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WELCOME TO THE SHELLFISH CONFERENCE

Welcome to the 10th ICSR in Vlissingen in the beautiful province of Zeeland. This low lying part of The Netherlands has strong links with the sea. For centuries land has been reclaimed, lost and reclaimed again. The Zeeland history is full of dramatic storm events with great losses and continuous defense efforts, resulting in an archipel protected by dikes against the tidal waters. A society of tough people has evolved, characterized by a strong religious commitment and a typical dialect and clothing for each island. Mirrors of this history can still be found in the landscape. The sea was a rich resource as well. Shellfish harvesting and culture is known since historic times. In the 17th century oyster trade occurred with areas in Scotland. Licences were given for oyster culture since 1825. At the end of the 19th century the village of Yerseke quickly developed as the centre of flat oyster culture, with goldrush-type of extremes.

The present shellfish culture in The Netherlands has evolved to a modern industry with a well equipped fleet of mussel dredgers that exploit bottom culture plots in the Wadden Sea and the Oosterschelde. Oyster culture is carried out in the Oosterschelde and the former estuary Lake Grevelingen. Processing industry is located in Yerseke and forms a turntable in the international market with a capacity of over 150 mln kg annual production.

The main topic for modern shellfish culture is to further develop a sustainable approach. As shellfish culture depends on natural processes and often occurs in nature conservation areas, sustainable exploitation requires knowledge on impacts and methods to stimulate positive effects. Therefore industry and government aim for innovations in exploitation and management.

The province of Zeeland and the actual innovation agenda form the right scene for the International Shellfish Conference. The theme for this years is "Innovation in management and exploitation of shellfish resources". The abstract book illustrates the many contributions to this topic and promises a highly interesting conference. We welcome participants from over 30 countries with over 130 paper and poster presentations. The organization is grateful to the sponsors that have made an essential contribution to the conference.

We wish all participants a successful conference and a pleasant stay in Zeeland.

Prof. dr. A.C. Smaal, conference chair

ICSR: FROM SEA TO SHINING AND ACROSS THE POND

Dorothy L. Leonard (The Grower, September 2007)

In the 1970s and 1980s the United States and Canadian governments recognized the decline in the quality of their coastal waters. Both NOAA's National Ocean Service and Environment Canada developed programmes assessing declines and developing methods to restore once productive estuaries. Word spread throughout coastal communities and soon there was a cadre of scientists, community, shellfish industry and government individuals who shared concerns about coastal quality and declining resources and needed a forum in which to exchange ideas and talk about solutions.

Anxious to turn the tide on declining environmental quality, a small group of government, industry, and community representatives came together in 1995 to plan the first International Conference on Shellfish Restoration (ICSR) held on Hilton Head Island, South Carolina in 1996. The first ICSR was designed to recognize the importance of shellfish as indicators of environmental quality and to examine how the health of coastal ecosystems could be improved through shellfish restoration. The second conference returned to Hilton Head in 1998 where over 200 scientists, resource managers, and government officials met to consider how community, regional, national and international partnerships can help the shellfish restoration process. The focus was on successful techniques and how they could be applied to multiple estuaries.

In October 1999, the ICSR conference was held in Cork, Ireland, where it took on a European dimension, the scope broadened to include non-molluscan shellfish such as sea urchin and lobsters. The emphasis throughout the conference was on the marriage of science and management. While highlighting shellfish as a valuable coastal resource, ICSR Europe also addressed important new restoration topics such as artificial reefs, interactions with birds, the carrying capacity of bays, red tides, and the genetic implications of sea ranching.

The Conference returned to Hilton Head in 2000 and, on the heels of that successful meeting, the ICSR continued an international tradition with a Canadian version held in Nanaimo, British Columbia in September 2001. The Canadian meeting showcased the importance of shellfish to the First Nations from the perspective of traditional use and current practice. The field trips, which have become an integral part of the ICSR program, showcased the farming techniques of two shellfish farms: Fanny Bay Oyster and Odyssey Companies. The major social event was The Traditional Feast of the Snuneymuxw First Nation.

There is a unique quality to the ICSR meetings in the US ...the lengthy breaks and social events. At most large conferences the audience is talked to by numerous scientists and students. We often rush from room to room, from one concurrent session to the next, trying to catch as many presentations as possible. A quick nod in the hallway or a moment or two at the coffee table is the extent of our interaction. At the ICSR the coffee breaks, box lunches and evening social events take centre stage. On centre stage are our own shellfish musicians, ranging from saxophone to drums to guitar and violin. We dance as though no one were watching and eat as many oysters as we can possibly manage. Is it fun? You betcha! And much of the collaborations between scientists, managers and community activists begin in these settings.

In 2002 ICSR moved to Charleston, South Carolina, one of the most beautiful coastal cities in the US. The hotel is situated right in the middle of the historic downtown area, a neighbourhood replete with gift shops and excellent restaurants. Heated discussions took place on the role of exotic species in coastal estuaries, fuelled by the potential introduction of the "Chinese" oyster, *Crassostrea ariakensis*, in the Chesapeake Bay. The field trips held prior to the meeting were a visit to Capers Island, a South Carolina Heritage Preserve and the ICSR Golf Tournament. We almost froze to death at the traditional oyster roast but kept warm with the hot debates and dancing. Charleston has remained the site for the ICSR held in the US on even year 2004 and 2006. The social traditions have remained constant but the focus of the meeting has shifted to topics such as the measurements (metrics) of success, community efforts in reef construction, shellfish repletion and restoration of indigenous species such as the Olympia oyster, *Ostreola conchaphila*. In contrast to the US meetings the ICSR in Europe covers all of the scientific topics related to shellfish. For example, the 2005 meeting in Brest, France had concurrent sessions that ranged from genetics, pathology, hatcheries and fisheries management to shellfish ecosystem linkages and the socio-economic, policy, outreach and education aspects of shellfish/habitat restoration.

On November 12-16, 2007, the ICSR will be held in Vlissingen, the Netherlands. Titled "Innovation in the Exploitation and Management of Shellfish Resources" the Dutch programme received over 200 abstracts covering recruitment (spatfall dynamics and management), ecosystem based management (carrying capacity, integrated multitrophic aquaculture), stakeholder involvement and management, (shellfish management and nature conservations, international legislation, education) and new technologies in offshore shellfish culture and hatcheries and nurseries. I asked the Co-Chairs, Aad Smaal and Jeroen Wijsman about their proposed program and why the European programmes are so scientific in nature.

Both Aad and Jeroen commented that the ICSR is the only shellfish forum in Europe* whereas in the US we have annual meetings of the National Shellfisheries Association, which now has a large percentage of international members and covers all of the scientific issues related to shellfish, as well as biannual meetings of the Interstate Shellfish Sanitation Conference which covers all aspects of water quality and public health.

There is a greater need than ever for the enhancement of our coastal ecosystems through shellfish restoration. Not only does the public have a keen interest in restoring water quality to shellfish growing areas, but also the aquaculture industry which is focused on advancing the quality assurance and safety of aquaculture products. The demand for seafood is expected to increase significantly in the next ten years, and the industry will need new sites with good water quality. Our goal is to provide forums throughout the world to draw attention to shellfish, shellfish water quality, and related issues, and to foster partnerships and the exchange of information to further the science of restoration and aquaculture.

Program

Day 0: Monday 12 November 2007

12:00	18:00	Pre-conference excursion to the shellfish industry in Yerseke
16:00	20:00	Registration and ice breaker, Cinecity

Day 1: Tuesday 13 November 2007

8:00	10:00	Registration, CineCity		
10:00	11:00	Opening Session: Conference Room 1 <ul style="list-style-type: none"> • Dr. A. Dijkhuizen (CEO Wageningen UR) • Minister Mrs. Verburg (Ministry of Agriculture, Nature and Food) • Dr. M. Heral (Scientific director Ifremer) • Dr. C. Heip (NIOO/NIOZ) • Mr. T. Verbree (Shellfish industry) • Dr. M. Scholten (Director Wageningen IMARES) 		
11:00	11:25	Coffee break		
11:25	11:30	Sneak preview film 1: Mussel bottom culture, impression of a traditional fishery: mr Leon Praet, ZZ5 Conference Room 1		
11:30	12:00	Plenary session 1: Michael Crawford (London Metropolitan University, UK) THE DETERMINANT ROLE OF SEA FOOD IN THE CEREBRAL EXPANSION THAT LED TO THE EMERGENCE OF <i>H. SAPIENS</i> : Conference Room 1		
12:00	13:15	Lunch CineCity restaurant		
13:15	13:45	Plenary session 2: Karsten Reise (Alfred Wegener Institute, Sylt, Germany) SHELLFISH RECRUITMENT IN COASTAL WATERS: Conference Room 1		
13:45	14:00	Break		
		Parallel session 1: Recruitment dynamics. Chairs: Luca van Duren, Karsten Reise: Conference Room 1	Parallel session 4: Impact of invasions. Chairs Jeroen Wijsman, Norbert Dankers: Conference Room 2	Parallel session 8: Nature conservations and stakeholder involvement. Chairs: Han Lindeboom, Hein Sas: Conference Room 3
14:00	14:20	Presentation 1.1 NEW OYSTER REEFS IN THE EAST FRISIAN WADDEN SEA (GERMAN BIGHT): CRASSOSTREA GIGAS AFFECTS THE COMMUNITY STRUCTURE OF NATIVE BLUE MUSSEL BEDS Alexandra Markert, Achim Wehrmann, Ingrid Kröncke	Presentation 4.1 ADDRESSING THE POTENTIAL INTRODUCTION OF NON-NATIVE MARINE SPECIES WITH MUSSEL SEED TO SITES OF MARINE CONSERVATION IMPORTANCE IN WALES – WITH REFERENCE TO A CASE STUDY. N. Clare Eno, Kate Smith, James Wilson, Gabrielle Wynn	Presentation 8.1 SHELLFISH AT RISK: A GLOBAL ASSESSMENT OF DISTRIBUTION, CONDITION AND THREATS TO HABITAT-FORMING BIVALVES Robert D. Brumbaugh, Michael W. Beck, Alvar Carranza, Loren D. Coen, Omar Defeo, Hunter S. Lenihan, Mark W. Luckenbach, Caitlyn Toropova, and Jeffery S. Vincent.
14:20	14:40	Presentation 1.2 SHELL BUDGETS FOR THE JAMES RIVER, VIRGINIA OYSTER RESOURCE. Roger Mann, Melissa Southworth, Juliana M. Harding and James Wesson	Presentation 4.2 THE IMPACT OF THE SLIPPER LIMPET (<i>CREPIDULA FORNICATA</i>) ON THE OYSTER FISHERIES OF SOLENT AND THE RIVER FAL, ENGLAND. Andrew FitzGerald & Peter Walker	Presentation 8.2 MOLLUSCS TRADITIONAL EXPLOITATION IN SENEGAL: <i>ANADARA SENLIS</i> L. (1758). BIOLOGICAL POTENTIALITIES AND RISKS Alvares G. F. Benga

14:40	15:00	Presentation 1.3 PREFERENTIAL SETTLEMENT OF BIVALVE LARVAE IN THE VICINITY OF ADULT POPULATIONS Luca van Duren, Kan van Dalfsen, Tom Ysebaert, Karin Troost	Presentation 4.3 <i>ENSI/ AMERICANUS</i> IN DUTCH COASTAL WATERS: FROM INVADER TO PERMANENT RESIDENT Joana F. M. F. Cardoso, Rob Dekker, Rogier Daan, Johannes IJ. Witte and Henk W. van der Veer	Presentation 8.3 WHAT FACTORS AFFECT THE RESTORATION SUCCESS OF COCKLE BEDS IN NEW ZEALAND? Islay Marsden and John Pirker
15:00	15:30	Tea break	Tea break	Tea break
15:30	15:50	Presentation 1.4 SPATIAL AND TEMPORAL VARIABILITY IN <i>Mytilus edulis</i> LARVAL ABUNDANCE AND SPATFALL AND SPAT GROWTH in the Dutch Wadden Sea and Oosterschelde estuaryPauline Kamermans, Marnix Poelman, Arnold Bakker, Ainhoa Blanco, Emiel Brummelhuis, Ad van Gool, Johan Jol, Jeroen Kals, Jack Perdon, Aad Smaal	Presentation 4.4 RISK ASSESSMENT OF BOTTOM CULTURE OF THE PACIFIC OYSTER, <i>CRASSOSTREA GIGAS</i> IN IRELAND Francis X. O'Beirn, Terry McMahon, Micheal O'Conneide.	Presentation 8.4 DYNAMICS OF MUSSEL BEDS AND IMPACT OF OYSTERS – DIFFERENT PERSPECTIVES FROM THE DUTCH AND THE NORTHERN GERMAN WADDEN SEA Georg Nehls, Heike Büttger, Norbert Dankers, Frouke Fey, Kees Goudswaard, Jenny Cremer
15:50	16:10	Presentation 1.5 THE IMPACT OF THE ADULT BLUE MUSSEL (<i>MYTILUS EDULIS</i>) POPULATION ON SETTLING OF CONSPECIFIC LARVAE. Per Dolmer, Ea Stenalt	Presentation 4.5 ECOLOGICAL CONSEQUENCES OF THE PACIFIC OYSTER (<i>CRASSOSTREA GIGAS</i>) INVASION ON COASTAL HABITATS IN WESTERN EUROPE. Hily Christian. and Lejart Morgane.	Presentation 8.5 SUSTAINABLE APPROACHES FOR THE MANAGEMENT OF MANILA CLAM (<i>TAPES PHILIPPINARUM</i>) SPAT IN THE VENICE LAGOON (ITALY) Emanuele Ponis, Rosella Boscolo, Federica Cacciatore, Giuseppe Chiaia
16:10	16:30	Presentation 1.6 MONITORING OF THE SETTLING OF <i>MYTILUS EDULIS</i> WITH SUSPENDED COLLECTORS – EFFECTS OF EXPOSURE TIME Uwe Walter & Inge Walter	Presentation 4.6 DEVELOPMENT OF THE PACIFIC OYSTER (<i>CRASSOSTREA GIGAS</i>) IN THE DUTCH WADDEN SEA Norbert Dankers, Frouke Fey, Kees Goudswaard	Presentation 8.6 COMBINING ECONOMIC AND ECOLOGICAL GOALS IN OYSTER MANAGEMENT IN THE CHESAPEAKE BAY, USA: EXPERIENCES FROM A MULTI-STAKEHOLDER ADVISORY PANEL Mark Bryer, Michael Lipford, and A. Thomas Leggett
16:30	16:50	Poster session 1	Poster session 1	Presentation 8.7 CONSULTING STAKEHOLDERS IN THE PERSPECTIVE OF INTEGRATED MANAGEMENT PLANS UNDER THE HABITATS DIRECTIVE (92/43): THE MORE, THE MERRIER? Frank Neumann
16:50	17:10	Poster session 1	Poster session 1	Presentation 8.8 THE ROLE OF ECOLOGICAL SCIENCE IN SHELFISH FISHERY POLICY MAKING: THE DUTCH EVA II-CASE Lucien Hanssen, Marieke van Katwijk & Etienne Rouwette
17:10	18:00	Poster session 1	Poster session 1	Poster session 1
18:30	20:30	Reception at the Provincial Government Abdij Middelburg		

Day 2: Wednesday 14 November 2007

9:00	9:05	Sneak preview film 2: Suspended mussel culture: 20 years experience in the Oosterschelde: mr Wim Schot ZZ10 Viskwekerij Neeltje Jans: Conference Room 1		
9:05	9:35	Plenary session 3: Wouter van Dieren (IMSA Amsterdam, The Netherlands) THE CASE OF THE WADDENSEA: HOW TO REVIEW THE ROLE OF SCIENCE IN POLITICAL DECISION MAKING: Conference Room 1		
9:35	9:50	Break		
		Parallel session 7: Benthic impact of mussel culture. Chair: Christian Hily, Per Dolmer: Conference Room 1	Parallel session 9: Education and extension programmes. Chairs: Gavin Burnell, Wilbert Schermer-Voest: Conference Room 2	Parallel session 11: Innovations in hatchery / nursery systems. Chairs: Pauline Kamermans, Rene Robert: Conference Room 3
9:50	10:10	Presentation 7.1 ENVIRONMENTAL IMPACTS OF MUSSEL FARMING IN AN EUTROHICATED DANISH INLET WITH EMPHASIS ON THE SEDIMENT <u>Carlsson MS</u> , Petersen JK, Marianne Holmer	Presentation 9.1 WHAT THE BAY HINGES ON: TEACHING ECOLOGY, RESTORATION, AND STEWARDSHIP <u>Cara Muscio</u> , and Gef Flimlin	Presentation 11.1 USE OF REMOTE SETTING METHODS TO PRODUCE DISEASE RESISTANT SEED STOCK FOR OYSTER RESTORATION IN DELAWARE'S COASTAL (INLAND) BAYS <u>John W. Ewart</u> , Frank Marengi, and Kate Rossi-Snook
10:10	10:30	Presentation 7.2 INFLUENCE OF MUSSEL AQUACULTURE ON BENTHIC ORGANIC ENRICHMENT IN A NUTRIENT-RICH COASTAL EMBAYMENT Barry Hargrave, <u>Peter Cranford</u> , Lisa Doucett, Brent. Law and Tim Milligan	Presentation 9.2 SHELLFISH RESTORATION: SCIENCE, EDUCATION AND ART AS STRANGE BEDFELLOWS. <u>Gef Flimlin</u> , Rick Bushnell, and Cara Muscio	Presentation 11.2 SHELLFISH HATCHERY AND NURSERY DEVELOPMENTS IN THE NORTHWESTERN UNITED STATES <u>Bill Dewey</u>
10:30	10:50	Presentation 7.3 BENTHIC MACROFAUNA AND FORAMINIFERA AS INDICATORS OF OYSTER FARMING EFFECTS ON INTERTIDAL AREAS IN THE PERTUIS CHARENTAIS (FRANCE) <u>Vincent M.P. Bouchet</u> , Pierre-Guy Sauriau and Jean-Pierre Debenay	Presentation 9.3 EDUCATION FOR TRANSLOCATION? <u>Janet H. Brown</u>	Presentation 11.3 FORMULATED FEEDS GIVE NEW PERSPECTIVES FOR BLUE MUSSEL HATCHERIES <u>Nancy Nevejan</u>
10:50	11:20	Coffee break		
11:20	11:40	Presentation 7.4 INDICATORS OF BENTHIC IMPACT OF MUSSELS CULTURE ON THE SEDIMENT IN A MACROTIDAL ENVIRONMENT (PERTUIS BRETON, FRANCE) <u>Alain Bodoy</u> , Jean-Louis Martin, Anne Gaelle Haubois	Presentation 9.4 CHILDREN'S WADING POOL CLAMS: A PROGRAM TO REAR MANILA CLAMS (<i>TAPES JAPONICA</i>) FROM HATCHERY SEED THROUGH AN INTERMEDIATE NURSERY TO FULL GROW OUT IN ONE METER DIAMETER CHILDRENS WADING POOLS (KIDDIE POOLS), AND ITS TRANSFER TO COMMUNITY OUTREACH AND ENVIRONMENTAL EDUCATION PROGRAMS IN THE RESTORATION COMMUNITY IN WASHINGTON STATE <u>Barth, D.</u> , Gibbons, J. L	Presentation 11.4 EFFECTS OF PHOTOPERIOD AND LENGTH OF CONDITIONING ON GAMETOGENESIS AND SPAWNING OF THE MUSSEL <i>MYTILUS GALLOPROVINCIALIS</i> <u>Dominguez, L.</u> , Villalba, A., Fuentes, J.

11:40	12:00	Presentation 7.5 COMPARISON OF SPECIES COMPOSITION, DIVERSITY AND ABUNDANCE IN SUB-TIDAL AND FLOATING OYSTER (<i>Crassostrea</i> <i>virginica</i>) GEAR HABITAT FROM DELAWARE'S INLAND BAYS Gulnihal Ozbay, Patrick Erbland, Frank Marengi, and Kate Rossi-Snook	Presentation 9.5 ROLE OF FISHERMEN ORGANISATIONS IN STOCK ENHANCEMENT UNDER "NEW" RULES <u>D. DEL PIERO</u>	Presentation 11.5 INFLUENCE OF DIET ASSEMBLAGE ON <i>OSTREA EDULIS</i> BROODSTOCK CONDITIONNING AND SUBSEQUENT LARVAL DEVELOPMENT GONZÁLEZ ARAYA, R., PETTON, B., MINGANT, C., LE BRUN L., <u>ROBERT, R.</u>
12:00	12:20	Presentation 7.6 ENVIRONMENTAL IMPROVEMENT OF AQUACULTURE FARMS BY SPREADING RED CLAY AT YEOJA BAY IN KOREA <u>Na, Gui Hwan</u> , So young Park, Myung sun Paik, Jung Chan Park	Presentation 9.6 EXPERIENCE SHARING IN MUSSEL FARMING IN DENMARK <u>Helle Torp Christensen</u> , Per Dolmer, Sisse Redeker, Hamish Stewart, Jan Bangsholdt, Thomas Olesen	Presentation 11.6 INTRA-CAPSULAR DEVELOPMENT AND HATCHING IN MARINE GASTROPOD <i>HEXAPLEX TRUNCULUS</i> (MURICIDAE) <u>Youssef Lahbib</u> , Sami Abidli, Moncef Boumaiza and Najoua Trigui El-Menif
12:20	13:30	Lunch CineCity Restaurant		
13:30	18:00	Excursion to Neeltje Jans, Storm surge barrier		
18:00	22:00	Symposium dinner Neeltje Jans Restaurant		

Day 3: Thursday 15 November 2007

9:00	9:05	Sneak preview film 3 Mussel seed collection, novel techniques for seed supply: mr Wout van den Berg, BRU6: Conference Room 2		Shellfish conference / Farmers days: Conference Room 1 Chair Albert Vermuë (Director Fisheries, Ministry of Agriculture, Nature and Food The Netherlands)
9:05	9:35	Plenary session 4: Peter Herman (Netherland Institute of Ecology, The Netherlands). CURRENTS, NUTRIENTS, FOOD AND PREDATORS: HOW TO CHOOSE YOUR NEIGHBORHOOD AS A MUSSEL: Conference Room 2		
9:35	9:40	Break		
		Parallel session 2: The role of shellfish in the food chain. Chairs: Peter Herman, Øivind Strand: Conference Room 2	Parallel session 10: Chances for offshore shellfish culture. Chairs: Bela Buck, Muki Shpigel: Conference Room 3	
9:40	10:00	Presentation 2.1 FEEDING BEHAVIOUR OF THE MEDITERRANEAN MUSSEL, <i>MYTILUS GALLOPROVINCIALIS</i> L., IN ALFACS BAY (N.W. MEDITERRANEAN SEA): A FIELD STUDY <u>Eva Galimany</u> , Montserrat Ramón, Irrintzi Ibarrola	Presentation 10.1 THE IMPLEMENTATION OF BIODIAGNOSTIC TOOLS HELPS TO SELECT APPROPRIATE SITES FOR OFFSHORE CULTIVATION OF BLUE MUSSELS (<i>Mytilus edulis</i> L) <u>Matthias Brenner</u> , Bela H. Buck, M. Stede, A. Koehler	10:00 Opening: Mrs. K Peijs, Governor of the Province of Zeeland
10:00	10:20	Presentation 2.2 FEEDING BEHAVIOUR OF <i>PECTEN MAXIMUS</i> AND <i>MYTILUS EDULIS</i> IN A LOW SESTON ENVIRONMENT <u>Tore Strohmeier</u> , Øivind Strand, Peter Cranford and Cathinka Krogness	Presentation 10.2 THE ATTECHMENT STRENGTH OF OFFSHORE GROWN BLUE MUSSEL <i>Mytilus edulis</i> L. THREADS ACCORDING TO THE HARD SUBSTRATES' NANOSTRUCTURE AT DIFFERENT CURRENT VELOCITIES <u>Andre Pechura</u> , Matthias Brenner, Bela H. Buck	10:15 Mussel farming in the USA: Theo de Koning
10:20	10:40	Presentation 2.3 FATTY ACID TROPHIC MARKERS IN <i>MYTILUS EDULIS</i> AND <i>CRASSOSTREA GIGAS</i> : ARE THEY REALLY WHAT THEY EAT? <u>Arnon Uppabullung</u> , Pauline Kamermans, Leon Moodley, Nicole A. Dijkman, Marco Houtekamer, Peter MJ Herman	Presentation 10.3 OFFSHORE SHELLFISH FARMING – A DEVELOPING PROSPECT IN NEW ZEALAND <u>K. G. Heasman</u> , N. Keeley, C. Batstone and B. Knight	10:45 Mussel farming in Chili: Alejandro Floras
10:40	11:00	Presentation 2.4 COMPETITION BETWEEN NATIVE BIVALVES AND AN INTRODUCED OYSTER THROUGH LARVIPHAGY? <u>Karin Troost</u> , Pauline Kamermans, Eize J. Stamhuis & Wim J. Wolff	Presentation 10.4 PROGRESS AND PROSPECTS OF EXTENSIVE AQUACULTURE WITHIN OFFSHORE WIND FARMS: THE ANSWER TO SPATIAL SCARCITY? <u>Bela H. Buck</u> , Gesche Krause	11:15 Mussel farming in China: Tian Zhen
11:00	11:20	Coffee break		12:00 Lunch and exhibition
		Parallel session 2 continuation	Parallel session 12: Genetics and genomics. Chairs: Piere Boudry, Jose Fuentes: Conference Room 3	
11:20	11:40	Presentation 2.5 THE NEAR DISAPPEARANCE OF STARFISH (<i>ASTERIAS FORBESI</i>) AND ITS EFFECTS UPON MOLLUSCAN LANDINGS IN THE ESTUARIES OF THE NORTHEASTERN U.S. <u>Clyde L. MacKenzie, Jr.</u>	Presentation 12.1 ADAPTATION CAPACITIES OF AN INVASIVE SPECIES, THE PACIFIC OYSTER <i>CRASSOSTREA GIGAS</i> , ALONG THE FRENCH ATLANTIC OCEAN COASTS <u>Anne-Leila Meistertzheim</u> , Nelly Le Goïc, Alain Marhic, Christian Tartu, Pierre Boudry and Marie-Therese Thébault	13:30 Position of Holland in Europe: Nicolas Ranninger

11:40	12:00	Presentation 2.6 THE IMPORTANCE OF MUSSEL BED PATCHINESS FOR FOOD SUPPLY: BALANCE BETWEEN GRAZING, TIDAL ADVECTION, VERTICAL TURBULENT FLUX AND SESTON CONCENTRATION. <u>C. Saurel</u> , J.K. Petersen, P. Wiles, M.J. Kaiser	Presentation 12.2 IDENTIFICATION OF <i>Mytilus edulis</i> COMPLEX SPECIES USING REAL-TIME PCR <u>P. Joana Dias</u> , Lauriane Sollelis, Stuart Piertney, Ian Davies and Michael Snow	14:00	Seed mussel collecting worldwide: Ruud Coers	
12:00	12:20	Presentation 2.7 INFLUENCE OF MUSSEL AQUACULTURE ON NITROGEN DYNAMICS IN A NUTRIENT ENRICHED COASTAL EMBAYMENT <u>Peter J. Cranford</u> , Peter M. Strain, Michael Dowd, Barry T. Hargrave, Jonathan Grant, Marie-Claude Archambault	Presentation 12.3 PHYSIOLOGICAL AND MOLECULAR BASIS OF GAMETOGENESIS IN TRIPLOID PACIFIC OYSTERS, <i>CRASSOSTREA GIGAS</i> . <u>Julien Normand</u> , Arnaud Huvet, Caroline Fabioux, Morgan Raguenes & Pierre Boudry	14:30	Results of seed mussel collection experiments: Pauline Kamermans	
12:20	12:40	Presentation 2.8 DOES HYDRODYNAMISM AFFECT SPATIAL DIFFERENCES IN BIOLOGICAL PERFORMANCES OF THE PACIFIC OYSTER, <i>Crassostrea gigas</i> OBSERVED IN THE BAIE DES VEYS ESTUARY ? <u>Karine Grangeré</u> , Alain Ménesguen, Sébastien Lefebvre, Cédric Bacher	Presentation 12.4 QTL MAPPING FOR RESISTANCE TO BONAMIOSIS IN THE EUROPEAN FLAT OYSTER <i>OSTREA EDULIS</i> Delphine Lallias, Andy Beaumont, Chris Haley, Serge Heurtebise, <u>Pierre Boudry</u> and Sylvie Lapègue	15:00	Governmental policy for off bottom installation: Annelie Boogerd	
12:40	14:00	Lunch CineCity Restaurant			15:30	Pause and exhibition
14:00	14:30	Plenary session 5: Sandra Shumway (University of Connecticut, USA) IMPACTS OF HARMFUL ALGAL BLOOMS ON REPRODUCTION AND RECRUITMENT IN SHELLFISH: Conference Room 2			16:00	Discussion with speakers on the future of the Dutch mussel cultivation
14:30	14:40	Break				
		Parallel session 6: Shellfish restoration: native or introduced species? For ecological or commercial benefit? Chair: Dorothy Leonard, Rick de Voe: Conference Room 2	Parallel session 13a: Shellfish as valuable seafood; 13b: Shellfish physiology and seaweed Chair: Joop Luten: Conference Room 3			
14:40	15:00	Presentation 6.1 BASELINE ASSESSMENT OF GIANT CLAM POPULATION (FAMILY TRIDACNIDAE) IN SAGAY MARINE RESERVE, NEGROS OCCIDENTAL, CENTRAL PHILIPPINES PRIOR TO STOCK ENHANCEMENT OF HATCHERY-BRED GIANT CLAMS <i>TRIDACNA GIGAS</i> FROM AN ADJACENT OCEAN NURSERY <u>Ma. Junemie Hazel L. Leбата-Ramos</u> , Koichi Okuzawa, Ronald J. Maliao, Jeff Bogart R. Abroqueña, Mark Darwin N. Dimzon, Terence U. Dacles	Presentation 13.1 CONTROL OF PUBLIC HEALTH RISKS ASSOCIATED WITH SEWAGE-CONTAMINATED SHELLFISH <u>Bill Dore</u>			
15:00	15:20	Presentation 6.2 EVALUATING THE POTENTIAL OF A NON-NATIVE OYSTER SPECIES (<i>CRASSOSTREA ARIAKENSIS</i>) TO RESTORE ECOLOGICAL FUNCTION TO THE CHESAPEAKE BAY, USA <u>P.R. Kingsley-Smith</u> , M.W Luckenbach, K.T Paynter Jr., S.K. Allen Jr., D.W. Meritt, H.D. Harwell and M.L. Kellogg	Presentation 13.2 OPPORTUNITIES IN MOLLUSC PRODUCT DEVELOPMENT AND MARKETING. Adriaan Kole, <u>Rian Schelvis</u> , and Joop Luten			

15:20	15:40	<p>Presentation 6.3 MAXIMIZING POTENTIAL REPRODUCTIVE SUCCESS ON RESTORED OYSTER REEFS: USING AGE- AND SIZE-SPECIFIC SEX RATIOS TO EVALUATE MANAGEMENT STRATEGIES <u>M. Lisa Kellogg</u> and Kennedy T. Paynter</p>	<p>Presentation 13.3 SUSTAINABLE EXPLOITATION OF LIVE CRUSTACEANS IN EUROPE INVOLVING SMES, INDUSTRY AND RTDS: CASE STUDY <u>António Marques</u>, Sara Barrento, Bárbara Teixeira, Sónia Pedro, Maria Leonor Nunes</p>
15:40	16:10	Tea break	
16:10	16:30	<p>Presentation 6.4 IMPORTANCE OF COMMERCIAL OYSTER STOCKS IN THE RECOVERY OF STOCKS OF NATIVE EUROPEAN OYSTERS, <i>Ostrea edulis</i>. <u>D. Roberts</u>, D. Smyth, R.J. Kennedy, J.A Strong & L. Browne.</p>	<p>Presentation 13.4 METABOLIC TEMPERATURE DEPENDENCE OF ACCLIMATIZED <i>MYTILUS</i> SPP. AND <i>MACOMA BALTHICA</i>, A MACROPHYSIOLOGICAL APPROACH. <u>Jeroen M. Jansen</u>, Sjoerd Wendelaar Bonga and Herman Hummel</p>
16:30	16:50	<p>Presentation 6.5 ECOLOGICAL IMPACT OF AN EXPERIMENTAL LARGE SCALE REMOVAL OF PACIFIC OYSTERS (<i>CRASSOSTREA GIGAS</i>) FROM NATURAL BEDS IN THE OOSTERSCHELDE. <u>Jeroen Wijsman</u>, Marco Dubbeldam, Erik Van Zanten, Aad Smaal.</p>	<p>Presentation 13.5 COMPARISON OF EASTERN OYSTER (<i>CRASSOSTREA VIRGINICA</i>) AND BLUE MUSSEL (<i>MYTILUS EDULIS</i>) FEEDING RATES AT LOW TEMPERATURES <u>Luc A. Comeau</u>, Fabrice Pernet, Réjean Tremblay, Stephen S. Bates</p>
16:50	17:10	Poster session 2	<p>Presentation 13.6 ENERGY FROM SEAWEED AS STARTING POINT FOR THE OPEN SEAFARM CONCEPT <u>W. Brandenburg</u></p>
17:10	18:30	Poster session 2	
18:30	20:00	Guided city walk and visit to maritime and water museum "Muzeeum" Vlissingen	

Shellfish conference / Farmers days:
Conference Room 1

Business demonstrations

Day 4: Friday 16 November 2007

9:00	9:05	Sneak preview film 4 Coastal defence and mussel culture: musselfarmer mr Johnny Dhooge and coastal engineer mr Leo Adriaanse about "sandhunger": Conference Room 2.		Shellfish conference / Farmers days: Conference Room 1 Chair Ron Barbé (mussel industry)
9:05	9:35	Plenary session 6: Muki Spighe (National Center for Mariculture, Eilat, Israel) Shellfish in multitrophic systems: Conference Room 2		
9:35	9:40	Break		
		Parallel session 5: Carrying capacity for shellfish exploitation and modelling. Chairs:Theo Prins, Marianne Alunno-Bruscia: Conference Room 2	Parallel session 3: Shellfish management, eutrophication and harmful algal blooms. Chair: Sandra Shumway: Conference Room 3	9:15 Oysters: Piere Boudry
9:40	10:00	Presentation 5.1 ENHANCEMENT OF CARRYING CAPACITY OF MUSSEL CULTURE IN FJORDS BY ARTIFICIAL UPWELLING OF NUTRIENT-RICH DEEP WATER <u>Øivind Strand</u> , Jan Aure, Tore Strohmeier, Lars Asplin and Svein Rune Erga	Presentation 3.1 EFFECT OF SELECTIVE MORTALITY ON STOCKING EXPERIMENTS. <u>Marcel Fréchette</u>	9:45 Clams, the Italian experience: Aurelio Zentelin
10:00	10:20	Presentation 5.2 HIGH RESOLUTION PHYTOPLANKTON DEPLETION MAPPING AT NORWEGIAN MUSSEL AQUACULTURE FARMS. <u>Peter. J. Cranford</u> , Øivind Strand and Tore Stroheimer	Presentation 3.2 CARRYING CAPACITY OF THE DUTCH WADDEN SEA FOR SHELLFISH AND IMPLICATIONS FOR FISHERIES AND BIRDS <u>Bert Brinkman</u>	10:15 Scallops: Alejandro Florás
10:20	10:40	Presentation 5.3 APPLICATION OF SATELLITE REMOTE SENSING TO AQUACULTURE ECOSYSTEMS <u>Jon Grant</u>	Presentation 3.3 TRENDS ON INTEGRATED COASTAL ZONE MANAGEMENT IN EUROPE AND ITS RELEVANCE FOR SHELLFISH AQUACULTURE <u>Gesche Krause</u>	10:45 Break and exhibition
10:40	11:00	Presentation 5.4 ASSESSING CARRYING CAPACITY OF BAIE DES VEYS (NORMANDY, FRANCE) WITH A BIOLOGICAL MODEL <u>A. Gangnery</u> , C. Bacher, K. Grangeré	Presentation 3.4 SHELLFISH FARMING IN GREECE <u>Theodorou J.A.</u> , Tzovenis I.	11:15 Growing mussels from spat: Nancy Nevejan
11:00	11:20	Coffee break		11:45 Culture of seaweed: Tian Zhen
		Parallel session 5 continuation: Conference Room 2	Parallel session 14: Energy for shellfish culture. Chair: Willem Brandenburg: Conference Room 3	12:30 Lunch and exhibition
11:20	11:40	Presentation 5.5 MODELLING THE GROWTH OF MYTILUS EDULIS (L.) BY COUPLING A DYNAMIC ENERGY BUDGET MODEL WITH SATELLITE DERIVED ENVIRONMENTAL DATA Yoann Thomas, <u>Joseph Mazurié</u> , Stéphane Pouvreau, Cédric Bacher, Francis Gohin, Caroline Struski, Patrick Le Mao	Presentation 14.1 THE GREEN SOLAR COLLECTOR A NOVEL PHOTO-BIOREACTOR FOR THE EFFICIENT PRODUCTION OF ALGAL BIOMASS ON SUNLIGHT. <u>Jan-Willem F. Zijffers</u> , Marcel Janssen, Hans Tramper and Rene H Wijffels	14:00 Inland farming: Jan Ketelaars
11:40	12:00	Presentation 5.6 BIO-ENERGETICS OF CRASSOSTREA GIGAS AS MODELLED WITH THE DEB THEORY. 1. WHAT'S NEW WITH THE OYSTER-DEB MODEL? <u>Yves Bourles</u> , Stéphane Pouvreau, Marianne Alunno-Bruscia, Didier Leguay, Christophe Arnaud, Bas Kooijman Philippe Goulletquer	Presentation 14.2 MICROALGAE AS FEEDSTOCK FOR BIODIESEL? <u>Marcel Janssen</u> , Maria J. Barbosa, René H. Wijffels	

12:00	12:20	<p>Presentation 5.7 BIO-ENERGETICS OF CRASSOSTREA GIGAS AS MODELLED WITH THE DEB THEORY. 2. APPLICATION OF THE OYSTER-DEB MODEL IN ARCACHON BAY (FRANCE) Stéphane Pouvreau, Danièle Maurer, Ismael Bernard, Yves Bourles, Nadine Neau-Masson, Myriam Rumebe, Marianne Alunno-Bruscia</p>	<p>Presentation 14.3 HAPPY SHRIMP <u>Gilbert Cutessi</u></p>	
12:20	12:40	<p>Presentation 5.8 MUSSEL CULTURES AND THE EUTROPHIC MARINE ENVIRONMENT IN THERMAIKOS GULF – NW AEGEAN SEA, GREECE Papathanassiou E., Pagou K., Giannakourou A., Krasakopoulou, E., Galinou-Mitsoudi S., Assimakopoulou G., Anagnostou Ch., Krestenitis I., Drakopoulou P., Zervoudaki S., Stroglyoudi E. & Pavlidou A.</p>	<p>Presentation 14.4 SEALAND SOLE: AN INNOVATIVE PILOT PROJECT ON INTEGRATED MULTITROPHIC AQUACULTURE <u>Jan Ketelaars</u></p>	<p>14:30 Aquaculture and preservation of the sea: Robert Brumaugh</p>
12:40	13:00	Lunch	<p>Presentation 14.5 co-management strategies AND BIOLOGICAL REGULATION of O BOHIDO CLAM FISHERY, RÍA DE AROUSA, GALICIA A. <u>Sánchez-Mata</u>; J. Molares; M. Rodal; P. Carreira; A. Crego; J.M. Parada; G. Martínez; C. Darriba y J. Mariño</p>	<p>15:00 Fitting shellfish culture into the landscape: Bill Dewey</p>
13:00	14:00	Lunch		<p>15:30 Pause and exhibition</p>
14:00	15:00	<p>Conference Room 2 Plenary discussion: Wrap-up sessions by session chairs</p>		<p>16:00 Discussion with speakers on new products and production methods; spatial planning and how to fit shellfish production into the landscape</p>
15:00	15:30	Tea break		
15:30	16:30	<p>Conference Room 2 Installation of thematic group EAS (Johan Verreth, Wageningen University) Ceremony best poster award Closure ICSR 2007</p>		

Keynote presentations

THE ROLE OF SHELLFISH AND SEA FOODS IN HUMAN EVOLUTION. M. CRAWFORD

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The thrust of this paper is that lipids derived from shellfish and sea foods were and are principle determinants in evolution. They played a critical role in the final phase of cerebral expansion in human evolution and are still modifying the present evolutionary phase of our species.

