we have much left to learn about the structure, function, and evolution of the visual systems of scallops. First, I will present new evidence that that the eyes of scallops are dynamic structures that demonstrate a light-evoked pupillary response and may be able to change shape voluntarily in ways that influence the qualities of the images that fall on the two separate retinas. Second, I will discuss the range of visually-influenced behaviors demonstrated by scallops to encourage discussion of why scallops – unlike almost all other bivalves – have complex eyes and specialized neural structures associated with the processing of visual information. Third, I will describe our recent efforts to map the central nervous system of scallops and trace the optic nerves that exit their eyes and travel to the lateral lobes of their parietovisceral ganglion (PVG). Here, we are curious as to whether the eyes of scallops innervate the optic lobes in a spatiotopic manner. If they do, we will have evidence that scallops may perceive the images gathered separately by their eyes as a single, coherent image of their environment. These considerations will build to a discussion of how scallops and their relatives may be useful for studying the co-evolution of sensory structures, forms of locomotion, and centralized nervous systems.

Between a rock and a soft place: how bad really is the effect of scallop dredging on marine ecosystems?

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Global landings of scallops have grown dramatically in recent decades and these fisheries are now among the most lucrative in several countries around the world. Despite this apparent success story, concerns have arisen about the wider ecosystem effects of scallop fisheries. This is particularly the case for the most common type of fisheries which use dredges to rake scallops off the seafloor. Considerable tensions have arisen between conservationists and the scallop fishing industry as a result, and, in at least some parts of the world, retailers and restaurants are under pressure not to sell dredge caught scallops. Is this an overreaction? Are dredge-caught scallops really that unsustainable?

Here the evidence for negative effects arising from scallop dredging are reviewed and suggest ways in which scallop fisheries might be better managed. In general, dredging causes loss of biodiversity and reduces the complexity of benthic habitats by flattening substrates and removing structurally complex species such as hydroids, bryozoans and seaweeds. This is significant because such habitats are key nursery and feeding areas for a wide range of species, including commercially important fish and shellfish. Scallop dredging also catches a variety of more mobile species such as crustaceans, echinoderms, fishes and in certain areas, sea turtles, which is clearly of concern. Despite these general rules, the magnitude of effects varies considerably in different habitats. The most severe are in biogenic reefs such as formed by maerl and mussels, so there is a strong argument for fully protecting such areas. Reef and cobble habitats also appear relatively susceptible, but soft sediments such as sand, mud and gravel (which are the focus of most scallop fisheries) appear more resilient, particularly in areas adapted to high levels of natural disturbance. Determining the full effects of dredging remains difficult, however, because most fishing grounds have been exploited for decades, long before scientific study began. Long-term protected areas are beginning to provide insights into the recovery and composition of benthic communities in the absence of dredging. Continued study of these areas will be key to gaining a better understanding in the future. In terms of reducing the ecosystem effects of dredging, we suggest an approach which combines effort control, gear modifications and spatial management. Spatial management is showing great promise where it has been applied as it can offer a win-win scenario which protects vulnerable habitats while boosting scallop stocks by providing breeding and nursery refuges; however, spatial management must be carefully planned to maximize biological benefits while accounting for socio-economic factors. Scallop fisheries must also be managed in unison with other fisheries in order to restore diversity and resilience to oceans facing an uncertain future of climate change and growing anthropogenic pressure.

Screening of candidate genes involved in orange shell coloration in bay scallops

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Scallop shell color has received much attention for its great diversity and complicated inheritance. A selected variety, named “zhongkehong”, characteristic of consistently orange-colored shells were successfully obtained in 2006 and has been propagated for 11 generations in the bay scallop *Argopecten irradians*. In this study, samples were taken from this variety right before and after the appearance of orange shell color with 3 replications. A total of 6 transcriptome libraries were used for pair-end sequencing. 289,839,646 paired-end reads were assembled into 70929 transcripts. Annotated against SWISSPROT, NR and KOG database using BLASTX and BLASTN, 30896 unigenes were successfully annotated. Gene Ontology annotation and Kyoto Encyclopedia of Genes and Genomes classification identified numbers of unigenes involved in biomineralization and pigmentation. The digital gene expression analysis revealed that melanin and trace metal elements may be potentially involved in shell coloration of *A. irradians*.

Three self-bred “zhongkehong” family, and three self-bred *A. irradians* with white shell color (both the lef and right shell) were set up. Genomic DNA from ten individuals of the F_2 generation from each family was equally pooled and the restriction-site associated DNA sequencing approach, 2b-RAD, was used to generate genome-wide single nucleotide polymorphism (SNP) genotypes for all samples. We identified 14 SNPs associated to orange shell color of *A. irradians*. To obtain more gene sequences, these 2b-RAD tags were mapped to a genome survey of *A. irradians* and 9 unique 2b-RAD tags were left for a further verification test. In the verifying experiment, 50 individuals with orange shell color and 50 individuals with white-black shell color of *A. irradians* were randomly selected from the two cultured population respectively. SNP detection of every individual was performed using SNaPshot. The results indicated that two of the nine SNPs, i.e., ref-125669-21 and ref-40155-24, were highly associated to orange shell color of *A. irradians*. The putative genes were under investigation.

The fisheries – aquaculture – certification – ranking seascape

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Seafood has been critical to human evolution, the development of civilizations and communities, and more socio-economic resiliency. This millennial seafood-human interdependency came to a head in the last half century as we began to take more animals than was biologically feasible. Compromised habitats and overfishing set us on two different trajectories that are now collapsing back on each other. The first trajectory was an increased interest in the captive culture of species being overfished. Aquaculture is an antiquated offshoot of agriculture. Captive production of animals lead to the formation of stable city-states, and producing aquatic animals was a means to increase food security for coastal and riparian communities. The development of aquaculture techniques could then be adapted to other animals, and business interests focused effort on economically valuable species. With roots in Japan in the 1930s, aquaculture of scallops has had various levels of success, but high market values will continue to keep aquaculture of scallops in the forefront.

