8th International Conference on Shellfish Restoration

Enhancement and sustainability of shellfish resources

Brest, France, October 2 – 5, 2005

BOOK OF ABSTRACTS

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October 2, 2005, Brest, France

Dear Conference Participants:

It is with great pleasure that we welcome you to the 8th International Conference on Shellfish Restoration (ICSR). Thanks to all of you, we have an array of excellent presentations, round tables, and workshops spanning 3 days. More than 230 presentations from participants in over 28 countries, this meeting has shaped up to be an exciting event and one of the biggest ICSR conferences to date. We hope that you will also take some time to enjoy this beautiful part of Brittany, France.

Brest, located on the western tip of the Brittany peninsula, is home to dramatic landscapes and seascapes. With a long maritime history, Brest is home to several oceanographic / marine research institutions, shipping industry and a naval base. The beaches and towns near Brest offer a glimpse into the rich history, gastronomic excellence, architecture, and life of this region of France.

We also wish to take this opportunity to thank our ICSR 2005 sponsors for their generous support: Centre National de la Recherche Scientifique (CNRS), Conseil Général du Finistère, Florida Gulf Coast University, Institut francais de recherche pour l'exploitation de la mer (IFREMER), Institut Universitaire Européen de la Mer (IUEM), Brest Métropole Océane (BMO), Ville de Brest, Organization of Economic and Cooperative Development (OECD), Région Bretagne, South Carolina Sea Grant Consortium, Virginia Sea Grant Consortium, and the Université de Bretagne Occidentale (UBO). The monetary and in-kind support of these organizations is largely responsible for the depth and breadth of the scientific program that you will experience in this conference.

We hope that this meeting will be a rewarding experience as well as a chance to meet colleagues, make friends, foster collaborations and learn more about the sustainability, restoration and enhancement of shellfish resources.

Thank you again for your participation.

Sincerely,

ICSR 2005 Organizing and Scientific Committees.

ICSR Series

8th ICSR: Oct 2-5, 2005, Brest, France.

7th ICSR: Nov 17-20, 2004, Charleston

6th ICSR: Nov 20-24, 2002. Charleston

5th ICSR: Sep 18-21, 2001, Nanaimo, Canada.

4th ICSR: Nov 15-18, 2000, Hilton Head

3rd ICSR: Sep 29 – Oct 2, 1999, Cork, Ireland

2nd ICSR: Nov 18-20, 1998, Hilton Head

1st ICSR: Nov 20-23, 1996, Hilton Head

ICSR 2005 Conference Overview

Throughout the world there is a growing commitment to the restoration of degraded coastal ecosystems. Major activities of economic importance, such as aquaculture and fisheries rely on the good health of our marine ecosystems. Political pressure by shareholders in the future of the world's coastal seas has renewed public interest in preserving and enhancing coastal biological resources at all levels of government. Scientists and many volunteer organizations have developed successful programs to identify problem areas, recommend improvements, develop scientifically-based restoration tools, monitor progress and evaluate the interactions between environment and biological resources. It is now widely recognized that shellfish resources are fragile and threatened by chronic and accidental pollution, habitat alteration, toxic algal blooms, emerging diseases, invasive species and other pressures associated with ecosystem perturbations.

In this context, the 8th International Conference on Shellfish Restoration (ICSR'05) will provide an opportunity for scientists, government officials, resource managers, users, community leaders, and concerned citizens and the public to exchange information about the biology, ecology and sustainable exploitation of shellfish resources, to discuss approaches to restore coastal shellfish ecosystems through management, enhancement, and restoration efforts, and to share innovative management, ecological, and social approaches toward the restoration of degraded shellfish habitat and the improvement of coastal ecosystem health.

The conference is scheduled for October 2-5, 2005 at the conference Center ‘Le Quartz” in downtown Brest, France, and will consist of invited key note and panel presentations, round table discussions and contributed poster presentations. More than 230 participants representing 28 countries are attending the conference.

Acknowledgements

We would like to thank Geneviève LEGRAND, Sylvie GROS, Jean-René LECOZ, Alphonse CARLIER, Susan FOHS, Caroline BRISKY, Peg FLYNN, Alain LAPONCHE and Marcos SCARDUA, for their help with technical assistance, web design and maintenance, and logistics related to the conference. They have worked diligently for countless hours to help make the meeting a success.

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ORAL COMMUNICATIONS

ASSESSMENT OF SHELLFISH HABITAT AND RESOURCES

MID-TERM (1998-2004) CLAM (*RUDITAPES DECUSSATUS*) AND COCKLE (*CERASTODERMA EDULE*) SHELLFISH RESOURCE ASSESSMENT IN THREE ESTUARIES OF THE BASQUE COUNTRY, NORTHERN SPAIN. J. Bald, A. Borja and I. Muxika

Marine Research Division, AZTI-Tecnalia, Muelle de la Herrera, s/n, recinto portuario, 20110, Pasajes (Gipuzkoa), Spain

Some of the estuaries of the Basque Country (Northern Spain) have clam and cockle exploitation areas, both by professional and recreational shellfishers. Due to the possibility of overfishing, the Department of Fisheries of the Basque Government needs to understand the real situation relating to these populations in order to achieve a sustainable management of these resources. Consequently, since 1998 the Marine Research Unit of the AZTI foundation develops the monitoring of shellfish resources in the Mundaka and Plentzia estuaries. In the Txingudi estuary, the improvement of the water quality in the last decade had led to the opening of the fishery in 2004 (which was closed due to sanitary constraints) and consequently the beginning of the resource monitoring. The main tasks of the resource monitoring in these estuaries are: - The evaluation and cartography of the clam and cockle stock and biomasses. - The establishment of the weigh-size and age-size relationships in order to understand the population dynamics of the resource. For this purpose, a monitoring network of 88, 65 and 25 sampling stations was established all along the Mundaka, Plentzia and Txingudi estuaries respectively. The sampling station is constituted by a 50x50 cm quadrat. The first 15 cm of sediments are sieved trough a 1 mm net and the obtained individuals are conserved in a 4% neutralized formaldehyde solution until analysis in laboratory. The sampling was undertaken in winter and summer. The management measures adopted in the Mundaka estuary have contributed to the sustainable exploitation of clam and cockle resources in this estuary. In Plentzia, the situation of the stock and biomass of clams and cockles achieve an historical minimum in 2003, and in the Txingudi estuary the results obtained seem to indicate an overexploitation of the resource. In the case of these two estuaries the adoption of management measures are necessary in order to reduce the fishing effort.

A MODEL OF THE IMPACT OF FISHING BOTTOM TRAWLS ON THE INVERTEBRATE COMMUNITIES OF THE GREAT MUDDY BANK (BAY OF BISCAY, FRANCE). F. Blanchard,[1] F. Le Loch[2] and R. Vergnon[3]

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Some shellfish resources are overexploited and the stocks depleted. The shellfish resources are part of benthic communities hence are linked to non commercial invertebrate species via biological interactions. These communities are threathened by bottom fisheries (trawlers and dredgers). Hence depleted shellfhis stocks could be more able to recover if the fisheries management would take the whole community into account. Moreover because of conventions (such as the convention on the biological diversity), the biodiversity must be conserved. We have analysed the impact of the trawlers on the benthic communities of the "great muddy bank" (Bay of Biscay, France). Macro-megafauna was sampled with a 2m-otter trawl at two sites: one site heavily exploited and one site moderately exploited (there was no unexploited sites within the area). The diversity of the whole benthic community of invertebrates was compared between sites. Diversity of subgroups of species was also compared between sites. The subgroups were built up according to family, individual size, diet or also according to the potential impact of the fishing gears defined a priori considering the morphological traits of the species: fragile, sensitive and unaffected species (by decreasing order of negative effects). The differences between sites were then related to the fishing effort. Several non exclusive processes could explain these impacts: differential fishing mortality according to size, morphological traits, and/or attraction of opportunist species. A size-based model of the community was built up including these processes. The objective was to test the ability of these processes to explain the differences observed at the two sites. The simulations showed that all the processes quoted were necessary to explain the differences observed between sites. Such analyses, spatial comparisons and simulations with the model, could allow us to define the level of fishing effort within areas that a given community may bear.

ASSESSING THE STATUS AND TRENDS OF NATURAL AND RESTORED SUBTIDAL AND INTERTIDAL OYSTER REEFS: 'TRIED AND TRUE' AND NOVEL METRICS FOR EVALUATING ECOLOGICAL FUNCTION, SUSTAINABILITY AND REEF SUCCESS. L.D. Coen (PLENARY TALK)

Marine Resources Research Institute, SCDNR, Charleston, SC 29412 USA

In the United States and elsewhere, managers and scientists alike have expanded their view that oyster populations, once valued exclusively as a fishery resource, are key elements of their native ecosystems. Specifically, oysters create complex, 3-d habitats utilized by fish, invertebrates, and numerous species of birds and mammals. Dense bivalve assemblages filter large quantities of water, thereby improving water clarity and quality, while also transferring nutrients and suspended sediments from the water column to the benthos. Critical for all shellfish restoration projects however, are explicit goals and appropriate metrics for their assessment. For example, although some ecologically-derived restoration benefits are evident immediately after shell ('cultch') is planted, many come only after oyster populations are well established and functioning at or near natural densities. As with most artificial reef construction projects, shell planting immediately supports an enhanced-assemblage of plants and animals, fulfilling some of the potential suite of 'ecosystem services.' For example, in our South Carolina study, we showed that intertidal reefs constructed of trays filled with shell initially attracted a similar transient assemblage (fishes and invertebrates), when compared with natural, oyster reefs in the same system. Hence, the live oysters themselves may not be critical to establish a simple transient reef community. In contrast, resident associates and the oyster/mussel assemblage require significantly more time to establish themselves (> 5 or more years). Furthermore, some reef-associated services may be fulfilled by other components within the ecosystem, possibly even redundantly. For instance, after removing oysters from intertidal creeks in South Carolina, Dame *et al* (2002) demonstrated biogeochemical coupling benefits were maintained via nekton feeding in creeks. Using inappropriate metrics to assess oyster restoration progress can also be problematic. Palmer *et al*. (1997) previously pointed out the importance of correctly choosing restoration endpoints and Craft *et al*. (1999) emphasized that habitat restoration success should not be solely dependent on the growth/survival of the targeted species. For instance, after two years, restored subtidal reefs in the Chesapeake Bay did not yet support any market-sized (75 mm or 3") oysters, but they did support extensive resident and transient assemblages of organisms, many of which were correlated with oyster size and density on the reefs. Comparing all of our South Carolina natural sites sampled over the last 10 years, market-sized oysters made up less than 10% of all oysters at most sites, with a maximum of 18% at two sites only. Similarly, although oyster-derived filtering rates were low in the young, developing reefs, mussels occurred in large numbers (> 1,000/m^2), potentially providing unrealized benefits, previously not associated with oyster reefs. Nesting sites for resident fish were also evident early as was 3-d structure for numerous decapod crabs. Using our work and that of our colleagues, I identify a set of potential restoration goals and discuss and rank the value of current approaches, sampling/monitoring methods, and associated metrics. I will also discuss the value of natural 'reference' sites when available and revisit the current status of the Oyster Restoration Metrics Working Group's efforts, including the development and implementation of novel sampling methods to assess the functioning and development of both intertidal and subtidal oyster reef habitats, recommending a potential strategy for collaborative sampling across broad latitudinal ranges. Craft, C. *et al*. 1999. Ecol. Appl. 9:1405-1419. Dame *et al.* 2002. Aquatic Ecology, 36:51-65. Palmer *et al*. 1997. Restoration Ecol. 5:291-300.