Life first evolved about 3 billion years ago on this planet. The earth's history is divided sharply into two parts:

1. During the first 2.5 billion years, the only fossils found in abundance in the pre-Cambrian era are the stromatolites. This vast Pre-Cambrian era was dominated by the Cyanophyta generally attributed to the blue green algae. Notably, they show no intracellular detail. Their photosynthetic systems synthesize and utilize $\omega 3$ fatty acids, particularly in the photoreceptor system.

2. The second part, is the Vendian followed by the Cambrian era of 600 million years ago when the oxygen tension had risen above the Pasteur point at which aerobic metabolism becomes thermodynamically possible [Fischer 1965]. The 32 phyla we know today, suddenly explode into the fossil record in a short period of time. These fossils provide considerable intracellular detail.

Of special interest was the emergence of differentiated cells. The intracellular detail is made largely of membrane lipid bi-layers. Different intracellular functions required organisation which was made possible by membrane lipids. Different cell functions required control by a nervous system which is largely lipid (60%) in its chemistry. Relevant to the species that ultimately led to human evolution was vision, a nervous system, and finally the brain. The lipids involved are enriched with long chain fatty acids (20 carbon chain length and longer). Of special interest are the super-unsaturated fatty acids particularly all-cis-docosa-4,7,10,13,16,19-hexaenoic acid (DHA). These lipids are closely associated with membrane proteins and alteration of their composition alters protein function. The membrane proteins, especially those of the plasma membranes, are the receptors, signalers, transporters and anti-oxidant defences. Influencing their function alters signalling as well as shifting the dynamics of the individual fatty acids acting as ligands for nuclear receptors (Chawla et al 2001). Lipid-derived second messengers with subsequent activation of protein phosphorylation cascades has emerged as one of the fundamental mechanisms of signal transduction in animal cells (Hinden et al 2000, Underhaug et al 2004, Rozengurt et al 2005).

Despite the wide genomic changes over the last 600 million years, DHA has been used in the photoreceptor and synaptic structures in the dinoflagellates, cephalopods, fish, amphibia, reptiles, birds and mammals. This extreme conservation is despite the fact that its immediate precursor all-cis-docosa-7,10,13,16,19-pentaenoic acid ($\omega 3$ DPA - C22:5 $\omega 3$) would have been more abundant, more readily synthesised and less susceptible to peroxidation. But it did not replace DHA. One could argue that for 600 million years whilst the genomes changed, the gene for DHA remained fixed. There are genes for enzymes involved in fatty acid synthesis but no known "gene for DHA". Conversely, as DHA stimulates the expression of over 107 genes involved in neural development, function and metabolism (Kitajka et al 2004), was the story the other way around? Was it the unique properties of DHA which determined the gene performance so rigidly for 600 million years?

During mammalian evolution all land based mammals lost brain size in relation to body size as they evolved into larger and yet larger animals. So one has to ask what were the critical considerations that enabled H. sapiens (Hs) to escape this degenerative biological trap of brain loss? The genetic evidence puts the separation of the line that came down to Hs at between 5-7 million years ago. The DNA of Hs is only 1.5% different from that of the chimpanzee. Thus the Hs DNA is ancient. The DNA does not change in composition in response to environment or diet so nor does protein composition change. The cell factor that readily changes in response to both environment and diet is the lipid component. Just as the environmental medium set the unchanging life forms for the first 2.5 billion years of prokaryotic life on the planet, is it possible that the influence of environment and the chemistry of the food web on lipids affected protein function, signalling and gene expression to regulate the balance between body growth and brain growth. The universal collapse of brain size as body growth expanded on land demonstrates that different principles are involved in body growth and brain growth the former being predominantly protein and the latter lipid. Studies on lipids in large land based mammals reveal a paucity of DHA (Crawford et al 1969, 1976) which in turn means if Hs had to rely on land meat there would be little preformed DHA to support brain development. By contrast, if an ape found the estuarine ecosystem and witnessed the birds eating the oysters and mussels, it would not have taken long for the realisation to set in that here was an abundant food supply ready for the taking. Settling at the seaside would have also sealed the separation from the great apes living in the trees. Moreover the traditional, male chauvinist view of macho men killing buffaloes for meat, forgets that the men are of least importance. It is the women that matter as they incubate the brain of the next generation and next generation. They would be able to feast on the richest food resource on the planet and yet still. Not only would the shell fish provide a rich course of preformed DHA but also iodine and selenium and other trace elements which are in short supply on land and cause such mental disorders from iodine deficiency. Fish stranded in rocky pools as the tide receded would have added to the rich food store meaning that women, no matter how pregnant, when breast feeding and their children would have easily satisfied their nutritional needs. They would also have had access to fruits and other land based foods growing at the sea side and estuarine shores. The brain evolved in the sea 500 million years ago and still needs the same marine cluster of nutrients today. The history of evolution of the brain is of degeneration on land. The only parallel example of large brains are in the marine mammals, especially the dolphin which has 1.8 Kg of brain. Continued evolutionary change of Homo sapiens is to be expected, either up or down. This notion is beginning to be suggested by others (World Science 2007) as affecting physical and mental states.

SHELLFISH RECRUITMENT IN COASTAL WATERS. K. REISE.

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Although mature individuals of exploited bivalve molluscs typically spawn millions of eggs, successful recruitment is in most species and areas a rather irregular and often rare event. Natural populations circumvent this dilemma by broadcasting their larvae and by assemblages of adults achieving considerable longevity. The latter is often curtailed in exploited populations, aggravating recruitment failures and leading eventually to a declining resource. Much ingenuity has been devoted to attract recruits and improve their survival while little attempts have been made to secure a rich stock of spawners. The relative importance of pre- and post-settlement processes is discussed in the light of new findings over the last decade, and special emphasis is given to changing relations between recruits and predators in coastal waters turning warmer.

THE CASE OF THE WADDENSEA: HOW TO REVIEW THE ROLE OF SCIENCE IN POLITICAL DECISION MAKING. W. VAN DIEREN

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History

- Shellfish traditionally are staple food/protein source since prehistory
- In known history, we find shellfish fishery around population centres, largely being estuarine areas (Mesopotamia, Nile Delta in protohistory; to Bay of Naples and Brittany in Roman Era; to Venice in Middle Ages to Chesapeake Bay and Hudson area in USA in early modern times)
- Ongoing fishery and population growth caused depletion of shellfish resources worldwide.

Current situation

- Shellfish cultures are widespread nowadays (Brittany, Spain, USA, Ireland), but fishing is continuing and so is depletion. 'Collateral damage' to natural areas (e.g. damage to other bottom dwelling organisms other than target species) also increases.
- Populations in estuarine areas have further increased.
- Shellfish are no longer an important protein source, but have become culinary icons, based on long-standing traditions (moules/frites, pasta con le vongole, fruits de mer, clam chowder)
- Simultaneously, social appreciation of nature has changed. Nature conservation has become important. Estuaries are key natural areas.
- 4 trends coincide in estuarine areas, around the world:
 - Population increase
 - Shellfish depletion
 - Culinary traditions
 - Nature conservation (more and more by law: VHR)
- This causes a conflict of interests, which is particularly deep since fishing communities tend to:
 - be closed in on themselves
 - ignore, or play down stock depletion and collateral damage
 - tend to think they know everything about sea and shellfish
 - meet nature conservation and its apostles with deep suspicion
- All this sharpens the conflict, in particular causing a clash between fishing communities and nature conservationists worldwide.

The nature of the conflict

- There are all kinds of technical solutions:
 1. Regulated fishery, combined with cultures at sea
 2. Less damaging fishing techniques (rope cultures, net cultures etc.)
 3. Hatchery-nurseries
 4. Combined techniques: 2 and 3 for seed growing/collection, further growth at sea
- But developing and implementing these options takes time (often 5-10 years)
- In the meanwhile fishermen want to fish
- And nature conservationists want to conserve
- And governments want to keep the peace
- And nobody has any patience, since X, Y, Z (fill in: income, marine life, cultural identity) is 'severely threatened', 'doomed', 'facing extinction' etc.

Some lessons from the Dutch Wadden Sea

- Cockle fishery: if fishermen do not want to listen to other stakeholders and refuse to change damaging practice (direct and/or collateral), their practice will be discontinued
- Mussel fishery:
 - adaptive management seems possible, even within the limits of the VHR
 - longer term technical solutions are becoming apparent
 - the conflict is deep, causing ongoing court cases and even causing the scientific world to be split
 - data do suggest that seed fishing does not cause irreversible damage
 - but objectivity of data is questioned by traditional suspicion between scientific schools
 - the cockle example is not likely to be followed: employment in the mussel sector is too high for such

interventions.

The Future

1. Science school conservation: has to adopt policy sensitivity. Unemployment at such a scale causes a clash in the legitimacy of all nature conservation.
2. Mussel sector: has to adopt sensitivity to the conflicts it keeps making. In the end, this will create a mega-gap between sector and society. License to operate is the key. This is not really understood.
3. Ongoing battles in court between conservation and fishing.

CURRENTS, NUTRIENTS, FOOD AND PREDATORS: HOW TO CHOOSE YOUR NEIGHBORHOOD AS A MUSSEL. P. HERMAN

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The primary interaction between suspension feeders and the ecosystem is through filtration and nutrient regeneration. This interaction is strongly moderated by physical characteristics of the system. I discuss the influence of physical factors (primarily horizontal advection and vertical mixing) and compare their influence to the main biological time scales of primary production and filtration. Using field data and models developed in the EU project MaBenE, I try to develop a coherent framework to understand differences in spatial distribution and temporal dynamics of suspension feeders between microtidal and macrotidal systems.

The horizontal spatial scale, relevant for suspension feeder distribution, is strongly related to the scale of advective flows in the system. In microtidal systems (example: Limfjorden) the horizontal distribution of suspension feeders is relatively homogeneous, with relatively low local biomass. Vertical mixing determines carrying capacity for suspension feeders in these systems. Field data show clear signs of interrupted filtration activity controlled by vertical mixing rates. Counterintuitively, models suggest that maximum biomass will occur at relatively low mixing frequency. In macrotidal systems (example: Oosterschelde), suspension feeders tend to occur in few dense beds with high local biomass. Locations of highest productivity are determined by the horizontal distribution of production, import and horizontal mixing. It is suggested that the degree of horizontal mixing overtakes the biomass-determining role played by vertical mixing in microtidal conditions. Mussel beds influence the current structure in these systems by increasing bottom roughness, but the effect is small.

In intermediate conditions (example Wadden Sea) vertical mixing may limit exchange of food and lead to highly structured beds that optimize both resistance to flow and food provision. By comparing these different conditions I derive a more general conceptual model of how suspension feeders adapt their spatial organization to the physical characteristics of the system in which they occur.

HARMFUL ALGAL BLOOMS, REPRODUCTION AND RECRUITMENT IN MOLLUSCAN SHELLFISH: IMPLICATIONS FOR ENHANCEMENT EFFORTS. S.E. SHUMWAY

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Molluscan shellfish are regularly exposed to harmful algal blooms (HABs) and can be severely affected. Several studies have highlighted the effect of HABs on the physiology and the survival of adult or juvenile bivalves; however, very little is known regarding possible impacts of HABs on the reproduction of molluscan shellfish. A few studies have shown deleterious effects of harmful algal cells on survival of larvae and on development in bivalve molluscs. Stage of larval development appears to be very important in determining the response of the larvae to a HAB exposure. In addition, the extent of exposure time of the larvae to the HAB and the concentration of the bloom also seem to be important limiting factors. A few studies on copepods and amphipods also have highlighted the effects HABs have on embryogenesis, i.e., the fertilization capacity and survival of embryos after the adults have been exposed, but similar studies have not been conducted on molluscan shellfish. Effects of HABs on recruitment of bivalve molluscs has been suggested from environmental observations, but no data are currently available confirming effects of HABs on the reproductive capacity of adult molluscs.

Comprehensive studies on the effects of harmful algal species, at different concentrations and for different exposure times, on different species of molluscan larvae at different stages of development are needed to assess the potential for successful enhancement and restoration efforts. Moreover, research is also needed on possible effects of HABs on specific steps in the reproductive process: gametogenesis in adult molluscs, fertility of gametes, fertilization rate, embryogenesis, and ultimate survival of the progeny. Effects of HABs on reproduction in molluscan shellfish is a surprisingly understudied field, and a systematic approach testing for effects of different HABs on individual species of molluscs, at all stages in the life cycle needs to be developed to assess the full range of effects of HABs on the population biology of these commercially- and ecologically-important animals. Without such data, informed decisions regarding sites of restoration and enhancement efforts of bivalve molluscs cannot be made.

BIVALVES AS BIOFILTER: EFFICIENT, PROFITABLE, AND TASTY AS WELL! M. SHPIGEL

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Bivalve production has increased dramatically worldwide in the last three decades. According to FAO, fishery and aquaculture production increased four-fold, reaching almost 12 million MT in year 2000.

Choice of a particular bivalve species for commercial culture involves considerations such as fast growth rate, low food conversion ratio, resistance to pests, and tolerance to a wide range of environmental conditions; the technology for its reproduction and culture

should be straightforward and user-friendly for the growers; and the mollusc should meet market demands with respect to appearance, taste, smell, texture, processing considerations and market behaviour. Profitability depends on yield per unit of area, grow-out time, harvest frequency, farm-gate price and the cost of waste treatment.

Bivalves can be cultured by sea ranching or in land-based facilities. Sea ranching usually involves bottom culture, rack culture, or suspended culture. In the open sea the bivalves are vulnerable to weather conditions, predation, red tide and poaching. Because they are generally cultured close to shore, they are also subjected to urban pollution. As filter feeders, bivalves can accumulate high concentrations of toxic and pathogenic material, which can affect the economics of bivalve culture. Land-based facilities, wherein bivalves are cultured in ponds, tanks or indoor hatcheries and nurseries, are safer because the quality of the incoming water can be controlled. Due to the high costs of construction, need for highly trained technicians, water pumping, food (microalgae) supply and waste control, bivalve monoculture in such systems is of doubtful profitability.

Polytrophic culture in integrated systems holds much greater economic promise because it saves resources such as feed and water purification, diversifies the farm's market products, allows intensification and optimisation, and is environmentally friendly. In this system, fishpond effluent, rich in dissolved nutrients, drains through an earthen sedimentation pond. The dissolved nutrients, coupled with the high incidence of solar radiation, generate an extremely high phytoplankton production, mainly of diatoms, that supports the growth of bivalves on the bottom of the sedimentation pond.

This presentation summarises the state of the art, research and development in the use of bivalves as biofilters and as a safe, valuable by-product in land-based integrated aquaculture systems, and thus as a valid alternative to open sea monoculture.

Parallel session 1: Recruitment dynamics. Chairs: Luca van Duren, Karsten Reise

NEW OYSTER REEFS IN THE EAST FRISIAN WADDEN SEA (GERMAN BIGHT): *CRASSOSTREA GIGAS* AFFECTS THE COMMUNITY STRUCTURE OF NATIVE BLUE MUSSEL BEDS. A. MARKERT¹, A. WEHRMANN¹, I. KRÖNCKE¹

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blue mussels and the other part was already densely covered by oysters. *M. edulis* persisted at the site colonized by *C. gigas*. The macrofaunal community at the oyster reef had increased values for diversity, species richness, abundance and biomass. The reef favoured particularly the colonization by more sessile species like anthozoans as well as a higher abundance of barnacles, i.e. *E. modestus*. We revealed an increase in abundance and biomass of vagile epizoic species like the shore crab *C. maenas* and the periwinkle *L. littorea*. The enhanced occurrence of deposit feeding oligochaetes, i.e. *T. benedii*, at the site colonized by oysters points to both higher oxygen consumption and H₂S-concentration while utilising high rates of biodeposits. However, the infaunal species composition was altered: more opportunistic, facultative filter-feeding polychaetes (*Polydora*-species) occurred in the oyster reef, whereas sediments of mussel beds without oysters were dominated by species feeding on organic matter on the sediment surface. The oyster reef constitutes a suitable habitat for the occurrence of more native species than in the former *Mytilus*-patch. Stability of oyster reefs and progressing habitat modifications by *C. gigas* as ecosystem engineer seems to be likely. Hence, further effects on the native community may be expected.

SHELL BUDGETS FOR THE JAMES RIVER, VIRGINIA OYSTER RESOURCE. R. MANN, M. SOUTHWORTH, J.M. HARDING AND J WESSON

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A goal of the oyster restoration in the Chesapeake Bay is the establishment of stable populations that maintain habitat through shell accretion, recruit regularly, and survive to sustain multiple year class population structure. In only one large subestuary of the bay, the James Rivers, has this demographic been maintained over the past two decades, despite disease challenges, a commercial fishery and no active intervention to support restoration in the form of shell substrate addition. The James River would therefore appear to be a suitable site to examine the balance of recruitment, mortality, habitat maintenance and exploitation as a quantitative model for bay wide restoration efforts. A continuing stock assessment for the James River oyster resource provides quantitative descriptors of oyster density and demographics, and shell mass (as both exposed "brown" shell available as substrate for recruitment and buried "black" shell) for both specific reefs and the entire survey region. The demographic data provide the basis for estimation of year class structure and rates of growth, age specific mortality, addition of shell to the habitat pool (accretion), and loss of shell through taphonomic processes. We examined data for the period 1998-2006 inclusive and present comparisons of mortality, shell mass present as live oysters, and in the brown and black substrate pools. Despite high recruitment rates, often exceeding 100m², oysters also suffer high mortality rates, with a very small proportion surviving past 4 years of age. A surviving oyster may contribute to only one major recruitment event in its life time, suggesting a fragile relationship between survival and long term stability of the population as a whole. The proportion of age 1+ oysters that contribute to the shell habitat pool is modest. The ratio of live shell mass to "brown" shell mass approximates a 1:2 ratio, suggesting turnover rates for the "brown" shell, that is available habitat, that are commensurate with recent estimates for the Delaware Bay. Even in this most stable of the bay populations the habitat budget is at best at long-term equilibrium rather than accreting as would be desired. We suggest this will not change until the population demonstrates increased survival with greater year class representation. This would not only provide a potentially slow but positive accretion of habitat, but it would also result in stable spawning stock structure over periods of varying recruitment.

PREFERENTIAL SETTLEMENT OF BIVALVE LARVAE IN THE VICINITY OF ADULT POPULATIONS. L.A. VAN DUREN¹, J. VAN DALFSEN², T. YSEBAERT³, K. TROOST⁴

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Most bivalves have planktonic larvae that spend several weeks in the water column prior to settlement. On reaching a critical size, larvae search for a suitable substratum to attach to. Since these larvae have swimming speeds in the order of a few mm s⁻¹, they are primarily distributed by the local currents. However, larvae may still have some level of decision power over their settlement sites. In relatively small-scale laboratory experiments it has been shown that larvae will actively modify their swimming behaviour in response to environmental cues to enhance sinking speeds. Furthermore, when larvae hit the bottom in an unsuitable area, they may exhibit

behaviours to enhance resuspension. To what extent these behaviours have any relevance in the field is currently under debate.

This study will present data from field observations from several bivalve species, epibenthic, reef forming ones (*Mytilus edulis* and *Crassostrea gigas*) and endobenthic (*Spisula subtruncata*). All these species show preferential settlement of larvae (spatfall) on or in close proximity to adult populations. Reference sites only a few hundreds of metres away from these adult beds clearly showed lower settlement rates. Thus larvae do not act solely as passive particles, and biological factors are also important in bivalve settlement. The environmental cues that trigger settlement behaviour are most likely chemical and in some cases mechanical. Our data suggest that small-scale behaviour of bivalve larvae has important consequences for the larger scale settlement and distribution patterns of bivalves.

Spatial and temporal variability in *MYTILUS EDULIS* LARVAL ABUNDANCE AND spatfall AND SPAT GROWTH IN THE DUTCH WADDEN SEA AND OOSTERSCHELDE ESTUARY. P. KAMERMANS, M. POELMAN, A. BAKKER, A. BLANCO, E. BRUMMELHUIS, A. VAN GOOL, J. JOL, J. KALS, J. PERDON AND A. SMAAL

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Recruitment of bivalves such as mussels shows large variability in time and space. In order to understand the dynamics better we collected data of larval concentrations and settlement of spat on collectors for 5 years (1999-2003) in the Dutch Wadden Sea and Oosterschelde estuary. A total of 7 stations were monitored. Weekly samples of 100 L surface water per station were taken and filtered over 55 µm mesh size. Spat collectors consisting of netting with a mesh size of 4 mm were employed every 2 weeks. In addition, in 2006 a series of collectors was placed at the beginning of the season of which some were retrieved every two weeks. This gave information on the growth rate of the spat.

A distinct peak in larval abundance was observed each spring. A second peak in late summer was less pronounced. Maximum concentrations in larvae were similar in the Wadden Sea and Oosterschelde. However, spatfall was generally better in the Wadden Sea. We found a good correspondence in the timing of larval peaks and spatfall peaks in spring but not in late summer. Spat can grow up to a size of 45 mm in a period of 24 weeks. Growth was higher in the Wadden Sea compared to the Oosterschelde. At one station there was an early larvae peak which coincided with an early phytoplankton bloom and resulted in high settlement both on the collectors and in the field. This indicates synchronization and highlights the importance of food availability and possibly food quality. However, further testing is required.

THE IMPACT OF THE ADULT BLUE MUSSEL (*MYTILUS EDULIS*) POPULATION ON SETTLING OF CONSPECIFIC LARVAE. P. DOLMER¹, E. STENALT²

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The choice of a mussel bed as settling locality by conspecific mussel larvae is a trade-off between reduced fitness due to an increased risk of larval predation and post-settling food competition with the filtering adults and the benefits from a reduced post-settling mortality due to a high habitat complexity in a mussel bed and then reduced mortality from benthic predation. In a field-experiment, the larval settling of blue mussels, *Mytilus edulis* was recorded on artificial substrate 0.25, 1 and 2 metres above the bottom during 6 periods in spring. The experiments were conducted at four stations with dense mussel beds located at two of these stations. Two of the four stations, one with mussel beds and one without, were located in a wind exposed area and the two other stations in a sheltered area. It was demonstrated that, the larval settling was reduced up to one meter above the mussel beds. A size analysis of the settled mussels indicated that the reduction in the settling intensity close to mussel beds was due to a post-settling process: the larvae were predated by the filtering adult mussels. Furthermore, the settling was significantly affected by wind-stress. During periods with a high mean wind-velocity and a turbulent water column the larvae showed a reduced settlement 1 meter above a mussel bed relative to 2 meter above, whereas the same patterns not could be observed outside a mussel bed. The importance of the filtration activity of the adult mussels and the behaviour of the larvae is discussed. The recruitment of blue mussels into a mussel bed was investigated. Here, significant positive correlations were observed between density of recruits and density of adult mussels and weights of empty shells. This indicates that the filtering mussels not only increase the mortality of larvae but also serve as important substrate reducing post-settling predation from benthic predators.

MONITORING OF THE SETTLING OF *MYTILUS EDULIS* WITH SUSPENDED COLLECTORS – EFFECTS OF EXPOSURE TIME. U. WALTER AND I. WALTER

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The traditional bottom aquaculture of mussels (*Mytilus edulis*) is currently facing the serious consequences of poor mussel spat supply. Therefore, the culture sector is testing different off-bottom culture methods. At the German Northsea coast first trials with long-lines were started in 2001. Due to the highly differing yield, even at adjacent locations, side selection proved to be very important. Together with the hydrodynamic conditions, the main criteria for a successful mussel harvest is the settling density.

In this paper, the effects of exposure times (a fortnight to four months) on the settling density have been studied. To offer space for mussel larvae to settle, special transversal rope collectors (trocs) were designed. 15cm long pieces of 10mm polypropylene rope were frayed to produce tufts. 3 tufts were attached to a carrier rope and deployed at each location at long-line sites in the Jade.

After short exposure cycles of two weeks, the sum of two fortnight sampling periods varied severely in comparison with the corresponding monthly samples.

The monthly settlement ranged between 5 000 to 148 000 in 2006. Collectors exposed for two months yielded at least the same or even higher spat numbers compared to the sum of the matching May and June collectors. Significant higher median shell length of 1.7mm were recorded at the 2-month-collectors with the highest spat density (Kruskal-Wallis one way analysis of variance). Thus it appears that the mussel growth is not density dependant in the first two months.

In contrast, densely settled collectors exposed for four months showed a density dependant decrease in spat number, due to the higher required space of the growing mussels (median size 10-15mm).

Spat numbers on the applied trocs showed an increase with a longer exposure time. The following conclusions could be drawn: settled collectors are more attractive for further settlers than unsettled. Up to two months 15cm long trocs are sufficient to provide space for 28 200 mussels of 0.3 to 7.7mm shell length equivalent to 188 000 spat m⁻¹. With longer exposure time, density-dependant processes lower the spat number. One argument against longer exposure times is the disproportional higher amount of work to analyse the samples due to a larger share of other organisms which have settled on the collectors during these two months.

Parallel session 2: The role of shellfish in the food chain.

Chairs: Peter Herman, Øivind Strand

FEEDING BEHAVIOUR OF THE MEDITERRANEAN MUSSEL, *MYTILUS GALLOPROVINCIALIS* L., IN ALFACS BAY (N.W. MEDITERRANEAN SEA): A FIELD STUDY. E. GALIMANY¹, M. RAMÓN², I. IBARROLA³

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Alfacs Bay is located in the Ebro Delta (N.E. Spain) and has a surface of 50km² and an average depth of 4m. It can be considered as an estuary with a variable income of diffuse fresh water and due to its peculiar conditions it is an ideal site to develop mussel (*Mytilus galloprovincialis*) aquaculture. Our focus was a field study on the feeding behaviour of the mussels using the biodeposition method. For this purpose, an attempt was made to simulate in vivo conditions of mussel feeding. This was accomplished by using a portable filter feeding system designed by the authors. The system was deployed in the same area as the grow out site, on top of a mussel raft.

The filter feeding experiments were performed during November 2006 and February and April 2007 to track changes throughout the year. Within the feeding system, organic and inorganic values were obtained from the ambient sea water, and from the feces and pseudofeces. With this data and the dry weight of the mussels, the following filter feeding parameters were calculated: clearance rate, filtration rate and absorption efficiency.

Between all the seasons sampled for filtration rates and clearance rates, only April 2007 showed a significant difference ($p > 0.05$). There were no significant differences found for absorption efficiency (58% to 68%) among all seasons. These increased values are explained by the percentage of organic material in the bay water, which could be higher than the 60%.

FEEDING BEHAVIOUR OF *PECTEN MAXIMUS* AND *MYTILUS EDULIS* IN A LOW SESTON ENVIRONMENT. T. STROHMEIER¹, Ø. STRAND¹, P. CRANFORD² AND C. KROGNESS¹

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Low seston environments occur under natural oligotrophic conditions and were high bivalve culture densities cause seston depletion. Bivalve culture in such conditions may suffer low growth or tissue wasting due to reduced feeding and negative net energy balance. A positive net energy balance in bivalves will require a certain level of seston consumption, which depends on seston concentration, composition and transport rate. Norwegian fjords and coastal waters are considered as low seston environments compared to sites where most studies on mussel feeding on natural seston have been carried out. Regulation or cessation in feeding activity at low seston concentration is likely to be related to optimising energy cost of food absorption. The principal objective of this study is to elucidate the relationship between feeding behaviour and bioenergetic balance for *P. maximus* and *M. edulis* in low seston environment. Initial results from laboratory and field experiments on feeding physiology in response to natural low seston concentrations will be presented.

FATTY ACID TROPHIC MARKERS IN *MYTILUS EDULIS* AND *CRASSOSTREA GIGAS*: ARE THEY REALLY WHAT THEY EAT? A. UPPABULLUNG, P. KAMERMANS, L. MOODLEY, N.A. DIJKMAN, M. HOUTEKAMER, P.M.J. HERMAN

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Fatty acid trophic markers have been shown to be a very powerful tool to reveal trophic relationship in different variety of ecosystems and organisms. In this study, we measured fatty acid composition in total lipids from size-fractionated (<20, 20-40, 40-60, 60-90, and 90-200µm) natural seston and compared with fatty acid composition of larvae and spat of mussels (*Mytilus edulis*) and oysters (*Crassostrea gigas*) collected during the reproduction season. The aim of this study is to determine if larvae and spat of these two economically important species depend on specific size classes of algae for their growth and survival. Comparison of fatty acid profiles of seston fractions were expected to reflect their food source. The study may lead to better understanding of food selectivity and preference and, subsequently, recruitment success of these young animals in Oosterschelde, The Netherlands. The results indicate that diatoms were a major component in small seston fractions, with a trend of shifting towards non-diatom species later in the year. However, based on principal component analysis, fatty acid composition of larvae and spat surprisingly showed a distinctive

separation from the fatty acid profiles of their food sources.

COMPETITION BETWEEN NATIVE BIVALVES AND AN INTRODUCED OYSTER THROUGH LARVIPHAGY? K. TROOST^{1,3}, P. KAMERMANS³, E.J. STAMHUIS² AND W.J. WOLFF¹

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While the introduced Pacific oyster *Crassostrea gigas* expanded rapidly in Dutch estuaries, stocks of native bivalves declined. With the rapid increase of these oysters in the Oosterschelde estuary, the total filtration pressure on this ecosystem also increased rapidly. This may have a large and negative impact on bivalve recruitment through filtration of bivalve larvae. The high recruitment success of Pacific oysters in Dutch estuaries may be partially due to better abilities of their larvae to escape filtration, compared to larvae of native bivalves.

In adult bivalves (*Crassostrea gigas*, *Mytilus edulis* and *Cerastoderma edule*) we compared clearance rates for oyster and mussel larvae to clearance rates for algae, to assess whether these larvae are able to avoid filtration. We also studied whether oyster and mussel larvae avoid filtration by migrating vertically in response to an adult oyster, and their escape responses to an artificial suction current. Additionally, we studied the fate of filtered larvae.

All three adult species filtered both oyster and mussel larvae. Mussel larvae were filtered by all three bivalve species with the same clearance rates as algae, whereas clearance rates for oyster larvae were roughly 50% lower than clearance rates for algae.

Oyster larvae avoided the vicinity of an adult bivalve by migrating to higher water levels. Mussel larvae did not show this behaviour. Both oyster and mussel larvae did not show escape responses to an artificial suction current, that simulated the inhalant feeding current of an adult bivalve.

Only low percentages of filtered oyster and mussel larvae were rejected in pseudofaeces. The majority of the larvae were ingested. Both rejected and ingested larvae most likely died.

THE NEAR DISAPPEARANCE OF STARFISH (*ASTERIAS FORBESI*) AND ITS EFFECTS UPON MOLLUSCAN LANDINGS IN THE ESTUARIES OF THE NORTHEASTERN U.S. C.L. MACKENZIE, JR.

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Since the 1980s, starfish (*Asterias forbesi*) have been relatively scarce in the shallow zones (< about 8 m) where mollusks grow in the estuaries from Cape Cod through northern New Jersey. They remain present in the deeper waters beyond the shellfish grounds. Starfish were once abundant in these zones and were considered a menace to the shellfishing industry, especially the oyster (*Crassostrea virginica*) growers in Long Island Sound where their destructiveness received much attention in the scientific community. Besides oysters, starfish also preyed upon the commercially valuable northern quahogs (*Mercenaria mercenaria*), bay scallops (*Argopecten irradians irradians*), and the less valuable blue mussels (*Mytilus edulis*). The scarcity of starfish in Connecticut is partly the reason for the huge upsurge in landings of oysters in that State during the 1980s to mid 1990s, and northern quahog landings during and since the 1980s. The oyster landings reached 3 740t (1.0 million bushels) with a landed value of \$32 million in 1993. The diseases, MSX and Dermo, killed most of the oysters afterward and a large decline in landings followed. The State's northern quahog landings reached 2 330t (428 000 bushels, or about half the landings along the U.S. Atlantic coast) with a landed value of \$10.7 million in 2004. The suspected cause of the decline in the starfish will be described.

THE IMPORTANCE OF MUSSEL BED PATCHINESS FOR FOOD SUPPLY: BALANCE BETWEEN GRAZING, TIDAL ADVECTION, VERTICAL TURBULENT FLUX AND SESTON CONCENTRATION. C. SAUREL¹, J.K. PETERSEN², P. WILES¹, M.J. KAISER¹

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Commercially re-laid intertidal mussel (*Mytilus edulis*) beds in the Menai Strait (UK) present a seemingly random pattern of bare and mussel patches. Annual mussel production is up to 11 000t.y⁻¹ for ~150ha exploited. In this system, food concentration is quite low for most of the year, ca. 1µg.l⁻¹ chlorophyll a (chl a), but can vary from 0.5 up to 5µg.l⁻¹ during summer season. We used an in situ approach to study the food concentration, the hydrodynamic conditions and the feeding activity. In the Menai Strait, mussels on intertidal beds were wide open, actively filtering (video survey, mean valve gape aperture > 70%) and their grazing rate was high (in situ clearance rate = 3.1l.ind⁻¹.h⁻¹). Low chl a concentrations were measured next to the mussel bed (6cm). Furthermore, food depletion of the water column above the mussel bed was observed on a patch scale (5m). The vertical turbulent flux of chl a to the mussels, determined by the gradient of chl a and the diffusion near the bed measured with an ADV (Acoustic Doppler Velocity), was smaller than the actual flux of chl a measured from mussel grazing, hence explaining the depletion in the near bed.

The explanation for such high feeding activity, despite the food depletion, near the mussel bed is the balance between the vertical turbulent flux of chl a, the strong tidal advection of chl a, the presence of bare patches and the mussel grazing activity. Over the bare patches, food replenishment of the water column next to the bed is due to the vertical flux and tidal advection of chl a, and no mussel grazing. Modelling of the interactions between hydrodynamic conditions, mussel grazing and chl a concentration allows the prediction of the best percentage cover/ mussel density for commercial mussel beds in order to optimise mussel growth and thus maximise carrying capacity.