The other trajectory set in motion by compromised habitats and overfishing was the public concern for the sustainability of seafood products. Starting in the late 1990s, the development of seafood certification has been an influential market tool to encourage consumers to be involved in actively selecting seafood produced with fewer environmental impacts. There have been parallel certification programs to address fisheries and aquaculture, and 25% of the 211 standards logged in StandardsMap.org can be used for seafood. In addition, other programs have such as ranking have been created to drive market behavior.

So currently for scallops, we have a situation where there are different methods of production (fisheries and aquaculture), and multiple ways to ensure scallops are produced with relatively fewer environmental impacts. In this talk, the fisheries – aquaculture – certification – ranking seascape will be unpacked. A roadmap will be presented to help set a pathway to ensure that the scallop industry, as with other seafood commodities, continues to improve. This will help ensure seafood continues to be an important part of human development for the foreseeable future.

RNA-seq analysis of differential gene expression in response to domoic acid-producing *Pseudo-nitzschia* in the digestive gland of *Aequipecten opercularis* (L.)

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Domoic acid, a toxin causing amnesic shellfish poisoning (ASP) in humans, is produced by some species of the diatom genus *Pseudo-nitzschia*. Filter feeding species like scallops can accumulate biotoxins in their tissues during harmful algal blooms, mainly in the digestive gland, which is the major organ involved in xenobiotic and toxin metabolism in bivalve molluscs. The accumulation of biotoxins in shellfish has adverse economic impacts, leading to harvesting closures. In this study, RNA-seq was employed to identify genes differentially regulated upon exposure to domoic acid in the digestive gland of the queen scallop *Aequipecten opercularis*.

The transcriptome of the *A. opercularis* digestive gland was *de novo* assembled based on the sequencing of 18 cDNA libraries, six obtained from control scallops and twelve from scallops naturally exposed to domoic acid producing *Pseudo-nitzschia australis*. The toxin-exposed scallops were divided into two groups according to the time of exposition and the domoic acid accumulation: a group with an average content of 6,680 ± 1,661 ng/g digestive gland wet weight (DA) and other group with an average content of 1,361 ± 804 ng/g digestive gland wet weight (DB). Illumina paired-end sequencing produced 968,035,762 filtered reads with an average read length of 100 bp. The percentage of reads with mean sequence quality ≥ Q30 was 95%. After *de novo* assembly with Trinity and Oasis, the assembled transcripts were clustered (homology > 90%) to reduce redundancy, thus 178,018 unigenes were obtained which ranged from 102 to 17,867 bp with an average length of 1,103.9 bp and a N50 length of 800 bp.

Differential expression analysis, using the DESeq2 algorithm, was performed in the digestive gland of *A. opercularis* following exposure to domoic acid. Genes were considered to be significantly differentially expressed if the absolute fold change was > 2 and the FDR adjusted p-value was < 0.05. A total of 29,627 and 23,462 differentially expressed unigenes were detected in the DA and DB groups, respectively, when compared to the control group. Genes that were differentially expressed in both groups were selected for further study (11,162 genes, 5,096 up-regulated and 6,066 down-regulated). Functional enrichment was performed using the Pfam (protein families database) annotations obtained from these genes, thus 418 domains were found to be significantly (p<0.05) enriched. Some of the most significantly enriched families contain genes coding for proteins involved in the metabolism and elimination of toxins (cytochromes P450, glutathione S-transferases, sulfotransferases, carboxylesterases and major facilitator superfamily transporters). Interestingly the genes belonging to these families were mostly upregulated.

Genetic tools and scallops

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Scallop genetics was not developed to further genetic research instead different genetic methods were applied using scallops as an experimental species.

Among the most typical practices in mollusc aquaculture was the capture of scallop spat from one population and their transport, dissemination and even introduction to several distant sea-based aquaculture sites. There were not studies on population structures and their impact. The first of such transplant experiments recorded were performed as early as 1916 in the US. In the 1990s some genetic studies were performed to determine the consequences of introducing scallops in terms of genetic diversity, possible hybridization, and other genetic effects. The first techniques used were enzyme electrophoresis.

Sea based scallop aquaculture was feasible in several inshore areas, however wild scallop beds were not always available to provide enough spat for the rearing process. There was a need back then to know about basic biology of scallops such us early development stages, physiology, reproduction, and others which will be key aspects to develop hatchery rearing techniques. This same basic biological information needed for hatchery development was required to apply chromosome manipulation and ploidization techniques. Hatcheries were successfully operated and scallop sea-based aquaculture was supplied either with spats from wild or induced spawns. There were differences from wild or hatchery spats regarding particularly the availability year around.

Target markets and business profitability stimulated research in rearing techniques, rearing engineering, feeding, physiology, and genetics. Genetics focused on reducing time to reach commercial size, increase muscle size, diminish gonad development, improve resistance to pathogens, etc. Genetics becomes an increasingly important management tool, and with the appearance of molecular tools, the research focuses more and more on very specific targets.

Actually the amount of information on scallop genetics and genomics is enormous, but a clear line towards application in fisheries and aquaculture of those findings is lacking. Scallops can be artificially reared and bred, they have a variety of reproduction strategies, different chromosome numbers and sizes, have a high variability, with commercially and ecologically important species and the group is cosmopolitan in distribution, so it became an interesting experimental animal and not all research will be directed towards an improvement towards its aquaculture.

In recent years concern about conservation of wild population as well of reducing the risk of introducing species is being considered.

Non-toxic photoactive release coatings for biofouling control

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Novel non-toxic antifouling coating technology developed for the aquaculture industry is presented which relies on the photoactive generation of hydrogen peroxide to reduce the settlement of biofouling organisms rather than the leaching of pesticides.