A COMPREHENSIVE ASSESSMENT OF SOUTH CAROLINA'S INTERTIDAL OYSTER RESOURCES/HABITATS USING HIGH RESOLUTION, MULTI-SPECTRAL DIGITAL IMAGERY FOR MANAGEMENT AND RESTORATION. **L.D. Coen,[1] K.E. Schulte,[1] G.M. Yianopoulos,[1] R.F. Van Dolah,[1] W.D. Anderson,[1] M.W. Vo,[1] M.A. Finkbeiner[2] and W.R. Stevenson[2]**

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The South Carolina Department of Natural Resources (SCDNR) is currently undertaking a state-wide (over 300 km of shoreline) assessment of its oyster resources as part of a multi-year, collaborative effort with NOAA's Coastal Services Center (CSC) and the U.S. Geological Survey. Previously, NOAA and SCDNR developed an approach for analyzing multispectral ¼ m digital imagery acquired by GeoVantage Inc.'s GeoScanner system. The finalized imagery is sent to PhotoScience as digital orthophoto quarter quads (DOQQs) for processing using Feature AnalystTM to derive oyster reef location (presence-absence), areal extent, and 'condition' with respect to the proportion of vertical shell coverage within the oyster bed boundaries. Two SCDNR teams are randomly surveying portions of 60 DOQQs using shallow draft boats at or near MLW for verification of the processed imagery. The field efforts utilize Trimble Pathfinder Pro XRTM surveying units to measure reef length and position, as well as to note oyster density ('strata') and average reef width. A real-time Digital 8mm video is recorded for each reef and is post-processed to determine estimates of percent vertical oyster coverage in defined time segments. Limited helicopter overflights are also being used for areas that are difficult to assess by boat. The post-processed imagery is validated by identifying the number of beds that are correctly and incorrectly identified. This project, when completed, will enable us to be able to: (1) complete future evaluations of oyster resources using high resolution imagery as an integral part of a longer-term monitoring plan to periodically assess changes in the condition of the state's shellfish beds; (2) provide both SCDNR and other interested users with updated maps of oyster resources within South Carolina's coastal zone, and make the detailed imagery available for other possible uses; and (3) focus our oyster bed restoration efforts relative to current state management plans and status and trends analyses.

ESTIMATING SCALLOP DREDGE EFFICIENCY AND BIOMASS OF SOWN POPULATIONS USING REPEATED DREDGE TOWS. M. Fréchette and D. Lefaivre

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Estimating dredge efficiency and actual scallop biomass on leases are key factors to efficient planning of harvesting and of financial aspects of restocking operations. Scallop dredge efficiency must be known, independently of season or site. It is well known that fishing techniques in many cases involve repeated dredging of the fishing grounds. Therefore methods based on the analysis of a single or a limited number of tows are likely not to reflect actual harvesting operations. We present a study based on the analysis of the catch along a series of repeated tows made on zones of different surface area. The decrease of the catch along the series of tows is a function of the number of tows made, of dredge efficiency, of the surface of the zone dredged, and of the uncertainty of the path of the dredge. Knowing the relative surface area of the zones allows us to take into account the effect of surface area of the zones dredged and of variability in the path of the dredge. We applied this approach to a wild Iceland scallop (*Chlamys islandica*) bed located in the northern Gulf of St. Lawrence. The study was made in June 2004, using Digby dredges linen with plastic mesh. We found that dredge efficiency was about 40% and scallop biomass was about 0.2 kg m^{-2} live mass. The experiment will be repeated in 2005, using standard dredges, without plastic mesh. We hope to eventually apply this approach to sea scallops restocking operations in Îles-de-la-Madeleine, Québec.

MANAGING FISHERIES TO PROTECT MARINE HABITATS. C.L.J. Frid. (PLENARY TALK)

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International agreements such as the Convention on Biological Diversity and the Bergen Declaration require conservation of biological diversity explicitly including the structure and functioning of the ecosystem. Many demersal fishing gears have the potential to impact on the biota and physical features of the sea floor. This papers reviews some of these impacts and then considers how fisheries might be managed to provide protection to marine habitats. This is based on a consideration of not just the scientific study of the impacting activities but also consultation with stakeholders as to the acceptability of management measures. It is concluded that a variety of management tools will be required including gear substitution and spatial closures to certain gears.

ECOLOGICAL IMPACTS OF SCALLOP DREDGES: EXAMPLE TO THE BAY OF BREST MAERL BEDS. B. Guyonnet and J. Grall.

Institut Universitaire Européen de la Mer, Université de Bretagne Occidentale, Laboratoire des Sciences de l'Environnement Marin (LEMAR), UMR CNRS 6539 Place Nicolas Copernic, 29280 Plouzané, France

Scallops and other bivalves are harvested in European seas using dredges that have developed into a variety of configurations, as efficiently as possible. A variety of habitat was prospected by fishermen: sandy, muddy or biogenic type. Intensification of these fisheries has concentrated in the productive shallow waters. Impact of scallop dredging concerning habitat, organisms and finally ecosystem will be discussed based on the example of directs impacts on maerl beds of bay of Brest were developed. Concerning habitat, biogenic type such as maerl bed are the most vulnerable. Maerl beds are patchily distributed in European coastal waters and are of international conservation importance. These habitats have also a longer recovery than other types. This vulnerability depends on the intensity and frequency of fishing impacts but also on other anthropogenic and natural disturbances. The major consequences on habitat are the reduction of complexity, displacement of physical structure, alteration of sediment texture, diminution of niche breadth, and destruction of epifauna. Direct impacts on benthic organisms were observed on damage and mortality on by-catch and also on non-capture organisms. Hence, benthic food chains are affected through the predominance of predators and scavengers; this induces consequences on the ecosystem functioning and structure of benthic community with possible reduction in biodiversity and in the ecosystem resilience. Consequently, scallop fishing-induced damage to ecosystem must be more thoroughly considered in fishery management and marine habitat conservation schemes. Thus, it is paramount to create protected areas, reduce fishing efforts, design and develop new gears so as to lower the capture of undersized fish and discards. In addition, more consideration must be devoted to the direct impacts to organisms and sensitive habitats need to an urgent protection.

ECOSYSTEM SERVICES PROVIDED BY OYSTER REEFS: AN EXPERIMENTAL ASSESSMENT. K. L. Heck Jr,[1-2] J. Cebrian,[2] S. P. Powers,[2-1] D.A. Byron,[1] C.D. Foster[2-1] and N. Geraldi.[2-1]

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We began a study in late summer 2004 to experimentally evaluate key expectations of the ecosystem benefits of oyster reef restoration, and to document the spatial scale at which such benefits could be measured. The project relies on a Before-After-Control-Restoration (BACR) design to measure the effects of adding living oysters at historically high densities to shallow marsh creeks in Mobile Bay, AL, USA. Specifically, we are assessing whether differences in water clarity, nutrient dynamics, benthic primary and secondary production and nursery value for fish and mobile invertebrates are associated with the experimentally planted oyster reefs. To date, three months after oyster additions, results show few changes in any of the response variables. However, we expect to begin observing increased water

clarity and enhanced benthic primary and secondary production, as well as increased levels of use by young of the year finfish, shrimp and crabs in marsh creeks containing oysters by the end of the growing season in 2005. Ultimately, we hope our results will help provide a conceptual and empirical basis for making accurate predictions of ecosystem benefits resulting from oyster reef restoration in the Gulf of Mexico.

LONG TERM DATA ON MOLLUSKS: WHAT CAN WE LEARN THAT MIGHT ASSIST IN RESTORATION EFFORTS. J. Kraeuter[1] and S. Buckner[2]

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Long term data sets (>25 years) are relatively rare, but can be instructive as a means to scale restoration expectations. In the past few years we have been involved in modeling exercises that evaluate population dynamics of two species of bivalves relative to environmental changes. These are the hard clam *Mercenaria mercenaria*, a shallow burrowing infaunal organism, and the American oyster, *Crassostrea virginica* an epifaunal reef forming species. Both species have been heavily fished, have suffered significant population declines, and are candidates for restoration activities. The population models are driven by parameters such as temperature, salinity and food levels, and require field verification to be sure that they produce realistic outputs. Verification is best done through the use of long term data sets. Finding and utilizing these data can be a challenge because of changes in personnel or methods through time, but we have two data sets that have been rigorously documented, one for each species. These data allow us to evaluate population abundance, natural mortality, fishing mortality, and recruitment. In addition, the oyster, provides and example of a species that exists along a substantial salinity gradient. Because different ecological process (disease and predation) are important along this gradient, restoration expectations concerning recruitment and survival will have to be scaled with the gradient. The importance of the numbers of annual recruits that can be expected on a large spatial scale for these two species is lower than many expect, and this in turn suggests that sampling schemes and expectations will require adjustment.

HOW HAS TRAWLING ACTIVITIES AFFECTED HABITAT AND ASSOCIATED COMMUNITIES OF THE NORWAY LOBSTER (*NEPHROPS NORVEGICUS*) FISHERIES OF THE NORTH BAY OF BISCAY, NE ATLANTIC? F. Le Loc'h[1] and C. Hily[2]

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Trawling is one of the main sources of disturbance for benthic communities on the continental shelf. The North Bay of Biscay continental shelf and particularly the "Grande Vasière" is an important *Nephrops norvegicus* fishery site, but since the sixty's no studies have focused on the evolution of the sedimentary habitat of the Norway lobster and associated benthic communities. Stratified sampling and a comparative study were developed to describe the spatial variability of the diversity and the structure of the macro- and mega-faunal communities and to test the hypothesis that changes in these communities has appeared since the sixties either under fishing pressure and/or climatic influence. The study was also aimed to uncover if as a feedback effect, these changes can affect exploitation. Multivariate analysis showed that three main macro-invertebrate benthic communities dominated the North Bay of Biscay continental shelf: Ditrupa sand communities towards the open sea, *Dasybranchus gajolae*, *Callianassa subterranea* and *Nephtys caeca* in the central part (muddy sands) and *Cirratulus* sp. and *Ninoe armoricana* in the coastal muds. An analysis based on trophic guilds was performed to help understand the trophic structure. In each community the epifauna was dominated by shellfish and showed less diversity, abundance and biomass in the areas most exposed to fishing. The endofauna, less vulnerable to the fishing gear, seemed not to be affected. Epibenthos, despite its low biomass compared with the endobenthos, plays an important role in fish diets. Results of a comparative study of the communities in 1966 and 2001 with the same methodology suggest changes: sediments became less muddy while benthic communities became less diverse and dominated by more tolerant muddy-sands community. We explained these results with a combination of natural evolution (decade erosion, current changes) and fishing impact. The knowledge of the trophic functioning of benthic communities should lead to better management scenarii of *Nephrops norvegicus* fisheries.

BALANCING OYSTER, *CRASSOSTREA VIRGINICA*, HABITAT ALTERATIONS WITH COASTAL WETLAND RESTORATION ACTIVITIES WITHIN THE BARATARIA ESTUARY, LOUISIANA, USA. E. Melancon

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Louisiana currently experiences 80% of the United State's coastal wetland loss at a rate of 6,475 to 7,770 hectares per year (25 to 30 square miles). The Barataria Basin (and estuary) has the highest wetland loss rate along the Louisiana coast. To help slow this loss, Mississippi River water has been diverted into the Barataria estuary through the Davis Pond Diversion, completed in 2002. The diversion has been operated minimally since its completion, but combined with natural drought, high-rain and wind events have allowed for a better understanding of how oyster metapopulations respond to varying estuary salinity. We have been monitoring a series of five stations along a salinity gradient in the Barataria estuary since June 2002. Oyster metapopulations have responded by experiencing reproductive success and failure, recruitment success and failure, dieing in low salinity and then rebounding with new recruitment as salinity

later increased. The most up-estuary population exhibited the greatest flux with mortality, spawning and recruitment. The two mid-estuary sites exhibited the greatest stability until the spring and summer of '04 when excessive rain and low salinity killed all oysters at one and prevented a spawn and recruitment at both. The two most down-estuary sites had no populations in '02-03 due to prevailing high salinity and established high predator abundance, until the summer of '04 as low-salinity shifted down estuary. The estuary presently exhibits a traditional bi-modal May and October peak in oyster spawning and spat recruitment. This may change to a more fall-dominated event since the greatest availability of Mississippi River water is during late winter through spring and would result in low salinity conditions in the estuary. As oyster habitats change within the estuary, once productive sack-fishery operations may convert to seed-fishery operations.