INFLUENCE OF MUSSEL AQUACULTURE ON NITROGEN DYNAMICS IN A NUTRIENT ENRICHED COASTAL EMBAYMENT. P.J. CRANFORD¹, P.M. STRAIN¹, M. DOWD², B.T. HARGRAVE¹, J. GRANT³, M. ARCHAMBAULT³

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The combined influences of intensive mussel aquaculture and watershed nutrient inputs on nitrogen dynamics in Tracadie Bay (Prince Edward Island, Canada) were examined using a nitrogen budget and an ecosystem model. Budget calculations and inputs and parameters for the model were based on extensive field data. Both approaches showed that mussel aquaculture has a dominant influence on all aspects of the nitrogen cycle and dramatically alters pathways by which nitrogen reaches the phytoplankton and benthos. A large proportion of phytoplankton production is supported by land-derived nitrogen and this anthropogenic input is important for sustaining existing levels of mussel production. The amount of nitrogen removed in the mussel harvest is small compared to agricultural nitrogen inputs and the amounts excreted and biodeposited on the seabed. Mussel biodeposition greatly increases the flux of nitrogen to the benthos, with potentially serious eutrophication impacts. Results from the observation based nitrogen budget and dynamic model were compared and both support the above conclusions. However, the ability of the model to test different scenarios and to provide additional information (e.g. fluxes) over a finer spatial scale led to insights unattainable with a nitrogen budget. For example, food appears to be less available to mussels at the head of the Bay than at the mouth, despite the lower density of grow-out sites in the former location. The number of fundamental ecosystem processes influenced by the mussels and the complexity of their interactions makes it difficult to predict the effects of mussels on many ecosystem properties without resorting to a model.

DOES HYDRODYNAMISM AFFECT SPATIAL DIFFERENCES IN BIOLOGICAL PERFORMANCES OF THE PACIFIC OYSTER, *CRASSOSTREA GIGAS* OBSERVED IN THE BAIE DES VEYS ESTUARY? K. GRANGERÉ^{1,2}, A. MÉNESGUEN¹, S. LEFEBVRE², C. BACHER¹

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The baie des Veys is an open estuary and intertidal ecosystem (37 km²) influenced by four rivers, with an important oyster farming activity (10 500 tons produced per year). At the bay scale, some spatial differences in the structure of phytoplanktonic and microphytobenthic communities and in the biological performances of cultivated oysters were observed. It is assumed that a trophic heterogeneity may exist, however the mechanisms controlling it remain unclear. In order to assess whether spatial interactions between oysters and the ecosystem may significantly affect phytoplankton availability and oyster growth, a three-dimensional (3D) hydrodynamic model was coupled to an ecosystem model. To optimize computation times, an horizontal rectangular grid was developed with irregular meshes allowing a more detailed approach for the area under study. The model was validated using in situ measurements of currents, water depth, salinity and temperature. Currents and water depth were measured by an ADCP current profiler. Salinity and temperature data came from 6 CTD probes located in the oyster farming area. The ecosystem model simulates the Baie des Veys nutrient-phytoplankton-oyster food web. The method consists of coupling a primary production model that simulates trophic resources and an oyster ecophysiological model (Dynamic Energy Budget model). The validation is still under progress. This coupled model will elucidate the influence of some factors such as trophic interactions, watershed supplies (freshwater, nutrients, suspended particulate matter...) or climate variations, on the seasonal and inter-annual variability of oyster physiological state (growth and reproduction). Furthermore, the integration of this coupled model in the hydrodynamic model will allow us to better understand the observed spatial differences in oyster biological performances in relation to the effect of water circulation on food production and availability for filter-feeders.

Parallel session 3: Shellfish management, eutrophication and harmful algal blooms. Chair: Sandra Shumway

EFFECT OF SELECTIVE MORTALITY ON STOCKING EXPERIMENTS. M. FRÉCHETTE¹, J. DUMAIS²

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Bivalve culture implies growing organisms at high local population density on individual culture units. The correct population density is assessed in stocking experiments, which are best analysed using body size-density relationships (Fréchette et al., 1996). Such curves allow analysis of various outcomes of stocking experiments, such as density-independent growth, density-dependent growth, and density-dependent growth and mortality, which result in self-thinning (ST) patterns. Analysis of published ST studies indicates that knowledge of the effect of underlying population dynamics processes on ST patterns is lacking (e.g., Reynolds and Ford, 2005). We modeled the effect of selective vs non-selective mortality on body size-density relationships, including ST, under the hypothesis of food regulation. Preliminary results indicate that ST curves follow similar trajectories in both cases. With selective mortality, however, ST proceeded at a faster rate, and total mortality and final biomass were higher. This caused body-size-density curves to peak at high density. In contrast, body size-density curves obtained with non-selective mortality tended toward a horizontal asymptote at high population density. Furthermore, with selective mortality, final population density was independent of initial conditions, but final biomass was not. With non-selective mortality, final biomass was independent of initial conditions, but final population density was not. Further results using individual-based modelling will be presented at the meeting.

CARRYING CAPACITY OF THE DUTCH WADDEN SEA FOR SHELLFISH AND IMPLICATIONS FOR FISHERIES AND BIRDS. A.G. BRINKMAN

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The western part of the Dutch Wadden Sea is a semi-closed tidal area, where water has a residence time of one to three weeks. Fresh water input originates from the river Rhine, which together with exchange processes with the adjacent North Sea determines the input and output of nutrients and organic matter. Turbidity, depth and nutrients limit primary and secondary production.

Primary and maximum secondary production in the system is estimated by the application of an integrated ecosystem model, which covers key processes such as nutrient cycles, remineralization of organic matter, primary and secondary production. It will be shown that during the last 30 years productivity decreased mainly as a result of reduced phosphate loads. Together with available data on mussel stocks, cockle stocks and bird numbers it will be shown how the system's function as shellfish source for birds and fishermen is under high pressure.

TRENDS ON INTEGRATED COASTAL ZONE MANAGEMENT IN EUROPE AND ITS RELEVANCE FOR SHELLFISH AQUACULTURE. DR. G. KRAUSE

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In coastal and offshore regions of the EU, human activities are increasing in type and intensity. Larger portions of the sea are sectioned off, dedicated for specific, often exclusive uses that cause rising conflicts between interests groups. As a case in point, site-selection criteria for shellfish aquaculture firstly aim at biological and physical issues whereas social and economic aspects are treated marginal. As a result many well-intentioned efforts towards informing the public on shellfish cultivation have failed because they were looked at in isolation. Site selection and spatial scarcity in aquaculture is thus not solely a technical definition problem but also depends on the social context it operates. ICZM can be seen as tool to overcome this conflict prone situation in aquaculture activities, as one of its key principles is to view problems faced by coastal zones in a wide context, thus to see and acknowledge the 'big picture' of coastal activities. ICZM can be regarded as a strategy for an integrated approach to planning and management in the coastal zone, providing management instruments that are not per se included or foreseen in the different policies and directives in such comprehensiveness.

The EU ICZM Recommendation (2002/413/EC) defined several items that are relevant to shellfish aquaculture and, at the same time, contribute to the ongoing strategic debate in ICES. In the EU, ICZM is foreseen to employ a strategic approach to planning, in which an ecosystem approach for sustainable coastal development is crucial. Eight principles of good ICZM practice have been identified, all of which link to a stronger or lesser degree to shellfish culture operations. In addition, the EU asks for a specific type of reporting process, including improved coordination with bordering countries and acting within regional seas approach as marine resources transcends boundaries.

This EU-ICZM policy can be used as a vehicle to recognise, address, and minimise these conflicts in a timely fashion before misunderstandings become obstacles. Furthermore, scope for added-value of ICZM for shellfish cultivation in the context of relevant existing and evolving Community policies/legislation exist. In the presentation a selection of relevant legal and policy frameworks are presented, which have a potential effect on shellfish aquaculture operations in Europe. Implications for future shellfish operations in Europe are discussed.

SHELLFISH FARMING IN GREECE. J.A. THEODOROU, I. TZOVENIS

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Shellfish farming in Greece is a relatively new industry based almost exclusively on the cultivation of the Mediterranean mussel *Mytilus galloprovincialis*. The industry is structured mainly in 1-3 ha single long line farm units of an average of 100 tons/ha production capacity.

In Greece, contrary to the well-developed seabass/bream aquaculture industry, there is a limitation of the expected expansion of the shellfish sector due to the characteristic oligotrophic seawater environment of the country, which restricts the suitable shellfish farming areas close to a few estuaries with sustainable eutrophication. A production of 35,000 tons in 2007 is expected, with a forecasted maximization up to 45,000-50,000 tons in the near future.

In business terms structural problems of the Greek shellfish aquaculture sector, such as the marginal profitability of the small farms, the poor marketing, the lack of organized expedition centers and purification plants, could lead to industry restructuring.

In national policy terms, environmental problems such as HABs, inadequate environmental monitoring systems, aquatic animal attacks, and short rainfall periods require a more sophisticated approach for the industry to be effective. Furthermore, new legislation is coming up to organize the farming sites of the sector in officially appointed "Organized Areas for Developing Aquaculture", expected to bring about disagreements regarding the production and ecological capacity of the sites, as well as problems to the stakeholders involved.

The future of the industry is based on the industrialization of the production methods and the development of scale in order to suppress the production cost and to support the branding of the product. Moreover, development of quality schemes along with advance marketing and promotion support of the product would help the industry to sustain profits and be competitive in the open markets.

Other commercially important species such as *Oyster edulis*, *Venus verrucosa*, *Modiolus modiolus*, are harvested by traditional fishing methods and frequently are overexploited, hence demanding research and funding for restocking programs. The development of suitable farming technology for these high value species in Greece is needed both for restocking and for diversification of the shellfish industry in order to sustain the future of the sector.

Parallel session 4: Impact of invasions. Chairs Jeroen Wijsman, Norbert Dankers

ADDRESSING THE POTENTIAL INTRODUCTION OF NON-NATIVE MARINE SPECIES WITH MUSSEL SEED TO SITES OF MARINE CONSERVATION IMPORTANCE IN WALES – WITH REFERENCE TO A CASE STUDY. N.C. ENO¹, K. SMITH¹, J. WILSON², G. WYNN¹

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Although the UK possesses some of the (strongest) legislation for controlling the introduction of non-native species, the subsequent process of restricting movements for non-natives that have gained a foothold, is less robust. By consideration of a case study where the slipper limpet was inadvertently brought into the Menai Strait Special Area of Conservation, as an undetected passenger species in association with a movement of mussel seed, the issues associated with this weakness in the control system are examined. Decisions made on the preferred and the most practicable courses of action are discussed along with implications of such an introduction to both the ecology of the site and the mussel industry. Initial and ongoing monitoring of the establishment and potential spread of this invasive species, including involvement of the public through media campaigns, and examination of historic records, is described. Proposals by the industry for voluntary codes to try and minimise the risk of future introductions are under consideration as a way of addressing the threat posed by potential invasive species that may be translocated with shellfish movements.

THE IMPACT OF THE SLIPPER LIMPET (*CREPIDULA FORNICATA*) ON THE OYSTER FISHERIES OF SOLENT AND THE RIVER FAL, ENGLAND. A. FITZGERALD¹ AND P. WALKER²

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Both of the principal fisheries for the native oyster *Ostrea edulis* in England have been impacted by the introduction of *Crepidula*. Using both quantitative and qualitative data collected on oyster surveys, the changes in abundance and distribution in the Solent and in the River Fal are described. *Crepidula* was already abundant in the Solent when the fishery began to develop there in the 1970s. Local fishermen, using powered boats and dredges, have learned to live with the presence of *Crepidula*. Although *Crepidula* has been present in the River Fal since at least the early 1970s, it has only been since 2002 that rapidly increasing abundance lead to concerns amongst local fishermen. In the River Fal the oyster fishery is worked from sail or oar powered boats and increasing bycatch of *Crepidula* in the dredges is leading to difficulties in hauling the gear and sorting catch. The oyster beds and neighbouring protected maerl beds are seen as being vulnerable to the effects of the cohesive muddy sediment produced by the *Crepidula*. Local fishery management of *Crepidula* in the Fal has been proposed as control measures and potential utilisation routes need to be adapted to the area's infestation status. Local plans require a good understanding of the *Crepidula* biomass and the rate of population growth. Fishery and conservation bodies recognise the potential problems associated with super-abundance of *Crepidula*, but opinions are divided about the degree of potential impact, how the problem should be managed and who should manage the response. The managers of the Fal oyster fishery commissioned a report to assess the information provided by previous studies in Britain and to put them into context with experience elsewhere in order to provide options for the management and utilisation of slipper limpets in the River Fal. The recommendations in the report could have applications in other parts of Britain where *Crepidula* populations appear to be increasing.

ENSIS AMERICANUS IN DUTCH COASTAL WATERS: FROM INVADER TO PERMANENT RESIDENT. J.F.M.F. CARDOSO, R. DEKKER, R. DAAN, J.IJ. WITTE AND H.W. VAN DER VEER

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The American razor clam *Ensis americanus* (also known as *Ensis directus*) was found for the first time in European waters in 1979, in the German North Sea coast. Since then, *E. americanus* has spread along the Dutch and German Wadden Sea and North Sea coasts. In Dutch coastal waters, the species was reported for the first time in 1982. For more than a decade, *E. americanus* was found mostly in low numbers and biomasses, with only high recruitment at the intertidal in 1991. However, this species is now present not only in the intertidal but also in the subtidal of the Wadden Sea and coastal North Sea waters. Only in recent years (from 2000 onwards), have densities and biomasses showed strong increases, both the Wadden Sea and the coastal area. Nowadays, *E. americanus* can be considered as a permanent resident species with densities of more than 10 per m², although interannual variability in numbers is high. *E. americanus* is characterized by events of mass mortality, of both recruits and adults. In adults, mortality events seem to be related to very low winter temperatures in combination with sediment disturbance during winter storms. Although mean winter temperatures in

the Dutch Wadden Sea have been increasing the last decades, no trends were found between recruitment and mean winter temperature, suggesting that temperature is not the main factor behind the large variability in recruitment. A one-year study of the subtidal Wadden Sea population suggested that low reproductive output could also be a cause for the low recruitment. It is possible that adults that survive mortality events will have low body condition and, consequently, no energy to spend in reproduction. The low fecundity of the population, in some years, will lead to the production of a low amount of larvae, resulting in low recruitment.

RISK ASSESSMENT OF BOTTOM CULTURE OF THE PACIFIC OYSTER, *CRASSOSTREA GIGAS* IN IRELAND. F.X. O'BEIRN, T. MCMAHON, M. O'CONNOR.

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The Pacific oyster, *Crassostrea gigas* has been cultured successfully in Ireland for approximately 30 years. Typically it has been cultured intertidally using conventional bag and trestle systems. More recently some licenses have been issued permitting cultivation of oysters subtidally in plots directly on the seafloor. There are a number of advantages for the grower with this arrangement in that it makes considerably more space available for culture, the subtidal location may increase oyster growth rates and performance, and the infrastructural requirements and operational costs are considerably reduced. On the other hand, however, the practice of culturing oysters directly on the seabed could result in the uncontrolled expansion of naturalized populations of *C. gigas* in Ireland as has been documented in The Netherlands and Germany. Initial assurances that conditions in Ireland (i.e. low water temperatures) would not support successful reproduction of oysters have proven to be unfounded, with the documentation of full gametogenesis in *C. gigas* throughout Ireland and the discovery of newly settled oyster spat in the wild in Counties Donegal and Galway. A number of additional perceived risks have also been identified. These risks include, inter alia, competitive exclusion of populations of the native oyster (*Ostrea edulis*), the risk of introduction of alien or nuisance species on seed oysters and the alteration of benthic communities by the addition of oysters that may influence the trophic status and structural complexity of the area. While some of the risks might be mitigated by the culture in areas where *O. edulis* do not occur, or the use of triploid oysters originating from hatchery sources, even these measures (along with any others) will require targeted research to fully evaluate their efficacy. This presentation will describe a preliminary risk evaluation associated with the on-bottom culture of *C. gigas* in Ireland and describe plans for a culture trial that will incorporate targeted research to address the concerns and evaluate the risks associated with the practice. The expected outcome will be a full risk evaluation of the culture of *C. gigas* on the seafloor in Ireland that will provide a scientific based management advice to the licensing process.

ECOLOGICAL CONSEQUENCES OF THE PACIFIC OYSTER (*CRASSOSTREA GIGAS*) INVASION ON COASTAL HABITATS IN WESTERN EUROPE. H. CHRISTIAN AND L. MORGANE.

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Since the nineties more and more sites are colonised by wild populations of the exploited exotic species *Crassostrea gigas* around the world. In Western Europe the invasion is oncoming in numerous sites, especially in Brittany (France) and populations reached thousands tons in many sheltered bays. Because the high complexity and heterogeneity of the shoreline of this region, Brittany can be considered as representative of the diversity of the intertidal habitats of Western Europe and consequently used as a pilot region to understand the patterns of the ecological invasion. We studied the set of habitats already concerned by the colonisation and the proliferation of *C. gigas* and identified the ecological capacities of the species by analysing the larger diversity of field situations in term of substrata, salinity, emersion and hydrodynamism. The results showed that *C. gigas* has broader capacities than all others indigenous and exotic species of the shores. Its behaviour (larvae and adults), its phenotypic plasticity and its tolerance to the hydroclimatic factors, explain the observed dynamics of the invasion. The species can become a key species in a wide set of habitats (referred to the EUNIS classification). When the substrata are totally covered by oysters, the original habitats lose their identity and become a new one: the oyster reef. This oyster reef occurred both on soft bottom in sheltered sites and hard bottom in sheltered and semi-exposed sites. If biodiversity in the oyster reef habitat is often higher than in the originated one by providing many microhabitats, in the other hand, at a large spatial scale, this mechanism could induce a decrease of biodiversity by the banalization and the homogenization of the habitats. A first conceptual model of the ecological invasion is proposed for this species. Because the global warming is a facilitation process to the proliferation and the geographical spreading of the invasion, and because the propagation of propagules by the oyster farms will remain, only local management seems conceivable to mitigate the ecological consequences of the invasion.

DEVELOPMENT OF THE PACIFIC OYSTER (*CRASSOSTREA GIGAS*) IN THE DUTCH WADDEN SEA. N. DANKERS, F. FEY, P.C. GOUDSWAARD

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The Pacific oyster was introduced into the Dutch Delta area in 1964 and later into the Wadden Sea where it was first found in 1983. In the first years after introduction the population developed slowly. From 1995 onwards distribution and abundance increased rapidly and now oysters occur all over the Wadden Sea. Pacific oysters compete with mussels and other native filter feeders for food and habitats. Human activities, like cultivation of mussels and recreation, can suffer from increase in oyster densities. In this presentation

the development of the pacific oyster in the Dutch Wadden Sea and possible future consequences on nature values and human activities will be discussed.

When oyster abundance was low the distribution and spreading was mapped on the basis of anecdotal information. When abundance increased surveys were specifically directed towards oyster reefs and mussel beds with considerable oyster abundance. The development of reef size, reef stability and population structure was studied. Oysters proved successful in settling on a variety of substrates. Regular mapping of individual reefs revealed that the reef edge was relatively stable, and population studies revealed that yearly settlement occurred mainly within the reef. Wadden Sea broad surveys revealed that the population is still spreading and oysters also occur as stray clumps in many areas on the intertidal flats.

On many mussel beds oysters developed and sometimes completely took over from the mussels. On other beds they provided settling room for spat fall of mussels and other organisms needing hard substrate.

Little information is available on the occurrence of oysters in the subtidal areas. Lessons can be learned from the situation in the Dutch Delta region where development started 20 years earlier, and where large subtidal reefs are now present.

The oysters are here to stay. They are going to be an important biocoenosis in the Wadden ecosystem, and may eventually have impacts on structure and function at Wadden Sea ecosystem level. Human activities may suffer from oyster growth on unwanted locations, but commercial use of oysters (hand-picking) can provide new economic possibilities.

Parallel session 5: Carrying capacity for shellfish exploitation and modelling. Chairs: Theo Prins, Marianne Alluno-Bruscia

ENHANCEMENT OF CARRYING CAPACITY OF MUSSEL CULTURE IN FJORDS BY ARTIFICIAL UPWELLING OF NUTRIENT-RICH DEEP WATER. Ø. STRAND¹*, J. AURE¹, T. STROHMEIER¹, L. ASPLIN¹ AND S. RUNE ERGA²

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Some of the most productive and successful mussel farming worldwide are based on nutrient enrichment from natural coastal upwelling. Studies on model simulations and small-scale enrichment experiments using deep-water have addressed the economic potential of developing artificial upwelling for shellfish culture. In order to enhance primary production rate for shellfish cultivation in fjords, a large-scale artificial upwelling experiment was carried out in a western Norwegian fjord in the summers of 2004 and 2005. The experiment was carried out in Lysefjorden, which is 50 km long (area 44 km²) with maximum depth of 450 m and sill depth of 15 m. During summer the thickness of the brackish surface layer is 3-5 m and a strong nutricline is typically observed at 15-20 m. Artificial upwelling was created using a vertically mounted pipe with an electrical pump to force brackish surface water at a rate of 2 m³ s⁻¹ down to 28 m depth. The pipe was mounted on a platform located 2 km from the head of the fjord. The calculated amount of upwelled water interleaving at depths of the pycnocline was 20-30 m³ s⁻¹. The entrainment of deeper water into the buoyant brackish plume resulted in a mean transport of about 450 kg d⁻¹ nitrate, 760 kg d⁻¹ silicate and 75 kg d⁻¹ phosphate to a mean intrusion depth of 8-10 m. The artificial upwelling approximately tripled mean biomass - chl *a*, chl *a* concentration and primary production rate during the summer, within an area of 10 km² area near the head of the fjord. The size of the area of influence and the relative increase of the algae biomass and primary production rate within it depend on both the water exchange and the photosynthetic effectiveness. The relatively high silicate content of the deeper water stimulated diatom growth inside the artificial upwelling area of influence. For the first time it is shown in a large scale experiment that the use of submerged brackish water to force artificial upwelling enhance phytoplankton production and stimulate diatom growth. This may have great potential for production of high quality mussels in fjords. Lysefjorden is proposed as an experimental facility for research and development of artificial upwelling.

HIGH RESOLUTION PHYTOPLANKTON DEPLETION MAPPING AT NORWEGIAN MUSSEL AQUACULTURE FARMS. P.J. CRANFORD¹, Ø. STRAND² AND T. STROHEIMER²

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Farming and sea ranching of suspension feeding shellfish is a growing industry in Norway and recent production increases and improvements in the mussel industry (*Mytilus edulis*) have demonstrated that development will proceed and a substantial increase in biomass is expected. Knowledge on ecosystem interactions with mussel aquaculture is needed to support the growth of a sustainable industry, to realize Norway's potential for aquaculture, and to develop an ecosystem-based management approach specific to this industry. Mussels have a remarkable capacity to filter the water column and to deplete the water of seston and, in intense culture, mussel production may become food limited. Food supply depletion can affect the productivity of cultured shellfish (i.e. negative feedback) as well as that of other resident organisms sharing the same food resource (e.g. zooplankton). Food depletion is therefore closely linked to the concepts of production and ecosystem carrying capacity. The spatial scale of phytoplankton depletion was documented at several mussel aquaculture farms in Norway using a computer controlled, towed undulating vehicle (BIO-Acrobat). Georeferenced data collected at 2 scans sec⁻¹ by in situ sensors (CTD, chlorophyll fluorometer and transmissometer) provided the intensive horizontal and vertical sampling needed to characterize environmental and food supply variations over spatial scales relevant to farm-scale depletion. The data are being used to support biophysical modelling efforts designed to assess mussel aquaculture productive capacity.

APPLICATION OF SATELLITE REMOTE SENSING TO AQUACULTURE ECOSYSTEMS. J. GRANT

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Natural and cultured suspension-feeding bivalves require phytoplankton as a primary food supply. Limitations on the extent and biomass of shellfish culture are often ascribed to primary production and diffusion/advection of phytoplankton biomass. Models of shellfish carrying capacity are dependent on boundary conditions of chlorophyll as a proxy for phytoplankton biomass. In addition, spatial distributions and time series of chlorophyll are essential in groundtruthing model output. Satellite detection of ocean color and

other variables provide an efficient way to obtain these types of data with prescribed limitations. Despite this potential, remote sensing has rarely been applied to aquaculture. Spatial resolution of satellite-derived chlorophyll is in many cases no better than 1 km, although 250 m data are available with additional processing. Other available satellite outputs include primary production, photosynthetically active radiation (PAR), turbidity, and wind stress, all potentially valuable input to ecosystem models. Examples are provided of satellite remote sensing data applied to coastal areas with bivalve farms, with initial assessment of their value and limitations in resolving both boundary conditions and spatial distribution of chlorophyll and other variables.

ASSESSING CARRYING CAPACITY OF BAIE DES VEYS (NORMANDY, FRANCE) WITH A BIOLOGICAL MODEL. A. GANGNERY^{1*}, C. BACHER², K. GRANGERÉ²

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The Baie des Veys is an important site of shellfish culture in Normandy (France). The Pacific oyster, *Crassostrea gigas*, is the main species in culture with in a lesser extent the blue mussel, *Mytilus edulis*. Oyster and mussel standing stocks are estimated around 10 200 and 250 tons, respectively. In the past, oyster culture had to face to several mortality crisis and oystermen wish to optimise organisation of the activity in the bay. They wish to examine the effect of a new spatial organisation of the rearing structures with an optimisation of rearing densities on the production. In this context, a first step was to develop a biological deterministic model to assess the carrying capacity of the bay from a trophic point of view. The model takes into account three basic compartments, which are nutrients, phytoplankton (diatoms) and oysters. Boundary conditions are given by a model at a larger scale and exchanges are driven by the water residence time in the bay, which has been estimated separately with a 3D hydrodynamic model. Inputs from the watershed were also taken into account. This model was coupled with an ecophysiological model simulating oyster growth and based on the DEB theory (Pouvreau et al., 2006). A first set of scenarios was undertaken with different values of standing stock in order to test the effect of density on oyster growth and to assess the trophic capacity of the bay. A growth indicator was then developed where growth is given as a function of the oyster number. Oyster growth also varies according to environmental conditions. A second set of scenarios was then undertaken in order to examine the effect of environmental variability (e.g. water temperature, light intensity, watershed inputs) on oyster growth. Carrying capacity is therefore derived from the relationship between growth and environmental indicators - e.g. primary productivity, water residence time, oysters filtration capacity. This set of indicators allows to compare Baie des Veys with other cultivated ecosystems.

MODELLING THE GROWTH OF *MYTILUS EDULIS* (L.) BY COUPLING A DYNAMIC ENERGY BUDGET MODEL WITH SATELLITE DERIVED ENVIRONMENTAL DATA. Y. THOMAS¹, J. MAZURIÉ², S. POUVREAU³, C. BACHER⁴, F. GOHIN⁴, C. STRUSKI⁴, P LE MAO⁵.

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Defining criteria for shellfish farming potential appears particularly useful in order to select new sites or estimate the carrying capacity of existing ones. That requires to integrate the response of bivalves to the environmental variations.

The method suggested here consists on coupling a dynamic energy budget approach (last generation of generic growth model) with environmental information extracted from satellite images (chlorophyll concentration and temperature): such data have the advantage over traditional measures of being extensive, validated and non-expensive.

DEB theory assumes common physiological processes across species and life stages via a set of common parameters. Recent promising applications led us to apply the DEB model to estimate the response of *M. edulis* to a natural trophic gradient observed in Mont Saint Michel Bay, a major shellfish farming area of North Brittany, France.

In a first approach, chlorophyll may be considered as an acceptable descriptor of the trophic resource. Since the launch of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) in 1997, followed by MODIS and MERIS, a considerable data set has been collected from satellites. Chlorophyll data have proved very useful for monitoring the phytoplankton dynamics in coastal waters.

After comparing satellite data with field measures for validation, this study included (i) a calibration of the growth model in one location of the bay where growth data are available, (ii) a validation of this model at the scale of the mussel culture area, and (iii) a large scale application of the method, covering the whole bay.

This study may be considered as a general method to account for environmental impacts (food depletion) and responses (growth, reproduction) of an organism in varying environments. Such biological response assessment may be used for site selection, when applied to a species of interest for aquaculture. It may also be usefully included into a Geographical Information System describing the potential uses of a coastal area.

BIO-ENERGETICS OF *CRASSOSTREA GIGAS* AS MODELLED WITH THE DEB THEORY. 1. WHAT'S NEW WITH THE OYSTER-DEB MODEL? Y. BOURLES^{1,2}, S. POUVREAU¹, M. ALUNNO-BRUSCIA^{1,2}, D. LEGUAY², C. ARNAUD², B. KOOIJMAN³, P. GOULLETQUER⁴

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Bio-energetics models are largely used for studying bivalve ecophysiology and growth. Since the two last decades, dynamic energy budget (DEB) models have gained increasing popularity among bio-energetics models. Recently, DEB models based on the DEB theory (Kooijman 2000) have been developed and tested for various bivalves species for the DEBIB project. The oyster-DEB model was successfully applied to simulate the growth and reproduction of the Pacific oyster (*C. gigas*) reared under different environmental conditions in three 'simple' culture sites, i.e. exhibiting no tide and low turbidity. However, the robustness of the oyster-DEB model still needs to be tested in more complex environments.

Thus, we decided to test the oyster-DEB model in an Atlantic coastal pond, where oysters were reared for 12 months in 2006. Forcing variables of the model are water temperature and food density (phytoplankton species, number of cells per liter), which have been measured regularly. First, we determined the temperature effect both on oyster physiology and on the energy fluxes in the model. During our study, water temperature in the oyster pond varied between 3°C and 30°C. Thus, we were able to estimate new boundary values for the temperature tolerance range, both for ingestion and respiration rates. Simulations of the flesh dry mass of oysters over 12 months were performed successively with different food quantifiers, e.g. chlorophyll a, particulate organic carbon, phytoplankton densities or biovolumes. Comparisons between simulated versus observed values of dry flesh mass of *C. gigas* showed that the best prediction by the model was obtained with phytoplankton density as food quantifier, and with the new boundary values of the temperature tolerance range. The resulting new version of the oyster-DEB model is tested in various environments where *C. gigas* is cultured (e.g. Arcachon Bay).

BIO-ENERGETICS OF *CRASSOSTREA GIGAS* AS MODELLED WITH THE DEB THEORY. 2. APPLICATION OF THE OYSTER-DEB MODEL IN ARCACHON BAY (FRANCE). S. POUVREAU¹, D. MAURER², I. BERNARD¹, Y. BOURLES¹, N. NEAU-MASSON², M. RUMEBE², M. ALUNNO-BRUSCIA¹

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Marine bivalves, and especially the Pacific oyster *Crassostrea gigas*, are economically important in French aquaculture. In several shellfish areas, oysters are then the dominant species in terms of biomass and production. In this context, there is a need for modelling tools to understand ecological processes in shellfish ecosystems and to help sustainable management of the oyster farming. Over the last 15 years, numerous energetic models that explain growth of bivalves according to the environment, i.e. temperature and food, have been developed. Recently, a model based on the DEB theory (Kooijman, 2000) has been successfully built up for the Pacific oyster (Pouvreau et al., 2006); some parameters of this DEB model have been modified ever since. Thus, the oyster-DEB model still needs to be tested in several ecosystems where *C. gigas* is dominant.

The scope of this study is to test the oyster-DEB model in an important French shellfish area, the Arcachon Bay. Datasets we used to test the model consist in a 18-year series (1988-2005) of oyster growth data and environmental data. Forcing variables of the model are water temperature and phytoplankton (number of cells per liter, by species). Simulations of the model are compared to observed growth data and we discuss whether they fit accurately observations, with a special emphasis on the effect of quality of the phytoplankton species. We show that from year to year the model successfully predicts the growth and reproduction of oysters, as well as the timing of spawning. The only parameter that varies among simulations is the half-saturation coefficient (X_K) because of inter-annual variations in the algae species, i.e. in the diet composition for oysters. Some algae species in Arcachon Bay are likely not well assimilated by *C. gigas*. This result could partly explain the growth variability of oysters that is reported among French shellfish areas.

MUSSEL CULTURES AND THE EUTROPHIC MARINE ENVIRONMENT IN THERMAIKOS GULF – NW AEGEAN SEA, GREECE. E. PAPATHANASSIOU¹, K. PAGOU¹, A. GIANNAKOUREOU¹, E. KRASAKOPOULOU¹, S. GALINOU-MITSOU³, G. ASSIMAKOPOULOU¹, CH. ANAGNOSTOU¹, I. KRESTENITIS, P. DRAKOPOULOU¹, S. ZERVOUDAKI¹, E. STROGYLOUDI¹ AND A. PAVLIDOU¹

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Thermaikos Gulf in the NW Aegean Sea, Greece, is a highly complex system and is considered to be one of the most polluted coastal

zones in Greece. It is the final receptor of both municipal and industrial wastewaters from the city of Thessaloniki and of two heavily polluted rivers, Axios and Aliakmon. Nutrient enrichment and consequent eutrophication, harmful algal blooms and hypoxia are the primary water quality issues of Thermaikos. The coastal area is used as an area for extensive mussel cultures. Toxic phytoplankton blooms result in economical losses in the shellfish industry that can reach several million Euros.

This communication reviews:

The interaction between the anthropogenic activity of the shellfish industry and the marine environment

An assessment of the carrying capacity of the marine system regarding the mussel production

This is carried out with the aim to apply the Integrated Coastal Zone Management principles in Thermaikos gulf.

In order to achieve the above objectives, physical, chemical and biological parameters were measured in the water column along with the suspended particles concentrations and fluxes on a seasonal basis.

The growth rate of the mussels was studied as well.

Finally, the current state of the mussel cultures area was recorded by aerial photographs and a proposal for a re-allocation of the mussel culture units is suggested to achieve a sustainable management regarding production, quality and economic activities of the shellfish industry in the area.

Parallel session 6: Shellfish restoration: native or introduced species? For ecological or commercial benefit? Chair: Dorothy Leonard, Rick de Voe

BASELINE ASSESSMENT OF GIANT CLAM POPULATION (FAMILY TRIDACNIDAE) IN SAGAY MARINE RESERVE, NEGROS OCCIDENTAL, CENTRAL PHILIPPINES PRIOR TO STOCK ENHANCEMENT OF HATCHERY-BRED GIANT CLAMS *TRIDACNA GIGAS* FROM AN ADJACENT OCEAN NURSERY. MA. J.H.L. LEBATA-RAMOS¹, K. OKUZAWA², R. J. MALIAO³, J. BOGART, R. ABROGUE¹, M. DARWIN, N. DIMZON¹, T.U. DACLES⁴

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To address the diminishing population of the giant clam *Tridacna gigas*, stock enhancement through restocking of hatchery-bred juveniles has been a popular approach. The Stock Enhancement Program of SEAFDEC Aquaculture Department, funded by the Government of Japan Trust Fund, has chosen Marine Protected Areas as sites for its restocking initiatives. Hatchery-bred giant clams *T. gigas* have been reared in an ocean nursery in the adjacent waters of Carbin Reef, Sagay Marine Reserve, Negros Occidental, central Philippines since 31 March 2006. These clams were intended for release to Carbin Reef upon reaching ≥ 20 cm shell length (SL) to minimize vulnerability to predators. While waiting for the clams to attain this size, giant clam population in Carbin Reef was assessed using 10 belt transects to have a baseline information on the population of giant clams belonging to Family Tridacnidae.

Four species of tridacnid clams were recorded, *Hippopus hippopus*, *Tridacna crocea*, *T. maxima* and *T. squamosa*. Of these species, *T. crocea* was the most abundant, comprising 12.5-93.9% of the clams in all 10 transects. Although there was no significant difference in clam density between transects, clam density between species significantly differ (ANOVA, $F=6.94$, $p<0.001$) with *T. crocea* having the highest density. Its density does not significantly differ with the total density of all the four species combined revealing dominance of this species in the reef. The absence of live *T. gigas* and the presence of its dead shells is indicative of its presence in the reef in the past.

Comparing growth and survival of two size classes of *T. gigas* reared in the ocean nursery, the 10 cm SL clams had significantly higher survival than the 8 cm SL clams (T-test: $T=8.05$; $p<0.05$). However, growth rates were the same for both sizes at 0.67 cm mo⁻¹. From these findings, the use of 8 cm SL clams for future projects is recommended since the survival obtained for this size, although lower can be compensated by its cheaper price. The absence of live *T. gigas* in the reef supports the aim of this project to release hatchery-bred *T. gigas* juveniles to provide breeders in the future that will repopulate Carbin Reef and the adjacent waters.

EVALUATING THE POTENTIAL OF A NON-NATIVE OYSTER SPECIES (*CRASSOSTREA ARIAKENSIS*) TO RESTORE ECOLOGICAL FUNCTION TO THE CHESAPEAKE BAY, USA. P.R. KINGSLEY-SMITH¹, M.W LUCKENBACH¹, K.T PAYNTER JR.², S.K. ALLEN JR.³, D.W. MERITT⁴, H.D. HARWELL¹ AND M.L. KELLOGG²

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Stocks of the native oyster, *Crassostrea virginica*, in the Chesapeake Bay, USA have declined dramatically during the last century due to over-harvesting, habitat degradation and endemic disease pressure. The economic and ecological losses associated with this decline, together with limited successes in native oyster restoration, have generated interest in disease-tolerant, non-native oyster species. The species currently under examination to restore ecological function and as an aquaculture product is the Suminoe oyster, *Crassostrea ariakensis*.