Biofouling, the unwanted growth of biological organisms on underwater surfaces, has long been recognized as a major problem for commercial aquaculture. Biofouling dramatically increases labor costs, reduces the value of product, and can harm cultured species. Fouling clogs gear, stops water flow and food delivery, can compete with culture organisms for food or space, and can directly affect the growth and survival of cultured organisms. As a result, considerable physical and economic effort is directed toward the prevention and control of biofouling at culture facilities. Cleaning of gear and use of toxic coatings are the primary methods employed by the industry to maintain biofouling-free surfaces. Time and energy expended to keep gear clean taxes aquaculturalists consuming as much as 30% of labor costs and contributing 15% to operational costs.

Traditional antifouling paints used for boat hulls are based on copper and often contain booster biocides. Copper is toxic to shellfish, impairs olfactory organs of anadromous fish, and persists in the environment. A non-toxic and bio-based solution to the biofouling problem was discovered that centers on soy-based polymers that release biofouling when exposed to visible light. These polymers are engineered to react with visible light and release biofouling by the gradual breakdown of the surface binder resin catalyzed by the photochemical generation of peroxides for polymer scission.

Biofouling resistance of photoactive release coatings was evaluated at the University of Connecticut (Avery Point) for 12 months. Biofouling weight and percent coverage of test surfaces is reported. Antifouling efficacy of photoactive release coatings applied to nylon and HDPE netting, PVC-coated cages used for shellfish and finfish aquaculture, and experimental panels were determined over 6 months in several geographic regions globally through a controlled series of biofouling settlement assays. Non-toxic claims of photoactive release coating technology were confirmed by results from toxicity testing with scallop and oyster larvae at concentrations of 0.02, 0.2 and 2.0 ppm.

Results from testing on oyster bags and scallop trays at WARD Aquafarms (Falmouth, MA) are presented that demonstrate how use of photoactive release coating technology improves growing conditions by reducing biofouling on aquaculture gear. Oysters and scallops grew significantly larger in treated bags and trays over a three month grow-out period. Treated gear requires less maintenance and can be reused without cleaning. Results from field testing demonstrate that photoactive release coating technology is a viable solution to the biofouling problem experienced by shellfish farmers, who rely on gear changes and cleaning to control biofouling.

Development of genomic tools for the systematic study of the biology and evolution of the Pectinidae

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Recent advances in the next-generation sequencing (NGS) technologies now allow for rapid generation of extensive genomic resources for potentially any organism. With rapid decline in sequencing costs, there is an urgent need for developing cost-efficient genomic tools based on the NGS platforms to enable conducting genomics-level analyses in less-studied organisms such as scallops. Here several genomic tools that have been recently developed by our groupare introduced, including: (i) 2b-RAD technique (Nature Methods, 2012), which adopts type IIB restriction enzymes in reduced genome sequencing, thus providing a flexible and reliable platform for genome-wide genotyping; (ii) RADtyping pipeline (PLoS One, 2013), which is an integrated package for accurate *de novo* codominant and dominant RAD genotyping in mapping populations; (iii) MethylRAD technique, which enables cost-effective genome-wide profiling of DNA methylation by using methylation- dependent restriction enzymes to achieve reduced genome representation; (iv) Multi-isoRAD technique, an advanced protocol that allows the preparation of five concatenated isoRAD tags for Illumina paired-end sequencing to achieve genome-wide genotyping at minimal labor and cost.

The evolutionary trajectories of bilaterian animals: insights from the scallop genome

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The nature of Urbilateria, the presumed last common ancestor of bilaterians from which 99% of the extant animal kingdom subsequently evolved, remains mysterious and has long been a subject of debate. Due to the absence of definitive fossil record, genomic reconstruction becomes essential to our understanding of Urbilateria, and deep sampling of ancient and slow-evolving bilaterian lineages may provide insights. Here the whole genome sequencing and assembly for Yesso scallop (*Patinopecten yessoensis*, Jay 1857), one of the most important maricultural shellfish in the north of China is reported. Sequencing a highly inbred individual in combination with an efficient assembly approach conquers the problem of high genome heterozygosity. The final genome assembly is 988 Mb, with a contig N50 size of 38 kb and a scaffold N50 size of 804 kb. The scallop genome encodes 26,415 protein-coding genes, and 39% of the assembled genome is classified as repetitive sequences. This analysis reveals unprecedented conservation of ancestral bilaterian gene families and linkage groups. Other ancestral features of the scallop genome include intact ParaHox and Hox gene clusters in presumed ancestral states, diverse phototransduction cascades and an ancient regulatory pathway for eye development. Scallop Hox gene expression follows a novel subcluster temporal collinearity that may provide flexibility in development patterning and underlie the great body plan diversity found in molluscs and other bilaterians. The finding of *Pax2/5/8* but not *Pax6* as a key regulator in scallop eyes suggests different evolutionary origins of cephalic and noncephalic eyes. The “fossil” genome of the scallop with many ancestral features supports molluscs as close relatives of Urbilateria and provides new insights into bilaterian evolution.

Bay scallop (*Argopecten irradians*) nursery and grow-out strategies

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The shellfish aquaculture industry in the northeast continues to expand, and many farmers are interested in producing additional species to diversify risk and bring in additional income. Bay scallop (*Argopecten irradians*) farming has been attempted by many aquaculturists, but success has been limited due to inefficient techniques in both the nursery and growout phases. The best nursery and growout techniques will vary in different environments, though research into all phases following the hatchery is necessary to produce bay scallops of a sufficient size to make a viable product. In 2016, Ward Aquafarms investigated different nursery and growout methods to optimize bay scallop growth in year one. Using custom designed downweller nursery systems, different bay scallop stocking densities were evaluated over the entire nursery period. Growth and survival of the bay scallops were calculated for each density every two weeks to determine the most efficient stocking density to maximize growth and yield. Once the bay scallops reached appropriate size, they were then moved to three distinct growout environments to observe growth and survival in three areas of diverse site characteristics over a three month period. At each site, three different growout methods were implemented using floating bags, hanging trays, and bottom cages. Growth and survival for each growout method at each site were documented to determine the most effective growout methods for bay scallop aquaculture.