DOES SHELLFISH FARMING AFFECT THE BENTHIC ENVIRONMENT OF THE BAY OF MONT SAINT-MICHEL? F. Olivier,[1] F. Bouyé,[1] C. Retière,[1] E. Thiébaut,[2] F. Gentil,[3] C. Bonnot[4] and P. Le Mao[5]

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Apart from its special historical interest, the bay of Mont-Saint-Michel constitutes an unique site due to its original environmental features related to extreme megatidal conditions (up to 15.5 m during equinoctial tides). Through the ages, humans have always used the benthic resources of the bay but shellfish farming has developed more recently with an annual production actually estimated to 16000t.year-1. Oyster and mussels cultures are mainly located under the mean tide level either on tidal flats (*Mytilus edulis* and *Crassostrea gigas*) or on shallow subtidal areas (*Ostrea edulis*). In 2003, shellfish farmers have been authorized to modify deeply the diagram of their concessions. Consequences of such a project on the general ecosystem functioning through direct alterations of natural benthic community structure or indirect modifications related to the proliferation of the invasive species *Crepidula fornicata* remain unknown. In order to assess such anthropogenic influence and because of the paucity of available data, macrozoobenthic communities potentially affected by shellfish farming have to be firstly identified and described. In spring 2002, we sampled 38 stations along 8 transects crossing decreasing isobaths from mean tide level to 6 meters below the 0 chart datum. Seven contrasting benthic assemblages were discriminated through cluster and MDS analyses; their spatial distributions were closely correlated with tidal depth and sediment texture, following a double gradient seashore and West-East in the bay. All the benthic assemblages associated with shellfish structures belonged to the *Abra alba* community. Further multivariate analyses on macrofauna directly associated to shellfish farming show that: 1) the structure of the intertidal *Ampharete acutifrons* assemblage seems to be mainly controlled by environmental parameters and not by cultivating practices; 2) the *Ostrea edulis* farming modifies extensively the structure of the subtidal *Sthenelais boa* assemblage in relation with its production cycle (total abundance and species richness decrease after oyster dredging) and with the concessions history (old vs recent parks); 3) *Crepidula fornicata* appears to be an engineer species controlling the composition and the structure of subtidal benthic assemblages which tend to evolve to a muddy heterogeneous coarse sediments community, decreasing the habitats diversity of the bay. Future impact of the shellfish farmer project on other natural assemblages will be discussed in the light of the present results.

STUDIES AND STOCK ASSESSMENTS OF JAPANESE CLAMS *RUDITAPES PHILIPPINARUM* IN THE GULF OF MORBIHAN, THE ARCACHON BAY AND THE VILAINE RIVER. I. Peronnet,[1] N. Caill-Milly,[2] M. Salaün,[1] J. Dimeet[1] and M. N. de Casamajor[3]

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In the Gulf of Morbihan, the Arcachon Bay and the Vilaine river, the Japanese clam (*Ruditapes philippinarum*) constitutes a neonatural population resulting from the aquaculture experiments carried out in the years 1980. The species found locally favorable conditions to a good development and became a new richness for these areas since it allowed to generate an important fishing activity. According to zones', its exploitation is carried out with dredge or by hand and is framed by measures of management such as licences, creation of areas of reserve, set up of quotas or determination of allowed fishing periods. By the side of these measures, other restrictions link to the preservation of the ecosystem can also exist. They come from environment protection directives and concern for example for the Arcachon Bay and the Gulf of Morbihan the protection of the "zoostera" herbaria or the protection of the wintering area of the Brent Goose. In this context and in order to provide required stock information for the structures in charge of the management of these halieutic ressources, Ifremer carried out stock assessments of these sites (since 1996 on Brittany, since 2000 on Arcachon). For a few years and from a point of view of quality process, the sampling protocols set up to evaluate these stocks have been standardized and from now on they are applied to all the sites. They allow: to quantify the biomass in weight and number with their associated variances, to estimate the exploitable fraction of the stock and to chart the indices of abundance. In this presentation, we will describe the strategies and the sampling protocols, present the main results characterizing these production sites and their evolution in relation to the fishing effort declared and show some examples of cartographic representations referring to it. At term and within the framework of

an integrated management of the coastal zones, this type of protocol should facilitate the study of the interactions between the fishing of these littoral species and their environment throughout the utilisation of SIG.

CONSERVATION AND RESTORATION OF OYSTER REEFS: EVALUATING THE SUCCESS OF SANCTUARIES IN THE PRESENCE OF MULTIPLE ENVIRONMENTAL STRESSORS. S. Powers[1] and C. Peterson.[2]

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Dramatic declines in populations of the eastern oyster (*Crassostrea virginica*) are now a universal symptom of estuarine ecosystem degradation along the Atlantic coast of the U.S.A. We sampled 102 oyster reefs within 12 harvest sanctuaries located in estuaries of North Carolina, U.S.A. to evaluate the success of oyster sanctuaries as a conservation tool. Age of sanctuaries ranged from 3 years to 30 years. Measurements of live oyster density, recruitment, abundance of market-sized oysters, and biomass, as well as vertical relief of the reef and disease prevalence and severity showed that 8 of the 12 sanctuaries met criteria for minimal success (defined as persistent presence of large living oysters and recruitment in one of two years). Burial appeared to be the primary cause of failure for reefs in two sanctuaries, poor water quality (low dissolved oxygen) in one, and poor recruitment of oysters in another. Only five sanctuaries were considered successful under commercial fishery success criteria (persistent recruitment and sustained density of market-sized oysters in excess of 30 m^{-2}), but six met criteria for ecological success (persistent recruitment and oyster biomass > 3.0 kg m^{-2}). Restoration of intertidal oyster reefs had a success rate of 100 % under all three criteria, whereas subtidal restoration ranged from 15 – 40 % depending on criteria used. Disease prevalence and severity were not elevated with high density and longevity of oysters in sanctuaries and disease infections were generally not intense enough to induce mortality. Evaluation of previous restoration efforts of the native eastern oyster and pronouncement of failure proves incorrect when a decade-long history of oyster reef sanctuary success is evaluated and when a broader definition of success reflects the provision of ecosystem services by oysters.

OYSTER ABUNDANCE AND SIZE STRUCTURE AS ECOLOGICAL METRICS FOR EVALUATING SUCCESS OF OYSTER REEF HABITAT RESTORATION IN VIRGINIA AND SOUTH CAROLINA, USA. P. Ross,[1] L.D. Coen[2] and M. Luckenbach.[1]

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Most U.S. states along the Atlantic and Gulf of Mexico have operated some form of oyster reef enhancement program over the past 50 years. Efforts were initially directed solely at oyster fisheries augmentation; however, more recently, emphasis has shifted to include restoration of ecological functions. A review of published abstracts and presentations at shellfish meetings over the past five years reveals more than 300 presentations related to oyster restoration, with fewer than 25% focused only on oyster fishery restoration. Unfortunately, nearly all these efforts lack well defined 'success criteria', with progress often judged solely using fisheries-based metrics such as the abundance of market-sized oysters. Broadly applicable and practical criteria for assessing the ecological success of oyster restoration efforts are needed in support of these ecological restoration efforts. Details of the relationships between oyster population structure and oyster reef ecology are crucial to understanding the reasons behind success or failure so that future efforts can be optimized. As a preliminary step, we discuss findings in Virginia and South Carolina, USA, regarding the value of potential restoration metrics using data from several different systems, studies, and approaches. Results of these studies reveal pair-wise positive correlations between the diversity and abundance of some important reef-associated species and the abundance and size structure of oysters. They do not indicate that market-sized (76 mm) oysters are requisite for supporting an abundant and diverse community. Until we are able to develop a more thorough understanding of the individual species interactions and mechanisms linking oyster populations reef community attributes, we propose that oyster abundance and size structure (but not necessarily the abundance of market-sized oysters) currently provides the most assessable quantitative measure of restoration success across broad geographic areas and in substantially different marine systems.

MULTIVARIATE APPROACH TO UNDERSTANDING SPATIAL VARIABILITY OF OYSTER-REEF COMMUNITIES. G. Tolley, A. K. Volety and M. Savarese.

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When monitoring and assessing oyster-reef habitat it is important to understand the spatial variability of associated organisms. How comparable is community structure among different sites within an estuary or between adjacent estuaries? To address these questions, multivariate techniques were employed to analyze decapod and fish abundance data collected during three wet and three dry months at three oyster reefs located along the salinity gradient (upper, middle, lower) in three Southwest Florida estuaries-the Caloosahatchee River and Estero and Faka Union Bays. Cluster analysis revealed that community structure present at the upper station for each estuary was distinct from middle and lower stations. Multidimensional scaling provided supporting evidence with samples from upper stations occurring in a group easily separable from middle and lower stations. To examine the relative contributions of intra- and inter-

estuarine variability in community structure, a two-way crossed analysis of similarity was performed with system and season as factors. Although Caloosahatchee samples overlapped those from Estero (R = 0.61) and Faka Union (R = 0.49), they were clearly distinct; in contrast, Estero and Faka Union samples were barely separable (R = 0.20). Analysis of similarity percentages identified *Eurypanopeus depressus*, *Gobiosoma robustum*, and *Panopeus* sp. as typical of the Caloosahatchee; Estero and Faka Union estuaries were typified by *E. depressus*, *Petrolisthes armatus*, and *Panopeus* sp. Comparing locations within estuaries, upper stations were well separated from middle (R = 0.87) and lower (R = 0.95), which, although separable from one another, exhibited considerable overlap (R = 0.46). Species contributing the most to similarity among stations included *E. depressus*, *G. robustum*, and *Gobiesox strumosus* for upper stations*; E. depressus*, *P. armatus*, and *Panopeus* sp. for middle stations; and *P. armatus*, *E. depressus*, and *Panopeus* sp. for lower stations. Regionally, community structure of oyster-reef associates may exhibit greater variability within an estuary than between estuaries.

METHODOLOGICAL APPROACH FOR IDENTIFYING AND EVALUATING NEW AREAS FOR SHELLFISH FARMING IN THE MAGDALEN ISLANDS (QUEBEC, CANADA). G. Werstink, G. Tita and J. Wilson.

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Shellfish farming is a relatively recent activity in Quebec, but rapidly growing since the late '90ies. Its steady and progressive development is based on the research and development of new technologies, as well as on the utilisation of new coastal areas. The latter are identified according to criteria and methods presently ill defined. However, in order to ensure a sustainable development of this industry, as well as an efficient coastal zones integrated management, it is of the greatest importance to develop rigorous approaches for selecting new farming areas. Their selection is indeed a process that may significantly affect farms' ecological and economical viability. In this regard, we here propose a method for identifying and evaluating areas with shellfish farming potential. This method couples a geographical information system (GIS) to a multicriteria hierarchical analysis (MHA). The former provides a numerical spatial platform, whilst MHA relies on an objective procedure enabling a qualitative evaluation of the different areas. As a case study, we applied this approach to the Magdalen Islands coastal areas where a further significant shellfish farming development is predicted. Mussel and scallop farming were aimed, as well as scallop seeding activities. Interviews to farmers and scientists were performed to select a series of environmental evaluation criteria and determine their respective weighing coefficients to be applied to the MHA. The available biophysical data were then employed to describe and evaluate the different marine sectors. Spatial usage conflicts were also included in the analysis in order to identify exclusion areas. As a result, lagoon and open-sea areas were analysed and plotted as maps showing levels of shellfish farming suitability. Additional numerical indices were generated in order to refine the spatial characterisation. Our study shows that the GIS-MHA combined procedure may be an interesting decision-making support for an integrated coastal zones management.

BAY OF BREST PANEL

SCALLOP FISHERIES IN BAY OF BREST: HISTORICAL CONSIDERATIONS. P. Arzel and S. Fifas.

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Scallop Fishery is a relatively recent activity along the French coasts. Although this species is well known according to its symbolic value, the fishery only started at the end of the 19th century, in the bay of Brest . Rapidly it extended to the southern coasts of Brittany and in the east part of the Channel (Normandy). At the beginning, it is noted a strong variability of the recruitment. In the following times however, a stabilization is noticed. It seems that this phenomena is linked with the thermal evolution of coastal waters.