Considerable research is underway in support of a federally-mandated Environmental Impact Statement (E.I.S) aimed at assessing proposed alternatives that include the intentional introduction of diploid *C. ariakensis*. Central to evaluating these alternatives is the accurate prediction of the comparative rates of survival and growth achieved by *C. ariakensis* under a range of environmental conditions.

Initiated in October 2005, this long-term, large-scale field study represents the first investigation of the survival and growth rates, disease tolerances and habitat value (reef complexity and associated faunal assemblages) of triploid *C. virginica* and triploid *C.*

ariakensis established side-by-side in “natural” bottom habitats. Oysters were deployed at sites covering a range of salinities, water depths, perceived disease pressures and relative predator abundances.

Highest growth rates of *C. ariakensis* occurred at the high salinity, subtidal site, while growth rates have been more similar at lower salinity sites. Survival of *C. virginica* and *C. ariakensis* remains highest at the lowest salinity site. *C. ariakensis* appears to be intolerant of intertidal aerial exposure, particularly above the mean low water mark, such that introduced *C. ariakensis* populations may be restricted to low intertidal and subtidal habitats. The spread of *C. ariakensis* following an introduction is likely to be strongly affected both by the geographic distribution of intertidal vs. subtidal habitat and its mortality rates in subtidal habitats.

MAXIMIZING POTENTIAL REPRODUCTIVE SUCCESS ON RESTORED OYSTER REEFS: USING AGE- AND SIZE-SPECIFIC SEX RATIOS TO EVALUATE MANAGEMENT STRATEGIES. M.L. KELLOGG AND K.T. PAYNTER

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In recent years, oyster reef restoration efforts in the Maryland portion of Chesapeake Bay, USA have focused on creating a system of oyster sanctuaries and managed reserves to address the dual purposes of restoring ecosystem services once provided by healthy oyster reefs and rehabilitating an oyster fishery that has declined to < 1% of historic levels. Both sanctuaries and managed reserves rely on planting hatchery-produced, disease-free spat-on-shell in low salinity areas where mortality rates are reduced and natural recruitment rates are extremely low (<1 spat m⁻² yr⁻¹). While sanctuaries are permanently protected from harvest, managed reserves are opened to harvest after minimum size criteria, more stringent than those for the fishery as a whole, have been met. Present regulations require a median oyster size ≥4” (102mm) and then allow harvest of all oysters > 3” (76mm). These regulations were developed based, at least in part, on the assumption that they would result in higher rates of reproductive success, as a result of increased size-specific fecundity and additional spawning seasons. The efficacy of this strategy may also depend upon how sex ratios of hatchery-produced oysters vary with age, size and environmental conditions. We have recently initiated studies on restored oyster reefs in Maryland to examine sex ratios of oysters in relation to these factors and evaluate the potential effects of alternative management strategies on overall reproductive success.

In 2006 and 2007, restored oyster reefs in Maryland were sampled and data on oyster size and sex were collected. Because natural recruitment rates to restored reefs were extremely low and the history of each reef was known, it was possible to assess sex ratios in relation to both oyster age and oyster size. Using these data along with data on the direct and indirect impacts of harvest on sex ratios, we predicted the sizes and sex ratios of post-harvest populations under a variety of management scenarios. These scenarios employed differing combinations of median size and minimum age requirements for opening the fishery, as well as minimum and maximum allowable sizes for harvest. Each scenario is considered in relation to its potential to maximize reproductive success.

IMPORTANCE OF COMMERCIAL OYSTER STOCKS IN THE RECOVERY OF STOCKS OF NATIVE EUROPEAN OYSTERS, *OSTREA EDULIS*. D. ROBERTS, D. SMYTH, R.J. KENNEDY, J.A STRONG & L. BROWNE.

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Wild *Ostrea edulis* was extremely rare in Strangford Lough, Northern Ireland from the 1900s until renewed spatfall was observed at a number of sites in the 1990s. Surveys undertaken in Strangford Lough between June and September in 1997 and 1998 revealed significant spatial variation in densities of oyster larvae with higher densities at sites closer to commercial stocks pointing to these as the main source of oyster larvae (Kennedy & Roberts, 2006). A larval flux study over a complete tidal cycle indicated a 90% net tidal movement of *O. edulis* larvae from the entrance of the bay, where commercial stocks were held to the main body of the lough. The maintenance of dense commercial stocks of flat oysters may therefore provide the key to the redevelopment of native oyster beds in Strangford Lough and elsewhere by providing an initial broodstock nucleus from which larvae can be exported. Field surveys in 2002 and 2003 revealed increases in standing stocks of intertidal oysters which can probably be attributed to larval export from commercial oysters beds. In addition, comparisons between the observed oyster distribution and predictions generated from a larval flux model showed good levels of agreement for the intertidal populations.. The model is currently being developed to include sources of juvenile and adult mortality, which might indicate why recovery was significantly greater in intertidal areas when compared to the subtidal zone. However, decreases in standing stocks of oysters after 2003 due to unregulated harvesting threatens this potentially important natural recovery process.

ECOLOGICAL IMPACT OF AN EXPERIMENTAL LARGE SCALE REMOVAL OF PACIFIC OYSTERS (*CRASOSTREA GIGAS*) FROM NATURAL BEDS IN THE OOSTERSCHELDE. J.W.M. WIJSMAN¹, M. DUBBELDAM², E. VAN ZANTEN³, A.C. SMAAL¹

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The Pacific oyster is an exotic species for the Oosterschelde. It was introduced in 1964 to compensate for the collapse of flat oysters

(*Ostrea edulis*) after the severe winter of 1992/1993. Since then, the oysters have proliferated the Oosterschelde and in 2005, 775 ha of the littoral area was covered with oysters which had an impact on the natural functioning of the ecosystem. In March 2006, a total area of 50 ha Pacific oysters (*Crassostrea gigas*), with a total biomass of 12.5 million kg, are removed with mussel dredges from natural littoral and sub-littoral oyster beds in the Oosterschelde. The oysters are dumped at designated dumping locations in the Oosterschelde where they would die from suffocation and starvation. Although the total fishing effort was high (940 boat hours), the oysters could be effectively removed from the oyster beds. The suffocation of the oysters at the dumping locations was not complete. After one year more than 10 percent of the total oyster biomass at the dumping location was still alive. Oyster beds could play a role in the stabilization of the sediments. At one mudflat (Zandkreek), some erosion took place during the fishing activities, however this did not persist after the fishery. Also the sediment composition was not greatly effected by the removal of the oysters. At another mudflat, Vondelingsplaat, a hard layer of shell remains were left after fishing, which protects the site against erosion and showed to be a suitable substrate for new spat fall of oysters. The benthic fauna in the sediment within an oyster bed differs from the benthic fauna outside the bed. As a result, most wading birds prefer oyster beds as a foraging site above the mudflats without oysters. However, this doesn't accounts for all species. The results of the study will be used by decision makers to decide if large-scale removal of oysters in the Oosterschelde is feasible and has no impact to the ecological values of the system.

Parallel session 7: Benthic impact of mussel culture. Chair: Christian Hily, Per Dolmer

ENVIRONMENTAL IMPACTS OF MUSSEL FARMING IN AN EUTROPHICATED DANISH INLET WITH EMPHASIS ON THE SEDIMENT. M.S. CARLSSON^{1,2}, J.K. PETERSEN¹, M. HOLMER²

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Shellfish aquaculture is growing worldwide and recently an enhanced interest in farming the mussels off-bottom in the water phase has been established in Denmark. Previous studies have shown a range of environmental impacts due to the farming. In this study we examine the temporal and spatial variation of effects on sedimentation, organic content, and benthic fluxes of mussel farms in a microtidal eutrophicated Danish inlet, Limfjorden, with 5-8 m water depth.

The temporal variations were tested by sampling sediment cores from a specific mussel farm in Limfjorden from 4 sites in every season in the period summer 2005 – summer 2006. The sites consisted of 1 reference site (ca 50 m outside the farm), 1 site at the edge of the farm, and 2 sites inside the farm. The organic content was high at all sites including the reference site and was apparently not affected by the mussel farm or seasonal variations. However, oxygen and nutrient fluxes were found to be significantly higher inside the farm compared to the reference site and edge site. Sediment oxygen consumption (SOC) was 2 – 3 times higher while Ammonium and Phosphate fluxes were 3 – 10 times higher and 2 – 8 times higher, respectively. In addition the findings showed a temporal variability as the most severe effects were observed during summer and autumn compared to winter and spring. Sulphate reduction rates (SRR) and total sulphur pools (TRS) showed the same pattern as the fluxes being 2-3 times higher inside the mussel farm comparing to the edge and reference site in summer and autumn. Regardless, the effects on SRR and TRS were not significant in winter and spring.

To get a better understanding of the spatial variations and correlations between sedimentation rates and benthic effects we examined 8 different mussel farms at different locations in Limfjorden in May 2007. To measuring sedimentation rates sediment traps were placed inside and outside the farms associated with sampling of sediment cores for examination of benthic conditions. This study showed somewhat variable effects as some of the farms showed consistently higher sedimentation rates and fluxes inside the farm comparing to the reference site while others showed the same tendency but less consistently. However, in general there was a good correlation between sedimentation rates and benthic effects.

From this study it is clear that mussel farming has an impact on benthic bacterial degradation rates which is due to the increasing load of organic material such as faecal pellets. The highest effects were observed during summer time which points at high temperatures as an enhancing factor on the observed effects. The spatial variation may be due to differences in current rates and resuspension conditions at the different mussel farm areas.

INFLUENCE OF MUSSEL AQUACULTURE ON BENTHIC ORGANIC ENRICHMENT IN A NUTRIENT-RICH COASTAL EMBAYMENT. B. HARGRAVE, P. CRANFORD, L. DOUCETT, B. LAW AND T. MILLIGAN

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Sediment modal grain size, bottom shear stress, porosity, organic matter (OM), redox potentials ($E_{h_{NHE}}$) and total free sulfides (S) were used to evaluate effects of intensive mussel (*Mytilus edulis*) aquaculture on benthic organic enrichment in a shallow, nutrient-rich embayment. Significant differences inside and outside (>25 m) of lease boundaries showed enrichment effects on inlet-wide scales. Oxidic conditions (OM <10%, E_h >+100 mV, S <1000 μ M) occurred in coarse-grained sediments in shallow areas (<4 m) where shear stress was >0.2 Pa. Modal grain size and E_h decreased and porosity, OM and S increased with depth. Hypoxic sediments (OM >10%, negative E_h potentials, S >1000 μ M) occurred where shear stress was <0.1 Pa in fine-grained deposits in deeper areas of the bay. White sulfur bacteria (*Beggiatoa*) occurred on sediments within mussel leases. Sediments with low E_h and relatively high OM occurred in a spat collection area receiving river discharges from agricultural areas, but S levels were lower than in mussel grow-out areas. K-means clustering and multi-dimensional scaling were used to group stations with similar geochemical characteristics along an organic enrichment gradient. Relationships between E_h and S and a Benthic Enrichment Index derived from porosity, OM and E_h were similar to previous descriptions for oxic-anoxic and S gradients in sediments in salmon aquaculture areas. Effects of benthic enrichment due to mussel aquaculture are most likely to be detected in low-current, shallow-water areas where biodeposits accumulate and can be detected on various scales using geochemical methods if sampling sites are sufficiently numerous and spatially distributed.

BENTHIC MACROFAUNA AND FORAMINIFERA AS INDICATORS OF OYSTER FARMING EFFECTS ON INTERTIDAL AREAS IN THE PERTUIS CHARENTAIS (FRANCE). V.M.P. BOUCHET^{1,2}, P. SAURIAU¹, J. DEBENAY³

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Oyster farming was initiated within the Pertuis Charentais (SW France) during the XIX century and has been intensively developed following the introduction of the Pacific oyster *Crassostrea gigas*. In oyster farming areas, organic matter fluxes toward sediment is increased. Pacific oysters reject faeces and pseudofaeces rich in organic matter as a result of filtration process. Organic matter can be consumed by benthic fauna, however, in excess, it can entails the reduction of benthic faunal species richness, abundance and biomass. Organic matter degradation also induce hypoxic (or anoxic) conditions in sediment and production of ammonia and sulfides in toxic concentrations. Only few studies have investigated these potential disturbances and not yet in Pertuis Charentais. The main objective of that study was to assess effects of oyster farming on benthic intertidal ecosystem in the Pertuis Charentais. Benthic macrofauna, living (stained) foraminifera, and physical and chemical characteristics of the water column and sediment were used as indicators to evaluate these effects.

Six oyster farming areas belonging to 24 sample sites were sampled once per season during one year. Chl a, total organic matter content, total carbon and nitrogen contents, size-grain analyses and sedimentary, pH, redox potential, salinity and temperature were recorded together with computation of AZTI Marine Biotic Index (AMBI) and foraminiferal species richness. AMBI permits to establish the ecological quality of benthic environment and is based on the response of macrofaunal ecological groups to natural and man-induced disturbances. In this study, we found that oyster farming enriches sediment in fine particles, organic matter (up to 12 %), particulate organic carbon (15-20 µg mg⁻¹) and leads to high microphytobenthic biomass. Consequently, benthic assemblages diversity decreases and species population dynamics is disturbed. In these conditions, tolerant benthic macrofaunal (*Cirratulidae*, *Spionidae* and *Capitellidae*) and foraminiferal (*Ammonia tepida* and *Cribroelphidium gunter*) species are promoted. AMBI index confirms "medium" ecological quality of oyster farming areas. On the contrary, across the control sites, sensible species are maintained (Amphipods, *Rosalina cf. vilardeboana*). Comparison of oyster farming techniques shows that on-bottom culture is less disturbing for benthic ecosystem than off-bottom culture.

INDICATORS OF BENTHIC IMPACT OF MUSSELS CULTURE ON THE SEDIMENT IN A MACROTIDAL ENVIRONMENT (PERTUIS BRETON, FRANCE). A. BODOY, J. MARTIN, A. GAELLE HAUBOIS

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On the Pertuis Breton (Atlantic coasts of France), 10 000 tonnes of mussels are reared on longlines. An attempt has been made to evaluate the resulting impact at the ecosystem level, in the frame of an European project (ecasa.org). Sediment samples were taken by divers along a transect, from the longlines and heading towards the direction of tidal currents. In this paper, indicators describing the spatial extent of the impact on physical and biochemical parameters related to the sediment are proposed and discussed. The mud proportion into the sediment decreased clearly with the distance from the mussels, while this parameter did not show any characteristic vertical variation within the 12th upper centimetres. The organic matter within the sediment was characterised by different methods, including ignition at different temperatures and carbon and nitrogen analyses. Samples far from the culture area have less total organic matter than those taken at the vicinity of the mussels. This was even more pronounced when considering the labile organic matter, as measured by ignition at 250 °C. Reciprocally, the refractory organic matter was more abundant into the sediments located near the mussels. These two parameters are combined into a sediment quality index, which clearly show a trend related with the distance from the mussels, regardless the depth at which the sample was taken into the sediment. The elemental analysis of particulate organic carbon revealed that the station beneath the longline was the only one to exhibit values higher than the others, including the reference station. Therefore, the particulate organic carbon did not seem to be an adequate indicator of the impact of mussels culture on the sediment, for the conditions observed in this site. The Chlorophyll a content of the upper centimetre was also higher beneath the culture than farther. The phéopigments content followed the same scheme, excepted that they were more abundant. The chlorophyllic pigments could only reveal the impact of mussels culture beneath the installations, but they failed to distinguish any spatial trend, or a difference with a reference status. From this study, the mud content and the sediment quality index are the best candidate as indicators of the spatial impact of mussels culture on the sediment.

COMPARISON OF SPECIES COMPOSITION, DIVERSITY AND ABUNDANCE IN SUB-TIDAL AND FLOATING OYSTER (*CRASSOSTREA VIRGINICA*) GEAR HABITAT FROM DELAWARE'S INLAND BAYS. G. OZBAY, P. ERBLAND, F. MARENGHI AND K. ROSSI-SNOOK

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The eastern oyster (*Crassostrea virginica*) is a keystone species in the estuaries of the mid-Atlantic United States. Their filtering activity and biodeposition play an important role in the ecology of these systems. Oyster reefs are one of the few sources of hard bottom habitat for colonization of fouling organisms and are the foundation of a rich biological community. The culture of eastern oysters (*Crassostrea virginica*) in containment gear has become a viable industry in many states on the East Coast of the United States, and it has been suggested that operations of this type may provide many of the same ecological services attributed to natural or restored reefs.

This was a two part study of the macrofaunal communities associated with sub-tidal, modified “rack and bag” aquaculture over the summer and fall of 2006 and with floating oyster cages over the summer and fall of 2007. In the first part of this study, we compared the diversity and abundance of species inhabiting subtidal *C. virginica* “rack and bag” type gear with an adjacent created *C. virginica* reef. This project was also designed to examine the impacts of oyster aquaculture gears on sediment infaunal community structure. The objective was to compare the diversity, evenness, abundance, and biomass of macro-infaunal and -epifaunal communities inhabiting a subtidal oyster cultivation area with adjacent open sand flat along with water quality data. The sediment composition and macro-infaunal communities below the oyster cages with a nearby control transect of open sand/mud bottom was examined over four months (June, August, September, and October of 2006). In the second part of this study, the habitat value of floating oyster aquaculture gear will be examined at three locations within Delaware’s Inland Bays (Rehoboth Bay, Bethany Beach, and Fenwick Island) over the course of four months (July, August, September, and October) in 2007. The three locations within the Inland Bays area represent a range of environmental quality and growing conditions. The objective was to compare the diversity, evenness, abundance, and biomass of macro-epifaunal communities inhabiting a floating oyster cultivation area from the three ecologically different Inland Bays in Delaware. Sediment characteristics and in-faunal community composition will also be examined in this study. The second part of this study is in progress and will be discussed. This part of the research aims to describe some of the changes brought about to local ecosystems that experience small-scale oyster restoration programs.

In the first study, a greater total abundance and species richness ($P < 0.05$) was found associated with the oyster gear, but greater species evenness ($P < 0.05$) was found on the reef. Samples were dominated by naked goby (*Gobiosoma boscii*) and Atlantic mud crab (*Panopeus herbstii*). *G. boscii* were significantly ($P < 0.05$) larger but less abundant on oyster reefs compared to oyster gear with no significant difference in biomass. *P. herbstii* were significantly larger ($P < 0.05$) and more abundant in oyster gear than on the reef, while the oyster reef supported a greater biomass. Blue crab (*Callinectes sapidus*), tautog (*Tautoga onitis*), American eel (*Anguilla rostrata*), sergeant major (*Abudefduf saxatilis*) and gag grouper (*Mycteroperca microlepis*) were unique to oyster gear. Skillefish (*Gobiesox strumosus*) was unique to oyster reefs. Of the seven most abundant infaunal taxa *Streblospio benedicti* Webster 1879 (Polychaeta: Spionidae) was the only species significantly different ($P < 0.05$) in abundance between treatments. This species may have been flushed away along with sediment silt and clay during disturbance from oyster culture activities.

The results of this study suggest oyster culture may support additional populations of ecologically and economically important macrofauna compared to a created reef, with little impact on sediments and infaunal communities. More information about possible benefits and detriments to estuarine ecosystems will help to shape the future fate and structure of shellfish aquaculture in the state of Delaware and other Mid-Atlantic States. Further understanding of the ecological costs and benefits of oyster culturing practices will help decision-makers and the general public to formulate opinions and policies.

ENVIRONMENTAL IMPROVEMENT OF AQUACULTURE FARMS BY SPREADING RED CLAY AT YEOJA BAY IN KOREA. NA, GUI HWAN, SO YOUNG PARK, MYUNG SUN PAIK, JUNG CHAN PARK

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From 1995, Korean government started to improve the aquaculture farms environmental quality ,especially sediment, to increase the quality of its products in coastal shellfish farms. We utilized the red clays covering the bottom with 1.7mm thickness on the oyster, the ark shell and pen shell farms for better conditions of sediment after the dragging the bottom with waste materials

At Yeoja bay, after we scattered the red clay with 68,683MT for 5,050ha in 2002, we surveyed the water quality, sediment and benthic organisms variation by comparing between spreading zone(10 stations) and non-spreading zone(5 stations) from 2003 to 2007 every 2 months.

As a result, the eutrophication indicator in bottom habitat, *Musculus senhousia* was the dominant species in non-spreading zone but it was eradicated after the dragging the sediment by ark shell harvesting device. After the improvement effort, the seedlings of commercial species, *Atrina pectinata* was developed in a strict distribution of red clay spreading zone.

Besides the shellfish industry, the period of the shrimps fisheries was postpones about 3 months and the fisheries grounds which originally was located at western part but after it was enlarged at the eastern part of the same fisheries grounds.

Parallel session 8: Nature conservation and stakeholder involvement. Chairs: Han Lindeboom, Hein Sas

SHELLFISH AT RISK: A GLOBAL ASSESSMENT OF DISTRIBUTION, CONDITION AND THREATS TO HABITAT-FORMING BIVALVES. R.D. BRUMBAUGH¹, M.W. BECK², A. CARRANZA³, L.D. COEN⁴, O. DEFEQ³, H.S. LENIHAN⁵, M.W. LUCKENBACH⁶, C. TOROPOVA² AND J.S. VINCENT⁷.

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Shellfish-dominated habitats are among the most globally impacted of all estuarine or marine ecosystems. Native shellfisheries have collapsed across Europe, the US and Australia, with commensurate losses in structured reef habitats for a diverse array of associated species. Provision of ecosystem services such as shoreline protection and the filtration of overlying waters have undoubtedly been diminished as well. Despite some examples from individual bays and estuaries, however, no comprehensive assessment of the condition of these ecosystems has been conducted on a global scale. The "Shellfish Reefs at Risk Assessment" is a collaborative effort modeled after a successful coral "Reefs at Risk" project, with the goal of describing the global distribution, condition and most significant threats to native molluscs (primarily bivalves and gastropods) that provide structured habitat for other species. Four broad categories of shellfish are being addressed through this assessment: (1) epibenthic reef-forming species that provide significant vertical structure (≥ 0.5 m) and are the dominant structural component of the benthos; (2) structurally complex epibenthic shellfish that occur at densities sufficient to form macro-relief (< 0.5 m) on the bottom; (3) epibenthic molluscan aggregations that provide secondary structure on top of other underlying hard substrate such as rocks or mangrove roots; and (4) other infaunal or epifaunal (primarily bivalve) molluscs that occur at lower densities and that generally do not provide the majority of benthic structure, but may provide some important ecosystem services.

The assessment is being conducted in several phases. The first phase focused on construction of a geo-database containing spatial data on key shellfish species, assembled with input from managers, scientists around the world. The second phase is an assessment of condition and threats using expert input and a literature review. In the final phase, we will attempt to model current condition against threats such as population density, sediment inputs and pollutant loading at a global scale. Several products are envisioned from this assessment: (1) a Shellfish at Risk state of the world report that identifies molluscan ecosystems around the world, their estimated risk of ecological extinction as low, medium or high; (2) an accompanying global database of the distribution of key bivalves in temperate waters; and (3) a model of factors that, taken together, describe the conditions of these ecosystems and the threats to them. The Nature Conservancy and partners will publicize and distribute these products widely to the environmental community, researchers, and management agencies.

SUSTAINABLE APPROACHES FOR THE MANAGEMENT OF MANILA CLAM (*TAPES PHILIPPINARUM*) SPAT IN THE VENICE LAGOON (ITALY). E. PONIS¹, R. BOSCOLO¹, F. CACCIATORE¹, G. CHIAIA²

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Intensive farming and fishing of Manila clam (*Tapes philippinarum*) take place in several coastal lagoons of the Northern-Adriatic Sea, supporting local economy but raising concerns on the environmental sustainability of such activity. After a peak of production raised in 1999, with a national production of 60 000t and a local production of 40 000t for the Venice lagoon, a decline in clam yield has occurred as a consequence of a lack of an effective management policy of such resource (overexploitation of the natural beds, illegal harvest, use of high-impacting fishing gear) and of a deterioration of environmental conditions. In order to face this situation local Government and Water Authorities (Provincia di Venezia and Magistrato alle Acque, 2000) have proposed a Master Fishing Plan for the Venice Lagoon, while a new Master Plan was set up more recently (2006) by the Consortium GRAL which includes all the clam growers of the Venice lagoon (about 1 000 peoples, divided in 90 cooperatives). Among the different directives promoted by both plans and aimed at the sustainable management of clam farming procedures, particular importance has been given to the rational management of natural spat. Unlike other forms of mollusc culture, clams farming in Italy depends almost exclusively from the collection of natural spat; for those reasons hatchery and nursery activities for the clam culture are poor developed locally. Local farmers are used to harvest large-size spat (> 10 mm) in order to avoid important losses due to predation during the growing phases, whilst a large amount of small or medium-size spat undergoes to high predation rate or is damaged during the harvest of seed of bigger size by the use of high-impacting fishing gears.

Based on the large data sets concerning the characterization of the Venice lagoon under several aspects (morphology, hydrology, sediments, chemical and physical features, phytoplankton, pollutants) a GIS oriented map has been prepared in order to recognize, among the areas managed by GRAL (about 3 200ha) the most appropriate areas where carrying out nursery activities; in the meanwhile, an investigation among the different nursery techniques currently available has been proposed for finding the systems that may fit more appropriately with the local conditions. Five different nursery techniques (FLUPSY, lanterns, plastic bags, nets, poches) have been identified and proposed to the growers; for each technique a protocol for the survey of the growing procedures has been assessed.

WHAT FACTORS AFFECT THE RESTORATION SUCCESS OF COCKLE BEDS IN NEW ZEALAND? I. MARSDEN AND J. PIRKER

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The intertidal cockle *Austrovenus stutchburyi*, locally known as tuangi, is endemic to New Zealand where it commonly occurs in sheltered sandflats and estuaries. While it is still abundant in some places, recreational collecting and habitat change have resulted in losses of shellfish beds. This talk reviews the current status of cockle resources in New Zealand and outlines some of the methods (including closures) that have been used to try to re-establish them. Cockle populations differ both within and between locations and recent research suggest that this is often site specific and correlated with habitat disturbance, sediment properties and contaminant levels. The paper also discusses the role of Customary Fishing Regulations and the management of Maori Marine Reserves in promoting cockles as a sustainable shellfishery.

DYNAMICS OF MUSSEL BEDS AND IMPACT OF OYSTERS – DIFFERENT PERSPECTIVES FROM THE DUTCH AND THE NORTHERN GERMAN WADDEN SEA. G. NEHLS¹, H. BÜTTGER¹, N. DANKERS², F. FEY², K. GOUDSWAARD², J. CREMER²

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Blue mussel beds are diverse and highly productive ecological communities on the tidal flats of the Wadden Sea. Mussel beds may cover about 1 – 5 % of the intertidal mudflats of the Wadden Sea and under favourable conditions individual beds may persist over decades. In this contribution, we will analyze long-term changes in area and structure of intertidal mussel beds in the Dutch and the northern half of the German Wadden Sea.

In the early nineties almost all intertidal mussel beds had disappeared from the Dutch Wadden Sea. Substantial spat falls in 1994, 1996, 1999, 2001, 2003 and 2005, yielded several new beds. Broad scale investigations indicate that beds reappear in areas where they have been mapped in the past. Many of the beds from these spatfalls disappeared during the following winters, but the survivors resulted in an increase in number and area of mussel beds. In 2006 more than 2600 ha is present again in the Dutch Wadden Sea.

In the northern German Wadden Sea (Schleswig-Holstein) good spatfall occurred only in 1996, but not on the following years. In fact, mussel bed area decreased to a third and mussel biomass decreased by more than 80 % since 1989. Although protected from fisheries mussel beds vanished in many areas and mussel densities and recruitment into existing mussel beds decreased. In the whole Wadden Sea, Pacific oysters have spread and turned many mussel beds into dense oyster reefs in the last years.

We will describe changes in the area and distribution as well changes in the structure of the mussel beds and discuss the possible reasons, the perspective and possible consequences of declining mussel beds. Recruitment failure in blue mussels and yet unlimited proliferation of pacific oysters apparently comply to recent theories on the role of predation and climate change in structuring bivalve communities in the Wadden Sea. However, marked differences in the development of blue mussel recruitment in different parts of the Wadden Sea put caution on simplified conclusions.

MOLLUSCS TRADITIONAL EXPLOITATION IN SENEGAL: *ANADARA SENILIS* L. (1758). BIOLOGICAL POTENTIALITIES AND RISKS. A.G.F. BENG

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The Saloum Delta has a great part in the senegalese fisheries because it represents one of the areas where malacological selective collect, mainly *Anadara senilis* L. (1758), holds an important place in the village economy, which benefits at the local women. The important exploitation of these natural resources requires an examination of the operating mode of this activity.

Since a few years, indices of overexploitation have been evoked. Consequently, an assessment of the available resources and the selecting level are necessary. Are the downswings of the medium productivity per day as well as the reduction of the average size of the selected arks sufficient to justify the overexploitation noticed?

The combination of several research methods (follow-up based on socio-economic considerations, finding of indices but also assessment of the available stocks) provided interesting results. From the potentiality-extraction ratio, the reflexion leads to a discussion on the situation of overexploitation and the biological rest for this species, at the local scale.

The conclusions open some prospects for rational exploitation and identification of selecting threshold, by actors, for a sustainable exploitation of the resource. Moreover, the effectiveness of the device of follow-up produces results of a high degree of accuracy which explain the periodic variations of the taking away effort.

The existence of strategic factors, controlling naturally the traditional exploitation, and the still manual character of the activity appear like main factors regarding the dynamics of this littoral resource.

However, there is still a difficulty: the concern of keeping a balanced approach between a socio economic motivation on the basis of the selective collect and an ecological sensibility in order not to forget the conservation of the biological potentiality.

COMBINING ECONOMIC AND ECOLOGICAL GOALS IN OYSTER MANAGEMENT IN THE CHESAPEAKE BAY, USA: EXPERIENCES FROM A MULTI-STAKEHOLDER ADVISORY PANEL. M. BRYER¹, M. LIPFORD¹ AND A. THOMAS LEGGETT²

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The oyster *Crassostrea virginica*, native to eastern North America, is a keystone species in estuarine systems throughout much of its range. It has sustained the culture, economy, and ecology of these systems for centuries, perhaps most notably in the Chesapeake Bay. Oysters have declined dramatically, however, since the 1800s in the Chesapeake due to a variety of causes. Largely lost are the economic benefits and critical ecological services once provided by this resource. In June 2006, the government of the state of Virginia (which has jurisdiction over the southern portion of the Chesapeake Bay as well as coastal lagoon systems) convened a panel of 20 stakeholders and requested it to recommend novel approaches for oyster management. These stakeholders came from a wide variety of backgrounds and interests, including the wild fishery, aquaculture, packing industry, academia, government, and non-government organizations. Over the course of a year, the panel developed its recommendations through information review, analysis, and deliberation. We present the seven major recommendations of the panel, which include short-term and long-term actions designed to improve both the harvest and the ecological benefits that oysters provide. We also discuss our experiences as stakeholders on the panel, and offer recommendations to others with similar opportunities to be stakeholders in shellfish management decisions.

CONSULTING STAKEHOLDERS IN THE PERSPECTIVE OF INTEGRATED MANAGEMENT PLANS UNDER THE HABITATS DIRECTIVE (92/43): THE MORE, THE MERRIER? F. NEUMANN

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Since the designation of sites under the Habitats Directive (92/43), in most Member States has been followed by the setting of conservation objectives and the development of management plans, increasingly also shell fisheries have to cope with the implications of such plans. Stakeholder involvement is one of these implications.

We will focus on stakeholder interaction with regard to shell fisheries in these management plans. What place does shell fishery have in the development of the plan? What actions are to be taken? And above all: how does the sector organise the discussion with its stakeholders and what are the tentative results in terms of fisheries?

These issues are depending upon many local factors as e.g.: The degree of organisation of the sector, the constraints of site protection and the willingness of stakeholders to enter debates. In most Member States, the sector was not used to and tuned to the inclusion of environmental stakeholders, but under pressure of the requirements following from the Habitats Directive this situation has changed considerably.

Cases will be described in two Member States –The Netherlands and one other Member State-. From an organisational perspective, the place of shell fisheries in the development of integrated management plans will be described. In addition, the inclusion of particularly nature protection organisations in planning fisheries is described and the results of these debates as far as known.

Finally, suggestions for further investigation will be given as well as tentative suggestions for stakeholder trajectories that could be valid for the policy situation in different Member States.

THE ROLE OF ECOLOGICAL SCIENCE IN SHELFISH FISHERY POLICY MAKING: THE DUTCH EVA II-CASE. L. HANSSSEN, M. VAN KATWIJK AND ETIËNNE ROUWETTE

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Between 2000 and 2003, the Dutch Ministry of Agriculture, Nature Management and Fisheries evaluated the effects of shellfish fisheries (EVA-II research programme). The approach was innovative and ambitious in the sense that it attempted to obtain the best available knowledge by using a steering group of scientists, policymakers and stakeholders, and an independent scientific audit committee. We were in the unique opportunity, financed by the Ministry, to thoroughly evaluate this case during 2006-2007 in collaboration with all policymakers, scientists, economic and ecological stakeholders involved (over 50 persons). From this we were able to supplement existing guidelines for interaction between policy and science (which we reviewed) with new guidelines. These new guidelines focus on scientific uncertainty and increasing the participation of stakeholders and scientists in the policy process. We stress that the use of science should primarily be facilitating, instead of pacifying.

From our review and case analysis we conclude that pacification, by providing neutral, indisputable knowledge in response to shared

problems, is difficult in complex, multi-actor issues, where scientific uncertainties abound and different values system play a role. Facilitation means that science does not (only) contribute content to the decision making process, but also ensures a process in which values and knowledge of stakeholders are elicited and confronted. Only by explicitly recognizing the requirements and limitations of both conditions, ecological science can become more relevant to a policy making process on complex environmental issues. Otherwise, scientific uncertainties may induce science to become a plaything in the hands of policy makers, instead of providing best available knowledge. We address novel ways to handle scientific uncertainties to realise adaptive and integrated coastal zone management, which is increasingly needed in times of increased (EU-)regulation and environmental urgencies related to for instance climate change and over fishing.

Parallel session 9: Education and extension programmes.

Chairs: Gavin Burnell, Wilbert Schermer-Voest

WHAT THE BAY HINGES ON: TEACHING ECOLOGY, RESTORATION, AND STEWARDSHIP. C. MUSCIO AND G. FLIMLIN.

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The Barnegat Bay Shellfish Restoration Program, currently in its third year, has won local support, significant press, and awards for its efforts to "ReClam the Bay". Its educational programs are reaching out to volunteers, citizens, and youth to increase environmental involvement, change behaviors, and raise awareness about the Barnegat Bay Watershed. What the Bay HINGES on is a twelve lesson curriculum activity guide designed for use in both formal and non-formal education. The guide teaches about shellfish biology, biological classification, Barnegat Bay ecology, water quality, pollution, seafood safety and nutrition, and stewardship. Its focus is on integrating shellfish biology, ecology of the Barnegat Bay, and human needs and actions to foster understanding of the complex nature of environmental issues. The guide was made available to educators in the summer of 2007, along with mini-Taylor Floats full of accessory materials for the lessons. Each lesson provides demonstrations and activities that increase understanding of the topics discussed. Through several workshops, these lessons have been used to instruct volunteers and educators statewide. The guide was also used as a basis for the six lesson "Clam Camp" taught at the St. Francis Community Center in 2006 and 2007. Over one hundred youth between the ages of 5 and 15 increased their understanding of shellfish aquaculture, bay ecology, and water pollution issues through the camp classes.

SHELLFISH RESTORATION: SCIENCE, EDUCATION AND ART AS STRANGE BEDFELLOWS. G. FLIMLIN, R. BUSHNELL AND C. MUSCIO

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Faced with declining hard clam (*Mercuraria mercenaria*) stocks, severe reductions in the number of commercial and recreational clamming licenses, and intense growth in the watersheds of the Barnegat Bay, a decision was made by Rutgers Cooperative Extension of Ocean County in 2005 to institute a community based shellfish restoration program. The program is partnered with the New Jersey Department of Environmental Protection Bureau of Shellfisheries.

In the first three years, the Barnegat Bay Shellfish Restoration Program trained about 100 volunteers. These volunteers grew a total of 3.3 million clam seed and 350,000 oyster seed (*Crassostrea virginica*). The program runs 7 upweller nursery systems on Barnegat Bay and two leases where the clam seed grow for a second year under predator control screens until they are harvested for public planting. The oyster seed is placed on old oyster reefs.

Providing education about water quality, shellfish, aquaculture, and the Barnegat Bay is key to the program. A myriad of educational opportunities exist to teach the citizens, both young and old, about these concepts. Initial funding was provided by Ocean County, the USEPA Barnegat Bay National Estuary Program, and the Exelon Corporation. A volunteer Non-profit corporation "ReClam the Bay, Inc." worked to develop alternative methods to raise funds to support the restoration program. This includes outside grants, bumperstickers, tee shirts, and fascinating public art pieces designed to attract people and teach science through a treasure hunt concept.