Investigating the "rust tide" (*Cochlodinium polykrikoides*) harmful algal bloom on a commercial shellfish farm and potential mitigation strategies to reduce future impacts

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Farming is, and always will be a risky business. Whether the particular challenge on the farm is primarily predators, flow, disease, theft, storms, or a mix of all of the above, it takes constant vigilance to keep the product growing and providing a consistent supply to the market. In the northeast, for the last 10 years, and increasingly in the last 5 years, a new threat has been added to the list: *Cochlodinium polykrikoides*, the causative microalga behind the recent "rust tides". While *C. polykrikoides* has been causing large biological and economic losses to the aquaculture industry in South Korea for decades, its emergence as a threat on the east coast of the US is a relatively recent phenomenon. This alga blooms in mid-summer when the water temperatures are the warmest, and typically does not completely disappear until the water temperature declines in the fall. Studies on the impacts on commercially important shellfish such as eastern oysters (*Crassostrea virginica*), bay scallops (*Argopecten irradians*), and northern quahogs (*Mercenaria mercenaria*) were performed both in laboratory trials and in field experiments during a bloom in 2016. Cell densities, nutrient concentrations, and additional environmental data were collected throughout the bloom period to understand more completely the impact of these annual blooms on shellfish farms in New England. From these experiments, strategies for mitigation have been evaluated to establish methods to reduce impacts from the harmful algae as the blooms become more common.

Using vessel monitoring systems (VMS) to evaluate time-area closures: a case study from the Atlantic-Canada scallop fleet

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Atlantic cod (*Gadus morhua*) and yellowtail flounder (*Limanda ferruginea*) abundances are near historic lows across Georges Bank and various management measures have been put in place to protect these species. Area closures are one of the measures being used in both Canadian and American waters; a primary goal of these area closures is to minimize by-catch of these species. In Canada the area closures are designed to minimize by-catch by the offshore scallop fishery when the Atlantic cod and yellowtail flounder are spawning; they are seasonal closures lasting 1 to 2 months. Both the timing and location of these seasonal closures has varied based upon the most recent scientific evidence of the species distribution. The effect of these closures on either the offshore scallop fishery or the species of concern has yet to be evaluated.

Although primarily used for enforcement purposes, we use vessel monitoring system (VMS) data to evaluate the impact of these closures on the Canadian offshore scallop fishery. Spatio-temporal patterns of VMS fishing effort were investigated to determine if the closures displaced the fleet to nearby banks, to other areas on Georges Bank, or to the closure areas immediately before or after the closure period.

Results indicate that the closure areas, especially for the yellowtail flounder closures, tended to be located in areas with below average scallop biomass and were therefore areas fished less intensely. Although compliance of these time-area closures was high, there was minimal impact on the overall spatio-temporal patterns of fishing effort.

This research is part of an ongoing initiative to better understand the spatio-temporal distribution of cod and yellowtail flounder in relation to the offshore scallop fishery. The current status of this initiative and our goals for the project going forward will be discussed.

Stress and observations of mortality of the monkfish *Lophius americanus* in the scallop dredge fishery

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Post-release mortality (PRM) studies are considered a primary research priority, particularly for species and fisheries where discard rates are high, and/or for overfished stocks and species of concern. Monkfish, *Lophius americanus,* the most lucrative finfish in New England, constitutes the second highest by-catch species within the scallop dredge fishery. Despite its commercial importance, no data exists on the mortality rates of monkfish for any gear type. Given these shortcomings, the goals were to evaluate the stress and PRM of monkfish captured in scallop dredge gear. This was accomplished by assessing various physical and physiological conditions. To quantify stress levels, blood samples were taken to measure cortisol, lactate, hemoglobin, and hematocrit concentrations. In addition, a series of reflex responses were tested and injury codes, ranging from 1 (uninjured) to 4 (dead), were assigned to each monkfish in order to develop vitality indices. To correlate the aforementioned parameters to discard mortality, monkfish were held in onboard flow-through seawater tanks and all stress indicators were reassessed after a 72-hour holding period. Preliminary results suggest that number of reflex responses decreased significantly as exposure time ($p<0.0001$), tow duration ($p = 0.007$), and air temperature ($p = 0.002$) increased. In addition, average cortisol levels significantly increased as exposure time (mean change: 2.5 to 12.0 ng/ml; $p = 0.003$) and tow duration (mean change: 0.9 to 2.4 ng/ml; $p = 0.0001$) increased. Analysis of the tank study indicated that 80% of monkfish placed in holding tanks died after 72 hours, regardless of initial vitality index.

Surveys and assessment of scallops in SCA 7, New Zealand

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Scallops (*Pecten novaezelandiae*) support important commercial and non-commercial (recreational and customary) fisheries in the Southern ('Challenger') scallop stock 'SCA 7' at the north of New Zealand's South Island. The SCA 7 stock comprises the three different substocks of Golden Bay, Tasman Bay, and Marlborough Sounds. Annual dredge surveys have been conducted in SCA 7 since 1994 to provide population estimates (distribution, size structure, abundance and biomass) and inform fisheries management. The surveys show that substantial declines in recruited biomass occurred in the 2000s in Golden Bay and Tasman Bay, and populations in these bays have since remained at very low levels. In Marlborough Sounds, recruited biomass followed an increasing trend from 1999 to 2009 and a declining trend since 2009. Following three surveys in 2015, and consultation on a review of sustainability measures for SCA 7, in 2016 the scallop fishery in Marlborough Sounds and part of Tasman Bay was closed for the 2016–17 scallop season (15 July 2016 to 14 February 2017). A January 2017 survey project was carried out to provide current estimates and compare them with those from previous surveys to establish if changes have occurred in the population. Additional work that was undertaken included estimating growth from multiple length frequency datasets, population projections, and developing soft and hard limit reference points for each substock. The results were used to inform fisheries management decisions for the 2017 fishing year.