SHELL DAILY GROWTH RATE ALTERATIONS IN THE SCALLOP *PECTEN MAXIMUS*: EVIDENCE OF NON-TOXIC DIATOM BLOOM NEGATIVE INVOLVEMENT. L. Chauvaud and Y.M. Paulet.

LEMAR UMR CNRS/UBO, IUEM, Place Nicolas Copernic 29280 Plouzané France

In a fluctuating environment, living organisms and particularly ectotherm animals have two alternative ways to survive depending on their locomotion abilities: to escape or to endure. Because of its ability to build a new ring each day, the sedentary scallop *Pecten maximus* (L.) is a good candidate for growth rate analysis, in order to use it as an “eulerian” sensor of environmental variations. In *P. maximus*, we measure the shell daily growth rate of 30 juveniles (age class 1) each year, from 1987 to 2004, and points out two major results: (1) under normal conditions (without toxic blooms), shell growth is mainly regulated by bottom-water temperature, and phytoplankton biomass is not a limiting factor of *P. maximus* growth; (2) blooms sedimentation of non-toxic diatoms have a recurrent negative effect on the diet and growth of *Pecten* juveniles. Finally, we will discus about the negative relation between suspension feeders and the sedimentation of bloom diatom even when biomass of primary producer stay below “eutrophication” threshold.

SCALLOP NUTRITION AND PELAGIC PRODUCTION IN THE BAY OF BREST: WHICH RELATIONSHIPS? A. Donval,[1] L. Chauvaud,[1] A. Lorrain[2] and Y.M. Paulet.[1]

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Scallops are generally considered as phytoplanktotroph bivalves in hatchery, cultured phytoplankton (diatoms and flagellates) is the only food provided. However, surprisingly, assimilation rate estimates, based on production and respiration budget from in the field, and *in-situ* experiments, have shown that wild scallop nutrition does not seem to rely directly on phytoplankton. In the aim to elucidate this apparent discrepancy, new tools have been developed. Firstly, isotopic analysis was performed to identify the trophic sources of scallops living in the bay of Brest. Secondly, different attempts to characterize the *in situ* feeding behaviour of scallops was performed: Seasonal variations of filtration rates and phytoplanctonic biomass uptake was measured using benthic chambers. In addition, analysis of the *in situ* diet of scallop was determined by comparing the phytoplankton composition of water and bivalve stomach content using HPLC pigment analysis. The complementary approaches used in this study provide important insights in scallop ecophysiology. The feeding activity of wild scallops on the phytoplanktonic biomass is not related to the dynamic of the pelagic production in the bay of Brest. The energy obtained from this nutritional source, almost for a part of the year, is far to cope for energetic demand and scallops have to derive their diet from additional food sources. Results acquired from isotopic analysis show great isotopic signature variations among studied organs and seasonal variations, nevertheless a trophic source exclusively composed of phytoplankton cannot account for the observed isotopic values.

MANAGING THE SPREAD OF AN INVASIVE SPECIES IN A COASTAL SHELLFISH FISHERY UNDER ECOSYTEMIC UNCERTAINTY: A COST-BENEFIT ANALYSIS WITH REFERENCE TO THE BAY OF BREST (FRANCE). M. Frésard,[1] J. Boncoeur[1] and J. P. Carval.[2]

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This paper deals with the economic impact of the invasion of a coastal scallop fishery (bay of Brest) by a slipper-limpet (*Crepidula fornicata*) that was accidentally imported some decades ago. This Invasive Alien Species (IAS) is a space competitor for a valuable shellfish stock *(Pecten maximus*) and its spread threatens the sustainability of the scallop restocking program which is operated in the bay. Facing this invasion, the local fisheries committee has initiated a containment project intending to make the restocking program consistent with the IAS presence in the fishery. The issue is complicated by the occurrence of occasional toxic microalgal blooms affecting the scallop fishery, as it is suspected that important IAS removal might increase the blooms frequency in a disturbed ecosystem. The paper presents a model dealing with the social cost of the invasive process, and a methodology for cost-benefit analysis of IAS management, including a possible link between the IAS presence and toxic algal blooms frequency. Based on provisional data, a numerical simulation is proposed as an illustration, and sensitivity tests are presented.

1983-2005: MORE THAN 20-YEAR DEVELOPMENT OF THE KING SCALLOP (*PECTEN MAXIMUS*) SEA-FARMING INDUSTRY IN THE BAY OF BREST (FRANCE): HISTORICAL RECORD, RESULTS, PROSPECT. C. Lambert,[1] P. G. Fleury,[2] J. P. Carval[3] and M. L. Muzellec.[4]

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During the cold winter 1962-63 the King Scallop (*Pecten maximus*) natural stock in the bay of Brest (France) was decimated. As a consequence, the annual production decreased from 2500 metric tons to lower than 100 mt. Faced with the poor results of natural spat collecting in the wild during the 1962-72 decade, first seeding experiments were done in the beginning of the eighties. Finally, fishermen, scientists and politics turned to hatchery technique to produce spat, and set-up new production plan (1983). Spat production increased gradually from 250.000 to 20 million post larvae a year. Intermediate cultures are performed in deep sea cages (30% survival) and seeding of one year juvenile (30 mm) are done either in the fishing areas, either in restricted areas. The setting and the development of this industry was sustained by grants from both the French state, the region of Brittany and Europe in 1993.The programme initially aimed to create a significant breeding stock. But the restocking impact of this stock could not be clearly demonstrated; therefore, in 1989, the juvenile production turned to a sea-ranching programme aiming to support the stock. The Tinduff hatchery has reached a level which allows a significant additional production (250 mt) in the bay of Brest. Since 1996, the industry has been only supported by the self-financing of the Brest fishermen (around 70 licenses x 4500 €). This success of recaptures in the bay of Brest has also aroused a new interest for this type of production and management in the other scallop beds of Brittany and West of France. But, in spite of its success, the industry remains economically fragile, depending on production hazards at each stage of production.

SETTING UP A COLLECTIVE APPROACH TO RESTORE BACTERIAL QUALITY OF SHELLFISH FARMING AREA IN THE BAY OF BREST. P. Masquelier[1] and M. Diverres.[2]

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The estuary of the river of Daoulas in the Bay of Brest suffers regularly from microbiological pollutions, clam shell in particular. This sector is a subject of a special monitoring organized in collaboration with different professionals concerned in 2003. Research group of elected members, technicians, representatives of agricultural sector and professionals of the sea domain meet regularly under the aegis of the Bay Contract of the Bay of Brest. The objectif of this group is to get more information on the pollution sources and to determine casual links with the dysfunctions recorded in shell-fish breeding. The group was created to work out: - a method for determination of pollution sources, - a plan for alert monitoring (follow-up), research of causes, putting observations into the network, information cross-checking, source characterizing on certain events, - a strategy for reducing the discovered pollution sources. A systematic approach by subsectors was applied to the estuary of the river of Daoulas in order to select black points and the most important pollution sources. The following analyses were performed: - Systematic analysis of all the effluents (faecal contamination), - Characterizing of each sub-basin in terms of present activity and sea ratio, - Simultaneous analysis of water and shell (shell-fish) in random weather conditions and in a rainy weather, - Study in order to visualize zones of spread of principal effluents, - Climbing up the river for water sampling and bacteriological analysis.

SCALLOP FISHERY IN THE BAY OF BREST: LOOKING BACKWARD TO PREPARE THE FUTURE. Y.M. Paulet,[1] F. Jean[1] and J.P. Carval.[2]

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More than twenty five years after the first trials of scallop artificial rearing at the Brest University (Marine biology Lab : Pr Albert Lucas), it might be helpful to have a look backward to prepare the future. In seventies and early eighties, the successive programs carried out by Ifremer (called Cnexo until 1984) and the University of Western Brittany, in tight cooperation with fishermen professional organisation, were restocking programs: the goal was to enhance the broodstock size. Indeed, at this time the major hypothesis to explain the very low level of Brest scallop population was a limitation by a lack of genitors in the bay. At the end of the eighties, programs were re-oriented to a real sea-ranching program, where seeded scallops were captured 3 years later for commercialization. These changes must be analyzed in the scientific context of this time, where the environmental forcings on marine population dynamics were re-discovered notably in the framework of the French National Progam on the Determinism of recruitment. During these years, our knowledge in scallops biology and ecology have significantly progressed. Are they sufficient to really improve scallop fishery in the bay ? The communication will look into this question, and will attempt to detect the major shortcomings. Also, the reflection will consider new major challenges unforeseeable twenty five years ago, like the invasion of the bay by the slipper limpet, the tremendous increase of nitrogen inputs and its correlates, and the global changes.

IMPACTS OF FEEDING ACTIVITIES OF THE INVASIVE SLIPPER LIMPET, *CREPIDULA FORNICATA*, ON SILICON CYCLE IN THE BAY OF BREST: THE SILICON BUDGET OF RAGUENEAU *ET AL*. (2002) REVISITED. G. Thouzeau, S. Martin, M. Richard, J. Clavier, L. Chauvaud, A. Donval, F. Jean, A. Leynaert, O. Ragueneau, J. Richard, R. Marc and E. Amice.

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Extensive spreading of an exotic gastropod, *Crepidula fornicata*, has modified the trophic structure of benthic communities in the Bay of Brest by increasing suspension feeder biomass. Subsequently, the following hypotheses on ecosystem functioning were made: *(1)* the decrease of chlorophyll biomass during the first spring bloom would result from silicic acid limitation and increased suspension feeder activity, *(2)* benthic filtration and biodeposition activities would enhance biogenic silica retention at the sediment-water interface, and *(3)* recycling of trapped biogenic silica would maintain diatom populations by providing silicic acid in summer and would reduce primary production seasonality. These hypotheses suggest that benthic organisms control the export rate of biogenic silica towards the open-water ocean and thus the specific composition of secondary phytoplankton blooms in the Bay. A first validation of these hypotheses was made by Ragueneau *et al*.(2002) from core incubations in the laboratory. The results confirmed silicic acid limitation and the role played by Crepidula on BSi retention and subsequent silicate release at the sediment-water interface. During summer, benthic fluxes measured at a site with a high density of *C. fornicata* are one order of magnitude higher than those measured at the site with no *C. fornicata*. Seasonal budgets of Si inputs and diatom demand were then calculated from the core data. However, in situ measurements of silicate release at the sediment-water interface, using benthic chambers, provided much higher fluxes than those measured from core incubations. The causes of these discrepancies, as well as the way seasonal silicon budgets could be modified, will be discussed in this talk.

CHESAPEAKE BAY PANEL

APPLICATION OF SELECTIVE BREEDING TO OYSTER RESTORATION: A UNIQUE STRATEGY OF GENETIC "REHABILITATION" IN THE CHESAPEAKE BAY. S. K. Allen and L. Degremont.

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One of the major impediments to restoration in the Chesapeake Bay is disease pressure from pathogens *Haplosporidium nelsoni* (causing MSX-disease) and *Perkinsus marinus* (causing Dermo-disease) affecting the native oyster *Crassostrea virginica*. Essentially, the problem is this. Wild oysters stocked onto reefs to enhance recruitment succumb to diseases before they reach adult sizes that would enjoy high fecundity. Restoration efforts in Virginia, then, incorporate the use of disease resistant strains to enhance survival and subsequent fecundity. To this end, the Aquaculture Genetics and Breeding Technology Center has a two pronged selective breeding program for developing lines for both restoration and aquaculture – the latter an untested, but potentially valuable adjunct to restoration in the Bay. The first approach is the development of domesticated lines using mass selection following disease exposure for the express purpose of selecting survivors. Presently, ABC has eight selected lines under development along with a unselected control, tested in a variety of location in the Virginia portion of Chesapeake Bay, and in Delaware Bay. The lines comprise germ plasm from a number of sources including Louisiana stocks. The second approach is family based selection where the aim is to identify the genetic bases of traits, the extent of environment x genotype interaction, and correlations among traits, e.g., growth and disease resistance. The family based selection will inform our line development, as well as maintain a concerted selection campaign to develop disease resistant brood stock for commercial aquaculture.