To learn more about the program, visit <http://www.reclamthebay.org/>

EDUCATION FOR TRANSLOCATION? J.H. BROWN

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Project work on shellfish movement in UK highlighted the extent to which shellfish farmers had concerns about shellfish movements and introductions of pest species. What are the best strategies for addressing these concerns and requests for knowledge? Is education in pest recognition a solution or is it in better understanding of the need for risk assessment before transfers are made? Does the answer lie with a more strictly demarcated zoning approach to shellfish movement?

CHILDREN'S WADING POOL CLAMS: A PROGRAM TO REAR MANILA CLAMS (*TAPES JAPONICA*) FROM HATCHERY SEED THROUGH AN INTERMEDIATE NURSERY TO FULL GROW OUT IN ONE METER DIAMETER CHILDRENS WADING POOLS (KIDDIE POOLS), AND ITS TRANSFER TO COMMUNITY OUTREACH AND ENVIRONMENTAL EDUCATION PROGRAMS IN THE RESTORATION COMMUNITY IN WASHINGTON STATE. D. BARTH, J.L. GIBBONS

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The Manila clam (*Tapes japonica*) was accidentally introduced into Puget Sound, Washington State during the 1930's and 1940's with shipments of Pacific oyster seed from Japan. The commercial farming of Manila clams soon followed. It now ranks as one of the top shellfish produced in the State. In 2005 the Washington State production was estimated at 3.9 million kilograms with a value of €12.6 million. Supplementing the reliance on natural set of seed, hatchery reared clams are now the major culture method used by farmers to source seed clams for intertidal beach planting. Survivability of seed is correlated to seed size, larger seed has higher survival. Cost and space to rear large seed is a limiting factor in supplying seed to farmers. Seattle Shellfish LLC, has developed a very simple method to boost small hatchery seed (4mm) to larger sizes (18 to 20mm) via an intermediate nursery system using containers (Kiddie Pools). From a trial experiment in 2005, through a pilot project to a full scale commercial operation we have been successful in developing these techniques. Additionally we are rearing Manila clams to full grow out commercial size (40mm and larger) in Kiddie Pools in 12 to 16 months. Yields have been as high as thirty kilograms per square meter. Not only have the nursery and grow out methods proven commercially successful they are a very useful tool to add to community restoration projects. Many times oysters are a key species to environmental education and community outreach programs, but adding Manila clam culture expands the possibilities for student and adult engagement in restoration work. The methods are directly transferable to small scale projects, environmental education school programs and backyard hobby/gardening of shellfish. Taking Manila clams from hatchery seed to final harvest (and eating) can add a new dimension to "doing science in the schools" and community based restoration. The presentation will provide information on the history and development of the methods used by Seattle Shellfish LLC. We will present information on the lessons learned, success and failures, experiments, protocols and cost/benefits. We will present an outline of a small scale education/outreach program for schools, backyard gardeners and the restoration community to rear Manila clams for reseeding beaches and commercial harvest.

ROLE OF FISHERMEN ORGANISATIONS IN STOCK ENHANCEMENT UNDER "NEW" RULES. D. DEL PIERO

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The increasing need for a better management of shellfish stock in Italy urged the fishermen organisations to promote innovative strategies both in fishery and commercialisation. In spite of skepticism of the larger part of the Academy and Research Institutes, the effort done in restocking and in rotation of the fleet pressure over the mollusk beds obtained important results, granting the last two fishery seasons. The more important feature seems to be the increment in size and in the population structure for *Chamelea gallina*. Good performances were also obtained for *Callista chione*, but the life strategy of this species requires more time for a full correct judgement of the benefits resulting from the adopted measures. In particular there is an ongoing project focused on closed and semiclosed areas, highly debated among fishermen. Some criticism may be found in the potential conflict between the fishermen organised in Consortia on compartmental basis, and the the Producers Organisations, (O.P.), a sovrapartimental, partly overlapping structure dealing mainly with the commercialisation, but willing to be more determinant in crucial decisions. It's sounds as a political question but potentially disrupting the equilibrium hardly "conquered" after long years debates over the exclusive competence of the fishermen Consortia in stock management.

EXPERIENCE SHARING IN MUSSEL FARMING IN DENMARK. H.T. CHRISTENSEN¹, P. DOLMER¹, S. REDEKER², H. STEWART³, J. BANGSHOLDT³, T. OLESEN³

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Production of blue mussels on longline systems in Danish fjords is a production form with a noticeably increasing number of farmers. During the last 5 years the numbers has grown from one or two small farms to 45 licenses to production areas in 2007. Alone between 2005 to 2006 the production increased from around 130 tons to around 400 tons. The development is supported by governmentally financed research and development aiming to develop production forms and gear adapted to Danish conditions. The farmers, themselves, are involved in a number of the central financed development projects, but furthermore they do local development work and adjustments at the farms, testing materials and gear. The aim of an experience sharing project is to collect local developed experience and share it among the group of farmers in order to ensure that the development of mussel farming is based on the best body of knowledge.

Parallel session 10: Chances for offshore shellfish culture.

Chairs: Bela Buck, Muki Shpigel

THE IMPLEMENTATION OF BIODIAGNOSTIC TOOLS HELPS TO SELECT APPROPRIATE SITES FOR OFFSHORE CULTIVATION OF BLUE MUSSELS (*MYTILUS EDULIS* L). M. BRENNER¹, B.H. BUCK^{1, 2}, M. STEDE³, A. KOEHLER^{1, 2, 4}

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The development of offshore wind farms offers a unique opportunity to co-use large marine areas with clean water and good O₂-conditions with submerged mussel culture systems. Modified and improved techniques withstand the high energy environment of the North Sea; however, will certainly cause higher investments costs. Therefore, site selecting criteria for a culture site should be clearly identified to calculate economic risks.

In a new approach biodiagnostic tools will be deployed to analyse the overall health status of mussels cultured in different areas. With these methods the tissue of the mussel's digestion system responsible for food uptake, storage of reserve substances and detoxification can be investigated and provide a clear signal on the health status of the mussel. The combinational analysis of macro- and micro parasites, extent of bacterial and viral infection and accumulation of toxins will allow a prediction of most rapid growth and best product quality for human consumption. By this approach higher investment costs for the culture systems are avoided and installations of functioning offshore aquaculture systems in the German Bight are supported.

The implementation of biodiagnostic methodologies to identify potential culture areas within the regions proposed for offshore wind farms is one focus of the project "MytiFit" financed by the Ministry for Construction, Environment and Transport in Bremen (Germany) and the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven (Germany). In a test field 17 nautical miles off the coast from the city of Bremerhaven, three test moorings with large buoyancy are deployed to investigate the described parameters in different water depths. The test field is in the vicinity of a planned offshore wind farm called "Nordergründe".

The aim of this approach is to accumulate all relevant information for interested parties for the selection of appropriate cultivation sites for mussels in offshore wind farm areas. First results show excellent growth rates and good health status of offshore cultivated compared to inshore cultivated as well as wild mussels.

THE ATTACHMENT STRENGTH OF OFFSHORE GROWN BLUE MUSSEL *MYTILUS EDULIS* L. THREADS ACCORDING TO THE HARD SUBSTRATES' NANOSTRUCTURE AT DIFFERENT CURRENT VELOCITIES. A. PECHURA^{1,2}, M. BRENNER², B.H. BUCK^{2, 3}

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The blue mussel *Mytilus edulis* L. is an important species for the aquaculture industry in Europe. Due to stakeholder conflicts and a shortage in spat availability in nearshore areas the expansion of this production sector is limited. In offshore areas wind farms offer good opportunities for growing mussels on longlines installed in between the wind turbines. However, the conditions off the coast in the open ocean are harsh.

This ongoing study aims to evaluate which material provides the best attachment to the byssal threads of *Mytilus edulis* under various physical, chemical and biological aspects. Therefore, different collector materials with settled mussels will be deployed in two test locations in the German Bight. One test area is 17 nautical miles off the coast in the vicinity of the lighthouse "Roter Sand" (offshore test location), and one test area is close to the Jade Bay in Wilhelmshaven (nearshore test location). A control facility is installed in the recirculating system in the institute lab.

The detachment force, which is needed to remove a single mussel from the collector material, will be measured with a digital force gauge. Further, the nanostructure of the collector material will be analyzed by using electron microscopy. The attachment strength to different materials and at various locations will be compared to design a collector for offshore mussel cultivation withstanding a high energy environment.

OFFSHORE SHELLFISH FARMING – A DEVELOPING PROSPECT IN NEW ZEALAND. K.G. HEASMAN, N. KEELEY, C. BATSTONE AND B. KNIGHT.

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Increasing social, recreational, environmental and governmental compliance issues in geographically protected and coastal waters within 1km of the New Zealand shoreline has generated a move by mussel farmers to develop farms several kilometres from shore.

There is one offshore farm presently permitted for staged development in New Zealand with others being processed.

The farm site used for trials is 6km offshore in 37m of water, is 2100ha in extent and positioned in the Hawkes Bay (East coast of North Island). A submerged structure 10m below the surface supports trials on mussels (*Perna canaliculus*), Scallops (*Pecten novaezealandiae*) and Oysters (*Crassostrea gigas*). The emphasis has however been on development of mussel farming. Trials to determine growth and condition of the three species under different growing conditions have been ongoing in conjunction with fouling, seston and phytoplankton sampling.

The ability to model structural designs has been developed. The models have been verified with loadcell data. New shellfish mussel farming designs can be modelled and tested prior to being deployed. Economic models are being developed and the financial potential assessed.

No structural designs will be discussed due to Intellectual Property rights however the biological and economic aspects of the potential of offshore farming are discussed.

PROGRESS AND PROSPECTS OF EXTENSIVE AQUACULTURE WITHIN OFFSHORE WIND FARMS: THE ANSWER TO SPATIAL SCARCITY? B.H. BUCK^{1,2}, G. KRAUSE³

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Along the German North Sea coast the strong competition of stakeholders for space has encouraged the development of integrated approaches for open ocean aquaculture in conjunction with offshore wind farms beyond the 12 nautical miles zone. For such a multiple-use of offshore enterprises an extensive cultivation of various species, such as the blue mussel (*Mytilus edulis*), oysters (*Ostrea edulis*, *Crassostrea gigas*) and seaweed (*Laminaria saccharina*), as well as aspects regarding bio-technological, economic, social, and regulative criteria are investigated. This will allow an assessment of the feasibility of an extensive marine aquaculture of shellfish and kelp within the German Bight.

The presentation will provide an overview on the current state of research of various studies covering the details of the prospects of implementation of a multi-functional use of open space on a showcase basis. Specific focus is put on recent farming developments. Not only are different scientific fields integrated but also private-public partnerships and the relevant institutional bodies subject of the ongoing research activities.

The cultivation of blue mussels in a high-energy environment off the coast is possible using modified cultivation strategies, such as submerged longline and ring systems. Further, if the site allows a substantial amount of active *Mytilus* larvae in the water column leading to a dense settlement an offshore cultivation is feasible. Due to better water quality (e.g. better oxygen concentration, less urban sewage) and no infestation of parasites (macro/micro) mussels grow faster in an offshore suspended culture. However, without the solid foundations of wind turbines which act as attachment devices for the installations of aquaculture equipment, the successful commercial cultivation of any aquatic organism offshore would be impossible. Therefore, tests from load measurements at offshore constructions have to be made to get an insight on forces impinging on the offshore turbine. Potential connection devices and system designs were modelled for longlines up to 800-1000m.

An economic analysis of different operation scenarios indicates that next to the installation requirements, the market price and the annual settlement success of juvenile mussels are the main factors that determine the break even of a mussel farm.

Multidisciplinary social science research reveals that the integration of relevant actors into the development of a multi-use concept for a wind farm-mariculture interaction is a complex and controversial issue. Including knowledge and experience of wind farm planners as well as mussel fishermen and mariculturists is probably the most important component for designing and developing an effective co-management regime. This approach aims to offer solutions for the problem of observed high spatial competition in the German Bight.

The proposed new Maritime Policy of the EU may generate a window-of-opportunity to intensify the efforts to limit the consumption of ocean space through multi-use concepts.

Parallel session 11: Innovations in hatchery / nursery systems. Chairs: Pauline Kamermans, Rene Robert

USE OF REMOTE SETTING METHODS TO PRODUCE DISEASE RESISTANT SEED STOCK FOR OYSTER RESTORATION IN DELAWARE'S COASTAL (INLAND) BAYS. J.W. EWART¹, F. MARENGHI² AND K. ROSSI-SNOOK²

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Restoring oyster populations for their ecological and commercial contribution to the health and viability of coastal estuaries is common priority and activity among community-based estuary programs. Along the eastern seaboard of the United States and the Mid-Atlantic region in particular, efforts to restore the Eastern Oyster (*Crassostrea virginica*) are largely in response to widespread mortality in natural populations from two diseases caused oyster pathogens MSX (*Haplosporidium* (= *Minchinia*) *nelsoni*) and Dermo (*Perkinsus marinus*) and other long-term effects from harvest pressure and habitat loss. While the impact of MSX disease has lessened over time, current oyster plantings are still highly susceptible to the occurrence of Dermo disease, especially as population densities are increased at formerly depleted estuarine sites.

Three regional hatcheries in Virginia (Virginia Institute of Marine Science), Maryland (University of Maryland at Horn Point) and New Jersey (Haskin Shellfish Research Laboratory) maintain lines of Dermo resistant brood-stocks used for oyster restoration programs in their respective states. Deployment of hatchery-produced Dermo resistant seed oysters, while highly recommended, is not a practical consideration in other more distant locations, however, due to the scale and logistics of transporting oyster spat on shell (cultch) and technical problems associated with handling very small (0.5 to 1.0 millimeter) and delicate post-hatchery oyster spat.

Remote setting is a hatchery process originally developed in Washington State and used by the Pacific Northwest oyster industry whereby mature (pediveliger) oyster larvae are concentrated, cooled, packaged and transported from the hatchery by surface or airmail to another "remote" location. The larvae are subsequently re-suspended in seawater and are temperature acclimated at their new location prior to being introduced to aerated setting tanks to complete spat production.

The presentation reviews important remote setting details along with facilities and methods utilized to produce seed oysters using Rutgers University NorthEast High Survival Resistant Line (NEHSRL) larvae. A package containing 1.2 million oyster larvae, produced at the Haskin Shellfish Research Laboratory's Cape Shore hatchery in Green Creek, New Jersey was transported across the Delaware Bay to Lewes, Delaware for settlement and nursery culture. The Dermo resistant spat are used to supply an ongoing oyster gardening and restoration effort being conducted by the Delaware Center for the Inland Bays (CIB), a nonprofit community-based organization established in 1994 by the state legislature to facilitate a long-term approach for the stewardship and enhancement of three coastal bays (Little Assawoman, Indian River and Rehoboth) within the Inland Bays watershed.

SHELLFISH HATCHERY AND NURSERY DEVELOPMENTS IN THE NORTHWESTERN UNITED STATES. B. DEWEY

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Shellfish culture on the west coast of the United States has been intensive for over one hundred years. Seed acquisition has evolved from collecting wild native oyster (*Ostrea conchaphila*) seed for planting on private or leased beds, to annual importations of *Crassostrea gigas* seed from Japan to hatchery/nursery production of seed for numerous shellfish species in modern hatcheries. Hatcheries in the Pacific Northwest region today produce cultched and cultchless *Crassostrea gigas*, *Ostrea conchaphila* and *Crassostrea sikamea* seed, cultchless *Crassostrea virginica* and *Ostrea edulis* seed, *Venerupis philippinarum*, *Panope abrupta*, *Protothaca staminea*, *Mytilus galloprovincialis* and *Mytilus edulis* seed.

Relying on natural sets of shellfish seed leaves farmers vulnerable to the whims of Mother Nature. Natural recruitment for many species is sporadic and unpredictable at best. Hatcheries have to a large degree eliminated this vulnerability and made seed cost and availability predictable. While hatchery production has had a stabilizing effect on shellfish production it is far from one hundred percent reliable. For the past two summers abundant *Vibrio tubiashii* in West Coast waters has resulted in major disruptions in hatchery production. Reliable seed production for the high value geoduck clam remains elusive much to the dismay of growers despite considerable research.

Along with hatchery technology nursery systems for various species of shellfish seed has similarly evolved. Land based upwellers and raceways fed with cultured algae are preferred methods of nursing small seed. Efficient floating upwell systems which rely on ambient algae and paddle wheels to move water are used for larger Manila clam and single oyster seed. Small plastic swimming pools filled with sand have become popular nurseries for geoduck clams.

Besides improving seed availability hatchery production has also provided an opportunity for improving cultured shellfish stocks

through selective and cross breeding. Breeding programs have focused on enhanced yield (survival and growth), shell shape and color. Attractive color patterns in Manila clams have been selected and bred. Sterile (triploid) oysters have also become a popular hatchery product providing farmers with faster growing oysters with high quality meats for summer raw markets.

FORMULATED FEEDS GIVE NEW PERSPECTIVES FOR BLUE MUSSEL HATCHERIES. N. NEVEJAN

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INVE Aquaculture is a world player in the aquaculture feed industry, reaching from enrichment products for life food (Artemia and rotifers) to starter feeds for shrimp and marine fish. Almost three years ago, INVE initiated a mollusk project to develop formulated feeds for bivalves. The use in bivalve hatcheries of formulated feeds that replace live algae, could substantially reduce production costs since it is not cost-effective to produce large quantities of different algal species as happens now for conditioning broodstock and growing spat.

A first series of products is now being commercialized for the blue mussels, *Mytilus edulis* and *Mytilus galloprovincialis*. The dependence on wild seed to restock the culture plots and ropes is becoming a serious problem in Europe. The unpredictable recruitment of wild seed makes the need for hatchery produced mussel seed very urgent. Since nutritional requirements change with life stages, the INVE "mussel line" includes two micro-encapsulated feed powders : MyStock, a broodstock conditioning diet and MySpat, a growth enhancing diet for spat.

MyStock is a very performing diet of which only 2 g per kg live weight is necessary per day. It allows hatcheries to condition mussels in a period of 6 weeks with only 1/8 of the amount of algae that is normally necessary to get the animals in spawning condition. The females spawn an average of 3.0 million good quality eggs. The very high hatching rate amounts to 80% and the larvae resulting from the MyStock-fed broodstock grow as fast as the larvae resulting from an algae-fed broodstock.

MySpat on the other hand replaces 2/3 of the algae while supporting a doubling of spat weight per week when supplied at a ratio of 2.8% on life weight. A large scale experiment in a commercial hatchery demonstrated that the mussel spat grew 1.6 times faster when supplemented 1.5% MySpat than the control animals which received only the standard amount of mixed algae species (25-25 cells μl^{-1} at a flow rate of 6 l min^{-1}). This means that the number of production cycles in a period of 6 months could almost be doubled from 5 (control) to 9.

Research continues at INVE to develop feeds for other commercially important species such as the cupped oyster.

EFFECTS OF PHOTOPERIOD AND LENGTH OF CONDITIONING ON GAMETOGENESIS AND SPAWNING OF THE MUSSEL *MYTILUS GALLOPROVINCIALIS*. L. DOMÍNGUEZ, A. VILLALBA, J. FUENTES

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Mussel cultivation is one of the most important businesses of the European aquaculture. This industry, based on the on-growing of wild mussel seed under different cultivation systems, is threatened by two important bioecological problems: the scarcity of mussel seed and the loss of meat content of market-size mussels during the spawning season.

These two problems can be overcome by using hatchery production techniques, which could provide mussel seed year-around and also not-maturing individuals, via triploid induction, to be harvested during the spawning season. An essential aspect of these techniques is the availability of mature mussels to be used as broodstock. The only way to obtain mature individuals out of the reproductive season is by artificial conditioning. Conditioning is one of the most expensive stages of the hatchery production because it requires heating and pumping seawater and producing high volumes of several species of microalgae. Therefore, the control of any factor that could reduce the length of this process would be of crucial importance for the economy of mussel seed producers. One of these factors could be the photoperiod, which has been shown to play a key role in the starting and development of gametogenesis in clams, scallops and oysters.

In this article, some results of a study on the conditioning of a *Mytilus galloprovincialis* broodstock from Galicia (NW, Spain) are presented. The effects of photoperiod (8:16, 12:12, 16:8 and 24:0; light:darkness) and length of conditioning (from 10 to 80 d) on the gametogenesis and spawning of mussels have been analysed. Results have shown that gametogenesis was mainly controlled by photoperiod and speeded up by increasing the hours of light of the photoperiodic regime. Under continuous light (24:0), only 20 days were needed to increase the proportion of mature individuals from 25% to 95%. However, the length of conditioning was the key factor controlling spawning of mussels, with photoperiod playing a secondary role. At least 60 days of conditioning were required to obtain acceptable responses in the spawning induction trials (>25 % of spawned mussels). These results suggest that gametogenesis and spawning in this mussel species are regulated by different environmental and/or endogenous mechanisms.

INFLUENCE OF DIET ASSEMBLAGE ON *OSTREA EDULIS* BROODSTOCK CONDITIONING AND SUBSEQUENT LARVAL DEVELOPMENT. R. GONZÁLEZ ARAYA, B. PETTON, C. MINGANT, I. LE BRUN, R. ROBERT

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The native oyster *Ostrea edulis* is traditionally cultivated in Europe and France since antiquity. Heavily affected successively by two epizooties in the 80s (*Bonamia ostreae* and *Marteilia refringens*) the production dropped from 20.000 tons to 1.500 currently. At the opposite of *Crassostrea gigas* and *Ruditapes philippinarum*, seed flat oyster production in hatchery is reported to be more erratic, with sudden and unexplained larval and post-metamorphosis mortalities. It becomes necessary accordingly to adjust the knowledge in hatchery process for that species. Broodstock was conditioned at 19 °C, and fed three different diets. Two were single diets *Rhodomonas salina* (cell volume $\approx 200 \mu\text{m}^3$) or *Thalassiosira weissflogii* (cell volume $\approx 900 \mu\text{m}^3$), while the third was a combination of both species. Fecundity expressed in number of released larvae, was 16, 29 and 38 millions respectively while expulsion was more steady when oysters were fed bispecific diet. When broodstock was previously fed *R. salina*, *T. weissflogii* or their combination, the initial larval size was 176, 181 and 174 μm respectively with a daily growth rate of 7,4, 5,5 and 6,6 $\mu\text{m d}^{-1}$ for larvae fed *Chaetoceros gracilis* (Cg: cell volume $\approx 70 \mu\text{m}^3$) after 11 days of breeding, and 8,1, 5,3 and 6,8 $\mu\text{m d}^{-1}$ for those fed bi-specific diet (T: *Isochrysis affinis galbana*: cell volume $\approx 40 \mu\text{m}^3$ + Cg: *C. gracilis*). At the end of the experiment, larval survival was 67, 74 and 50% approximately and metamorphosis 26, 30 and 60% for larvae fed TCg and originated from broodstock previously conditioned with solely *R. salina* or *T. weissflogii* and bi-specific diet (*R. salina* + *T. weissflogii*). Best results were obtained with conditioned parents fed bi-specific diet, able to release numerous larvae over a shorten period with high larval development and consequent metamorphosis.

INTRA-CAPSULAR DEVELOPMENT AND HATCHING IN MARINE GASTROPOD *HEXAPLEX TRUNCULUS* (MURICIDAE). Y. LAHBIB, S. ABIDLI, M. BOUMAIZA AND N. TRIGUI EL-MENIF

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The objective of this study was to provide more detailed information on the intra-capsular development stages of embryos in the banded murex *Hexaplex trunculus*. Spawning was carried out in the laboratory. To examine the developmental stages within the egg capsule, samples of eggs were taken from a selected individual spawn daily during the first week of development and weekly during the remaining period. The different stages of development, including abnormal larva, were photographed and filmed under a stereomicroscope. The number of normal and abnormal hatched juveniles per capsule was recorded. Results showed that *Hexaplex trunculus* is a spiralian unequal-cleaving gastropod with the development of a large polar lobe at the first and the second cleavage containing approximately one third of the egg volume. Embryos develop within the egg capsule through the provision of nurse eggs as an extra-embryonic source of nutrition. From the fourth week of development, the body of the embryo began to coil. Intra-capsular development was completed when the juveniles grew to about 2.5 shell whorls, between the five and the sixth weeks. After approximately seven weeks, young juveniles started to emerge through the escape aperture of the capsule. Juveniles were benthic despite the presence of a large 4-lobed velum. After 1-2 days of life, juveniles lost their velums and left the capsule mass to toward the search of food. The number of normal hatched juveniles per capsule varied between 7 and 23. In some cases, abnormal juveniles were detected with a number varying from 1 to 3 individuals per capsule.

Parallel session 12: Genetics and genomics. Chairs: Piere Boudry, Jose Fuentes

ADAPTATION CAPACITIES OF AN INVASIVE SPECIES, THE PACIFIC OYSTER *CRASSOSTREA GIGAS*, ALONG THE FRENCH ATLANTIC OCEAN COASTS. A. MEISTERTZHEIM¹, N. LE GOÏC¹, A. MARHIC¹, C. TARTU¹, P. BOUDRY² AND M. THÉBAULT¹.

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The Pacific oyster *Crassostrea gigas* is an important commercial species in France. Oysters cultured over extensive areas essentially form one large genetic pool because of important natural and human-mediated gene flow between populations. The wide spreading of this species during the last decade quickly led to the development of "wild" populations mainly on rocky intertidal zones. *C. gigas* now is considered as an invasive species in Northern Europe. In fact, more has to be understood about mechanisms of adaptation and plasticity of these species. The purpose of this work was to study the genetic variability and to measure some physiological indicators of health and fitness-related traits in populations sampled during one year in three sites (north, south and intermediate) located in Brittany. Molecular markers were used to assess if any genetic neutral effect might modify the genetic pool. Allelic frequencies at 7 allozyme loci and 7 nucleic sequences discriminated the intermediary population from the others. Variation of growth, reproductive traits and survival were observed between the intermediate and the two other sites. To eliminate any artefacts arising from the complex life cycle of the species, comparisons of physiological index were performed between individuals at the same maturity stage. Slightly significant differences were found between the three populations corresponding to differential physiological performances. In conclusion, these preliminary results suggest that local selection would enable *C. gigas* to successfully populate a broad ecological niche.

IDENTIFICATION OF *MYTILUS EDULIS* COMPLEX SPECIES USING REAL-TIME PCR. P.J. DIAS^{1, 2}, L. SOLLELIS¹, S. PIERTNEY², I. DAVIES¹ AND M. SNOW¹

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European mussel aquaculture production is generally thought of as broadly consisting of *M. edulis* from the Atlantic and North Sea Coasts and *M. galloprovincialis* from the Mediterranean. In Scotland, shellfish production is dominated by the Blue mussel *M. edulis*, the endemic species. However other species, like *M. galloprovincialis* have been reported from some areas and the real extent of non-*edulis* species and their hybrids in Scotland is not clearly known.

A more accurate knowledge of *Mytilus* species distribution is imperative, particularly from aquaculture areas where this industry could be faced with the problem of dealing with the production of more than one species which may show differences in growth rate and environmental preferences or breeding times. This can raise important issues for the industries, for example if growers wish to cultivate a single species, or perhaps wish to export seed to customers who require single species seed.

In order to assess the presence/absence of *M. edulis*, *M. galloprovincialis* and *M. trossulus* alleles in samples of mussels taken at several sites around Scotland, a molecular method for identification using real-time PCR was developed. Three Taqman®-MGB probes and one set of primers were designed, based on the previously described Me 15/16 primers targeting the adhesive protein gene sequence. Efficiencies of primers and probes were assessed using triplicate 10 fold serial dilutions of DNA extracted from adult mussel of the three species.

The identification of *Mytilus* species was for a long time based on controversial, time consuming protocols focusing mainly on the highly plastic morphological characters of the shell, and only more recently readdressed using modern DNA based methods. Real time PCR is a rapid, sensitive, highly specific and potentially quantitative technique that can be most useful in the identification of these species. The assay developed shows considerable potential for application to large bulk samples of individuals from larger surveys, or at a more regional scale to the identification of the individuals at adult, seed or even larval stages.

PHYSIOLOGICAL AND MOLECULAR BASIS OF GAMETOGENESIS IN TRIPLOID PACIFIC OYSTERS, *CRASSOSTREA GIGAS*. J. NORMAND¹, A. HUVET², C. FABIoux², M. RAGUENES² AND P. BOUDRY¹

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Genetic improvement of the Pacific oyster, *Crassostrea gigas*, can be achieved through triploidisation, which leads to partially sterility,

allowing higher growth and survival together with improved meat quality during the reproductive period. Most triploids are not fully sterile and the genetic and environmental factors involved in their partial fertility remained to be investigated.

We examined gametogenesis by image analysis of histological cross sections in diploid (2n) and triploid oysters obtained either by crossing tetraploid and diploid broodstock ("natural triploids": 3nn) or from second polar body retention ("chemical triploids": 3nc). 5-month-old triploid spat reared in a standard intensive nursery system only showed a 50% reduction in gonadic occupation compared with control diploids. However, triploid oysters showed retardation of gonadic maturation and 3nc were more frequently hermaphrodite (15%) than diploids (0%). A similar analysis is currently being performed on one-year old oysters.

We also made a comparison of reproduction between 5 to 8-month-old 2n and 3nn oysters at the molecular level by studying the expression of the vasa-like gene (*Oyvg*) by real time PCR and in situ hybridisation (ISH). *Oyvg* is a specific marker of germ cell development in *C. gigas*. Results of ISH corroborate the development of germinal stem cells and gonia in all triploid oysters as well as in diploids. As a result, the origin of the reduced fecundity of triploids is not found in the first stages of gametogenesis but rather at the point when spermatozooids and oocytes differentiate. This could explain the relatively high but delayed (i.e. restricted to early stages) gametogenesis in most triploid oysters. A significantly higher level of *Oyvg* mRNA was observed in triploid compared to diploid oysters, suggesting that the transcription level of this gene is directly proportional to the structural gene dosage. However, *Oyvg* mRNA level appeared to be much more variable between triploids than diploids.

Higher sterility of triploid oysters, obtained either by selecting appropriate genotypes or adapting rearing practices would benefit both aquaculture and the environment.

QTL MAPPING FOR RESISTANCE TO BONAMIOSIS IN THE EUROPEAN FLAT OYSTER *OSTREA EDULIS*. D. LALLIAS^{1,2}, A. BEAUMONT¹, C. HALEY³, S. HEURTEBISE², P. BOUDRY^{2*} AND S. LAPEGUE²

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The flat oyster *Ostrea edulis* is an endemic European oyster species, found on both Atlantic and Mediterranean coasts. Its aquacultural production has dramatically decreased due to two successive diseases caused by the intracellular parasites *Marteilia refringens* and *Bonamia ostreae*. Since 1985, Ifremer has undertaken a breeding program to produce oyster families which are tolerant to *Bonamia*. In this context, a genetic map was therefore established as a basis for Quantitative Trait Loci (QTLs) analysis. The reference family was an F2 family coming from a first bi-parental cross between a wild oyster and an individual from the fifth generation inbred line of the *Bonamia* tolerance selection program. This inbred line had shown no mortality when reared in sites where the parasite was present. Twenty microsatellites and 60 AFLP (Amplified Fragment Length Polymorphism) primer pairs were scored. Linkage analysis was carried out using CRIMAP v.2.4. Among the polymorphic markers, 296 AFLPs segregated in the mapping family: 235 were used in the linkage analysis as well as 16 microsatellites. The linkage map of the first parent consisted of 137 markers grouped into 8 linkage groups (2n=20). The linkage map of the second parent consisted of 149 markers grouped into 9 linkage groups with more than 5 markers and 3 doublets. Moreover, three sex-average linkage groups were built with more than 3 microsatellites as anchor loci. Average marker spacing was 6 cM and length spanned from 69 to 98 cM. Then a QTL search for resistance to bonamiosis was performed after an experimental challenge to *Bonamia ostreae*. A total of 550 F2 individuals cohabited with over infected wild oysters with the parasite. Mortality was checked daily during six months and smear achieved on dead oysters to detect the presence of the parasite. Among the 105 dead oysters, 46 very infected oysters were randomly chosen, as well as 46 oysters among the 445 live individuals, where no parasite was detected. After a multistage testing strategy (marker by marker analysis), 15 AFLP markers showed a significant difference of allele frequencies between the "dead" group and the "alive" group. The classical QTL analysis detected 6 QTLs. Some of the 15 markers identified in the marker by marker analysis were mapped in the same locations as the QTLs, strengthening our results. Those QTLs will be further investigated and more precisely located by adding codominant markers such as microsatellites.

Parallel session 13a: Shellfish as valuable seafood; 13b: Shellfish physiology and seaweed. Chair: Joop Luten

CONTROL OF PUBLIC HEALTH RISKS ASSOCIATED WITH SEWAGE-CONTAMINATED SHELLFISH, B. DORE

Bivalve molluscan shellfish such as oysters and mussels can accumulate human pathogenic bacteria and viruses when grown in sewage-contaminated waters. Regulations exist within the European Union to control such microbiological risks. These are currently based on routinely monitoring shellfish for faecal bacteria, both before and after harvesting, to determine sanitary quality. However, whilst this has significantly reduced the occurrence of bacterial infections, there remains a significant risk of viral illness associated with bivalve shellfish consumption. Currently within Europe, and elsewhere in the developed world, viral contamination of bivalve molluscs is recognised as one of the major causes of illness associated with seafood. Outbreaks of infectious hepatitis and gastroenteritis (diarrhoea and vomiting) caused by hepatitis A virus (HAV) and norovirus respectively are the most frequently documented problems and can involve many hundreds of cases of illness. These risks can act as a barrier to wider exploitation of shellfish as a valuable resource.

As a consequence it is now widely recognised that existing microbiological controls are insufficient to protect the consumer against viral infections and improved procedures are required. A major barrier to improving controls is the absence of reliable standardised tests for pathogenic viruses in shellfish. Such tests may provide the opportunity to set legislative standards for viruses in bivalve shellfish. In addition availability of virus methods will also enable the identification of key environmental factors, such as rainfall and sewage discharges, often responsible for viral contamination in shellfish harvesting areas. Identification, and management, of such critical control points provides an alternative approach to reducing the virus risk and may permit the development of enhanced harvesting area sanitary controls for bivalve shellfish. A number of key initiatives are currently underway in Europe to establish standardised methods within Europe. This includes research undertaken as part of the SEAFOODplus integrated research project.

This paper presents a summary of the current control measures and highlighting technical developments in the control of the public health risks associated with sewage-contaminated bivalve shellfish. The presentation draws on information produced from the SEAFOODplus project and other sources and highlights potential routes to the production of safe shellfish.

OPPORTUNITIES IN MOLLUSC PRODUCT DEVELOPMENT AND MARKETING. A. KOLE¹, R. SCHELVIS² AND J. LUTEN^{2,3}

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The EU market for molluscs is a large market with high demand. For example, Dutch exports from oysters doubled between 1998 and 2002, from 3800 to 8500 tons. Biggest growth was to be found in Belgium (50%) and Italy (25%) (Eurostat-Comtext, 2004). Next to France, The Netherlands are the largest exporters of molluscs into Belgium.

Other data indicate that generally the consumption of molluscs, especially oysters, is limited to a restricted set of occasions and consumers. Typical consumers are older (>50), and rather traditional consumers and consumption is typically highest at festivities or other specific occasions and at restaurants. Among consumers molluscs are usually not associated with environmental concern, whereas NGO's do increasingly raise these issues. Therefore, it seems that there is a large unused potential in the market for new products that might appeal to new consumers and fit different usage situations. Also addressing societal issues like nutrition, sustainability and regional production might offer companies new market opportunities.

The presentation will give an overview of recent studies that are related to product development and marketing of molluscs in Europe. Based on this overview market niches and new opportunities for mollusc markets and product development will be outlined as well as a systematic approach to address these opportunities.

SUSTAINABLE EXPLOITATION OF LIVE CRUSTACEANS IN EUROPE INVOLVING SMES, INDUSTRY AND RTDS: CASE STUDY. A. MARQUES, S. BARRENTO, B. TEIXEIRA, S. PEDRO, M.L. NUNES

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Crustaceans play a central role in the European gastronomy being a high priced food item. Especially in Mediterranean coastal areas (e.g. Portugal, France, Spain) there is an ancient tradition of keeping crustacean species alive until culinary preparation as a freshness guarantee. Species usually traded alive are edible crab (*Cancer pagurus*), American and European lobsters (*Homarus* sp.), spider crab (*Maja squinado*), spiny lobsters (*Palinurus* sp. and *Panulirus* sp.), velvet crab (*Necora puber*) and green crab (*Carcinus maenas*). Since national productions of live crustaceans are not sufficient to satisfy the high consumer demands, significant amounts have to be imported. The trade of live crustaceans is an interlinked and complex chain from fishing, transportation and deposit stations to the end-

consumer, where animals face several stress conditions (e.g. emersion, hypoxia, temperature, salinity, chemical changes in seawater, handling). These stressors are reflected in high mortality rates, low nutritional quality and safety, significant economical losses for traders and considerable wastes of these important marine resources. Such problems still restrict the access of this European sector to distant markets. Additionally, the European fishery sector of live crustaceans is presently subjected to a strong competitive pressure from non-EU countries. In this context, the EU-funded CrustaSea project was created, involving SMEs, industries and RTDs, aiming to develop codes of practice for professionals of this sector and new technologies that will be compared to the traditional ineffective systems.