Evaluating a by-catch avoidance program based on real-time communication in the US sea scallop fishery

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In collaboration with scallop fishermen, a voluntary by-catch reporting protocol to support near real-time by-catch avoidance of yellowtail flounder (*Limanda ferruginea*) in the U.S. sea scallop (*Placopecten magellanicus*) fishery was developed. Data were gathered from the scallop fleet to identify spatial patterns of by-catch, which were analyzed and returned to the fleet as a map and a list of by-catch hotspots. Effectiveness of the program through fleet participation statistics and apparent avoidance behavior was evaluated. Log linear models identified significant associations between advisories and fishing location and considered average scallop catch as a covariate to account for the effect of scallop density on fishing location decisions. By-catch avoidance behavior was interpreted using odds ratios of reported tow frequency and occurrence of advisories across different by-catch classifications. Nominal participation (number of vessels that requested advisories) increased annually from 122 vessels in 2010 to 254 vessels in 2014; however, active participation (percent of participating vessels that sent reports to SMAST) increased from nearly 20% in 2011 to 34% in 2012, then decreased to approximately 16% in 2013-2014. Evidence of avoidance behavior varied over the course of most fishing years, was most significant in 2012, and weakest in 2014. Decreases in participation and avoidance behavior coincide with revised by-catch allocations and management of the fishery, which appear to have decreased the sense of urgency and incentives for by-catch avoidance. Depending on fishery management approaches and industry incentives, real-time communication of by-catch appears to be an effective means of by-catch reduction.

POSTER PRESENTATIONS

(indicates student)*

Effect of temperature and stocking density on larval growth and survival of the scallop *Pecten sulcicostatus*

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The effect of temperature and density on the growth and survival of cultured larvae of *Pecten sulcicostatus,* from D-larvae to pediveliger, was investigated. Rates of growth and survival were determined at temperatures of 12.5, 15.5, 18 and 22 ºC. Mean growth rates of larvae increased with temperature ranging from 5.16 to 8.17 µm day^{-1}. These growth rates are similar to those of other commercial scallop species; for example, the reported growth rates of *Nodipecten nodosus, Chlamys Hastata* and *Placopecten magellanicus* all fall within the above range. The larvae of *P. sulcicostatus* with the fastest growth rate, i.e. those cultured at 22 ºC, typically reached the pediveliger stage 14 days post-fertilization. Larval survival at the experimental temperatures was low with a maximum survival of 12.4% at 22 ºC. The mean growth rates of larvae cultured at 22 ºC at densities of $4x10^3$, 10 $x10^3$ and 15 $x10^3$ larvae L^{-1} ranged from 6.11 to 6.54 µm day^{-1} with higher growth at the lowest density. Maximum larval survival at these experimental densities was 2.9%. The low survival in all experiments was neither correlated to temperature nor stocking density. Other factors such as sub-optimal food concentrations, system design and water changing techniques need to be investigated to ascertain the causes of low survival.

Temporal changes in the larval *Placopecten magellanicus* population in a small-scale fishery closure area in coastal Maine, USA

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The Midcoast Maine Collaborative Scallop Project was established by policy makers, scientists and fishermen to implement a small-scale closure area on local populations of the Atlantic sea scallop (*Placopecten magellanicus*) in coastal Maine and to assess the response of the scallop population. Closures have been employed successfully to manage the US federal scallop fishery, and the Maine Department of Marine Resources has adopted them widely at the state level. Understanding the larval dynamics in a closure area is key to evaluating the recovery potential of the population and for future population stock levels. The project team has been monitoring the effect of the closure on adult and larval scallop populations in the area since 2013. Using spat bag data, this study seeks to determine: 1) if larval abundance has changed over the three-year closure period, and 2) if larval abundance varies inside the closure area as compared to adjacent fished areas.

Spat bags are deployed to collect scallop larvae during its earliest life stage while the larvae are floating in the water column. In this study, spat bags served as a metric to gauge the abundance of larval scallops inside and adjacent to the closure. In early October of 2013, 2014 and 2015, 12 lines of spat bags were distributed in areas north, south and inside the closure. In June of 2014, six of the 12 lines were recovered, in both 2015 and 2016, four of the 12 lines were recovered. Lines were not recovered from the same locations each year which is a potential limitation of this study. To process each spat bag, scallops were separated from other settling organisms and counted. A before-after-control-impact (BACI) design was used to determine if recruitment increased within the closure.

In 2014 and 2015, higher abundances of larval scallops were recorded in the closure area and in areas south of the closure as compared to north of the closure. Abundances did not change from year to year in the area north of the closure. Higher larval abundances in these locations could indicate a rise in the adult spawning population increasing the larval supply for this particular area. This would require that larvae produced from the local population would stay in the area. To understand local oceanographic dynamics, commercial fishermen from the area were interviewed about dominant current directions and tidal patterns in the Muscle Ridge area. This information will be used to develop an expected direction of larval transport and to determine if larvae are likely to stay local. Additional research could potentially explore the effect of local currents on the retention of scallop larvae in the area, potentially playing an important role as a source population for the surrounding area.

Ferritin expression is heritable and associated with growth in the scallop, *Argopecten purpuratus*

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Ferritins are iron storage proteins that play a pivotal role in iron metabolism and homoeostasis of most organisms. Iron stored in ferritins is used to synthesize iron co-factors for respiration and DNA synthesis. Thus, ferritins have a central role in physiology and they are essentially ubiquitous. Due to the need of iron in processes of calcification and biomineralization, this protein has been associated to the development and formation of the shell in mollusks. We have recently characterized the molecular structure of a *ferritin* gene for *Argopecten purpuratus* scallop (namely *Apfer1*), which transcriptional level in mantle tissue was positively correlated with growth rate.