OYSTERS IN LARGE-SCALE RESTORATION OF CHESAPEAKE BAY. L. Bahner.

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Oysters, once the largest fishery in Chesapeake Bay (USA), are being restored to rebuild the fishery and to provide biological filtration to help improve water quality for Bay restoration. The challenges for oyster restoration in Chesapeake Bay include oyster diseases, excess sediments that foul oyster habitat, and low reproductive success. Since 1999, the National Oceanic and Atmospheric Administration (NOAA) has been funding oyster restoration with multiple partner organizations to restore Chesapeake Bay. In 2004, a successful harvest of four inch oysters was largely due to restoration techniques employed in 2001 that reduced disease by building on-bottom oyster bars with clean shell substrate, planting young disease-free oysters on the clean bars, and planting the bars in low salinity waters that would help resist the spread of disease. The current restoration strategy builds on that success and also includes: 1) large-scale bar cleaning to remove diseased oysters; 2) benthic mapping using sonar to assess the quality and quantity of habitat that can be restored; 3) assessing sediment inputs from riverine and shoreline erosion and their impacts on oyster habitat; 4) developing a strategy to reduce suspended sediments; and, 5) developing a strategy to improve reproductive success through large-scale hatchery production of larvae and seed oysters. A new conceptual strategy is being developed that incorporates oysters as a component of large-scale integrated habitat restoration. Conceptually, oyster bars would be used as structural elements to minimize wave energy. Sand from dredging projects would be used to build shallow beaches in-shore of the oyster bars that could then be planted with grasses to minimize shoreline erosion and provide increased wetland habitat. Implementation of such a concept would provide an integrated approach to large-scale restoration of oysters, reduce wave energy and coastal sediment erosion, and provide soft-shoreline wetland habitats for more abundant fish and shellfish.

OYSTER RESTORATION IN CHESAPEAKE BAY THROUGH AQUACULTURE: EXAMPLE OF OYSTER CULTURE USING BAGS FIXED ON RACKS. L. Dégremont and S. K. Allen.

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Diseases, over fishing, loss of habitat have contributed to the sharp decline of wild populations of the eastern oyster *Crassostrea virginica* in the Chesapeake Bay during the last 40 years. As a consequence, ecology and water quality have been modified and oyster fisheries have collapsed. Furthermore, the remaining oyster industry removes the disease resistant (market size) oysters, potentially reducing the genetic variability by continuing to harvest the few wild populations remaining on the oyster bars. In order to enhance both oyster populations and fisheries, two major ways are available. The first is to build oyster reefs, which could be colonized by wild populations or repopulated using selected hatchery strains. Oyster restoration of this sort is currently broadly used in Virginia, but predators like crabs and rays can easily decimate the oysters. The second way is the use of aquaculture techniques. Several techniques are currently used, such as Taylor floats and longline bags, but these techniques do not allow large production, while cages and racks can. Also, only aquaculture methods can be used in order to test stocks. We report here the system of oyster culture used to test stocks in our breeding program, including materials, costs, procedures, maintenance and care used as well as associated organisms and make some projections on their use on a broad commercial scale.

RESTORATION PARTNERSHIPS: BREAKING DOWN BARRIERS TO DEVELOP STRONG PARTNERS. C. S. Frentz.

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The Oyster Recovery Partnership's (ORP) mission to bring back viable oyster populations and its related benthic habitat to the Chesapeake Bay involves close working relationships with various federal, state, business and community partners throughout the watershed. The focus of this presentation is the trust and support developed by the ORP with watermen throughout the Chesapeake Bay region in an effort to incorporate scientific and cost effective logistical restoration techniques which support their commercial interests while complementing the ecological goals of environmental and governmental partners.

STATUS OF THE PROPOSED INTRODUCTION OF A NON-NATIVE OYSTER, *CRASSOSTREA ARIAKENSIS*, IN CHESAPEAKE BAY. J. King.

NOAA Chesapeake Bay Office, 410 Severn Avenue, Suite 107A Annapolis, MD 21403 USA

Decline in abundance of the native oyster, *Crassostrea virginica*, in the Chesapeake Bay has lead to the collapse of a formerly productive fishery and the loss of significant ecological services. Two oyster diseases, MSX and Dermo, have contributed at least in part to the decline, and continue to challenge oyster restoration efforts. In response to this situation the states of Maryland and Virginia have proposed to intentionally introduce a non-native oyster species, *Crassostrea ariakensis*, which has greater resistance to the pathogens responsible for MSX and Dermo. Considerable controversy exists over the proposed course of action and many questions remain about the implications of such an introduction. In 2003 the U.S. Congress called for an Environmental Impact Statement (EIS) to examine both the risks and benefits of introducing this species to the Chesapeake Bay. The EIS is being conducted by the U.S. Army Corps of Engineers, the states of Maryland and Virginia, the U.S. Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Fish & Wildlife Service (FWS). The EIS will consider the following alternatives to the proposed action: 1) No action (status quo), 2) Expand native oyster restoration, 3) Harvest moratorium, 4) Aquaculture of native oysters, 5) Aquaculture of triploid non-native oysters, 6) Introduce an alternative species/strain of non-native oyster, 7) Introduce *C. ariakensis* and discontinue native oyster restoration, and 8) Combination of alternatives. The EIS process is currently in the data gathering and risk assessment phase. In 2004 the NOAA Chesapeake Bay Office initiated a research program aimed at providing the biological and economic information needed to perform these assessments. Numerous scientific studies with *C. ariakensis* are currently underway, following guidance from the National Research Council (NRC) and the Scientific and Technical Advisory Committee of the Chesapeake Bay Program (STAC). This presentation will describe the status of the EIS process, and will provide an overview of the research program.

AN AQUACULTURE APPROACH TO RESTORING CHESAPEAKE GOLD, *CRASSOSTREA VIRGINICA*. T. Leggett, A. Blow, S. Reynolds and B. Goldsborough.

Chesapeake Bay Foundation, P.O. Box 412 , Wicomico, VA 23184 USA

The Chesapeake Bay Foundation (CBF) is the largest regional non-profit education and advocacy organization dedicated to protecting and restoring the Chesapeake Bay. The Chesapeake Bay oyster population has declined by nearly 99% since colonial times as a result of over harvesting, habitat loss and degradation, and oyster disease. The goal for oyster restoration in Chesapeake Bay is a ten-fold increase in the oyster population by 2010. In 1997, CBF began a small-scale aquaculture restoration program by training private citizens and school children to grow oysters and then transplant them onto state managed sanctuary reefs for stock enhancement. The program has expanded since 1997 and has produced over 2 million adult native oysters that were transplanted to state sanctuary reefs. To compliment the oyster gardening program, CBF started a commercial scale oyster farm in 2000, with a goal of producing 1 million selectively bred native adult oysters per year for stock enhancement of Virginia sanctuary reefs. After five years the CBF oyster farm has produced and stocked 4.5 million adult oysters onto state sanctuary reefs. Several small tributaries have shown significant increases in oyster biomass as a result of the small-scale restoration efforts by CBF. Secondary goals of the farm were to promote commercial oyster aquaculture using the native oyster and educating decision makers, citizens and students about oyster restoration and the value of oysters in the Chesapeake Bay. In addition, the farm has been used as a platform for testing and developing new oyster aquaculture techniques and evaluating selected strains of the native oyster for aquaculture. Several commercial oyster grow-out operations have recently begun and interest in native oyster aquaculture continues to increase. CBF is currently working with state and federal agencies and industry to develop a long-term strategy for restoring oysters using aquaculture as the vehicle for restoration.

THE GREAT WICOMICO RIVER OYSTER RESTORATION PROGRAM: A MULTI DISCIPLINARY APPROACH TO RESTORING A COMPLETE ESTUARINE SHELLFISH POPULATION. R. Mann, S.K. Allen, E. Burreson and M. Luckenbach.

Virginia Institute of Marine Science, P.O. Box 1346, Gloucester Point, VA 23062 USA

Restoration of shellfish in a coastal estuary requires knowledge of a large number of site-specific critical quantitative events in the life cycle of the targeted species. Without such information we cannot evaluate the causes of temporal and

spatial variability in the stock – recruit relationship, and hence the efficacy of the restoration protocol. We describe a multifaceted collaborative effort, focused on native oyster (*Crassostrea virginica*) restoration in the Great Wicomico River, a small watershed subestuary of the Chesapeake Bay. The program has seven major elements. These are (1) brood stock development for field deployment through a combination of line breeding in combination with disease challenge, (2) molecular genetics characterization of both the selected lines and wild types in the targeted river system (3) a continuing effort to monitor restoration site oyster disease status (both selected lines after deployment and wild types), (4) monitoring of oyster abundance, demographics and fecundity pre and post deployment, (5) monitoring of oyster larval abundance and recruit abundance post deployment in concert with examination of substrate quality, (6) placing events in elements (3)-(5) in the context of environmental change over the study period, and (7) development of quantitative models of impacts of broodstock addition through population and genetic data. The project web site can be viewed at www.vims.edu/mollusc/NORM.

CIRCULATION IN RESTORATION SITES: IMPLICATIONS FOR RETENTION OR DISPERSAL OF SHELLFISH LARVAE IN RESTORATION PROGRAMS. R. Mann,[1] J. Shen,[1] M. Southworth[1] and A. Erskine.[2]

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The larval form of many commercially and ecologically important bivalves are planktotrophic, remaining in the water column for periods of several weeks. As an example the genus *Crassostrea* has a larval development period of approximately 3 weeks, and is presumed to disperse during this period. However, the primitive molluscan planktotrophic larval form evolved primarily to feed in the plankton; dispersal therefore is a secondary trait. So how far do larvae disperse, and how far do they need to disperse? What are the implications of retention or dilution of larval sources on restoration efforts if the intent is to minimize dispersal in geographic regions of interest? As part of an assessment of potential dispersal of larval *Crassostrea ariakensis*, dye release and tracking studies were completed at 4 sites in the lower Chesapeake Bay (York River, Rappahannock River, Piankatank River and Yeocomico River) in 2004 using fluorescent dye as a surrogate for the larval form. We describe the rates and eventual estimated magnitudes of dye dispersal over time frames commensurate with larval planktonic development in river basins with differing retention characteristics. The eventual «footprints» for recruitment vary between one (minimum) and over ten square kilometers. We discuss how these predicted recruitment signals might relate to both habitat variability and eventual recruitment patterns resulting from point sources of larvae in these systems.

OYSTER RESTORATION IN MARYLAND. K. Paynter and T. Lederhouse.

University of Maryland, 0105 Cole Field House, College Park, MD 20742 USA

Oysters are believed to be an integral part of the Chesapeake Bay ecosystem that has been almost entirely removed during the last century. Stocks are now thought to be less than 1% of historic levels and two diseases threaten rehabilitation efforts. Maryland waters, however, are generally low in salinity, which retards disease virulence and enhances oyster survival. Strategies to restore oyster populations include planting the native species, *Crassostrea virginica*, in high densities in low salinities to create large reef structures and testing a non-native species, *Crassostrea ariakensis*, for disease resistance and reef formation. Restoration efforts to date show that oysters planted in low salinities and protected from fishing will live relatively long lives and create substantial reef structure. These reefs may have far-reaching ecological value. Low salinity reefs protected from fishing experience 10 to 15% mortality annually and grow 2 to 3 cm/yr. When planted densely (250 to 500 seed oysters/m^2) they create substantial and complex benthic structure. These structures, in turn, serve as valuable habitat to a variety of benthic species whose abundances are much higher on restored reefs compared to non-restored reefs. Because these reefs are composed of large animals in dense aggregations, the potential contributions of the oysters in a spatial context (/m^2) may be quite high. Calculations based on literature values for filtration rates, nitrogen removal and larvae production suggest these reefs may filter vast quantities of water, remove ecologically-relevant amounts of nitrogen and produce many trillions of larvae on a per acre basis. These contributions will be discussed in both an economic and ecological context.