In order to achieve a better understanding about the problems affecting this industry in Portugal, a survey was developed to twenty-two deposit facilities, representing 90% of live crustaceans' volume commercialized across the country, to thoroughly probe the infrastructure and animals storage conditions. Crabs maintained in these facilities presented higher average mortality rates (e.g. velvet crab: 35.4%; edible crab: 19.9%) and lower duration in captivity (e.g. velvet crab: 9 days; edible crab: 19 days) than lobsters (e.g. American lobster: 1.4% mortality and 40-90 days in captivity). Edible crab and spiny lobsters are usually maintained at higher densities (0.16-0.35 kg/l) than the remaining crustaceans.

Presently, new cost-effective technologies are being tested to minimize the actual problems: a) grading unit to distinguish animals into different qualities based on meat content; b) shipping boxes comprising a floodable system to flush animals and remove their metabolic wastes; and c) water treatment system to remove ammonia from seawater. Synergies between SMEs, RTDs and industry, promoting innovation and technological developments, are fundamental tools to assure the viability of this important European productive sector.

METABOLIC TEMPERATURE DEPENDENCE OF ACCLIMATIZED *MYTILUS SPP.* AND *MACOMA BALTHICA*, A MACROPHYSIOLOGICAL APPROACH. J.M. JANSEN¹, S. WENDELAAR BONGA² AND H. HUMMEL³

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The study of the metabolic response of an organism to temperature is one of the leading edge topics in ecological research. The effect of changes in temperature on ectotherm metabolism depends on the preceding period of acclimatization. While the response to an acute change in temperature has been studied extensively, work that includes acclimatization to field conditions is rather scarce. The way in which *M. balthica* and *Mytilus* spp. adjust their metabolic rate to such gradual changes in temperature was the main aim of our study. To achieve this aim, we analyzed the respiratory response to temperature from 21 *Mytilus* spp. populations and 10 *M. balthica* populations distributed along the European coastline, during different seasons. From the obtained data, we determined respiration rates and temperature quotients (Q_{10}) as a function of the acclimatization temperature.

The results show that acclimatized respiration rates increase only gradually with temperature. While temperature quotients can be high in cold-acclimatized mussels and clams, they narrow down in warm acclimatized specimens and reaching limits ($Q_{10} = 1$) in warm marginal populations. This extensive study shows the extent of metabolic plasticity in mussels and clams, and reveals physiological limitations that coincide with the biogeographic limits of mussels. The results have important implications for metabolic theory. The data indicates that temperature acts as a limiting factor. It shows linearization of the relation between acclimatized metabolic rates and temperature, and reveals the absence of significant compensatory adjustment to cold circumstances.

COMPARISON OF EASTERN OYSTER (*CRASSOSTREA VIRGINICA*) AND BLUE MUSSEL (*MYTILUS EDULIS*) FEEDING RATES AT LOW TEMPERATURES. L.A. COMEAU¹, F. PERNET², R. TREMBLAY³, S.S. BATES¹

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Abstract: Eastern oysters (*Crassostrea virginica*) and blue mussels (*Mytilus edulis*) were collected in the Gulf of St. Lawrence, at the northernmost distribution area of *C. virginica*, and maintained in cold water (0, 4 or 9°C) over a 63-day period. Inter-species differences in feeding behaviour were examined using three metrics: mean clearance rates (CR), maximal CR, and the percentage of experimental animals showing positive CR values. At the lowest temperature (0°C), only 5% of the oysters and 37% of the mussels were feeding. There was generally no significant difference between species in CR values, which were below 1.7 l h⁻¹ g⁻¹ of dry tissue. At 4 and 9°C, however, mussels were clearly feeding more intensively (up to about 5.4 l h⁻¹ g⁻¹). Statistically, mean CR and maximal CR for mussels were significantly higher compared to those for oysters, often by several orders of magnitude (up to 108-fold difference at 4°C and 83-fold difference at 9°C). In addition, nearly all mussels (>90%) were clearing particles at 4 and 9°C, whereas relatively few oysters were feeding at the same temperatures (14% at 4°C, 31% at 9°C). These findings suggest that *C. virginica* is physiologically disadvantaged in terms of grazing on seasonal phytoplankton blooms, including toxic blooms, which typically occur at water temperatures ranging from 4 to 9°C in eastern Canadian waters.

ENERGY FROM SEAWEED AS STARTING POINT FOR THE OPEN SEAFARM ZEEWIER. W.A. BRANDENBURG

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The finiteness of the global natural resources is urging us to look at the most optimal usage of them. Consequently – as human activities are predominantly situated at the landside – competing claims force civil societies to consider in this respect the marine environment and to reconsider sustainable management of the coastal zone in terms of integrative approach of the sea and the land part of it.

10,000 years ago one of mankind's greatest achievements was the development of agriculture. It causes a revolution in the organization of civil societies:

From dwelling to settling;

From hunting to keeping;

From collecting to growing.

Above shifts form the base for our modern society. Although, however, our global society is ever expanding, there are limits to the growth of agricultural production. These limits force us to the next revolution: the blue revolution: sustainable production of marine animals and marine plants in open sea.

The open seafarm concept starts from mixed cropping agricultural farm, in which input and output is balanced between animal and plant productions and with a closed nutrient cycle. The ambition is to design such systems with the least possible impact on surrounding marine ecosystems as one of the lessons learned from agricultural practices.

In the open seafarm plant production is its fundament. Moreover, by smart choices of seaweeds we may benefit from the variation in photoreceptor pigments and so come to enhanced productions.

As seaweeds are rich of carbohydrates, they can well be applied as biofuel crops. One of the conditions is then that we also process at sea and we make multiple use of the same area, e.g. by combining seaweed production by offshore windmill parks.

The Dutch energy policy is that in 2020 20% of the energy should be renewable. By application of seaweed it will be feasible to achieve that within the territory of the Netherlands by a seaweed park in the North Sea, counting for 10% and 10% from energy production from waste chains. With agricultural production, such is not the case.

Parallel session 14: Energy for shellfish culture. Chair: Willem Brandenburg

THE GREEN SOLAR COLLECTOR. A NOVEL PHOTO-BIOREACTOR FOR THE EFFICIENT PRODUCTION OF ALGAL BIOMASS ON SUNLIGHT. J.F. ZIJFFERS¹, M. JANSSEN¹, H. TRAMPER¹ AND R.H. WIJFFELS¹

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A novel photo-bioreactor for cultivating micro algae, the Green Solar Collector, has been developed. It is an area efficient photobioreactor for the outdoor cultivation of micro algae. The overall goal has been to design a system in which the delivery of sunlight to the algae and use of light by the algae is optimized. First, systematically and rationally a statement of goals is formulated and constraints are specified. Second, specifications are generated for a prototype whose form and function achieve the stated goals and satisfy the specified constraints. Leading to a design in which sunlight is captured into vertical PMMA light guides through the focusing of sunlight by dual-axis positioning of linear Fresnel lenses. Sunlight is scattered from the light guide into flat-panel photobioreactor compartments at such intensities that it can be efficiently used by the algae inside the bioreactor. Finally, the potential for efficient algal cultivation is discussed based on experiments performed in a lab-scale flat-panel photobioreactor.

MICROALGAE AS FEEDSTOCK FOR BIODIESEL? M. JANSSEN, M.J. BARBOSA, R.H. WIJFFELS

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The search for renewable energy sources is one of the global focuses of today.

The concept of microalgae biotechnology hides a great potential; solar energy as energy source, carbon dioxide as carbon source, marginal land and brackish water to produce a variety of compounds, among which energy.

Microalgae, like higher plants, produce storage lipids in the form of triacylglycerols (TAGs) which can be used to synthesize fatty acid methyl esters (a substitute for fossil-derived diesel fuel), via a simple transesterification reaction in the presence of acid or base and methanol. The technology is available to produce biodiesel from TAGs, and there are growing biodiesel industries both in the United States, Europe and Asia that use soybean, rapeseed and palm oil as feedstock, respectively. Biodiesel derived from oil crops is a potential renewable and carbon neutral alternative to petroleum fuels. The existing sources cannot realistically satisfy even a small fraction of the existing demand for transport fuels. Moreover the disadvantages of using these crops are clear: 1) production is often not sustainable (net energy production is questionable); 2) production capacity per hectare of land is limited; 3) land suitable for agriculture is used, competing therefore with food production; 4) fresh water is needed.

Microalgae represent a very attractive alternative compared to terrestrial oleaginous species because their productivity is much higher, up to 50 times higher, and it does not compete for land suitable for agricultural irrigation or consumption by humans or animals, providing therefore food security.

In the present work a technical and economical feasibility study for 3 different cultivation systems was done: raceway ponds and 2 different photobioreactors (flat panels and horizontal tubular reactors). These systems were compared in terms of biomass production cost and energy output.

A sensitivity analysis has also been performed in order to pinpoint the process parts which need to be further developed in order to decrease biomass production cost.

Results show that the possibility to further reduce production costs and the urge to develop new renewable energy sources in the near future makes microalgal biotechnology a potential new technology where further investments and development are still required for its full realization.

HAPPY SHRIMP G. CUTESCI

SEALAND SOLE: AN INNOVATIVE PILOT PROJECT ON INTEGRATED MULTITROPHIC AQUACULTURE. J.J.M.H. KETELAARS

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The focus of the project 'Sealand Sole' is the development of a new and competitive economic sector involving the land-based production of sole (*Solea solea*), integrated with the culture of ragworms (*Nereis virens*), shellfish and saline crops, and embedded in an attractive saline landscape. The new sector will cover the entire chain of primary production up to the sale of novel products to consumers in the Netherlands and abroad.

The project has a duration of six years (2007-2012). Objectives are: the foundation of a pilot farm for land-based saline aquaculture, the completion of a R&D program on sustainable production and commercialization of sole, ragworms, shellfish and saline crops, the development of a training program for farmers interested in land-based aquaculture, and the creation of public support in order to obtain a license to produce.

The project will be implemented in the Province of Zeeland, the Netherlands, but wants to be an inspiring example for other coastal regions where climate change and economic drivers ask for adaptation of land use patterns. The project is a joint activity of nine private companies, Wageningen-University and Research Centre, and HZ University.

Central to the project is the hypothesis that combining culture of sole, ragworms, shellfish, and saline crops into an integrated multitrophic system (IMTA) will provide farmers with the advantages of higher profitability due to synergetic effects, enhanced income security by providing alternative sources of income, and cleaner production by increased nutrient recycling. Sole will be grown in outdoor ponds together with ragworms serving partly as live feed for the fish and partly as a product to be harvested and used as a high-value ingredient for aquaculture feeds. Thinning of the ragworm population by the sole is expected to increase pond productivity beyond the level achievable with a ragworm monoculture. Inputs of ragworm feed will induce spontaneous algal production in the ponds. Algae in turn will be valorized as a feed for ragworms and shellfish. Residual nutrients in the pond effluent may serve as a fertilizer for saline crops.

Research topics that will be addressed in the first phase of the project include: interactions between sole and ragworm populations, design and operation of salt water ponds, marketing perspectives for ragworms and sole, and public perceptions toward IMTA.

co-management strategies AND BIOLOGICAL REGULATION of O BOHIDO CLAM FISHERY, RÍA DE AROUSA, GALICIA. A. SÁNCHEZ-MATA¹, J. MOLARES¹, M. RODAL², P. CARREIRA², A. CREGO², J.M. PARADA², G. MARTÍNEZ², C. DARRIBA² AND J. MARIÑO³

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O Bohido shellfishing area, located in Ría de Arousa, Galicia, NW Spain, has been for years a highly productive zone for a number of clam species as *Tapes aureus* (Gmelin, 1791), *Venerupis senegalensis* (Gmelin, 1791), *Tapes (Ruditapes) decussatus* (Linnaeus, 1758) and *Dosinia exoleta*, (Linnaeus, 1758). In recent years, successive annual mortality episodes on some of these species, mainly originated as a consequence of overexploitation resulted on a progressive fall in the productivity and the practical disappearance of the shellfishery.

In March, 2005 the Galician Fisherires and Maritime Board, in a trial to recover the clam production started a pilot plan of action based on a co-management model adapted and improved from our previous five-year co-management experience in Lombos do Ulla, Ría de Arousa cockle fishery.

The co-management concept used in this study to enhance yields on clam production is connected with McGoodwin (1990) widely accepted definition, that relies on the joint efforts and consensual decision-taking of fishermen, stakeholders and researchers.

With this idea in mind, the Bohido co-managed Action Plan was launched with a four-fold aim:

1.- The co-management and control of clam-fishing activity in the area during the autumn-winter period (Personnel involved: fishermen associations, CIMA researchers and the Galician shellfishery Board, Xunta de Galicia).

Clam-catches survey and control were carried out by means of an equipped raft anchored within the fishing zone, in which daily catches per species (pullet carpet-shell, grooved carpet-shell, rayed artemis and golden carpet-shell) and boat were weighted so as to assure that quotas established by the annual exploitation plan were respected. Fortnightly controls on clam species size were made during the fishing campaign. Furthermore, real-time analyses on daily landings, effort and catches per effort unit were recorded for an accurate advising on the best distribution of fishing activity in a rotatory basis. A control point – sale points checking on clam-catches was also daily made so as to detect irregularities and avoiding fishing illegal actions.

2.- A mapping of the reproductive stock and detection of the recruitment areas during the late spring and early autumn (before and after the annual clam-fishing campaign). Personnel involved: CIMA researchers.

3.- A monthly survey of clam populations for recruitment, growth and mortality rates analyses. Personnel involved: CIMA researchers.

4.- An annual design of exploitation plans and marketing strategies for clam commercial species. (Personnel involved: fishermen associations, CIMA researchers and the Galician shellfishery Board, Xunta de Galicia).

Poster presentations

1 COMPARISON OF OYSTER BAR POPULATION ESTIMATES VIA GEOGRAPHIC INFORMATION SYSTEM (GIS) ANALYSIS OF PATENT TONG SURVEYS AND BAR CLEANING DREDGE ESTIMATES IN RELATION TO OYSTER RESTORATION EFFORTS IN THE CHESAPEAKE BAY S. ALLEN AND K.T. PAYNTER

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The accuracy and comprehensiveness of oyster (*Crassostrea virginica*) population estimates in the Chesapeake Bay are of vital importance to current and future restoration efforts. In an attempt to lower transmission of the parasite *Perkinsus marinus*, oyster bars are dredged prior to new plantings. The bar cleaning dredges provide an opportunistic prospect for ground-truthing GIS spatial analysis applied to patent tong survey estimates of oyster bar populations. Six oyster bars in the Chester River were surveyed using patent tong grabs at 50-270 locations within each bar before bar cleaning dredge efforts in 2006 and 2007. From the patent tong data, pre-dredge oyster bar populations were estimated using natural neighbor interpolation via GIS spatial analyst tool (ArcGIS). Number of oysters available for removal (in bushels) per bar was calculated from these estimates. The GIS estimates were then compared to the actual number of oysters collected during the exhaustive cleaning effort (uncorrected and effort-corrected by Leslie and DeLury models). Correlation between the patent tong /GIS and the Leslie bar-cleaning estimate was significant ($r=0.8249$), as was the correlation between the patent tong /GIS and the raw number of bushels removed ($r=0.8360$); a significant linear regression was created to predict bar population from the GIS estimate ($p<0.05$). Our data suggest patent tong subsampling with concordant GIS analysis may be a powerful population estimation tool with proper calibration. Our second year of data suggests the DeLury model of estimation may be sensitive to large differences in boat effort.

2 DEEP-WATER, SUSPENDED PACIFIC OYSTER (*CRASSOSTREA GIGAS*) FARMS IN BRITISH COLUMBIA, CANADA: THE ROLE OF COMPREHENSIVE ENVIRONMENTAL DATA IN ESTABLISHING ECOLOGICAL INTERACTIONS. P.A.G. BARNES¹, S.E. SWITZER¹, B.J. BURD² AND W. FRIESEN¹

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In Canada, the potential for a significant increase in the number and size of commercial bivalve aquaculture operations has led to increased interest in the potential ecosystem effects, including biodeposition and benthic impacts, associated with this culture. Our study investigated the effects of biodeposition from *C. gigas* farms on sediment physical and geochemical parameters and on benthic faunal community composition. We studied two Pacific oyster farms, sited in areas with different hydrography and bathymetry, which used the same culture method with oysters of comparable age. At each of the sites, 7 stations (including 2 reference stations) were located along a transect that ran through the centre of the oyster farm, parallel to the dominant current direction. The study ran for 15 months, with quarterly sampling trips to capture seasonal variation in the parameters measured. In addition to an initial hydrographic survey, twenty-seven parameters were measured at the 7 stations at each site, on every field trip; parameters measured included deposition rates, water column characters and benthic variables.

A significant, but spatially discrete, increase in organic carbon deposition rates occurred at the raft stations in comparison with all other stations at each site. Deposition rates for total particulate material, inorganic carbon and total nitrogen demonstrated a similar trend. Deposition rates at the two farm sites were not significantly different from each other. Despite high and comparable deposition rates, however, sediment geochemistry differed at the two sites. While there was no significant difference in sediment %TOM between any of the Site 1 stations, sediment %TOM at the Site 2 raft station was significantly higher than that at the other Site 2 stations. Sediment free sulfides at the Site 1 raft station were significantly higher than those at other Site 1 stations, while there was no significant difference between sediment free sulphides at any of the Site 2 stations. These results are discussed in reference to site-specific influences on sediment dynamics. The benthic community at the raft station at each site showed no sign of faunal impoverishment. However, the benthic invertebrate community structure at the raft station was distinct from that at the other stations, largely because of the abundance of hard-substrate fauna. The role of biodeposition and benthic impact, related to *C. gigas* culture, in structuring benthic invertebrate communities is discussed. This study emphasizes the importance of a comprehensive approach in establishing the ecological interactions of bivalve culture.

3 EXOSKELETON CHEMICAL AND MINERAL COMPOSITION OF THE AMERICAN LOBSTER *HOMARUS AMERICANUS* AND THE EUROPEAN LOBSTER *HOMARUS GAMMARUS*. S. BARRENTO, B. TEIXEIRA, A. MARQUES, P. VAZ-PIRES, M.L. NUNES

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American lobster *Homarus americanus* and European lobster *H. gammarus* are high priced and much appreciated crustaceans, representing an important income. In the last decade, the increasing demand for ready-to-eat products promoted the availability of a wide variety of crustacean products including fresh and frozen lobster meat, canned and frozen secondary processed lobster products such as hepatopancreas and roe. This industry produces significant quantities of inedible parts, such as exoskeletons, which can cause environmental imbalances as a result of uncontrolled dumping. Therefore, the upgrade of lobster by-products is presently of great interest for this industry, not only to enhance their profitability, but also to provide more complete utilization of its primary product resource. The crustaceans exoskeletons are known to be rich in macro and trace elements that are essential for human health, thus with potential use as raw material for health products and as ingredient in feeds for aquaculture. So far, the knowledge of the chemical composition of Homarids exoskeleton is scarce. Therefore, the aim of this study was to investigate the exoskeleton chemical and mineral composition of two Homarid species in order to explore possibilities for its utilization by industry.

The exoskeleton of twenty one American lobsters and twenty European lobsters was analyzed for the proximate composition (protein, fat, ash, moisture, carbohydrates, chitin and carotenoids). The essential and toxic elements were also determined with two different techniques: a) energy-dispersive X-ray fluorescence (EDXRF) to quantify P, S, Cl, K, Ca, Mg, Zn, As, Rb, Br, Sr; and b) flame atomic-absorption spectrometry to analyze Na, Mn, Cd, Hg, and Pb.

Preliminary results indicate identical proximate and mineral composition in the exoskeleton of both species. The proximate composition on a wet weight basis indicates a high ash content (40 %) and carbohydrates (20 %), while total proteins and lipids showed lower values (10 % and 0.1 % respectively). The mineral composition showed high concentrations of macro elements: calcium (258 g/kg), phosphorous (200 g/kg), sulphur (12 g/kg), chloride (10 g/kg), sodium (7 g/kg), magnesium (g/kg), strontium (3 g/kg) and potassium (2 g /kg), but also for some trace elements, such as brome and manganese (258.0 and 88.4 mg/kg). As an example, phosphorous is known as a limiting macro element in fish aquaculture to assure an optimal growth and health. Therefore, Homarids exoskeletons, which present high phosphorous concentration, can potentially be used as a feed supplement in fish aquaculture.

4 SETTLEMENT, POST-LARVAL GROWTH AND GONADAL DEVELOPMENT OF *CHLAMYS GLABRA* L. IN AN OFF-SHORE SITE OF THE NORTHERN ADRIATIC SEA (ITALY) A. CHINELLATO, L. DA ROS¹, M. BRESSAN²

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A study on the settlement of Pectinidae on artificial collectors ("onion-bags"), focussed on *Chlamys glabra*, was carried out nearby a mussel culture plant, one mile off-shore in the Northern Adriatic Sea, northwards from the lagoon of Venice. Samplings were collected every three months, from August 2005 to August 2006. Each sampling consisted of twenty bags suspended at different depths (5m, 7m, 9m, 11m, 13m).

The peak of settlement was in the summer at -13m (average 119 individuals m⁻² day⁻¹). Very small unidentified Pectinidae were the largest component, predominantly close to the sea bottom; *Chlamys varia*, *C. glabra* and *Chlamys proteus* settled almost uniformly at any depth. The summer-autumn settlement was mostly represented by *C. glabra* and *C. proteus*, that preferred to settle at -11m and -13m (average 51 and 87 ind m⁻² day⁻¹, respectively). During winter, only small quantities of very small unidentified Pectinidae settled. *A. opercularis* was collected, even if not very abundant (<15 ind m⁻² day⁻¹), in the spring sampling; it preferred deep collectors, particularly those at -11m (average 14 ind m⁻² day⁻¹).

The multivariate statistical analysis confirmed that most of the identified Pectinidae species prefer to settle near the sea bottom at any season.

From November to April, in order to assess post-larval growth, bimonthly length measures of specimens of *C. glabra*, collected in the same site during the previous summer and kept in experimental holders, were carried out. The growth was slow between November and February, showing a mean increase of 2mm between November and December, 1mm only between December and February. In April, the mean size increased to 2.4cm (maximum 3.6cm).

The gonadal development of *C. glabra* was followed from October to April in specimens from the same holders. The gonadal maturity was reached after eight months, with a length of 4 cm. The scallops did not show the presence of any parasites.

Such practises in the experimental site, which demonstrated suitability of *C. glabra* for farming, should help to reduce the fishing effort, which is currently contributing to depletion of the natural scallop beds, and moreover increasing impact on the Northern Adriatic benthic communities.

5 ENVIRONMENT INTERACTIONS OF MUSSEL FARMING IN THE NORTHERN ADRIATIC SEA: DEVELOPMENT OF AN INTEGRATED NUMERICAL MODEL. DANIELE BRIGOLIN¹*, GABRIELE DAL MASCHIO¹, TOMAS LOVATO¹, PIERRE REGNIER², ROBERTO PASTRES¹

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In the last decade, mussel production in Italy has been steadily increasing, reaching the 7% of the worldwide production in 2002. This trend is mainly due to the increase in landings from mussel culture, which, in 2002, accounted for about 70% of the country annual production. Half of the whole Italian production is concentrated along the western Adriatic coast, where the number of suspended mussel culture sites has rapidly increased. Such a rapid growth is raising questions concerning the impact of mussel farms in relation

to the ecosystem carrying capacity. Recent studies have shown that long-line mussel farm can act as sinks of suspended particulate matter and phytoplankton, and sources of nutrients for the water column. In some instances, the intense organic enrichment underneath the mussel farms, may locally alter sediment biogeochemistry and nutrient fluxes at the water-sediment interface. In this paper, we present the preliminary results of a thorough investigation of the interactions between mussel farming and the pelagic and benthic ecosystem, which was carried out by means of an integrated mathematical model. The model was developed in the framework of the EU projects ECASA (<http://www.ecasa.org.uk>).

The integrated model is made up of four modules: a) a module for the simulation of the individual growth of *Mytilus galloprovincialis*; b) a 3-layer pelagic ecological module, based on a reaction-transport equation c) a particle-tracking deposition module, named DEPOMOD; d) a 1D reaction-transport module of early diagenesis, which was developed using the KB-BRNS simulation environment. The model was applied at a typical Adriatic mussel farm located off-shore Venice, in order to investigate: i) the interactions between the farm and dissolved nutrients and phytoplankton density; ii) the long-term impact of the farm on sediment geochemistry and nutrient recycling. Each module was separately tested by comparing the results with original field data collected at the farm site, and site-specific literature data.

Preliminary results suggest that, at the investigated site, mussel farming does not have a relevant negative impact on the pelagic ecosystem. In fact, hydrodynamic condition at the farm site seem to assure a sufficient dilution of ammonia released by mussel excretions. As far as the impact on the sediment is concerned, the model results indicate that there are visible modifications of pore water chemistry and nutrient fluxes at the interface underneath the farming area, due to organic matter.

6 UNEXPLAINED MASS MORTALITIES OF *CERASTODERMA EDULE* (L.) IN THE BURRY INLET, SOUTH WALES, UK. R. CALLAWAY¹, K. FICKEN¹, K. JONES¹, A. POWELL¹, G. PROFFITT¹, R. SHIELDS¹, S. WILLIAMS²

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The Burry Inlet in South Wales, UK, is known for its persistently high cockle (*Cerastoderma edule*) harvests. About 50 licensed cockle gatherers harvest up to 33% of the shellfish by hand raking, a method that has been successfully deployed for over a century. The Burry Inlet enjoys a high conservation status. It is a Ramsar Site, SPA (Special Protected Area) and a SAC (Special Area of Conservation). The estuary is of international importance for oystercatchers and knots, which feed predominantly on cockles.

The cockle population consisted of spat (0 yr class) to 5 year old cockles. However, in July 2003 mass mortalities of 1 year old cockles and older were observed. Since then, almost no cockle survived beyond its first year in the Burry Inlet. The sequence of events is repeated annually: high spatfall in May and June culminates in densities approaching 9000 individuals m⁻². From July onwards mass mortalities of the previous year class occur, resulting in the obliteration of almost all 1 year old cockles.

The mortalities pose a threat to both the local fishing industry and nature conservation. Since the cause has not been identified so far, a cooperative project was started between scientists and local cockle fishermen under the auspice of the WISE Network (Welsh Institute for Sustainable Environments), an EU funded project promoting closer cooperation between Welsh Universities and Industry.

Four sites with different degrees of cockle mortalities were sampled in August 2007. Population parameters such as densities and size to weight relationships were established and $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ ratios of juvenile and adult cockles were analysed. Sediment and cockles were analysed for heavy metal concentrations and moribund and healthy 1 year olds were screened for blood bacterial loading and parasites.

Densities of 0-year class cockles were lowest at the station least affected by mortalities (40m²) and 600-800 m⁻² at the other three sampling station. In contrast the densities of 1 year olds were highest, 60 m², at the least affected station, while no cockles older than spat were found at the most affected station. Heavy metal concentrations (Cu, Zn, Cd, Pb, Mn, Cr, Mn, Fe, Co, Ni) were generally low. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ and C/N ratios differed significantly between the samples from the Burry Inlet and reference areas along the Welsh and English coast. Inside the estuary spat had a lower C/N ratio (5.61 ± 0.33) than 1 year olds (7.33 ± 0.34) due to greater %N in spat. No obvious blood parasites were detected. Total haemocyte counts were significantly lower in moribund cockles than in apparently healthy ones buried in the sediment, while total bacteria loads were significantly higher in moribund cockles.

The results so far do not give a clear indication of the possible cause of cockle mass mortalities in the Burry Inlet. High bacterial blood loads and low haemocyte counts in moribund cockles are probably an indication of a secondary, opportunistic infection rather than the prime cause. The stable isotope analyses suggest a change in diet from spat to 1 year olds. Further studies will be carried out on the diet and a possible negative link with sewerage outputs and high spat densities.

7 TRANSFER AND IMPACT OF ALIEN SPECIES MEDIATED BY AQUACULTURE IN THE MEDITERRANEAN SEA. D. SAVINI

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Aquaculture in the Mediterranean sea follows the world exponential positive trend. New market strategies increase the demand for alien species, generally more productive and adaptable to environmental stress, thus worthy of use in term of costs vs benefits. As a result, both voluntary introduction of target species (e.g. the Manila clam, *Ruditapes philippinarum*) and of involuntary associated introduction of non target hitchhikers (e.g. the Rapa whelk, *Rapana venosa*) are causing impact to the receiving ecosystem. Environmental impact is always a consequence of a new species introduction, although changes in native ecosystem changes may be unclear or difficult to detect on a short time scale. Addition of new functional groups in the food web, competition, predation, habitat alteration, toxicity, hybridisation, associated introduction of pathogens are all categories of impact that raise interest only when a manifest easy-

quantifiable threat to human activities occurs. Nevertheless, some preventative actions can be designed and deployed. Within this context, the most challenging task for the scientific community is to provide administrators and stakeholders with effective decision support systems, minimising environmental impact of alien species introduction without smothering economical growth. This task cannot be accomplished without a solid scientific knowledge covering all issues of the Ecology of Bioinvasion.

The aim of the present talk is to draw an overall picture of the existing information concerning the environmental impact of alien species introduced by aquaculture practices in the Mediterranean Sea, directly (target species) or indirectly (non target species). Selected study cases will be presented and critically revised, highlighting gaps of knowledge and needs for action.

8 IMPACT OF DREDGING OF *MYTILUS EDULIS* AND *CRASSOSTREA GIGAS* AT INTERTIDAL BEDS IN THE WADDEN SEA. H.T. CHRISTENSEN, P. DOLMER, P.S. KRISTENSEN

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In the Danish part of the Wadden Sea dense populations of *Crassostrea gigas* are established during the last 5 years. The populations may constitute a valuable fishery resource. During the last 4 years the fisheries of *Mytilus edulis* have been closed due to low stocks. In 2006, assessments indicated that a quota of 500-1000 tonnes could be given. Exploitation of bivalves in the Wadden Sea is restricted by the NATURA 2000 directives and no permits to fishery of *M. edulis* or *C. gigas* is given before the impact of the fisheries is assessed according to Habitat- and Bird directives. To test how the resource can be exploited, and what effect an exploitation may have on the surrounding habitat, an experimental fishery is carried out in summer 2007. The study is conducted as a BACI-design where samples on both *C. gigas* and *M. edulis* locations are collected immediately before and after the fishery and again after three months. The experimental dredging of *C. gigas* include fisheries with hydraulic dredge, mussel dredge and 35 kg oyster dredge on an oyster bed east of Rømø. Furthermore, experimental mussel dredging is tested on mussel beds north of Esbjerg. The efficiency of the dredges and the impact on macro benthos and sediment is tested to investigate the regeneration of the mussel beds and oyster reefs. With this study it will be possible to show the effects of dredging on both *C. gigas* and *M. edulis* and from that decide how the resource can be exploited in a desirable manner.

9 MUSSEL SHIPMENTS FROM IRELAND TO THE NETHERLANDS – A POSSIBLE ROUTE FOR THE IMPORT OF NEW SPECIES IN THE TARE OF MUSSEL BAGS. A. ENGELBERTS¹, H. STEGENGA², P. VAN AVESAATH¹, H. HUMMEL¹

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Presently blue edible mussels *Mytilus* sp. from Ireland and the Irish Sea are imported to the Netherlands.

The mussels are shipped in 'big bags' of 1.5 m³ with 800 to 1500 kg of material. With these 'big bags' also other species than mussels can be imported, being included in the tare of the bags.

From autumn 2006, a volume of about 10 liter of tare was sampled seasonally from mussel bags to assess the amount of species that accompanied the mussel shipments, and to assess among them the degree of species that are new to the Netherlands.

All invertebrate and algal species were determined if possible to species level.

The amount of species in the tare of the 'big bags', other than mussels, differed per season from 10 to 34 algal species of which about 30 % (3 to 9) still did not occur in the Netherlands.

Also more than 20 invertebrate species were imported with the tare, yet consisting of few or no species new to the Netherlands.

This study is carried out in cooperation with Aad Smaal and Jeroen Wijsman of Wageningen IMARES

10 EFFECTS OF COCKLE FISHERIES ON A MUD FLAT IN THE EASTERN SCHELDT ESTUARY, NETHERLANDS: SEDIMENT AND MACROBENTHOS CHARACTERISTICS BEFORE AND AFTER FISHING. V. ESCARAVAGE AND H. HUMMEL

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To assess the impact of cockle fisheries in the Oosterschelde, the Netherlands, 45 locations distributed among nine sampling sites on the Dortsman mudflat were sampled immediately before and after the harvesting of the cockle beds with suction dredgers operated from fishing boats. Three of the nine sampling sites, that were completely excluded from any fishing activities as agreed with the fishermen, served as control sites.

The samples were analysed with respect to the sediment granulometry and the macrofauna community characteristics. The macrofauna was analysed for species composition, numbers and biomass.

Within the six weeks between the two sampling dates no changes were observed in the sediment or the macrofauna characteristics at the control sites.

Neither the sediment nor the macrofauna characteristics (except cockles) showed any changes at the fishing sites between the two sampling dates.

This allows to conclude that, under the circumstances prevailing in the studied area, the suction dredger used for harvesting cockles had no short term effects (six weeks) on the sediment and macrofauna characteristics at the fishing sites.

Moreover, the significant decrease observed in cockle biomass at the fishing sites confirmed the selective harvesting of cockles by the suction dredger. Primarily large cockles (>15 mm) appeared to be harvested by the fishing.

This study is carried out in cooperation with Aad Smaal and Johan Craeymeersch of Wageningen IMARES

11 THE USE OF SIDE SCAN SONAR IMAGES IN A STUDY ON THE EFFECTS OF MUSSEL SEED FISHERIES ON SUBTIDAL MUSSEL BEDS IN THE WESTERN WADDEN SEA. F. FEY¹, K. KERSTING² EN B. BRINKMAN¹

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For a study on the effects of mussel seed fisheries on the Subtidal mussel beds a Side Scan Sonar was used to provide images of the mussel distribution in the research plots.

Ten sites were selected in the western Wadden Sea. On each site two adjacent square plots of 200x200 meters are present of which one is closed for mussel seed fisheries, while the other is accessible. The locations were surveyed with the Side Scan Sonar before fisheries started and again after seed fisheries in the spring of 2007. Some image samples are demonstrated; conclusions which could be drawn from these images are discussed.

12 BOUNDARY-EFFECTS OF MUSSELSEED FISHERIES ON RESEARCH PLOTS: A STUDY WITHIN THE FRAMEWORK OF PRODUS. F. FEY¹, B. BRINKMAN¹, H. HEESSEN¹, J. JOL¹, M. VAN STRALEN² AND A. SMAAL¹

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In the framework of the research project PRODUS (sustainable shellfish fisheries) some areas in de Dutch Wadden Sea were closed for mussel fisheries, in order to investigate the effects of fishing and non-fishing on the benthic community, the sub-project being called: "a study on effects of mussel seed fisheries on subtidal mussel beds in the Dutch Wadden Sea."

Therefore, we had to know the necessary size of these closed areas, in order to eliminate most of the possible boundary effects. It was investigated whether these boundary effects actually occur and how far they penetrate into the closed research plots. Such effects may arise when silt and/or mussels whirl up and wash from or to the research plots. The change in sediment composition and mussel densities before and after a fishing experiment was monitored in both the fished and the non-fished areas.

The 10 study areas consisted of two adjacent squares of 10 ha of which one was closed for mussel seed fisheries (the research plot). In the two adjacent squares a transect was mapped out from the centre of the closed square (the research plot) to a point 100 meters from the boundary (within the for fisheries accessible square). On these transects the mussel biomass and the composition of the sediment were measured prior to mussel seed fisheries (T0) and after the fisheries (T1).

After the spring fisheries it appeared that only in three of the ten accessible squares (bordering the research plots) fisheries had taken place. Because of this and because of the high variation within and between the study areas it was not possible to draw conclusions on the presence and extent of boundary effects of mussel seed fisheries on closed research plots. The results from this study, thus, can not reject the 0-hypothesis; which stated that no boundary effects occur. The results, however, also show high variability between the research areas. This in combination with the fact that only three of the areas were actually fished results in a very low statistical power. The fact that the HO-hypothesis can not be rejected does thus not mean that boundary effects are absent. There are indications of the presence of boundary effects, but if these are the result of fisheries or other factors can not be concluded from this study.

13 SELECTIVE BREEDING PROGRAMME FOR BONAMIOSIS TOLERANCE OF THE EUROPEAN FLAT OYSTER *OSTREA EDULIS* IN GALICIA: PRELIMINARY RESULTS. J. FUENTES, A. VILLALBA

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Galician oyster farming was developed in the middle of the past century as an alternative to the exhaustion of the natural populations due to overfishing. The cultivation was based on the importation of large amounts of oysters from several countries because of the lack of a reliable supply of local oyster seed. With these transfers, the protozoan *Bonamia ostreae* was also introduced. Since then, this parasite cause mass mortalities in late stage-ongrowing-oysters and it is the main impediment for the development of this industry in Galicia. To survive, the oyster industry shifted to a strategy based on the importation of submarket sized oysters, which are ongrown in Galician waters for short periods of time and sold before bonamiosis decimates the oyster stocks. This strategy is close to storing rather than farming and involves a risky dependence on the availability of foreign oysters.