In recent years, growth rates of cultured *A. purpuratus* have decreased; therefore, the characterization of proteins to be used as molecular markers for growth increment of this species appears as an potential tool to support its culture, for example through selective breeding programs. The success of a selective breeding program depends on the existence of genetic variability for the target traits in the population. The proportion of total phenotypic variance in a population that is attributable to the additive effect of the genes is the heritability (h^2). This study aimed to estimate the h^2 and potential response to selection (G) for the ferritin protein level in *A. purpuratus* mantle tissue. For this, based on *Apfer1* sequence, a polyclonal antibody specific for an epitope sequence of *A. purpuratus* ferritin was designed and generated. Antibody specificity was evaluated by Western blotting and ferritin quantification was evaluated by the enzyme-linked immunosorbent assay (ELISA) method using *A. purpuratus* mantle tissue. In order to estimate h^2 of ferritin variation, 354 scallops belonging to 37 full-sib families were sampled and ferritin protein levels in mantle were measured by ELISA. Ferritin levels in fast and slow growing scallops belonging to a same cohort were further evaluated in order to verify the association of this molecule with growth rate at protein level. Results showed a high and significant h^2 for ferritin expression (0.5 ± 0.14); with an estimated response to selection of 14% per generation if the 5% (i.e., a selection intensity i = 2.063) of the scallops with higher ferritin expression are selected from the population as broodstock. In parallel, it was observed that ferritin levels in mantle of fast-growing scallops were 44% higher than in slow-growing individuals. In conclusion, a positive association between ferritin levels and growth performance of *A. purpuratus* is shown; and variation in this trait is heritable and has an important potential to respond to selection. Thus, ferritin levels could be used as a molecular marker or a target trait in a selective breeding program for this scallop species.

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The effect of small-scale closed areas on populations of *Placopecten magellanicus* in Maine

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Due to the success of groundfish closures in rebuilding sea scallop (*Placopecten magellanicus*) populations in the US federal fishery, resource managers implemented a system of rotational and targeted closures to restore sea scallop stocks in coastal Maine; however, little is known about the effect of small-scale, inshore closures on resident scallop populations.

To understand how small-scale closures influence local populations of sea scallops, we conducted drop camera and SCUBA dive surveys to monitor juvenile and adult abundance and size distributions inside and outside the Lower Muscle Ridge closure, which has been closed to harvesting since October 2013. SCUBA dive surveys were also conducted inside and outside the Ocean Point closure, which has been closed since 2009 and provides a comparative site to Muscle Ridge. At Ocean Point, there was a significant location effect throughout 2014 - 2016. At Muscle Ridge, our SCUBA surveys revealed location did not have a significant effect until 2015, two years after the closure was established. Independent drop camera surveys at Muscle Ridge in 2015 and dive surveys in 2016 showed elevated numbers of juveniles relative to previous years, suggesting the scallop population in the area is rebuilding. Results on density, abundance, shell height, spatial patterns and changes over time will be presented.

The monitoring project has been a collaborative effort between commercial fishermen, scientists, and managers. Fishermen partners have been engaged throughout, from initiating closure implementation to helping with data collection. Through the collaborative approach, factors critical to the success of the project were identified, including recognizing the true cost of peoples' involvement and developing ways to adequately compensate participants for their contributions and developing a data use and sharing policy that guides how and with whom project results are shared. By combining the quantitative survey data with the collaborative approach, this project increases the capacity of the state to collect long-term data about scallop population dynamics while simultaneously providing engaged fishermen with an opportunity to invest in rebuilding the local scallop resource.

Integrated spatial modeling of gray meat intensity in Atlantic sea scallops

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The Atlantic sea scallop fishery is the highest valued fishery in the Northeast U.S. However, scallops with small, darkened and stringy adductor muscle (gray meat) have been reported in temporally and spatially specific locations along the Eastern Seaboard, and appear to be increasing in frequency. Gray meat scallops are associated with reduced harvestable biomass and mass mortality events. A predictive model of areas susceptive to gray meat outbreaks was developed to understand not only the spatial distribution of gray meat, but also environmental factors that may contribute to gray meat outbreaks. Fishermen's knowledge, information collected at auction and during fishery independent surveys, along with environmental data and oceanographic model output to predict the spatial and temporal locations of gray meat occurrence were used.

A geostatistical model for gray meat intensity was simulateneously fit to three data sources: (1) gray meat locations and qualitative assessments of intensity from interviews with scallop captains, (2) data on gray meat presence from sampling of commercial scallop lots at the Whaling City Seafood Display Auction, and (3) gray meat locations from fishery independent surveys. These data sources have different properties (e.g. quantitative and qualitative information), and a separate likelihood component is modeled for each data source. For example, data on gray meat prevalence during interviews with fishermen is recorded using an ordinal qualitative scale ("None", "Few", "Medium but Fished", "Too Many"), and a cumulative link model is used to describe these data. Environmental covariates at observed locations include include both physical characteristics (e.g. temperature, depth) as well as covariates describing the fishing history at locations, and the density and size of scallops. Model selection criteria were used to determine parsimonious sets of environmental covariates that appear to correlate with gray meat outbreaks. Parameter estimation is conducted in R using Template Model Builder to account for spatial autocorrelation in the intensity of gray meat. Considering all sources of data simultaneously in the same modeling framework enables a proper accounting for uncertainty and a logically consistent method for making use of information contained in different data sets to inform about the common latent process (gray meat distribution and prevalence).

Through modeling, the aim is to describe the spatial location of gray meat outbreaks and environmental attributes of these locations to advise management on methods to reduce the occurrences and mitigate the effects of gray meats. Further work will link the output of the model to an economic model to provide policy-relevant advice for fisheries managers.