STOCK-RECRUIT RELATIONSHIPS IN SHALLOW WATER ESTUARIES: EXAMPLES AND IMPLICATION FOR SHELLFISH RESTORATION STRATEGIES. M. Southworth, R. Mann and J. Harding.

Virginia Institute of Marine Science, P.O. Box 1346, Gloucester Point, VA 23062 USA

Stock recruit relationships are one of a suite a biological reference points commonly used in finfish fishery management plans, yet they are rarely estimated for shellfish populations in either coastal or estuarine conditions. This is unfortunate because they offer valuable information on both fishery catch limits to promote natural resource rebuilding and estimates of required brood stock additions where stock enhancement is planned. We present estimates of stock recruit relationships from long-term population monitoring programs in three subestuaries of differing size and circulation patterns within the Chesapeake Bay ecosystem. These are the James River, Piankatank River and Great Wicomico River. The oyster populations of these rivers are approximately 10^{10}, 10^7 and 10^6 adult oysters respectively. We examine the metapopulation implications of aggregations within the population in explaining the large variance in the predicted recruitment at any chosen stock level, and suggest approaches for (a) estimation of minimum population size for population maintenance and (b) management strategies for a mixture of fishing limitation and brood stock enhancement to support rebuilding and restoration efforts.

ENVIRONMENTAL QUALITY MONITORING AND IMPROVEMENTS

A MULTIPARAMETRIC APPROACH BASED ON IMMUNOTOXIC RESPONSES FOR MONITORING POLLUTED COASTAL WATERS. M. Auffret, S. Rousseau, M Duchemin, J. Baron, I. Boutet, A. Tanguy and D. Moraga.

UMR CNRS 6539-LEMAR, Institut Universitaire Européen de la Mer, Technopôle Brest-Iroise 29280 Plouzané, France

Chronic chemical contamination of coastal waters is a major subject of concern for marine resources management since various alterations generated by physiological stress may compromise optimal stock farming and even, individual survival. As a part of a multidisciplinary programme (EC BEEP project), a three-year study aimed to validate immunological biomarkers in mussels, *Mytilus galloprovincialis*, from three industrial areas known as "hot spots" in Western Mediterranea. The status of the immune system has been assessed by measuring several immunopathological and immunocompetence parameters in spring and autumn samples. Total hemocyte counts, lysosomal stability and phagocytosis were among the most responsive parameters in polluted stations and suggested immunosuppressive conditions in mussels. An immunotoxicological index was calculated from the set of individual data. By providing a single value per sampling station to score immunological alterations in mussels, this novel approach allowed to recognize a gradient of perturbation correlated to pollution intensity in two of three sites monitored. Processing a set of biological parameters by this method was found to increase the ecotoxicological relevance of such multiparametric studies and to provide environmental scientists with risk assessment procedures.

SPACE-TIME EVOLUTION OF THE CONTAMINATION OF THE MOROCCAN ATLANTIC COASTS BY CADMIUM USING THE MUSSEL *MYTILUS GALLOPROVINCIALIS* AS BIOINDICATOR. S. Benbrahim, A Chafik, M. Siefeddine, F. Z. Bouthir, A. Semlali, M. Jayed and M. Ramdami.

Institut National Recherche Halieutique 2, Rue de Tiznit 20000, Casablanca, Morocco

A regular follow-up of seasonal sampling of the mussel *Mytilus galloprovincialis* during 2000-2003, was carried out with an aim of determining the factors influencing the contamination of the Moroccan Atlantic littoral by cadmium. This species of mussel, considered by many authors as bioindicator of pollution, accumulates cadmium and other heavy metals. Results obtained reveal variable Cadmium contents according to sites and seasons. The high values are recorded in the site of Jorf Lasfar in the south of Eljadida and in the site of Jorf Lihoudi around Safi. Sites sampled in the littoral ranging between Eljadida and Dakhla have contents more raised than the sites located in the North part of the country. The rejections of the processing industries of phosphates, the marine hydrodynamics and the upwelling in the southern area would be at the origin of this strong contamination. The samples resulting from the aestival and autumnal periods reveal more important cadmium concentrations in the shells whereas the winter and spring samples show low contents of this metal element.

TROPHIC TRANSFER OF SEDIMENT-ASSOCIATED CONTAMINANTS FROM MICROPHYTOBENTHIC COMMUNITIES TO BIVALVE SPECIES. A. Croxton[1-2] and G. Wikfors.[1]

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This research is examining the possible effects of organic pollutants, acquired through a microphytobenthic, food-web pathway, upon the cellular immune system of eastern oysters, *Crassostrea virginica* – a bivalve that currently is the subject of restoration efforts in the eastern USA. The microphytobenthos is a community of microalgae and cyanobacteria living at the sediment surface in clear or shallow waters where ample light reaches the bottom to support net photosynthetic production. When compared with phytoplankton, microphytobenthic communities are rarely acknowledged for their importance as primary producers in clear, oligotrophic tropical and subtropical coastal seas. Microphytobenthic primary production can constitute an important food source for bivalves, following resuspension by wind or tidal turbulence. As microphytobenthic organisms are displaced into the water column, however, they can also serve as vectors for trophic transfer of sediment-associated pollutants into bivalves, leading to possible tissue contamination or physiological effects. The ability of a bivalve species to «defend» against multiple environmental stresses depends on various aspects of health status; disease resistance mediated by the immune system is especially important in oysters. Thus, physiological effects of contaminants could further decrease survival and production of oyster populations already weakened by diseases. We are conducting laboratory experiments in which cultures of a microphytobenthic diatom are contaminated with selected organic pollutants and fed to oysters. Following these exposures, oyster immune functions are measured, including hemocyte aggregation, oxidative burst, phagocytosis, and viability, all by flow-cytometric techniques. A preliminary laboratory experiment showed measurable effects of environmentally-realistic sediment concentrations of an organic pollutant on immune functions of the oyster. The goal

of this research is to provide new information on the effects of organic pollutants on the immune capabilities of shellfish necessary for survival in areas experiencing chronic or episodic organic contamination and being considered for restoration programs.

METALLOTHIONEIN GENE IDENTIFICATION AND EXPRESSION IN THE COCKLE (*CERASTODERMA EDULE*) UNDER PARASITISM (TREMATODES) AND CADMIUM CONTAMINATIONS. C. Desclaux,[1] P. Gonzalez,[2] M. Baudrimont,[2] J. P. Bourdineaud[2] and X. De Montaudouin[1]

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Among benthic species, bivalves are characterized by their high bioaccumulation capacities for heavy metals leading to metallothioneins (MT) induction. MT are cytoplasmic metal-binding proteins involved in cellular essential metal ion (copper, zinc) regulation and toxic metal (cadmium, mercury) detoxification. These proteins can also be induced by a wide range of other factors, such as hormones, second messengers, physical stress, parasitism, etc… MT quantification in relation to parasitism has never been reported in literature so far, while parasites are omnipresent and have deleterious impacts on bivalves. Despite their use as metallic pollution's biomarkers, only a few number of MT genes were characterized from molluscs. Consequently, the aims of this study were: (i) to determine the MT cDNA sequences of the cockle *Cerastoderma edule*, (ii) to elucidate the MT gene expression levels in cockle in response to metal ions contaminations, and (iii) to quantify the impact of parasitism on these expression levels. In this way, total RNAs were extracted from gills of Cd-contaminated cockles, and were reverse transcripted to obtain a cDNA library. This library was used to identify the cockle complete MT gene sequence and to determine MT specific primers usable in quantitative real time PCR. MT gene expression and MT protein levels were quantified on individuals selected under different conditions: free or infected by the digenean *Labratrema minimus*, and under cadmium exposure at 15µg Cd L-1 or not.

OYSTERS AS A POTENTIAL INDICATOR OF WATERSHED MANAGEMENT SUCCESS. M.S. Jones.

P.W.S Sarasota County, Florida, Sarasota County, 2817 Cattlemen Road, Saraota, Florida 34232 USA

Florida coastal watershed drainage has been altered for development and agriculture. These alterations have often increased freshwater discharge to estuaries resulting in altered salinity regimes. Oysters have specific environmental requirements and are susceptible to fluctuations in the environment. Salinity is a primary factor that affects oyster status. Research has shown that optimal salinity range for oysters is 14-28 ppt. The relationship in freshwater discharge and salinity levels to the number of live and the ratio of live to dead oysters was investigated for Dona and Robert's Bay in Venice, Florida. The numbers of live and dead oysters were counted twice a year from October 2003 through October 2005 within three randomly chosen 0.25m x 0.25m quadrats in six different bay segments of the study area. Available salinity and discharge data was compiled for the same period of record. During seasons with high precipitation and discharge resulting in prolonged decreases in salinity, oyster mortality and the ratio of dead to live oysters were higher than wet seasons with less precipitation. Dead to live oyster ratios were highest in bay segments with the lowest average salinities and lowest in bay segments with a more stable salinity regime. The observed response suggests that oysters are a good indicator of the ecological potential of managing freshwater discharge to estuarine environments.

THE IEVOLI SUN WRECK: TOXICITY AND OLFACTORY THRESHOLD OF STYRENE IN MARINE ORGANISMS. S. Le Floch and F. Merlin.

Cedre, 715 rue Alain Colas, CS41 836, 29 218 Brest Cedex 2 France

After the Ievoli Sun sank, while carrying three chemical products (styrene, isopropylic alcohol, methyl ethyl ketone), the French Ministry for Land Planning and Environnement entrusted Cedre with carrying out experimental work to assess the impact of styrene on aquatic fauna, and more specifically on edible crabs (*Cancer pagurus*), mussels (*Mytilus edulis*) and oysters (*Crassostrea gigas*). The experiment was carried out in two steps: exposure to dissolved styrene in seawater followed by a decontamination process. The evolution of styrene content in water was followed by GC-FID (Gas Chromatography and Flame-ionization detector) and by Purge and Trap. And the styrene bioaccumulation in tissues was monitored by GC-SM (Gas Chromatography and Mass Spectrometry) analyses. In addition, olfactory analyses were performed. After exposure, tissues of studied animals show styrene concentration greater than styrene concentration in water (2 mg/L), suggesting an accumulation phenomenon. A saturation plate was observed during the exposure stage, very clearly for crabs, less for mussels. However, the concentration factor remains relatively low: around 12 for crab tissues, and slightly more for branchia. Decontamination process in biological tissues appears to be divided in three steps: a rapid evolution during the first 24 hours, followed by a standstill and one last purification step, much slower, after 76 hours in pollutant-free water. Purification process appears to be much faster for mussels, with no apparent standstill phase. The presence of styrene in tissues appears difficult to identify. For instance, olfactory tests results show a large variability. However, the olfactory detection threshold can be established at

5000µg/kg for raw and cooked crabs. The identification for raw mussels is more representative. The Olfactory detection threshold can be established at 1000µg/kg.

NUTRIENT TRADING COMBINED WITH SHELLFISH FARMING – A NEW TOOL FOR COASTAL MANAGERS TO IMPROVE WATER QUALITY. O. Lindahl and S. Kollberg.

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Eutrophication of coastal waters is a serious environmental problem with high costs for society globally. This development has resulted in a number of negative effects, for example reduced visibility of the water, anoxic bottom conditions and formation of algal mats in shallow bays – a development which demands immediate environmental action along many coastal sites. Mussel farming has since the 1980's been recognized by Swedish environmental authorities as a possible measure to improve coastal water quality. However, useful tools to stimulate the mussel farming have been missing, but new concepts and management strategies on how to combat coastal marine eutrophication have recently been developed. The main principle is nutrient trading which imposes demands on those who emit the pollution through emission quotas which are traded and bought by the emitter. This is particularly straightforward when the nutrients are discharged from a point source but should also be possible for diffuse sources. A nutrient quota will thus be the currency traded between the market economy and the environmental economy. According to an EC-legal assessment, it is possible to exchange the nitrogen removal in a sewage treatment plant by mussel farming in the recipient if the «same» nitrogen can be removed through harvest of the shellfish. The first case of this new concept, which has been permitted as a trial to 2011, is the town of Lysekil situated on the Swedish west coast. The Lysekil sewage plant will continue to emit nitrogen, presupposed that the same amount of nitrogen is «harvested» and brought ashore by 3 900 tons of farmed blue mussels.