Selective breeding programmes have been carried out with encouraging results for the restoration of commercially-exploited oyster populations affected by other devastating diseases. Therefore, in 2000 the CIMA decided to start a selective breeding programme with

the objective of producing *O. edulis* strains with increased tolerance to bonamiosis in Galicia. The first stage of this programme was an evaluation of the performance of 19 full- and half sib families produced from broodstocks coming from four oyster populations of Greece, Ireland and two localities in Galicia: Ortigueira and Coroso (4 to 5 families from each origin). In 2005 a second stage started with the production of 8 families of the first generation of selected oysters, using as broodstocks combinations of oysters from the most favourable families of the previous stage, and also 4 families of non-selected oysters from broodstocks of two Galician natural populations. The performance of all these families is now being compared under raft-cultivation conditions in an area heavily affected by bonamiosis.

This article shows some results obtained until now in this second stage. Although oyster on-growing stage was not finished yet, a significant advantage of selected families versus non-selected for survival and growth rates has been already observed. Selected families coming from the autochthonous Ortigueira origin were the most favourable.

14 THE DIGENEAN TREMATODES OF *CERASTODERMA GLAUCUM* (VENEROIDAE, CARDIDAE) FROM THE LAGOON OF BIZERTE AND THE PORT OF SFAX. K. HOSNI¹, LAMIA GARGOURI BEN ABDALLAH², NAJOUA TRIGUI EL MENIF¹ AND F. MAAMOURI²

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The examen of the cockle *Cerastoderma glaucum* (2540 specimens) taken from the lagoon of Bizerte and the port of Sfax revealed the presence of two species of trematodes belonging to two distinct families: Bucephalidae (sporocyst and cercariae of *Labratrema minimus*) and Gymnophallidae (metacercariae of *Meiogymnophallus fossarum*). The cockle constitutes the first intermediate host for the Bucephalidae and the second host for the Gymnophallidae. Sporocysts and cercariae of *Labratrema minimus* observed in gonads and digestive gland present an important prevalence (24.63%). These larvae can induce a decrease in the recruitment of the bivalve following its castration. The metacercariae of *Meiogymnophallus fossarum*, with a prevalence of 12.99%, were distributed in several types of microhabitats within the host. These larvae freely live in the extrapallial liquid and were often placed inside the furrow periostracal bordering the pallial lobes and generally, under the hinge. This particular localization is the cause of the disturbance recorded for the shell growth. In addition, the important number of metacercariae (n=32) that was found only in specimens with reversal position in the sediment suggested the impact that have these metacercariae on the behaviour of the cockle. This new attitude makes the mollusc visible and accessible to the *Haematopus ostralegus* (final host).

15 *BACCIGER BACCIGER* (TREMATODA, FELLODISTOMIDAE) IN *DONAX TRUNCULUS* (BIVALVIA, DONACIDAE) FROM THE TUNISIAN COASTS. L. GARGOURI BEN ABDALLAH, N. TRIGUI EL MNIF AND F. MAAMOURI

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In the study on the parasites of the bivalves coming from Tunisian coasts we record for the first time, in the Eastern Mediterranean, the fellodistomatidae larvae of *Bacciger bacciger* (Rudolphi, 1819), in *Donax trunculus*. Sporocysts containing cercariae occur in gonads and digestive gland. These trematode larvae were found in 258 of 2062 specimens examined (Prevalence : 12.51%). Infection levels ranged from a few sporocysts to heavily infected clams containing hundreds of daughter sporocysts with developing cercariae. Most of the clams with advanced stages of infection show a dense mass of sporocysts that replace a gonadal tissue. This reduces clam reproduction by castration and cause large-scale fluctuations in the abundance of *Donax trunculus* populations.

Only absent in the winter, these larvae present highest prevalence in the summer, that decreasing during autumn and increasing again in spring.

The life cycle, according to Palombi (1934), is as follows: the adults found in the intestine of *Atherina* spp (definitive host) produce eggs which are evacuated in the vicinity of the bivalve's first intermediate host. These are infected by miracidia and release many asexually formed cercariae produced by sporocysts. The cercariae penetrate and encyst (as metacercariae) in the Amphipoda, *Enchthonius difformis* (second intermediate host). The adult stage of the parasite is reached when *E. difformis* is eaten by definitive host. On the Tunisian coasts, adult was found in *Atherina boyeri*; only second intermediate host remain unknown to date.

16 COMPARISON OF RESIDENCE TIME, PHYTOPLANKTON TURNOVER AND OYSTER FILTRATION TIME IN AN ESTUARINE BAY (BAIE DES VEYS, NORMANDIE, FRANCE) TO ASSESS INTERACTIONS BETWEEN CULTIVATED OYSTERS AND ECOSYSTEM. K. GRANGERÉ^{1,2}, C. BACHER¹, S. LEFEBVRE²

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The carrying capacity of an ecosystem is defined as the maximum biological production for aquaculture. Growth and mortality of cultivated shellfish depend on environmental characteristics like temperature, food concentration, suspended particulate matter... Shellfish production therefore depends on key factors : food availability (primary production), renewal of sea water (residence time) and

food utilisation (ecophysiology). The combination of these factors allows to assess and compare the carrying capacity of several ecosystems, using mathematical models, in order to define relevant indicators of aquaculture impact and potentiality.

The study site is an estuarine bay called baie des Veys located in Normandie (France). This intertidal ecosystem (37 km²) is influenced by four rivers, and characterized by an important oyster farming activity (10 500 tons produced per year). To define indicators, a three-dimensional (3D) hydrodynamic model was coupled to a transport model and an equation for oyster filtration. Interactions between the oysters and the ecosystem were assessed by simulating the transport of a tracer with or without oysters for several cases of forcing functions (e.g. tide level, river flows, wind forces and direction). The residence time was also estimated and compared to oyster filtration time and measured phytoplankton turnover time. Comparison with similar characteristics in other systems will allow to assess whether interactions between oysters and baie des Veys ecosystem play a key role in ecosystem functioning. The next step will consist in linking a biological sub-model to the existing hydrodynamic model with the general aim of predicting oyster growth as a function of environmental conditions.

17 MUSSELS FROM THE DUTCH OOSTERSCHELDE AND SEAS AROUND UK AND IRELAND ARE GENETICALLY SIMILAR, WITH A BIT OF MEDITERRANEAN FLAVOUR. H. HUMMEL¹, R. WENNE², T. KIJEWSKI²

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With the import of mussels from the coast of Ireland and the UK, there could be a chance of introducing non-indigenous mussel groups into the Oosterschelde, the Netherlands. The risk of such an introduction is depending on the presence of mussel-groups in Irish and British areas that are different from those in the Oosterschelde. In this study the genetic constitution of the mussel populations of the Oosterschelde as well as Irish and British areas are analysed and compared.

Due to the high morphological similarity and common hybridisation in European populations, it is not possible to identify *Mytilus* taxa using simple traits as measurements of shell. Mussel specimens can be assigned to species status using (a combination of) molecular markers based on nuclear DNA. So far, a few nuclear DNA markers are known to be diagnostic for all three European *Mytilus* taxa and their hybrids.

In order to identify species and hybrid composition of mussel samples collected from mussel shipments, culture and natural populations, we used three molecular markers: ME 15-16, M7 and EFbis. Fifty samples of mussels and within each sample about 40 mussels were analysed.

A genetic difference between the studied populations appeared not to be prominent. The mussels originating from Ireland, UK and the Netherlands belong to the same genetic group of *Mytilus edulis* with a similar degree of introgression from other groups (*M. galloprovincialis* and *M. trossulus*; degree of introgression estimated by Me 15-16 estimated to be 0,5 and 0.02 %, respectively). The degree of introgression by other mussel groups is estimated differently by the 3 markers – the M7 marker being more sensitive towards *M. galloprovincialis* (indicating 17 % introgression), the EFbis marker more sensitive towards *M. trossulus* (indicating 2 % introgression).

This study is part of the PRIMUS project and carried out in cooperation with Aad Smaal and Jeroen Wijsman of Wageningen IMARES.

18 MORPHOLOGICAL DISTURBANCES OBSERVED AT *RUDITAPES DECUSSATUS* *MYTILUS GALLOPROVINCIALIS* AND *LITHOPHAGA LITHOPHAGA* COLLECTED IN THE NORTH OF TUNISIA. FERDAOUS JAAFAR KEFI¹, LAMIA GARGOURI BEN ABDALLAH² & NAJOUA TRIGUI EL MENIF¹

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The morphological anomalies of the clam *Ruditapes decussatus*, the mussel date *Lithophaga lithophaga* and the mussel *Mytilus galloprovincialis* were studied on samples collected in the northern coast of Tunisia. In the European clam, the anomaly consists of the differentiation of two supplementary siphons inhaling and exhaling occurring of the two usual siphons, completely separated, inhaling and exhaling. The siphons in form of Y thus have 4 functional openings instead of 2. The point of attachment of the secondary inhalant siphon was ~ 1 cm from the orifice of the principal inhalant siphon. At mussel date *L. lithophaga*, burrowing annelids and sipunculians live inside galleries on external side of the valves. The abnormalities are clearly observed because the thin thickness of the shell. These calcareous tubes or membranous tubes are open in dorsal or posterior side, near to the site of the siphons of the mussel. Some specimens (with annual rate of 0.26%), show a bulge exaggerated at the base of some tubes of annelids. The *M. galloprovincialis* (~ 2450 specimens) were examined and revealed disturbances on the internal shell such yellowish and soft mass in the former area. This mass of ~3 cm long and 1-1.5 cm width, is firmly attached to the shell by a hard, brownish structure. The removal of this yellowish formation reveals the absence of the layer of pearly. The mass contained numerous, yellowish, elliptical eggs measuring 180-200 µm. The three abnormal individuals form part of shares of 165 and 142 mussels collected in March and May 2003. At 6 individuals out of 185 examined in April 2003, we observed, the same formations, containing embryos with various sizes and consequently at various stages of evolution. The ultimate stage shows a tubicolous annelid emerging from the perforation of the tube.

19 EFFECT OF METALS, ELEMENTS AND DIFFERENT PHYSICO-CHEMICAL PARAMETERS ON THE GROWTH PERFORMANCE OF *CATLA CATLA*, *LABEO ROHITA* AND *CIRRHINA MRIGALA*, REARED UNDER SEMI-INTENSIVE CULTURE SYSTEM. M. MUNIR, A. SHEHZAD AND S. M. R. DILSHAD

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In this study, the effect of different metals, elements and compounds (manganese, magnesium, chloride, sodium, potassium, calcium, ammonia, nitrate and phosphate) and physico-chemical parameters (pH, electrical conductivity, water temperature, dissolved oxygen, total hardness, total alkalinity and dry weights of plankton's biomass) were determined. Fingerlings of *Catla catla*, *Labeo rohita* and *Cirrhina mrigala* were exposed to different concentration of metals and elements for 30 days. During the exposure period, all three fish species showed negative growth with weight increment values of -0.22, -0.72 and -3.90g, respectively. After 30 days both treated and control fish were shifted to outdoor earthen ponds for semi-intensive culture and monitored for a period of six months. The ponds were fertilized with poultry droppings at the rate of 0.16g nitrogen per 100g net fish weight daily. Moreover, supplementary feed (35% digestive proteins) was also dispensed to fish pond. A growth and limnological studies of the ponds were carried out. Analysis of variance on wet weight, fork and total length of the three fish species showed that fortnight, species and treatments exerted significant effects ($p < 0.01$). Among three fish species, *Catla catla* gained significantly higher weight, followed by *Labeo rohita* and *Cirrhina mrigala*. *Cirrhina mrigala* showed significantly higher values of fork and total lengths, followed by *Catla catla* and *Labeo rohita*. Only manganese, sodium and nitrate contents among all metals, elements and physico-chemical parameters which were measured in mg L⁻¹ showed statistically significant differences ($p < 0.05$) between controlled and experimental ponds in all three fish species. However, control fish showed significantly higher weights, fork and total lengths as compared to elements and metals stressed fish reared under semi-intensive culture system. On the basis of these investigations and due to the concern of increased industrialization, it was concluded that stressed major crops under sub-lethal concentration of manganese showed significantly lower value of weight, fork and total lengths than control fish when reared under semi-intensive culture system.

20 CONTRIBUTION TO BIVALVE FISHERY SUSTAINABILITY IN ALGARVE (SOUTHERN PORTUGAL): DEFINITION OF THE MOST SUITABLE STRATEGY FOR PULLET CARPET SHELL *VENERUPIS PULLASTRA* RESTOCKING. S. JOAQUIM¹, M. GASPAR¹, D. MATIAS¹, W. ARNOLD²

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The pullet carpet shell *Venerupis pullastra* is a commercially important species of the Portuguese coasts. This species was once plentiful in the Ria Formosa lagoon (southern Portugal). However in the early 1980s, the abundance of this species declined dramatically due to over-fishing. Despite the high commercial value of the species, the lack of interest by fishermen in the Ria Formosa lagoon for harvesting this species leads us to suppose that the population density in Ria Formosa has decreased below a threshold level such that natural recovery is not possible. Therefore, an active intervention may be necessary to restore stocks to reproductive viability. This poster describes a project that applies aquaculture techniques to test different approaches to restock this important species in Ria Formosa. First, to minimize the deleterious effects of hatchery practices on the genetic make-up of released stock, the founder (broodstock) population will be obtained from the natural population to be restocked. However, if polymorphism of this population is proven to be low and the population to be in a genetic decline, then the genetically closest population will be used. As no information is currently available on the genetic variation within Portuguese populations of *V. pullastra*, besides the Ria Formosa population, the genetic structure of 3 other representative natural populations (Ria de Aveiro, Estuário do Tejo e Ria de Alvor) will be analysed. In a second phase of the project, we will define the optimal reproductive time for restocking purposes and to develop/improve breeding and rearing techniques (spawning induction, adequate larval feeding regimes and zootechnical conditions) to produce high quality larvae and juveniles for the restocking program. Two different restocking strategies (seeding of juveniles and direct injection of fertilised eggs) will be tested within a presently closed but previously overfished area to determine the most ecologically and economically feasible approach to enhance *V. pullastra* populations. The results gathered in this study will be used in Bivalve Restocking Programs which will contribute to rebuilding *V. pullastra* populations in the Ria Formosa lagoon.

21 TECHNOLOGY DEVELOPMENT FOR A RELIABLE SUPPLY OF HIGH QUALITY SEED IN BLUE MUSSEL FARMING. P. KAMERMANS¹, E. MARISSAL², S. SCHOT³, J. WILSON⁴, M. FRANCO LEIS⁵, D. MURPHY⁶, A. LEIJ⁷, P. BOUDRY⁸, A. BEAUMONT⁹, J. FUENTES¹⁰

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The objectives of the EU project BLUE SEED are to secure a reliable supply of blue mussel seed and to develop techniques allowing farmers to market blue mussels year round. A problem blue mussel producers face is the unpredictability seed supply. Seed is mostly harvested from suspended collectors or mussel beds. The amounts of wild seed available are extremely variable from year to year. A reliable supply of seed from hatchery sources will allow mussel farmers to overcome this. A second problem is that recently spawned mussels cannot be sold due to insufficient meat content. Producers will benefit greatly from a hatchery-based technique, such as triploid induction, that produces non-maturing mussels that can be marketed year round. In this project mussel farmers and sellers, a network for training and technology transfer, universities and research institutes collaborate. Attention is given to broodstock conditioning and larval rearing, production of triploid larvae and tetraploid broodstock, spat settlement and on rearing of diploid and triploid spat to seed size. In addition, the allowed costs of hatchery produced seed with conventional wild-caught seed is compared. Considering the normal 2 to 3 year production cycle for blue mussel in Europe, the focus of this 2-year project is on spat and seed production. The project outcomes include a reliable method to produce triploid seed, allowing year-round production of high quality mussels, protocols for spat and seed production, and an analysis of the economic feasibility of the new techniques developed.

22 RELAYING YOUR RESULTS – THE ROLE OF THE NEWSLETTER. I. LAING

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Researchers traditionally publish their work in international peer reviewed scientific journals, but these are not easily available to the average industry person. In 1996 the UK Ministry of Agriculture, Fisheries and Food (now Defra) commissioned its agency Cefas to produce a twice-yearly publication called Shellfish News and distribute it to the shellfish farming industry. The aims of Shellfish News are to improve the level of communication between the industry and those conducting research and development (R&D) and provide information on policy and government legislation relating to the sector.

Shellfish News is posted free of charge to all registered shellfish farms within England and Wales. Production of the magazine by the relevant authority facilitates such distribution. It is also sent to other official bodies with responsibilities for the industry (e.g. trade associations, regulatory authorities, conservation bodies etc.). Research workers and anyone else with a legitimate interest in receiving copies can be added to the mailing list on request. As many industry workers do not have access to the Internet we continue posting hard copies. Nevertheless, a PDF file copy is also placed on the Cefas web site and this receives a lot of attention, particularly from readers abroad (<http://www.cefas.co.uk/news-and-events/shellfish-news.aspx>). An email alert is used to inform registered subscribers of new editions.

The format of the publication was initially based on that of a sister publication Trout News. A readership survey in the 5th issue of Shellfish News helped to formulate the content of the magazine, from which the current look has evolved. Articles on research and development are commissioned through contacts in the research community, and written in a format (including photographs) directed at the industry. There is also a section where the editor provides a synthesis of other published research of relevance. The readership survey showed this to be the most popular item, with 70% finding it extremely or very useful. Annual production figures are also published, enabling an analysis of trends and changes in the industry.

Individual operators in the shellfish industry are increasingly involved as partners in multi-disciplinary research consortia and this is as it should be, given that they are major stakeholders in the results, particularly where restoration projects are concerned. It is important to disseminate results of this and any other research of relevance in the most efficient way. The newsletter format of Shellfish News has successfully fulfilled this role for the last 11 years.

23 THE OYSTER RECOVERY PARTNERSHIP: RESTORING OYSTER REEFS THROUGH COLLABORATION AND INNOVATIVE TECHNOLOGIES. T.M. LEDERHOUSE¹

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The Oyster Recovery Partnership (ORP), a non-profit group created in 1994 as a result of the Maryland Oyster Roundtable, is comprised of more than a dozen organizations dedicated to restoring native oysters (*Crassostrea virginica*) in the Maryland portion of the Chesapeake Bay, USA. These organizations represent various stakeholder groups including federal, state, and local governments, environmental advocacy groups, university scientists, seafood industry representatives, and local waterman associations. The restoration activities conducted by the ORP include the rehabilitation of historic oyster bars through the process of shell reclamation, the production of disease-free oyster seed, and the planting of spat-on-shell onto restored oyster habitat. These restoration projects have resulted in more than 1 billion spat-on-shell being planted in the Chesapeake Bay since 2000.

Research and monitoring conducted by government and university scientists at our partner organizations has led to the development of many innovative processes used to improve our understanding of where oysters may best be able to grow and survive in spite of ongoing disease pressures. Such processes include acoustic sonar bottom mapping, GPS tracking of planting boat movement, and a classification system for determining bottom type using diver tactile and visual surveys. Extensive monitoring of the restored oyster reefs has also allowed us to determine more effective planting strategies for providing important ecological services. These innovative processes have led to an increased restoration success rate resulting in hundreds of millions of oysters still alive in the bay.

As part of its restoration activities, the partnership began a cooperative aquaculture program with Maryland watermen, planting 500 million oysters on managed reserves oyster bars throughout several bay tributaries. The reserves are closed to harvest until oysters reach 100mm which is larger than current legal harvest limits. The reserves are also subject to much more rigorous harvest restrictions. This allows oysters to remain in the bay for a longer period of time thereby providing important ecosystem services, as well as a greater economic return to the watermen as the larger oysters have a higher dockside value after harvest. This unique

partnership of stakeholder groups has allowed the Oyster Recovery Partnership to become the largest group in Maryland actively restoring oysters to the Chesapeake Bay.

24 VITELLOGENIN GENE EXPRESSION IN THE PACIFIC OYSTER, *CRASSOSTREA GIGAS*. T. MATSUMOTO

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Reproductive processes in the Pacific oyster are well-understood. As temperatures rise in spring, gamete development and growth begin, and mature gametes are spawned in summer. In marine bivalves as in most oviparous animals, a large amount of yolk protein (vitellin) is accumulated in oocytes during ovarian maturation. Yolk protein is synthesized from a precursor, vitellogenin. In previous studies we have isolated the oyster vitellogenin cDNA from the ovary and showed that vitellogenin mRNA was expressed strongly in the follicle cells in the ovary. In the present study, we analyzed the pattern of expression of vitellogenin mRNA. The real-time RT-PCR assay was used to measure the levels of vitellogenin mRNA in ovaries of oysters at different stages of reproductive cycle. The vitellogenin mRNA reached the highest level more than one month before the spawning and thereafter showed a rapidly decrease. However, in an organism infected by the protozoan parasite *Marteilioides chungmuensis*, the vitellogenin mRNA level increased again in the spawning season and in situ hybridization analysis revealed that the expression was found in the follicle cells. These results suggest that the parasite might be involved in the control of vitellogenesis.

25 OOCYTE ACTIVATION IN *MYTILUS EDULIS* BY *CRASSOSTREA GIGAS* SPERMATOZOA. H. MCCOMBIE¹, F. CORNETTE², A. BEAUMONT¹ AND P. BOUDRY²

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The development of hatchery production techniques for blue mussels is receiving increased research attention in Europe as it could offer an alternative source of spat for the industry ('Blue Seed' Project, Kamermans ICSR 2007). Among the necessary techniques are those of controlled spawning and fertilization, and techniques of triploidisation that can offer increased seasonal availability, yield and/or decreased growing time in the subsequent production stages.

In several experiments, *Mytilus edulis* oocytes, obtained by thermally induced spawning, were fertilized with *Mytilus edulis* spermatozoa obtained in the same way or by stripping. Parallel treatments examined the effect of mixing *Mytilus edulis* oocytes with spermatozoa stripped from the Pacific oyster *Crassostrea gigas*.

Initially considered as a potential stimulant for mussel spawning, the sperm of *C. gigas* was actually found to activate mussel oocytes, which were observed to slowly expulse their 1st and 2nd polar bodies. This form of activation was repeated in four separate trials in 2006 and 2007. No reciprocal effect was observed when oyster oocytes were mixed with mussel sperm.

Examination of the embryogenic stages by epifluorescence revealed that though *C. gigas* sperm attached to the mussel oocytes, no penetration occurred. Resulting embryos would therefore be haploids. No viable haploid D larvae were obtained by this technique while the treatments with mussel sperm (spawned or stripped) produced good larval yields. Such a means of oocyte activation without fertilization could however be useful for induction of gynogens, and a later polar body retention experiment produced small numbers of D larvae.

The capacity of oyster sperm to activate and thus bring about a reduction in available mussel oocyte numbers might also have implications for the cohabitation of these two species, notably in the context of *C. gigas* as an expanding invasive species in Northern Europe. The main spawning periods of these two species are different in the wild (i.e. early spring for mussels, summer for oysters) but climatic change and indications of expanding spawning period in both species may increase the likelihood of their gametes coming into contact in the future.

26 SUMMER MORTALITY IN PACIFIC OYSTER *CRASSOSTREA GIGAS*. MOREST PROGRAM. JEAN-FRANÇOIS SAMAIN¹, HELEN MCCOMBIE^{2*}

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Mass oyster mortalities have been known for many years throughout the world, but no strictly pathological explanation has been found. The Morest program, organised by Ifremer between 2001 and 2006, investigated how environmental influences, reproduction, stress, genetics, pathogens and temperature contribute to oyster summer mortality in France. An interaction model was derived from the results and recommendations made for forecasting and managing risk factors. The Morest program was conducted by more than 15 teams from research institutes and industry, working as an interdisciplinary network. It united diverse scientific disciplines using common field sites and laboratory experiments to thoroughly examine the oyster summer mortality problem. Its findings are to be published in a forthcoming book published by Editions Quae (<http://www.quae.com>).

Chapters: 1. Evaluation of summer mortality risk factors in shellfish farming ecosystems,

2. Mortality risks associated with physiological traits of oysters during reproduction,

3. Oyster summer mortality risks associated with environmental stress,

4. The genetic basis of summer mortality in Pacific oyster spat and potential for improving survival by selective breeding in France.

5. Phenotypic characteristics of 'R' and 'S' oyster lines, selected for resistance or susceptibility to summer mortality,
6. Oyster summer mortality risks associated with pathogens,
7. Temperature as a risk factor in oyster summer mortality,
8. A synthesis of the Morest program and recommendations for forecasting and managing oyster summer mortalities.

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27 NEWLY DISCOVERED OYSTER REEFS OF THE BLACK SEA: IN TIME FOR RESTORATION?. D. MICU¹, V. TODOROVA² AND W. WOLFF³

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Throughout the summer of 2007 the authors carried out a series of diving expeditions along the Western Black Sea coast with the main goal of identifying sites suitable for designation as marine protected areas.

During this expedition we discovered huge biogenic reefs built by the native flat oyster *Ostrea edulis* L., 1758 along the Bulgarian Black Sea coast.

The reefs occur in clear marine waters, far from sources of freshwater input. The reef aggregations form barriers parallel with the shore between 7 and 23m depth. Individual reefs are massive, erect biogenic structures attaining 7m height, 30-50m length and 10m width and develop on rocky or shelly flat bottoms. Smaller oyster reefs may also occur on rocky offshore reefs or as a sponge-like structure adhering to rocky vertical drop-off faces.

Two sites were investigated around Cape Maslen Nos and information gathered from fishermen suggests that similar oyster reefs are present all along the Bulgarian coast south of Burgas Bay. We also found a third, more northerly site with oyster reefs at Cherni Nos, suggesting that oyster reefs are present along at least two thirds (235 km) of the Bulgarian coast, but with relatively low connectivity. We have pictures of live oysters from the same area dating from the 80s and local people have recreationally harvested oysters from the reefs until two years ago. However, no live oysters were found at the sites investigated by us. This suggests that the habitat is declining at present. The cause of oyster mortality has yet to be elucidated, in order to take measures for restoration of these unique oyster reefs.

28 EFFECT OF SUBSTRATE TYPE AND PRESENCE OF ADULTS CARPET-SHELL CLAM (*RUDITAPES DECUSSATUS*) ON THEIR RECRUITMENT IN A INTERTIDAL AREA OF GUADIANA-CARRERAS RIVER (HUELVA, SOUTHERN SPAIN). I. PALANCO AND Ó. MORENO

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The success in settlement of shellfish juveniles is close related to environmental conditions in sediment. An active behaviour of larvae for choosing the settlement place has been described, selecting the conditions to ensure the survival. The effect of sediment granulometry and the presence of adults of carpet-shell clam on settlement of juveniles was studied.

In a intertidal sand flat in Guadiana-Carreras river four 8 x 8 m plots were established in a tidal coefficient of 0.80. Two plot were treated adding gravel (diameter between 0.5 and 2.0 mm), with aim to change the granulometry diameter for enhancing the juveniles settlement. The other two plots keep untreated. Five sediment samples and benthic fauna were taken for treatment and untreated plots. Later, in one untreated and one treated plot, 20mm length carpet-shell clams were added in a density similar to observed in this area (40 individuals per square meter).

Cores of 15cm diameter and 15cm depth were used for sampling. During 4 months, twice per month 5 sediment samples will be taken for plot. The samples will be filter in a 500µm sieve and the material over this size will be preserved in formaldehyde 5% and tinted with Rose of Bengala. The number and weight of carpet-shell clam juveniles and the number and weight, in fresh and AFDW, of the other benthic fauna will be determinated.

29 THE BARNEGAT BAY SHELLFISH RESTORATION PROGRAM: RESTORATION AS EDUCATION. C. MUSCIO AND G. FLIMLIN.

Rutgers Cooperative Extension of Ocean County, 1623 Whitesville Rd, Toms River, NJ 08755

Ocean County, New Jersey has a long association with the coast, the waters of Barnegat Bay, and the natural resources of its estuary. The Barnegat Bay Shellfish Restoration Program, currently in its third year, has won local support, notable press attention, and awards for its efforts to "ReClam the Bay". Rutgers Cooperative Extension runs the program in cooperation with the New Jersey Department of Environmental Protection's Division of Fish and Wildlife Bureau of Shellfisheries, and through funding provided by the County of Ocean and the United States Environmental Protection Agency's Barnegat Bay National Estuary Program. Thus far, the program has trained

about 100 volunteers, and grown 3.4 million clam seed and 350 000 oyster seed. Volunteers have formed a non-profit organization (ReClam the Bay!) to help secure funds for the continuation of the program into the future.

Public outreach is an important aspect of the program, and emphasizes the connection between shellfish restoration, citizen stewardship, environmental involvement, and the overall health of the water, habitat and resources of Barnegat Bay. Several educational programs are run by the Shellfish Restoration Program including Clam Camp, workshops for educators, on site upweller demonstrations, fair and festival displays, a curriculum guide for educators, and a public art and education project/scavenger hunt. These programs not only raise awareness of the shellfish restoration program, but also assist in changing behaviors, and increasing environmental involvement in the Barnegat Bay watershed.

30 OYSTER (*CRASSOSTREA VIRGINICA*) GARDENING PROGRAM FOR RESTORATION IN DELAWARE INLAND BAYS. G. OZBAY¹, E.J. CHALABALA², J. EWART³, E. LEWANDOWSKI², F. MARENGHI¹ AND K. ROSSI-SNOOK¹

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Oysters are a keystone species in coastal embayments. They provide unique services in these systems by filtering sediments and algae from the water column. Their reefs are a valuable component of estuarine ecosystems, providing a unique reef habitat for many ecologically and economically important species. Unfortunately, the Eastern oyster (*Crassostrea virginica*) in mid-Atlantic and along the Gulf Coast population has drastically declined since the late 1800's as a result of overfishing, physical habitat degradation, reduced water quality, and increased in disease mortality from Dermo and MSX diseases.

Our Oyster Gardening Program initiated during the summer of 2003 with cooperative efforts among the Delaware Center for the Inland Bays, Delaware Sea Grant Marine Advisory Program and citizen volunteers living along Rehoboth Bay, Indian River Bay and the Little Assawoman Bay. During the fall of 2006, Delaware State University joined the program team with the funding to support the program for additional three years. This funding provides additional staff and students to expand the program to include quantitative assessment of oyster growth, habitat types, water quality, and sediment quality at the gardening sites. This program will also involve oyster gardeners in water quality monitoring led by the University of Delaware Sea Grant College Inland Bays Citizen Monitoring Program. In this program, workshops and training are provided to the volunteers for building aquaculture gear (i.e. Taylor floats), maintenance and cleaning of the floats, water quality monitoring and oyster growth. Selected gardening sites are used for in-depth monitoring of the habitat value of the containment gear.

Volunteer gardeners support the program by caring for small 6-7mm spat attached to old oyster shells in Taylor float baskets tied to their docks. The gardeners keep the oyster spat clean and protected from predators. Based on the previous efforts, oysters held off bottom had better conditions for growth due to increased water flow and greater access to particulate foods, therefore reach a planting size of 30-38mm much more rapidly than oysters on the bottom.

Because of the gardeners' efforts, damages due to predators and fouling organisms are greatly minimized, resulting in larger and healthier oysters for building reefs and other restoration work in the area. During the 2006 summer season, 65 volunteer oyster gardeners were growing oysters at 45 locations around the three Inland Bays. In 2007, request for participation in and training for oyster gardening have more than doubled. We expect interest and participation from the public to increase every year with continuing success in the oyster gardening program.

31 DELAWARE BAY OYSTER (*CRASSOSTREA VIRGINICA*) MANAGEMENT AND RESTORATION. G. OZBAY¹, K. ASHTON-ALCOX², R. BABB³, J. JOSEPH³ AND E. POWELL²

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The Delaware Bay Oyster Restoration Project is a cooperative initiative currently underway to revitalize Eastern oysters (*Crassostrea virginica*), a keystone species that produce valuable habitat and serve as a biological filter for the Delaware Bay. The Delaware Bay Oyster Restoration Task Force was established to complete revitalization of Delaware Bay oysters and the industry that once thrived upon them. The primary objective of this task force is to manage existing beds, restore oyster reefs and increase recruitment in the Bay.

Over the past century, Delaware Bay oyster populations decreased dramatically due to the climate change, habitat loss, fishing, other natural factors and oyster diseases (i.e. MSX disease in the 1950s, Dermo disease in the 1990s). Despite such setbacks, many remain hopeful for the recovery of the species in the Bay. Since 2005, the Delaware Bay Oyster Restoration Project has succeeded in generating \$50 for every \$1 invested by bringing together local, state, and federal partners to revive an oyster population that has suffered for decades. The oyster beds are being planted with clean ocean sea clam and oyster shell that is strategically placed in the Delaware Bay. These shell-planting sites provide surfaces to which oyster larvae can attach in order to grow. Once the larvae are attached, they will remain on these beds. This restoration project also focuses on transplanting oysters from lower in the Bay with higher salinity to the areas further north in the Bay where they have a better chance of surviving. The Oyster recruitment and

monitoring process has been formalized through a rigorous stock survey, a stock assessment workshop and the development of a coupled fisheries-disease model to permit projections of yearly harvest. Each seed bed is divided into a series of 25 acre grids for most sampling sites. A quasi-random sampling approach collects approximately 130 bushels from most of the beds. Starting 1999, survey dredge tows (distance) are measured and dredge calibration corrections are utilized to determine catch efficiency. These data are utilized to estimate the total number of live oysters per square meter on each beds as well as the number size-class breakdown on each bed. It is estimated that the site would contribute 13,393 bushels to the 2006 oyster harvest. This is a 26% increase. This is expected to have an ex-vessel value of nearly \$500,000 and a total economic benefit of nearly \$3 million dollars. While this six-acre project site represents only one percent of the 600-acre Bennies Sand seedbed, it represents 58 percent of all of the marketable oysters on this bed.

Significant progress has been made toward stabilizing oyster production and the Bay consistently produces a high value oyster for food market. In the first two years of implementation, the Delaware Bay Oyster Restoration Project has doubled oyster recruitment in targeted areas of the Bay. If this same progress can be maintained over time, the result will be an economic boost to the many bayshore communities that have staked their livelihood on the shellfish industry for more than a century. To them, healthy oysters represent their past, present and future.

32 MONITORING WATER QUALITY, TOTAL BACTERIA AND VIBRIONACEAE CONCENTRATIONS IN EASTERN OYSTERS (*CRASSOSTREA VIRGINICA*) COLLECTED FROM OYSTER GARDENING SITES IN DELAWARE INLAND BAYS. J. FAY AND G. OZBAY

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Historically, the Eastern oyster (*Crassostrea virginica*) has been a keystone species in Delaware Inland Bays, forming reefs that supply habitat to numerous vertebrate and invertebrate species. Oysters also play an important role in filtering large volumes of water on a daily basis, therefore improving water quality by removing sediments, nutrients, and bacteria from the water column and adding nutrients to the benthos. Using shellfish as a water quality indicator has proven to be successful in water quality monitoring due to the bioaccumulation of different types of microorganisms that may be present in their surrounding environment. In addition to water quality monitoring, oysters are also commonly tested for seafood safety purposes. If they are not properly handled before consumption, shellfish can have harmful impacts on human health. One of the foremost naturally occurring marine bacterial groups is Vibrionaceae, which may cause seafood-borne illnesses of great concern.

In attempt to enhance the oyster population in Delaware, an oyster gardening program has been established at various sites within the Inland Bays. The primary objective of this study was to evaluate the total bacteria and Vibrionaceae levels in *Crassostrea virginica* collected at two large oyster gardening sites at Fenwick Island within Delaware Inland Bays, and to determine the relationship between measured water quality and bacteria levels. One gardening site selected was located at the end of a man-made canal while the other gardening site was in an open location within Little Assawoman Bay, Delaware. A simple colony overlay procedure for peptidases (COPP) was used to quantify Vibrionaceae in oyster tissue. Preliminary studies measuring the total bacteria and Vibrionaceae levels in oysters have shown an increase in total bacteria and Vibrionaceae levels over time during the summer months. Average total bacteria concentrations for the canal site and the open bay site respectively, were 138,000/g of oyster tissue and 80,000/g of oyster tissue for June and 2,800,000/g of oyster tissue and 1,010,000/g of oyster tissue for July. Conversely, average Vibrionaceae concentrations for the canal site and the open bay site respectively, were 14,350/g of oyster tissue and 52,300/g of oyster tissue for June and 140,000/g of oyster tissue and 181,000/g of oyster tissue for July. In relation to the total bacteria, total Vibrionaceae for June and July respectively, were 10% and 5% at the canal site, and 65% and 18% at the open ocean site. At the canal site, the average total nitrogen range was between 1.1mg/L and 3.2mg/L, and the average total phosphorus range was between 0.59mg/L and 1.38mg/L, each which are relatively low levels for summer months. In the future, more research should be conducted to monitor the water quality and bacterial levels at more oyster gardening sites in Delaware Inland Bays. This information can then be utilized by the oyster gardening program and serve as beneficial when deciding where to harvest oysters.

33 THE NEW EUROPEAN ON-LINE JOURNAL "AQUATIC INVASIONS": SERVICES FOR MARINE BIODIVERSITY RELATED INFORMATION SYSTEMS. V. PANOV¹ AND S. GOLLASCH²

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Aquatic Invasions is a rapid on-line journal with a focus on (a) biological invasions in European inland and coastal waters and (b) potential donor areas of aquatic invasive species for Europe (ISSN: 1818-5487, <http://www.aquaticinvasions.ru>). The journal provides the opportunity of timely publication of first records of biological invaders for the consideration in risk assessments and early warning systems. Also, the journal provides the opportunity to publish relevant technical reports and other accounts not publishable in regular scientific journals. Conference proceedings may be published as Special Issues.