Spatial-temporal variation in the reproductive aspects and shell height/meat weight of Atlantic sea scallop (*Placopecten magellanicus*) in the northern edge of Georges Bank

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The reproductive aspects and the spatial-temporal variations in the meat weight of sea scallops were evaluated by the examination of 5,009 scallops collected between August 2015 and June 2016 on the Northern Edge of Georges Bank. In addition to trip and station level data, individual-based data including scallop shell height, adductor muscle weight and quality, sex, reproductive stage, and gonad weight were recorded for each sampled animal. Based on these data, we constructed a predictive model of sea scallop meat weight that included scallop shell height, water depth, adductor muscle color and trip month as explanatory variables. Parameters estimated with a generalized linear mixed modelling approach were reasonably precise and as expected, predicted increasing meat weight as a function of increased shell height. Meat weights were slightly higher in the spatial management area (Closed Area II) relative to stations outside of the area. The temporal trend indicated that meat weights were elevated through their peak from June-August and decreased to a trough from October-November. February and September represented transitional months. Two attributes associated with product quality were also shown to be significant predictors of meat weight. Adductor muscle color was assessed on a qualitative scale and as the observed color deviated from the typical “White” and transitioned through “Light Brown” to “Brown” to “Gray”, the predicted value of meat weight decreased. Additionally, the presence of observable stringiness of the meat (associated with poor meat quality) also showed a similar effect on predicted meat weight. This species began developing its gonads for spawning in the spring, and ripe individuals were observed in August, and spawning occurred between October and November.

Marine protected areas limit the spread of the invasive tunicate *Didemnum vexillum* on Atlantic sea scallop *Placopecten magellanicus* habitat on Georges Bank

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While the success of marine protected areas (MPA) in promoting increased fish biomass in some fisheries has been well-documented, less well known is how MPA might serve to protect against impacts from invasive species. In 1998, an invasive colonial tunicate (*Didemnum vexillum*) was discovered on Georges Bank, and it has since spread both inside and outside of the MPAs located there. It can form dense mats on gravel substrates that are also a preferred habitat for the Atlantic sea scallop (*Placopecten magellanicus*), which supports a highly valuable commercial fishery. Habcam, a vessel-towed underwater imaging system, was used to investigate the spatial distributions of *P. magellanicus* and *D. vexillum* both inside and outside of an MPA. Results indicate that *D. vexillum* is more common in areas open to fishing than in the MPA, even taking bottom substrate effects into account. Additionally, a negative correlation between *P. magellanicus* and *D. vexillum* was found, suggesting that *D. vexillum* competes with the scallops for substrate. Results support the hypothesis that *D. vexillum* is more prevalent in the areas open to bottom-fishing and the spread of this species may be linked to fishing. This research highlights the potential for MPA to protect essential fish and invertebrate habitat from degradation due to invasive species.

Changes in size distribution of sea scallops (*Placopecten magellanicus*) in eastern Maine during period of rotational management

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Rotational management of the sea scallop (*Placopecten magellanicus*) fishery in Maine state waters began in 2012-13 following three-year closures of 13 areas along the coast. Management zone 2 (which extends from Penobscot Bay east to Quoddy Head) was divided into seven (7) areas with 1/3 of each area open to fishing each year. The remaining 2/3 of the area is closed for two (2) years.

A fishery-independent dredge-based survey has been used to assess the Maine scallop resource since 2002. A spring survey of the rotational areas scheduled to be open in the upcoming season has been conducted annually since 2013. Approximately 20-50 tows are completed in each area, depending on the size and extent of the scallop resource. The survey produces estimates of seed, sublegal and harvestable scallop density and geographic distribution patterns for the rotational areas as well as biomass estimates. This information is used to gauge the effectiveness of management measures such as harvest limit, dredge bag ring size, season length and area closures.

Landings have increased during the period of rotational management (Fig. 1). Reports from fishermen and dealers have indicated scallop meat (adductor muscle) size in the fishery has increased from mostly 20-30 count to 10-20 count following the period of closures and under current rotational management. In consideration of this, survey data for the more productive and intensively-fished eastern Maine areas in 2011-17 (prior to and during rotational management) will be examined for change in scallop size and meat weight in order to determine the extent of this factor in the landings increase.

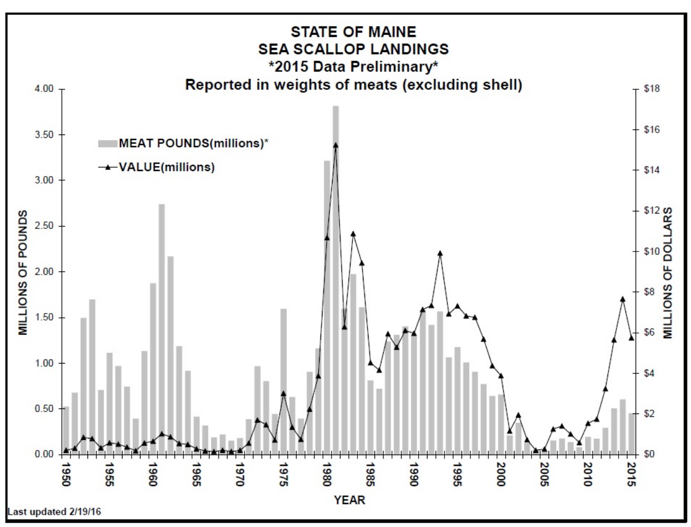

Figure 1. Maine scallop landings 1950-2015 (source: ME DMR).

Field testing of antifouling coatings on scallop aquaculture gear and sites in Chile and Brazil

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Fouling is a big problem for the aquaculture industry, because any gear deployed into the sea is a possible surface for settlement of any kind of organisms. The amount, coverage and diversity of fouling seem to be specific to the geographical area and season when it is tested. To find a treatment that reduces significantly the fouling without toxic side effects is a necessity.

To test a new coating treatment under different conditions, nets and racks with treated/untreated panels were deployed into the sea at Tongoy Bay, Chile (31ºS). The racks as well as the small sized nets were hung from a longline holding scallop pearl-nets and lanterns. The experimental gear was inserted in between regular culture systems. The panels were facing the bottom, and the depth for panels and nets was approximately 0.75m below the surface.