IDENTIFICATION AND MEASUREMENT OF PESTICIDE RESIDUES IN FLESH FROM FARMED AND WILD *CIRRHINA MRIGALA*. S. Mahboob.

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Farmed and wild samples of two weight categories designated as W1 (501-900g) and W2 (901-1300g) of *Cirrhina mrigala* were collected from a Commercial Fish Farm from river Chenab at Trimu Head Jhang respectively. Fish flesh, clean up was done by GPC and 11 pesticides analysis carried out through reverse phase HPLC technique. Endosulfan *f*Ñ, p, p¡¦-DDT, methamidophos, carbofuran, diazinon, parathion methyl, dimethoate, malathion, chlorpyriphos, cypermethrin, carbosulfan and isoproturon were detected in farmed fish. All of these pesticide residues except for methomidophos were also identified in the flesh of the wild fish. The level of all pesticide residues was lower than maximum residue limit but carbofuran exceeded the MRL (0.1 ppm) in farmed (0.11 ppm) and wild fish (0.21 ppm). Total concentration of pesticide esidues was found to be highest in farmed (0.06 ppm) as compared to wild fish (0.05 ppm). Environmental contamination is recognized as a world wide problem. Part of this problem is caused by the application of pesticides that are used in agriculture, horticulture and forestry as conservative against pest infestation. Some of the pesticides and their terminal products are carcinogenic, mutagenic, tumerogenic and teratogenic. The use of pesticides through out the world is increasing and will continue to increase as the race between food production and population continues. Injudicious use of pesticides in agriculture can lead to health hazards to hundred percent via polluting both ecosystems like water, soil, food gain etc Results Many pesticides in the present study showed that both wild and farmed *Cirrhina mrigala* were contaminated with endosulfan *f*Ñ, p, p¡¦-DDT, methamidophos, carbofuran, diazinon, parathion methyl, dimethoate, malathion, chlorpyriphos, cypermethrin, carbosulfan and isoproturan. Concentration of endosulfan in farmed fish was recorded as 0.02±0.001 and 0.01±0.001ppm and W1 and W2, whereas in wild, the highest concentration was 0.009±0.001ppm under W1.

OIL SPILL AND SHELLFISH RESTORATION. C. Mailly, M. Girin and A. Le Roux.

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This presentation intends to review the main impacts of oil spills on crustaceans and molluscs and the possible restoration options for injured shellfish populations. The viewpoint is that of an adviser, who, in an emergency oil spill situation, is in charge of providing responsible authorities with quick and accurate advice on the pollutant, the related environmental risks (particularly its actual or potential damage to biological resources), and the best applicable response techniques. Advice must encompass adverse environmental effects of counter-measures and take into account economical and social priorities. The presentation first summarizes how oil affects shellfish, through both direct and indirect effects, as individuals and as members of ecological communities. This is illustrated by three case studies. First, the release of 84,700 t of crude oil by the Braer in Shetland, in which most of the non evaporated oil was dispersed naturally through the water column by wave action. Secondly, the discharge by the Sea Empress of 73,000 t of crude oil in southwest Wales, leading to 15,000 t of emulsified oil which came ashore along 200 km of coastline. Thirdly, the 19,000 t heavy fuel oil spill of the Erika, which impacted 400 km of the French Atlantic coast. In all 3 cases, comparable patterns were registered: contamination spread rapidly, wild and/or cultivated shellfish exploitation bans were imposed, contamination declined relatively rapidly in crustaceans, much more slowly in molluscs. As a whole, wild and exploited shellfish populations were only temporarily impacted, in a proportion often within natural

inter-annual variations after the first year, making it a challenge to prove a direct relationship between observed long-term effects and a particular spill.

HOW DOES ONE MEASURE DEGRADATION OR IMPROVEMENT OF SHELLFISH HARVEST AREAS? D. J. McCoubrey. (PLENARY TALK)

New Zealand Food Safety Authority, P O Box 1254, Auckland, New Zealand

Internationally there is growing concern about degradation of the environment. We hear about international policies to ameliorate the effects of global pollution e.g. air pollution and climate change. When it comes to the marine environment, how do we measure the environmental pollution risks associated with food safety? This is important so that we monitor harvest waters for increasing or decreasing food safety risk. Science and research play an important part in the political policy cycle. Uptake of scientific advice will depend on identifying the problem, correctly framing the questions for science to address, good communication and trust between scientists and policy makers. The USA and the European Union have systems to classify bivalve shellfish harvest areas. However, these systems are designed to measure the current status of an area. It is important that there are tools to measure degradation or improvement of marine areas over time. New Zealand has a large commercial aquaculture industry, growing mainly Pacific Oysters (*Crassostrea gigas*) and Greenshell mussels (*Perna canaliculus*). Our coastal areas are under increasing pressure due to population drifts to the coast, tourism, etc which may adversely affect the shellfish industry. We are currently developing a multi-factorial risk measurement scale to evaluate the microbial food safety risk of a harvest area. This scale will identify if areas are degrading or improving in food safety risk. This assessment takes account of environmental factors, social influences, industry practices, historical sampling information and government policy factors. Manipulation of the assessment integers will assist forecast likely improvements or degradation of an area. Salient environmental science, appropriately communicated to the policy decision makers and all community stakeholders is seen as fundamental to ensure appropriate environmental policy is enacted within communities. It is hoped with such a forecasting tool that appropriate timely actions can be taken to secure safe food harvesting areas.

SHELLFISH RESOURCES ABUNDANCE BY BOTTOM HABITAT AMELIORATION. G. Na[1] and Y. Lee.[2]

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For the sustainable production of bottom dwelling molluskan commercial species, Korea government carry on the national aquafarm cleaning project. At first step, aquafarms are divided into some sectors by the situation of its environment factors and then aquafarm bottom has ploughed and heaped up the waste materials which was originated from aquaculture activity and human activity. After ploughing, the surface layer of sediment has mixed with loess for ameriolating the bottom chemical condition. We discussed the variation of abundance of resources and compared the species composition and productivity especially cockles and pen shells in the sector where this plan was applied in Jeonnam Province in the shellfish aquqculture centerwhere it has been continued about 30 years.

PRELIMINARY STUDY ON IMPOSEX IN *THAIS HAEMASTOMA* (MOLLUSCA: NEOGASTROPODA) AS AN INDICATION OF CONTAMINATION BY TRIBUTYLTIN (TBT) IN THE COASTLINE OF CEUTA – M'DIQ (NORTH-WESTERN MOROCCO) A. Benhra,[1] S. Benbrahim,[1] B. El Haimeur,[1] M. Ramdani,[2] and N. Elmenif[3]

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The imposition of male secondary sexual characteristics in female gastropods as result of endocrine disruption, currently denominated imposex, is one way to detect the contamination by tributyltin (TBT). This biotoxic ingredient used as biocides in naval antifouling paints has severely affected several species of marine gastropods. The appearance of a non-functional vas deferens and a penis in females was examined in 100 individuals of *Thais haemastoma* sampled in three stations in the coastline of Ceuta – M'diq (North-western Morocco). Results of this preliminary study confirm the occurrence of imposex observed in south-eastern of M'diq harbour (96% females exhibited imposex), south of Fnidek (14% females exhibited imposex), and south of Fnidek village (2% females exhibited imposex). These stations were distributed in a NW-SE orientation from the fishing port along the coastline, following the general circulation pattern of the area. The higher levels of contamination were presented by the samples from M'diq coast, closest to the harbour.

USE OF ARTIFICIAL UPWELLING TO RESTORE CARRYING CAPACITY OF MUSSEL CULTURE IN FJORDS AFFECTED BY HYDROPOWER PLANTS. Ø, Strand and J. Aure.

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Nutrients in freshwater discharged into Norwegian fjords is a major source for new primary production during summer. Use of this water for hydropower production causees a reduction in discharge during summer and increase in winter. The impact from hydropower production in Lysefjorden (Western Norway) is estimated to reduce annual primary production by 20%. Modelling studies and small scale experiments using deep water have implied an economic potential of using artificial upwelling for shellfish culture. This paper reports an experiment carried out in Lysefjorden,

which is 50 km long (area 44 km^2) with maximum depth of 450 m and sill depth of 15 m. A strong nutricline is typically observed at 15-20 m depth during summer. Artificial upwelling was created using a vertically mounted pipe with an electrical pump to force brackish surface water at a rate of 2 m^3 s-1 down to 28 m depth. The pipe was mounted on a platform located 2 km from the head of the fjord. The estimated amount of upwelled water interleaving at depths of the pycnoclin was 20-30 m^3 s^{-1}. During April-September 2003 and 2004 we monitored 7-12 stations along the length axis of the fjord. Temperature, salinity, flourucense, turbidity, currents were recorded and samples were taken of phytoplankton, nutrients, particulate material and mussels. The results demonstrated a distinct response of the artificial upwelling extending about 9 km outward the fjord, but were clearly influenced by dilution effect caused by wind driven currents. For the first time it is shown in a large scale experiment that the use of submerged brackish water to create artificial upwelling enhance phytoplankton production and stimulate diatom growth. This may have great potential for restoring the primary production and thus the carrying capacity of mussels in fjords affected by hydropower plants.

OBSERVATIONS OF IMPOSEX IN *HEXAPLEX TRUNCULUS* (MOLLUSCA: MURICIDAE) FROM TUNISIAN WATERS: GEOGRAPHICAL DISTRIBUTION AND DEVELOPMENT INTENSITY. N. Trigui El-Menif,[1] Y. Lahbib,[1] M. Ramdani,[2] M. Le Pennec[3] and M. Boumaiza.[1]

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The superimposition of male sexual characteristics in neogastropod females, or imposex, was used as a reliable bioindicator for the evaluation of sea water tributyltin (TBT) contamination. We recorded in Tunisian coasts the first observations of this phenomenon in *Hexaplex trunculus* in 16 stations, among 19 investigated sites, from Bizerte (north of Tunisia) to Djerba (south of Tunisia). Imposex indices revealed a frequency of 100% in high shipping activity areas such as the Bizerte channel, Menzel Bourguiba, Menzel Abderrahmen, NPK Sfax, Sfax Harbour fishing and the Adjim channel, with a VDS index value of between 4 and 5 in the Cement factory station, generating a sterility of 8%, while the RPL index values oscillated between 29.96 and 69,13. In the other stations, the imposex rate varied from 0 to 93% with a variable VDS index of 0 to 3.32 and an RPL index ranged from 0 to 8. The Correspondence Factorial Analysis (tree clustering), of all the stations where this anomaly was found, taking into account the female length of the penis and VDS index, enabled us to highlight 3 groups of sampling intensity of imposex.