Aquatic Invasions is an important part of the developing Pan-European and regional early warning systems on aquatic invasive species, with an important protection service of author rights on primary geo-referenced records on introduced species. In 2006, more than 50 research articles and short communications in 4 regular issues of the first volume of Aquatic Invasions included geo-referenced information on range expansions and European first records of highly invasive species, such as Conrad's false mussel *Mytilopsis leucophaeata*, Wedge clam *Rangia cuneata*, grapsid crab *Percnon gibbesi*, Chinese mitten crab *Eriocheir sinensis*, ctenophore *Mnemiopsis leidyi* and round goby *Neogobius melanostomus*. Further a European distribution update of the Asian sea squirt *Styela*

clava was published.

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Each manuscript submitted to Aquatic Invasions are reviewed by at least two independent experts. Accounts on inland invaders may be submitted to Vadim Panov (rbic@zin.ru) and for coastal invaders please approach Stephan Gollasch (sgollasch@aol.com).

34 SMIDAP PROJECT 2007 : HYDRAULIC AND BACTERIOLOGICAL STUDY ON A OYSTER FARMING SITE (PAYRE ESTUARY, FRANCE). F. PATICAT, G. THOMAS, A. FILLON & J-M. CHABIRAND

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1- Introduction

This study is focused on a oyster farming site (Payré estuary) affected by recurrent series of contamination. This estuary is connected with large watersheds characterized by a high diversity of agricultural and urban uses. We decided to analysis both hydrology and oyster biological contamination in order to answer to stakeholders and local administration requirements of the ecosystem functioning and oyster growing risks.

2- Materials and Methods

High frequency measurements were used to monitor hydrology. Water parameters of the two channels and entrance of Payré estuary were recorded with an acoustic doppler current profiler (water velocity and water height) and a multiparameter probe (temperature, salinity, pH, chlorophyll a, turbidity). Complementary water samplings were realized to improve these high frequency results.

Two campaigns were planed to record Payré estuary hydraulic characteristics according to local meteorological conditions. A first sampling period was realized during dry season (May-June) and a second from November to December when rain events are expected. Two methods are privileged to keep bacteriological track of oyster rearing sites. The first one consist in monitor channels salinity with sensors, to find limit between freshwater and saltwater. Microbiological analysis were realized bimonthly during 10 months (September 2007 to June 2008), after deployment of oysters bags in channels.

3- Results

Results deals with first hydraulic campaign (11 May to 30 May). The main result demonstrated that ecosystem and hydrology were very sensitive to local meteorology and watershed effects. After a storm event (20 May), multiparameter probes results confirmed that freshwater inputs have similar effects for the two channels. Sensors recorded during several days, a decrease of salinity from 35 to 5. Furthermore, each channel presented similar temperature, chlorophyll a and turbidity results. Oysters reared in channels were directly affected by these meteorological and hydraulic characteristics. After this rain event, oysters mortality rate increased drastically.

4- Conclusion

Oyster farming in Payré estuary is an important activity for local development. Ecosystem survey and hydrology knowledge are essentials conditions to maintain and develop this economic practice. Our project, based on high frequency measurements of water parameters and on oyster contamination process observation, is a first approach for understand local ecosystem functioning and assess future directions.

35 MONITORING OF THE *TAPES PHILIPPINARUM* RECRUITMENT IN THE VENICE LAGOON (ITALY). M. PELLIZZATO, T. GALVAN, R. LAZZARINI, P. PENZO.

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The species *Tapes philippinarum*, introduced in the lagoon of Venice in 1983 for experimental purposes, rapidly colonised wide areas making the lagoon the most important European producer of clams, with a production between 4 500t and 40 000t over the last fifteen years and with a peak registered in the period 1995-1996 of around 50 000t. To guarantee criteria of environmental and economical sustainability of the shellfish sector, the production of Manila clam in the Venice lagoon is now changing from free-access fishing to clam-culture in restricted areas

All mollusc-farming practices, and therefore also breeding of *T. philippinarum*, require seed to begin the productive cycle. Current breeding practices in the Venice lagoon are also almost completely based on the gathering of wild clam seed in nursery areas where the juveniles settle as a consequence of favourable environmental conditions, and are then seeded by the farmers in authorised water areas. The main problems concern on one hand seed supply and, on the other, careful management of the nursery areas, in order to protect both reproduction banks, by replenishing them, and newly settled clams, by more critical harvesting techniques. This work therefore had the objective of characterising the main nursery areas in the lagoon using the study of recruitment of the species, with the aim of supplying the Public administration and clam producers with a useful tool for a sustainable management of this resource in the Venice lagoon. From over six years (2002-2007) the recruitment of *T. philippinarum* was studied through samples of newly settled clams made with an experimental hydraulic dredge from March to October. The monitoring evidenced periods and areas of greater settlement and made it possible to evaluate the growth of newly settled clams (class 0+).

First cohorts were usually identified from May on, whereas the peak of the seed density was recorded in September and October with annual fluctuations due to harvest activities and environmental conditions. The highest observed densities were of about 2 000 ind/m². The cohorts settled in late spring (May and June) grew 3-5mm per month during summer, while in November-March the monthly growth rate was only 0.7-0.9mm.

The research results led to a more detailed knowledge of the species' reproduction as well as the localisation of a wide nursery area for *T. philippinarum* in the Venice lagoon useful for the local fisheries plan.

36 GENETIC STRUCTURE OF PINK ABALONE HALIOTIS CORRUGATA IN NORTHEASTERN PACIFIC. N. DIAZ-VILORIA, P. CRUZ, R. PEREZ-ENRIQUEZ

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The abalone fishery (*Haliotis fulgens* and *H. corrugata*) is the main economic activity of many communities in Baja California, Mexico, that has suffered a serious production decrease from 5,993 ton in the 50's to 300 ton in 2005. Management strategies have been applied to revert this trend setting up capture quotas, capture seasons, and minimum size. From 1981 recuperation plans have included restocking strategies by the release of larvae that have been produced in hatcheries. To develop responsible restocking strategies it is essential to know the genetic composition of wild populations and to assess the potential genetic effect of the release. In this study we describe the genetic composition of the wild population of *H. corrugata* along the Northeast Pacific, based on eight polymorphic microsatellites. Samples came from four locations (San Clemente Island (USA), Isla Natividad, La Bocana and San Juanico (Mexico)) from which DNA was obtained. PCR products were size screened on 5% denaturing polyacrylamide gels and visualized by silver staining. Estimators of genetic diversity ranged widely. The number of alleles ranged from 2 to 17, and the observed and expected heterozygosities ranged from 0.224 to 0.694 and from 0.262 to 0.754, respectively. All microsatellites loci were in Hardy-Weinberg equilibrium and in Linkage-Equilibrium. Preliminary results with two microsatellites showed that common alleles are shared between locations with some differences in frequencies, with exclusive alleles in some locations, although in low frequencies. Further results will be discussed in terms of population differentiation. The potential use of microsatellites as a pedigree analysis tool in a restocking experiment, in which *H. corrugata* adults were transplanted, is also being evaluated.

37 DEEP SEA PRAWN RESOURCES ARE VULNERABLE TO SEQUENTIAL DEPLETION - THE MULTIFACETED DECLINE OF DEEP PRAWN FISHERIES IN SOUTH INDIA. S.R. RADHIKA RAJASREE¹, B. MADHUSOODANA KURUP² AND N.MANOCHARAN¹

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The Quilon Bank located between latitudes 8°30'-9°10'N in the continental slope off Kerala support some of the most commercially significant deep sea crustacean stocks in the world. The innovative small and medium shrimp trawlers ventured in to the deep sea prawn fishing in the Quilon bank for the first time in the history of Kerala in November 1999 defying the long held concept that deep sea prawn resources could be harvested only with the help of large trawlers. This endeavor proved successful with the realization of 23426t during November 1999 and March 2000 from 3 harbours and 48675t from 10 harbours of Kerala lasting between September 2000 and April 2001. Among the 15 species of deep sea prawns landed at various harbours of Kerala, the commercial fishery was mostly focused on 5 species viz. *Aristeus alcocki*, *Heterocarpus woodmasoni*, *H. gibbosus*, *Parapandalus spinipes* and *Metapenaeopsis andamanensis* in their order of preference. Due to the encouraging results realized from the deep sea trawling operations during the first year, the deep sea trawl units engaged in trawl fishery showed almost a double fold increase during 2001-02 and consequently there was an exponential increase in the fishing effort. As a result, the deep sea prawn landings showed a drastic decline from 48675t in 2000-01 to 19285t in 2001-02, thus registered a sharp decline to the tune of 60.35% in the landings during the second year.

From the results arrived at on the growth rates of deep sea prawns based on monthly distribution of length frequency collected from commercial landings, it appeared that the growth rate of deep sea prawns are very slow and have high longevity when compared to traditional commercial species from the coastal waters off Kerala. The relative yield per recruit analysis of *H. woodmasoni* also showed that the present level of exploitation has exceeded the optimum exploitation rate in males while the females were subjected to the over exploitation when compared to males. In *H. gibbosus* also, the males were over exploited than females beyond the sustainable level. The deep sea prawn stock therefore may not be in a position to withstand the rapidly increasing fishing pressures exerted in the deeper waters off Kerala and this situation calls for fishing effort management for the sustenance of stock. This paper thus examines trends in catch, recruitment and abundance of deep sea prawns and discuss existing evidence of over fishing and management options.

38 INTERANNUAL VARIABILITY OF MUSSEL (*MYTILUS GALLOPROVINCIALIS*) SEED COLLECTION AND INITIAL GROWTH IN ALFACS BAY (EBRO DELTA, NE SPAIN). M. RAMÓN¹, EVA GALIMANY², MERCÈ DURFORT³

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Mussel aquaculture in Catalonia (NE Spain) is conducted in fixed rafts in the two Ebro Delta bays, Fangar and Alfacs, with an annual production of about 3000 Tm y⁻¹. Traditionally, mussel farmers collect the seed to start with a new culture cycle each year by hanging collector ropes from the rafts from early January to September, as spawning takes place mainly from February to April. Recently, most of the farmers prefer to use the seed that settle directly onto the culture ropes instead of using the collector ones. When using this method, the seed is then separated from the adult mussels at the end of spring-early summer, when adults reach commercial size and the new culture ropes are prepared for another culture cycle. The aim of the present study is to determine the seasonality of seed (>2mm) collection and the variability between years, as well as its growth during the pre-fattening period.

Monthly sampling was carried out from February 2003 to August 2006 in Alfacs Bay. All mussels (adults and recruits) covering a surface of 40cm from the central part of a four meters culture rope were collected. Sampling at the top (just below sea level) and at the end (2m) of the rope was also performed the first year. Individuals were measured to the nearest 1 mm using an electronic calliper or a stereoscopic microscope if mussel size was <7mm.

Results showed that the presence of individuals <5mm are common from April to August. Seed collection peaked just once (April) in 2004 and 2005, with an average mussel length of 10.45 and 6.21mm, respectively. During 2006 at least two peaks took place, one before February and the second one in April. No differences were found in seed abundance between depths. Abundance was similar in 2004 and 2005 but reached higher values in 2006, due to the second recruitment peak. Growth rates were higher during summer for the first two years (around 4-6mm/mo) and in spring 2006 (7-8mm/mo).

39 THE INRAM PROJECT: INTEGRATED RISK ASSESSMENT AND MONITORING OF MICROPOLLUTANTS IN THE BELGIAN COASTAL ZONE. K. RAPPE¹, M. CLAESSENS², E. MONTEYNE³, H. NOPPE⁴, H. DE BRABANDER⁴, C. JANSSEN², J. MEES⁵, P. ROOSE³ AND M. VINCX¹

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The INRAM project is an integrated project funded by Belgian Science Policy in order to detect the risks of micropollutants to the Belgian coastal zone. The transfer of micropollutants of the three Belgian coastal harbours and the Scheldt estuary to, and their contribution to, coastal water contamination and/or pollution will be examined. The selected test/monitoring organisms are representative for the different trophic levels in coastal zone ecosystems and include commercial fish, crustacean and mollusc species. The cellular, physiological and organism level effect of micropollutants will be assessed with resident and transplanted species.

Micropollutants to be analysed in water, sediment and suspended solids are mainly those on the OSPAR list of priority chemicals and on the list of the EU Water Framework Directive. In addition, body burdens of these micropollutants will be analyzed in biota (mussels, oysters, shrimps and flatfish) and linked with in situ biometric and biomarker responses in resident populations. Field samples and in situ studies run over four years (January 2007 – December 2010). The field study allows an identification of potential problem chemicals which will be evaluated through laboratory exposures. Novel analytical techniques, an innovative combination of laboratory and field ecotoxicological studies and extensive ecological assessment and monitoring will be integrated to establish both environmental effects and food chain transfer to man and seabirds of these chemicals. The final result of the project will primarily be a novel approach to integrated monitoring for the assessment of the health of the state of the marine/coastal ecosystem. In this presentation, an in situ field assay with *Mytilus edulis* and *Crassostrea gigas* is presented. Animals collected in the Eastern Scheldt were transplanted to cages at stations situated in the inner harbour of Zeebrugge, at open sea and at a reference site in Oostende. The organisms, exposed for a period of five months (June 2007 – October 2007), are monthly sampled. Growth, condition index and gonad development are recorded. Contaminant tissue concentrations are measured. The experiment will allow an evaluation of the existence of biometric differences between the different sampling stations and a possible correlation with the presence of micropollutants. <http://www.vliz.be/projects/inram>

40 OUTDOOR BATCH PRODUCTION OF *SKELETONEMA COSTATUM* – COMPARISON BETWEEN FRENCH AND DUTCH SALT GROUNDWATER. I. REIS BATISTA^{1,2,3}, J. HAURE², P. KAMERMANS³, M.T. DINIS¹, J. HUSSENOT²

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Massive culture of selected strains of live microalgae represents a fundamental step of spat production in bivalve hatcheries and nurseries because of their use for broodstock conditioning and larvae and juvenile feeding. Around the Bay of Bourgneuf (namely in Bouin) a low cost outdoor batch culture of *Skeletonema costatum* using salt groundwater as culture media has been successfully used for more than 20 years. Saline groundwater is also found in Yerseke, situated in the Province of Zeeland which is responsible for most of the blue mussel production in the Netherlands. The objective of this work was to compare the groundwater from Yerseke and Bouin in terms of its composition, characteristics and potential as a possible culture media for microalgae. A first survey of the two groundwater showed that there are statistical differences in the concentrations of silica, phosphorus, dissolved inorganic nitrogen

(DIN), iron, manganese and salinity, while the pH was not significantly different between the two waters. With the exception of iron, all nutrient concentrations determined were more elevated in the groundwater from Yerseke, whereas the salinity was higher in Bouin. Concerning the nutrient ratio defined by Hussenot (2003) as optimal to obtain a mass culture of *S. costatum* (N:P:Si of 10:5:1) and the mean ratios found in the waters (9.5:4.4:1 in Yerseke and 17.9:9.8:1 in Bouin) we could conclude that both waters seem suitable for the growth of marine diatoms. However in Yerseke the stability of the measured parameters should be evaluated by a more frequent survey. Given the data gathered, tests on the outdoor culture of *S. costatum* were carried out, in Bouin and Yerseke, using only the local groundwater as culture medium, in March and September 2006, respectively. The cultures reached cellular concentrations of 1.10×10^6 cells.ml⁻¹ in Bouin (after 4 days of culture) and 1.05×10^6 cells.ml⁻¹ in Yerseke (after 6 days of culture). Significant differences between the cultivation conditions in both locations were found in the culture salinity and temperature, as well as in the concentrations of phosphorus and DIN. The daily photosynthetic available radiation (PAR), cellular concentrations achieved and silica concentration were not significantly different between the cultures of Bouin and Yerseke. According to the results of Yan & Zhou (2002), salinity values lower than 25 have an effect on the growth rates of *S. costatum*, which could explain the slower growth rate in Yerseke (average salinity of 22) than in Bouin (average salinity of 31.5). These results demonstrated that it was possible to produce the marine diatom *S. costatum* using the groundwater from Yerseke but in order to be able to achieve 10^6 cells.ml⁻¹ in a shorter period of time essays on the benefits of higher salinity should be made.

41 DYNAMIC ENERGY BUDGET (DEB) GROWTH MODEL FOR *CRASSOSTREA GIGAS* LARVAE. B. RICO-VILLA, S. POUVREAU, I. QUÉAU, C. MINGANT, R. ROBERT.

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Dynamic Energy Budget (DEB) theory aims to quantify the energetic framework of an individual organism as a dynamic model from the uptake of food to the utilisation for metabolic processes (maintenance, growth, development and reproduction). The only difference between species lies in a different set of parameters values used in this energetic model. The objectives for the present study were (1) the estimation of these DEB parameters and (2) the construction of an energetic model for the Pacific oyster *Crassostrea gigas* in its larval life stage. A methodological procedure was developed to calculate the primary parameters values (e.g. shape coefficient, maximum ingestion and assimilation rate, maintenance costs, Arrhenius temperature) from available laboratory data in terms of ingestion and growth for larvae related to phytoplankton densities (lean, restricted and ad libitum diets) and temperature (17, 22, 27, 32°C) as environmental factors, as well as the compound parameters (maintenance coefficient, energy investment and conductance) from starvation experiments. All calculated parameters for oyster larvae followed the physiologic al statements of the DEB theory: ingestion rate depended hyperbolically on the available food density; shell length growth and uptake rate showed an Arrhenius relationship; structural body scaled with larval size to the power three. This set of parameters allowed to generate a DEB model to simulate successfully the growth for larvae by means of the dynamics of the energy budget under different environmental conditions. These simulations illustrated an efficient tool which can be applied to explain larval development in various shellfish ecosystems.

42 TRIALS ON PACIFIC OYSTER (*CRASSOSTREA GIGAS* THUNBERG, 1793) REARING IN THE MIDDLE ADRIATIC SEA BY MEANS OF INNOVATIVE TRAYS. A. RONCARATI, A. FELICI, A. DEES, L. FORLINI, L. GENNARI, P. MELOTTI

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The yearly production of *C. gigas* in Italy has estimated in less than 500 t whereas the domestic demand is about 10,000 t. Imports to the Italian market seem to increase (+6% in 2006 compared to 2005) with a general upward price trend (€2.70-2.99/kg). Based on these interesting possibilities, an increasing number of Italian shellfish farmers is turning their efforts to the rearing of the Pacific oyster. The aim of the present work was to compare the growth of Pacific oysters juveniles reared with the suspension technique using two different types of trays fixed to long-lines of a mussel farm located along the middle Adriatic coast in front of San Benedetto del Tronto, far away 1.7 mile from the seashore.

The trial started on July 2006 when 25 000 oysters juveniles (weight 2.22g; length 26.8mm), were distributed in two different types of PVC trays: thesyp EXP, consisted of innovative 5 circular polymer trays with a diameter of 60cm and 9cm deep and thesyp CON represented by 10 PVC round units placed one upon another, of 40cm diameter and 8cm deep. Culture density was at 0.03oysters/cm² in both the types of systems. Morpho-biometric parameters and mortality rate were periodically monitored. Contemporarily, physico-chemical water quality was monitored. On harvest (April 2007), growth performance and death rate were calculated and proximate composition and fatty acid profile of oysters of the two batches determined.

After 9 months, no significant differences were showed between the main biometric parameters: weight ranged between 67.13g (EXP) and 64.5g (CON); length varied between 98.89mm (EXP) and 94.2mm (CON); width and height were comprehended between 60.01mm and 29.9mm (EXP) and 59.12mm and 28.52mm (CON), respectively. On the contrary, important differences were noted in terms of mortality rate that was higher in CON group (9.2%) compared to EXP batch (2.8%) demonstrating the good efficiency of the innovative type of tray to rear the Pacific oyster.

The chemical composition (moist flesh weight basis) of the oysters grown in the two types of trays was similar: protein ranged between 8.82±0.76% (EXP) and 8.91±0.97% (CON) whereas fat varied between 2.25±0.15% (EXP) and 2.36±0.35% (CON). The polyunsaturated fatty acid fraction was predominant followed by saturated and monounsaturated categories in both the batches. The fatty acid mostly present was C22:6n3 (23.78% in EXP trays; 23.42% in CON trays), followed by C16:0 (17.96% in EXP trays; 18.21%

in CON trays) and C20:5n3 (13.63% in EXP trays; 13.56% in CON trays). The n6/n3 ratio resulted 0.25 in both the groups of oysters. This trial was supported by SFOP Fund - Marche Region, Project n.06MI050505.

43 CURRENT STATE OF KING-SCALLOP FISHERY IN THE GALICIAN RÍAS UNDER THE HARMFUL ALGAL BLOOM THREAT. A. SÁNCHEZ-MATA¹; J. MOLARES¹ A.G. SÁNCHEZ-MATA^{1,2} & T. VARELA^{1,2}

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Scallop fisheries are worldwide valuable resources which require monitoring and protection to maintain sustainability. Their potential may be enhanced by good fisheries management together with the introduction of aquaculture techniques to rejuvenate stocks (Bartley and Bell, 2006). Throughout the world there is a growing commitment to the preservation, maintenance and restoration of coastal ecosystems and there is recent evidence worldwide of success in scallop stock enhancement, using combinations of fishery management and aquaculture (Fleury et al., 2003; Marsden and Bull, 2006).

Shellfish toxins such as amnesic and paralytic shellfish poisons (ASPs and PSPs) occur regularly inking-scallop harvested areas from Galician waters with both groups responsible for periodic harvesting bans on human health, domoic acid being responsible for closures in the majority of Galician scallop fisheries for the last decade. Although the main effect of harmful algal blooms is to human health, they can be the cause of mortalities among fishes and invertebrates, including smothering of stocks as the bloom sinks to the sea bed (Chauvaud et al., 1998). Scallop species are also considered sensitive to species that produce toxins. The toxin effects on the king scallop (*Pecten maximus*, L., 1758) galician fishery brought together a dramatic economic loss since at present most scallop fishing areas remain closed.

For a first ecological approach on the knowledge of galician scallop populations status, scallop grounds were mapped at Ferrol, Ares, Muros, Arousa, Pontevedra and Vigo, the six major Galician rías so as to set the scallop-bank dimensions, stock distribution and harmful algal toxin effects, as a first step to evaluate damages and find solutions to enhance this fishery and in a trial to remediate this situation.

Scallop natural populations were mapped by means of a conventional scallop-dredge. Data on scallop density, biomass, size, weight and biotoxin content were recorded and GIS mapped. Scallop abundance was first used to identify and quantify scallop bank dimensions at each ría. GIS charts on scallop density and biomass distribution jointly analysed with water and sediment environmental variables were relevant to determine which areas assembled the best conditions necessary for the king scallop growing to commercial size.

Scallops have been shown to have relatively long depuration times for algal toxins, which could be an important factor in area selection for re-stocking and / or aquaculture activities since long or frequent regulatory closures to harvesting have a significant negative impact on economic viability.

44 FRESH WATER BIVALVES PROTECTION STRATEGIES. A. SAXENA

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In fresh water land locked states of India the culture of Indian and exotic carp is very popular. For culture of these finfish in management practices the molluscs are removed. Though in wild ecosystem they are an integral part of complex food webs. Fresh water bivalves have certain natural adaptations for their protection as they bury themselves, to ensure their young means not to sweep with downstream they retain their eggs with in shell. The larvae attach to the fish. Formation of cyst is another reproductive strategy for protection and survival. But because of manmade obstruction sand destruction these are struggling. To maintain them in a habitate in optimum the awareness is important and their hatchery production is required for their optimal use.

45 RESEARCH PROGRAM FOR SUSTAINABLE SHELLFISH CULTURE (PRODUS). A.C. SMAAL, J.W.M. WIJSMAN, J. JANSEN, P. KAMERMANS & F.E. FEY-HOFSTEDE

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Dutch shellfish industry and the Ministry for Agriculture, Nature and Food have given a contract to a consortium headed by IMARES for a research program on sustainable shellfish culture. The program runs for 5 years and started in 2005.

The program is focused on the following issues

- Mussel culture yield and culture practice

The approach aims at quantifying stock and yield of mussel bottom culture in relation to mussel culture techniques. Annual field surveys are conducted to quantify the mussel stock on culture plots in autumn, and an electronic logbook has been introduced to the farmers in order to have quantitative data on mussel transfers. These data will be integrated into a production model that should give insight in the critical factors in the culture process and in the net impact of mussels culture on the total stock, hence in food availability for birds

- Stability of mussel seed resources

Mussel seed is derived from natural sublittoral seed beds and the fishing strategy is focused on unstable beds to be fished prior to winter storms. Research is focused on the factors that determine stability of mussel beds and includes field surveys of seed stock and

distribution in spring and autumn. A specific study will focus on the role of predation in mussel seed bed survival. Data will be integrated in a habitat model.

- Innovation in mussel seed collection and growout

New techniques for mussel seed collection are being developed by the shellfish industry and research is focused on yield per type and unit of collector system, spatial variability and environmental impacts. Also growth and survival of seed from various sources (bottom, rope, hatchery) are being tested as a function of location and predation.

- Impact of mussel seed fishery on sublittoral biodiversity

Fishery for mussel seed is normally carried out in autumn and spring on natural seed beds in the western part of the Dutch Wadden Sea. As most beds are fished there is no unfished reference area, hence fishery impact on mussel recruitment, sediment and species composition of the benthic community is largely unknown. Research is carried out by analyzing impacts in a number of closed and open areas following a BACI approach. In 2008 a large scale field study will be conducted to address species richness over a bay wide scale, that will include mussel seed areas, mussel culture plots and other sublittoral habitats.

- Cockles: from fishing to farming

Cockle fisheries is nowadays restricted to handraking in most areas and mechanical fishery in the Delta area if stock size exceeds food reservation levels. Therefore there is an interest in development of cockle culture. An experimental approach will start in 2008 in the Oosterschelde. Spat from elsewhere will be seeded on tidal flats in the Oosterschelde and a monitoring program will be conducted of cockle growth and survival, and impact on sediment, benthos and birds. Laboratory based studies will focus on spat collection, acclimation and survival.

- Carrying capacity for exploitation

46 EXPLOITATION CAPACITY FOR SHELLFISH IN THE OOSTERSCHELDE ESTUARY (SW NETHERLANDS): THREATENED BY THE INTRODUCED PACIFIC OYSTER ? A.C. SMAAL * & J.W.M. WIJSMAN

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The Oosterschelde estuary (SW Netherlands) has been in use for oyster and mussel bottom culture for over 100 years. Mussel culture is done on 2250 ha culture plots and the annual yield varies from 20 – 50 million kg fresh weight. The culture of flat oysters (*Ostrea edulis*) suffered from severe winters and *Bonamia* disease, and has stopped; instead the actual culture species is Pacific oysters (*Crassostrea gigas*), cultured on 1550 ha bottom plots with an annual yield of 3 million kg. In contrast to expectations the Pacific oyster has reproduced and is now spreading over the whole area, and also to other areas like the Wadden Sea. The wild oyster has colonized intertidal flats and coverage increased from 15 ha in 1980 to over 800 ha in 2005. Growth of cultured mussels and oysters recently showed a dramatic decrease, and the research question is what factors can explain the decrease in growth and yield of the existing shellfish culture with special focus on the impact of the wild oysters on the systems carrying capacity.

Standing stocks of benthic filter feeders in the Oosterschelde is 4.8 million kg ash-free dry weight (14 g/m²) with limited variation over time. The oyster stock has increased, and the cockle has slightly decreased. Mussel stock consists of mussels on culture plots, there is hardly any wild mussel stock. The estuary is dominated by the benthic filter feeders, and the clearance time (time to potentially filter the whole waterbody) is 5 – 10 days. Water residence time is 50 – 100 days, hence the filter feeders have a large impact on internal nutrient dynamics.

Based on data of mussel landings, flesh content of mussels is decreasing since 2002. Also lower oyster growth rates are reported by farmers. As no routine growth trials are carried out, we started a growth measurement program in 2005 in the framework of the EU Keyzones project. Indeed relatively low growth rates were recorded particularly in 2006.

Data on food availability show average chlorophyll values of 5 mg/m³, 1-2 g/m³ POM and up to 20 g/m³ TPM. There was no clear trend in food availability over time but primary production has decreased since 1996. Nutrient concentrations do not show a trend but there has been a slight increase in turbidity.

It is hypothesized that the decrease in mussel and oyster growth is related to direct and indirect impacts of the expansion of the Pacific oyster. The oysters colonize former cockle beds and mussels on culture plots and the large filtration capacity may induce a shift towards dominance of smaller phytoplankton species, hence a decrease in food availability for the filter feeders and increased food competition.

47 OYSTER RECRUITMENT AND SURVIVAL ON CONSTRUCTED SANCTUARY REEFS IN CHESAPEAKE BAY SUBESTUARIES. M. SOUTHWORTH, J. WESSON, J.M. HARDING AND R. MANN

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Oysters create and maintain their habitat. Habitat construction would therefore appear defensible as a tool in oyster resource restoration. Indeed, shell planting has been actively pursued in the mid Atlantic states for at least 150 years. Shell plantings have, however, been driven by commercial rather than restoration purposes. In the Chesapeake Bay the first dedicated shell planting for restoration and in a three-dimensional design was constructed in the Piankatank River in 1993. The philosophy of reef construction was that provision of substrate would encourage oyster recruitment in high concentrations, that the initial absence of oysters would result in predominantly disease free populations, that the vertical relief would facilitate oyster growth and survival, that resulting high densities of oysters would improve fertilization efficiency at spawning, that oyster populations would increase with subsequent generations throughout a positive feedback loop, and that robust, self sustaining populations would prevail to improve ecological services, provide complex habitat, and improve water quality. Additional reefs were constructed in the Great Wicomico, Coan, Yeocomico, and James

Rivers, and Lynnhaven Bay. Recruitment was modest at 50-70 oysters m⁻². Endemic diseases became established. A modification in restoration strategy was adopted when the Great Wicomico reef was provided with supplementary broodstock in December 1996. A remarkable recruitment event followed in 1997 (Southworth and Mann 1998, J. Shellfish Res. 17(4): 1101-1114), encouraging an increase in the construction of sanctuary reefs, generally with addition of broodstock. To date over 100 sanctuary reefs of various sizes have been constructed in the Virginia portion of the Chesapeake Bay. We present a critical evaluation of sanctuary reefs with focus on the time sequence and intensity of recruitment post construction, and the survival and growth of oysters from the recruited cohort(s). Recruitment patterns, in both the presence and absence of supplementary broodstock additions, are generally highest in the first year of construction, but exhibit a diminishing recruitment signal in subsequent years. This multi-year signal can be described by a decay function that provides a proxy for substrate quality. Rarely, exceptional recruitment events, such as that observed in 2002 throughout the study region, override this otherwise dominant pattern. In the current environment of disease challenge, variable recruitment, and high mortality, sanctuary reefs have generally not demonstrated the ability to develop and sustain high densities of resident oysters with multiple year class representation over extended periods of time.

48 IN SITU MICROCOSMS, A TOOL TO ASSESS XENOBIOTIC IMPACTS ON *C. GIGAS* SPAT. S. STACHOWSKI-HABERKORN¹, F. QUINIOU², M. NEDELEC³, R. ROBERT⁴, G. LIMON⁵, D. DE LA BROISE¹

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The effects of the herbicide Basamaïs® (bentazone) and the fungicide Opus® (epoxiconazole) were assessed on *Crassostrea gigas* spat during two field experiments of 13 and 9 days, using in situ microcosms. Spat used in experiments A and B were 6 and 12 weeks old (mean size of about 1000µm and 1750µm, respectively). Spat were collected on PVC plates, and immersed in glass bottles filled up with 200µm filtered seawater. Bottles were maintained 6m depth underwater and the water in bottles was changed every other day. While no growth difference occurred between control and pesticide treatments at 10µg.L⁻¹, oysters treated with a mix of 10µg.L⁻¹ Opus and Basamaïs showed a 50% significant growth reduction compared to the control (Mann-Whitney, p<0.0001), suggesting a synergistic effect of contaminants. Laboratory controls, based on spat maintained in a tank with natural seawater and submitted to natural filtered light, were not significantly different from in situ controls, for mortality (32.5% ± 14%), organic weight content (21% ± 7%) or growth (121% ± 5.6%) (Mann-Whitney, p>0.05). This original in situ experiment in microcosms allowed us to conclude that: 1. Oyster spat can be kept in natural local conditions for about two weeks without food supplementation, exhibiting growth and low mortality. 2. This microcosm system is reliable and easy to use for environmental toxicity tests with *C. gigas* spat, in spite of the fragility of such early stage organisms. 3. Such microcosm system can be run in a lab thermostated tank instead of immersed field experiments, more difficult to handle. 4. Synergistic effects observed here, at a concentration sometimes observed for some pesticides during high agricultural run-off events, suggest that pesticide impact could be a real threat on oysters in estuarine areas.

49 REVIEW OF THE ATLANTIC STATES MARINE FISHERIES COMMISSION'S ROLE IN MANAGEMENT OF WESTERN ATLANTIC COAST SPECIES - EMPHASIS ON MOLLUSCAN SHELLFISH HABITAT. L.L. STEWART

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The Atlantic States Marine Fisheries Commission is a U.S coastal management authority for over 26 species ranging from Maine to Florida. ASMFC committees address policy and information documents for guidance in the conservation, exploitation, and habitat protection of fishery populations. A recent publication, "The Importance of Habitat Created by Molluscan Shellfish to Managed Species along the Atlantic Coast of the United States", describes shellfish habitats and their varied ecological value, categorized by reef-forming species, aggregations of living shellfish, shell hash accumulations, and ecosystem services provided to various fish life stages. The status of environmental conditions for over 10 molluscan species and relations to recruitment/growth success of 20+ marine and estuarine fish species is presented. The aspects of shellfish aquaculture, with increasing seabed utilization, are to be analyzed for contribution of niche habitat and 3-D structure enhancement in coastal embayments.

50 CARRYING CAPACITY OF SHELLFISH CULTURE IN NORWAY. Ø. STRAND¹, J. AURE¹, T. STROHMEIER¹, L. ASPLIN, C. BACHER², P. CRANFORD³, S. RUNE ERGA⁴, J. GRANT⁵, C. KROGNESS¹, R. ROSLAND⁴ AND A. SMAAL⁶

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The utilization of the Norwegian coastal zone is rapidly increasing and the aquaculture industry faces the challenge of competing for

space with other users. To effectively take the advantage of available areas it is thus necessary to realize Norway's potential for aquaculture. Farming and sea ranching of suspension feeding shellfish (*Mytilus edulis*, *Pecten maximus*, *Ostrea edulis*) is a growing industry, and its development in Norway is dependent on sound management that must be based on targeting market demands on quality. This requires scientific knowledge on ecological interactions related to bivalve production, both on carrying capacity estimations and measures for localization of farming. Shellfish farming is mainly located in coastal fjord systems, of which there is extensive knowledge that could be integrated in the management of the mussel industry. There is a need to integrate our ecological knowledge and modeling practice in fjords with the international expertise on modeling of bivalve eco-physiological and particle dynamics. This poster presents the ongoing CANO project (Carrying capacity in Norwegian Aquaculture – WP2) that aims to provide scientific knowledge, competence and modelling capacity that can meet the demands on assessments of carrying capacity of bivalve suspension feeders, and provide practical application of this expertise to develop a culture management system for Norwegian coastal waters.

51 MUSSEL COLLECTORS IN THE DUTCH LANDSCAPE. M.R. VAN STRALEN¹, D.M. PARLEVLIET ¹, H. SMIT ², J. DE JONGE ² EN H. LUISMAN²

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In the Netherlands the largest part of the mussel production takes place in bottom cultures. The necessary seed is fished in autumn and spring on wild beds in the Wadden Sea. The availability of mussel seed is highly variable due to the annual fluctuations in spat fall. During the last decades mussel seed became increasingly scarce as fishing areas were lost due to more restrictive nature regulations and the construction of the Delta-works. The mussel industry responded to this increasing scarcity by importing mussel seed from abroad and by developing innovative techniques. These techniques utilise ropes or nets suspended in the water column to “catch” suspended seed. Experiments with these mussel collector systems in the Netherlands started early 2000 and were subsidized by the Dutch Government. The results of these experiments are so promising, that the industry now wants to expand the experiments to a commercial scale.

In a highly populated country like the Netherlands, the space for expansion is limited. People are also concerned that the floating systems will negatively influence the currently still quite serene landscape views. The classic response to this problem is that the systems must be invisible (submerged) or that the floating boys must be in the colour “rain clouds grey”. This approach, however, conflicts with the visibility demand for boating.

In stead of taking a defensive point of view in which the floating systems must be “invisible:” it is possible to choose an offensive approach. In this approach the main question is: How can the floating systems be designed so that they are a part of the landscape, as a new and appreciated addition to the Dutch landscape, like other human activities found there place in this landscape of open water, dikes, wind mills and open skies. To explore the possibilities a creative workshop was organized with landscape architects and local artists who had a strong affinity with the landscape and with people from local and national authorities and fishermen. This resulted in a number of attractive ideas and concepts for the development of mussel collector systems and in criteria how to implement them in the various types of open water along the Dutch coast and its estuaries.

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