In Chile the experimental materials were deployed in December 2016 to take advantage of the summer months when biofouling is heaviest. In Brazil, racks were deployed in October 2016 and retrieved in December. Monthly observations were recorded at both sites.

The fouling was so intense in Chile that after 1 month already the tags were overgrown and had to be cleaned to see the numbers. The duct tape indicating the upper side could not be distinguished after 2 months in the sea. In Brazil, differences between treated and not treated panels were not so clear. Results will be presented for all experiments.

Panels (left), nets (middle) deployed in Chile after 60 days, and Brazil (right) after 70 days of deployment

Conservation of the Lophotrochozoan *Lox5* gene in the black scallop, *Mimachlamys varia* (L.)

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The Lophotrochozoa are characterized by the presence of *hox* genes of the *Lox5*, *Lox2*, *Lox4*, *Post-1* and *Post-2* types that have not been described in non-lophotrochozoan phyla. De Rosa et al. (1999) found that the *Lox5*, *Lox2* and *Lox4* genes were presented in molluscs. The presence of these *hox* genes in a particular animal can be indicative of its phylogenetic relationships and may help to assign it to one bilaterian clade or another. The aim of this work was search for the presence of *Lox 5* gene in the pectinid *Mimachlamys varia* and to compare its homeodomain sequence with those available from other bivalve molluscs.

Specimens of the black scallop *Mimachlamys varia* were collected from Noia, Galicia (Spain). Genomic DNA isolation from the muscular mass of adult scallops was performed as described in Pérez-Parallé et al. (2016). DNA was amplified, cloned, isolated and sequenced using the conditions specified in Mesías-Gansbiller et al. (2013). Sequences were aligned to the related known homeodomains of Bivalvia by Clustal Omega (Sievers et al. 2011). Phylogenetic analyses were performed by the maximum likelihood (ML) method (Jones et al. 1992) using the MEGA6 package (Tamura et al. 2011).

Following PCR amplification of DNA, a homologue from the *Lox5* gene was isolated. The derived amino acid sequence was designated Cvox Lox5, for *Mimachlamys varia* homeobox. The PCR amplification products corresponded to homeodomain amino acid positions 22 to 44. Residues 39-44 of the third α helix of the homeodomain were well conserved. The orthologue assignment of this *Lox5* gene was determined by phylogenetic analyses by the maximum likelihood and/or the presence of key diagnostic amino acid residues.

Cva Lox5	**AM773680**	**-YNRYLTRRRRIEIAHLLGLTERQ---**
Pma Lox5	Q599Q1	-YNRYLTRRRRIEIAHLLGLTERQIKI
Pye Hox6	Q59HW6	HYNRYLTRRRRIEIAHLLGLTERQI--

The *Lox5* sequences from pectinids: Cva *Lox5*, Pma *Lox5* (Canapa et al. 2005) and Pye Hox6 (Iijima et al. 2006) presented a key signature residue which is characteristic of Lox proteins in lophotrochozoans, Gly39. These Lox homeodomains had significant amino acid sequence identities with other bivalve members of the PG-5 class (91-96% identity). The assignment of these *Lox5* fragments was also confirmed by phylogenetic analysis. Cva *Lox5*, Pma *Lox5* and Pye *Hox6* are grouped into a single clade with other *Lox5* fragments from clams and oysters with moderate/low bootstrap values.

Cadmium-binding proteins of digestive gland of *Mizuhopecten yessoensis* from different anthropogenic impact areas

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Investigations of the effect of anthropogenic pollutions on marine aquatic life are relevant in present time. Because of the ability to accumulate heavy metal cadmium in tissues without any apparent pathological effect scallop, *Mizuhopecten yessoensis,* is a good indicator organism of anthropogenic impact on the marine environment. *M. yessoensis* has a unique well-developed biochemical mechanism of cadmium detoxification presented by the synthesis of high-molecular weight MT-like proteins (72 and 43 kDa) under exposed organism.

The aim of this study was to identify features in the accumulation and distribution of cadmium among cadmium-binding MT-like proteins of the digestive gland of *M. yessoensis* depending on different kind of anthropogenic impact. The three habitats were studied: an area with chronic anthropogenic pollution, near the urban area runoff and tank farms – Pervaya rechka; area of combined effects of heavy metals and ionizing radiation (Chazhma Bay) and clean area - Pos'et bay (control).

The study showed that high molecular weight MT-like proteins of digestive gland of *M. yessoensis* from the three study areas are able to bind cadmium. In the digestive gland of the investigated scallops obtained from two impact regions the main metal-binding protein is the 72 kDa MT-like protein. Whereas in the ecologically clean area Pos'eta bay the main cadmium-binding protein is a 43 kDa.

Scallops from the Pervaya rechka the ratio of cadmium in the proteins of 72 kDa and 43 kDa is 16.5. Thus, the basic cadmium-binding protein is 72 kDa protein. In addition, the analysis of the content of Zn, as the main cadmium competitor for binding sites in proteins, showed that 43 kDa protein from the studied region executes zinc-binding function. Nevertheless, despite this fact, the 72 kDa protein binds zinc in greater amount than 43 kDa protein. Thus 72 kDa is main zinc-cadmium-binding protein for zone of active of anthropogenic exposure. Scallops obtained from Chazhma Bay, a site of a nuclear accident in 1985 and is radioactively contaminated have similar Cd-binding proteins as scallops from Pervaya rechka. Cadmium ratio to 72:43 kDa proteins is 4:1, it shows that 72 kDa protein is main for binding of cadmium.

Results show that aquatic organisms in the Pervaya rechka location are experiencing an increased load of heavy metals and had higher levels of synthesis of the MT-like cadmium-binding protein 72 kDa. Less polluted area is the Chazhma Bay despite the ionization radiation impact and chronic heavy metal contamination. However, scallops from Chazhma Bay also are exposed load compared to the control area. Thus, high molecular weight MT-like cadmium-binding proteins of scallop *M. yessoensis* may serve as biomarkers of anthropogenic pollution of the marine environment.

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