EXOTICS/INVASIVE/INTRODUCED SPECIES CONSIDERATIONS

IS THE PORTUGUESE OYSTER *CRASSOSTREA ANGULATA* IN SOUTHERN EUROPE ENDANGERED BY THE EXPANSION OF THE PACIFIC OYSTER *C. GIGAS*? F. Batista,[1-2] P. Boudry,[2] S. Lapégue,[2] S. Heurtebise[2] and C. Monteiro.[1]

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The Portuguese oyster, *Crassostrea angulata*, was introduced from Portugal to the French Atlantic Coast in the 1860s. *C. angulata* quickly settled and expanded and leaded to the development of a new aquacultural industry in France. In the late 1960s, mortality associated with the detection of an iridovirus, led to the wipe out of *C. angulata* from French Atlantic waters and to the massive introduction of *C. gigas* to sustain production. In Southern Europe, similar symptoms were also observed in natural stocks of *C. angulata* from Sado River (Portugal) and from the area of Cadiz (Spain). Nowadays, only very few «pure» populations of *C. angulata* remain in southern Europe. These populations are potentially endangered by the current expansion of *C. gigas* aquaculture, as well as the pollution of their habitats. In October 2002, cupped oysters from Sado and Mira estuaries (Portugal) were sampled and analysed using a mitochondrial DNA marker previously shown to be diagnostic for *C. angulata* and *C. gigas*. All oysters analyzed revealed haplotypes characteristic of *C. angulata*. We also analyzed wild cupped oysters from Ria Formosa (Southern Portugal), an area where *C. gigas* is known to be farmed. These samples were analysed with a «pseudospecific» nuclear DNA marker previously developed to differentiate populations of *C. angulata* and *C. gigas*. In addition, a new mitochondrial marker was developed that also allows the identification of other oyster species that exist in the area, namely the European oyster *Ostrea edulis* and the rock oyster *Ostreola stentina*. Despite the sympatric occurrence of *C. angulata* and *C. gigas* in Ria Formosa our results suggest that there is minimal hybridization between the two taxa. Furthermore, despite very limited natural beds, *C. angulata* seems to recrute much more than farmed *C. gigas*, indicating a differential ability to settle of these two taxa in Ria Formosa.

AN EXOTIC PATHOGEN AND DEVELOPMENT OF RESISTANCE IN THE AFFECTED OYSTER POPULATION. S. Ford.

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Efforts to restore or replace native oysters in estuaries on the east coast of the USA are frequently take place because those populations have been destroyed by pathogens. One of the pathogens, *Haplosporidium nelsoni*, cause of MSX Disease, was first recognized in Delaware Bay in 1957 and over the following two years, killed 90-95% of the oysters, *Crassostrea virginica*, in the lower, high-salinity portion of the Bay and about half of those in the upper, lower-salinity section of the Bay. Although *H. nelsoni* remained prevalent in the Bay and continued to kill 90-95% of previously unexposed imported *C. virginica*, the death rate of new year-classes of native Delaware Bay oysters – survivors of the 1957-59 epizootic – declined. Within a few years, their survival was equal to that of first-generation selectively bred oysters. For two decades, no further change in the wild population occurred, although steady improvement was achieved by continued selective breeding. Survival of the wild population is though to have reached a plateau because most oysters inhabited the upper bay and were protected from *H. nelsoni* by low salinity. In the mid 1980s, however, a severe drought, allowed the pathogen to move upbay where it caused greater mortalities than at any time since the original epizootic. After the late 1980s, the maximum prevalence of *H. nelsoni* in wild oysters, which previously had ranged from 50 to 90%, declined abruptly and has rarely exceeded 30% since then. The parasite is still present in the Bay because unselected oysters continue to become heavily infected, and molecular detection has indicated that infective stages are present throughout the Bay. The evidence suggests that through natural selection alone, which occurred in two discrete epizootic mortality events, the native oyster population in Delaware Bay has now become highly resistant to disease caused by an introduced pathogen.

TRANSPORT OF HARMFUL ALGAE VIA RELOCATION OF BIVALVE MOLLUSCS. H. Hégaret,[1] S. E. Shumway[1] and G. H. Wikfors.[2]

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Restoring local populations of bivalve molluscs, including oysters, clams, scallops and mussels, often includes moving individuals from one body of water to another. Our study tests the hypothesis that harmful algae ingested by source populations of shellfish can be introduced into new environments by means of these shellfish relocations. Several cultured strains of harmful algae, including *Pfiesteria piscicida*, *P. shumwayae*, *Prorocentrum minimum*, *Alexandrium fundyense*, *A. monilatum* and *Heterosigma akashiwo*, were fed to various species of bivalve molluscs, *Crassostrea virginica* (Eastern oyster), *Argopecten irradians* (bay scallop), *Mercenaria mercenaria* (northern quahog = hard clam), *Mytilus edulis* (blue mussel) and *Perna veridis* (green mussel) to assess the ability of the algal cells to pass intact through the digestive tract of the shellfish and subsequently grow. Shellfish were exposed to the algae at natural bloom concentrations, or to a control of a commonly-used microalgal food, *Rhodomonas* sp., for four hours. Clearance and feeding rates were measured; feces and pseudofeces were collected and observed under the microscope for presence or absence of intact, viable cells or temporary cysts of the algae. Ten bivalves of each species were also exposed for two days to a simulated harmful algal bloom at a natural bloom concentration. The algae were removed after two days of exposure, and bivalves were kept for two more days in ultrafiltered seawater. Biodeposits were collected and observed under the microscope after 24 and 48 additional hours to evaluate again the occurrence and condition of any algal cells. Subsamples of biodeposits were transferred into algal culture medium and filtered seawater and monitored microscopically for algal growth. Intact algal cells of *Pfiesteria piscicida*, *P. shumwayae*, *Prorocentrum minimum*, *Alexandrium fundyense*, *A. monilatum* and *Heterosigma akashiwo* were seen in biodeposits; generally these re-established growing populations. These data show evidence that transplanted bivalves may be vectors transporting harmful algae.

INVASIVE POTENTIALS OF THE JAPANESE OYSTER *CRASSOSTREA GIGAS* IN THE ENGLISH CHANNEL AND FRENCH ATLANTIC COASTS A FIRST APPROACH. C. Hily, M. Lejart and S. Guduff.

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Since the sixties, natural *Crassostrea gigas* populations have settled in several localitions on the French Atlantic coast. While theorically, sea temperature conditions had been considered to prevent the complete reproductive cycle, larvae originating from aquaculture have settled on natural habitats of estuaries and sheltered bays, and progressively constituted perennial populations. In the last few years this phenomena has amplified, and nowadays the oyster can be locally considered as an invasive species with dynamics of proliferation which can induce strong modifications to the ecosystem functioning. The first approach to studying this phenomenon was to identify the diversity of the habitats and biocenosis impacted by the proliferation and to deduce the potential of the species to invade the coastline in the future. We showed that the species colonizes not only sheltered and mixed-haline habitats but also exposed and marine shoreline. The substrates concerned by the invasion can be natural and artificial, shells on soft substrates and other indigenous shellfish species. Even if most of the populations are intertidal, some subtidal fields can occur. So the Japanese oyster can be considered as the temperate zone species with has the largest ecological possibilities to live in

the intertidal and shallow infralittoral zones, which suggest an enormous potential of proliferation in the future. To conclude, the various ecological and economical problems which can be induced by the proliferation are considered.

DELIBERATIONS ON INTRODUCING *CRASSOSTREA ARIAKENSIS* TO THE CHESAPEAKE BAY: THE ROLE OF SCIENCE AND UNCERTAINTY IN THE DECISION-MAKING PROCESS. M. Luckenbach. (PLENARY TALK)

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In response to a dramatic decline in abundance of the native oyster, *Crassostrea virginica*, in the Chesapeake Bay, U.S.A., state and federal governments are considering an introduction of the non-indigenous oyster species *C. ariakensis*. The process is fraught with competing interests, uncertain legal jurisdictions and numerous misconceptions regarding the state of our knowledge about this species. Nevertheless, the deliberations are proceeding at a measured pace with a central emphasis on the acquisition of valid scientific data on which to base a decision. I will review the current state of our knowledge about this species, indicate areas of ongoing research and discuss some issues about which a high degree of uncertainty remains. Specifically, findings related to growth and survival, disease susceptibility, competitive interactions with native oysters, predator susceptibility and larval behavior will be reviewed. Significant uncertainties still remain regarding population growth projections, the long-term outcome of competition, the potential for facilitating secondary invasions and higher order interactions. A rational decision on whether or not to introduce this species will need to carefully weigh our knowledge and uncertainty about this species and attempt to resolve competing interests.

CAN PHENOTYPIC PLASTICITY EXPLAIN A PART OF THE INVASION'S SUCCESS OF *CREPIDULA FORNICATA* ON THE EUROPEAN COAST? J. Richard,[1-2] M. Huet,[1] G. Thouzeau[1] and Y. M. Paulet.[1]

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The slipper limpet, *Crepidula fornicata* originating from the East coast of North America was introduced to UK at the end of the XIXth century and had now spread from Norway to Spain. The impact of this species on the ecosystem structure and functioning is well studied but the spatial spreading ability rate is poorly understood. The successful establishment of an invasive species depends on many parameters, among them reproduction and growth, which are critical for sustainable local recruitment and settlement. The aim of this project is to establish the variations of growth and fecundity on two scales: the European coast and the Bay of Brest, France. The slipper limpet, a protandrous hermaphrodite, has an original reproduction system with the individuals living in stacks in which the females are found under the males and fertilization is internal. To study the spatial variations of reproduction and growth, six sites were chosen for the European scale (from Germany to Southern France) and nine sites inside the Bay of Brest for the small scale. Several parameters were measured: dry weight of the animal, length of the shell, number of eggs per brood and stage of development of the eggs. Spatial variations in fecundity and growth are high at the European scale and also at the bay of Brest level. For example the fecundity in the Bay of Brest varies between 3000 and 14000 depending on the sampling station in the bay and these differences are not only due to the variations in growth but site effect is also involved. Hence the variations observed are rather owed to the environment and suggests that the expression of life history traits might be attributed to phenotypic plasticity.

ECOLOGICAL AND BIOLOGICAL CHARACTERISTICS OF THE INVASIVE PEARL OYSTER, *PINCTADA RADIATA* IN KERKENNAH ISLANDS (TUNISIA) AND RELATIONSHIPS WITH THE PROTECTED SPECIES OF PINNIDAE, *PINNA NOBILIS*. E. Soufi-Kechaou,[1] N. Aloui-Bejaoui[1] and M. Le Pennec.[2]

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The expansion of the Lessepsian migrant *Pinctada radiata* in the shallow waters of Kerkennah Islands represented a great adaptability of this species to colonize new sites far from its native area (Indo-Pacific, including the Red Sea). This archipelago is characterized by particular environmental conditions, and the presence of the endemic and protected Mediterranean species, *Pinna nobilis*. We focused on the eco-biology of the population of *P. radiata* in two sites in the North-eastern of Kerkennah islands, depending on the presence or absence of *P. nobilis*. In the first site (station 1), *P. nobilis* was absent and *P. radiata* was found on sandy-muddy substrates. In the second one (station 2), individuals of the pearl oyster were fixed in high density, until 50 adults, on the valves of the Pen-shell. The mapping of the distribution and densities of *P. radiata* and *P. nobilis* revealed a spatial competition between the two species. Environmental parameters analysis indicated that station 2 presents the highest values concerning phytoplankton productivity, suspended matter and hydrodynamics. Relative growth analysis of *P. radiata* did not show any differences between the two sites. Thus, there are no signs of trophic competition between the two species at first sight. The histological analysis revealed that the reproductive activity of *P. radiata* is almost continuous with spawning peaks in July and August and a little period of sexual rest in December. The most important number of gametes in station 2 could be due to a greater availability of nutrients. Biochemical analysis of the adductor muscle revealed an important

mobilization of reserves during gametogenesis and concentrations of lipids and proteins for specimens of station 2. Hence, the absence of trophic competition between *P. radiata* and *P. nobilis* was explained by a more important availability of nutrients.

HARMFUL ALGAL ROADBLOCKS TO EASTERN OYSTER RESTORATION – *PROROCENTRUM MININUM* AND *KARLODINIUM MICRUM*. G. H. Wikfors[1], G. Ozbay[2], A. R. Place[3], J.Y. Li[1], S.L. Meseck[1], H. Hégaret[4] and J.H. Alix[1].

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Laboratory and field studies have demonstrated that the dinoflagellates *Prorocentrum mininum* and *Karlodinium micrum* can have harmful effects upon eastern oysters, *Crassostrea virginica*. Effects can include changes in feeding behavior, tissue and cellular pathologies, and modulation of hemocyte-mediated immunocompetence. *Karlodinium* produces linear polyketide toxins (karlotoxins) which elicit their toxicity through sterol-dependent pores in biological membranes. Toxins produced by these dinoflagellates are hemolytic, cytotoxic, icthyotoxic and, in the case of *Karlodinium*, neurotoxic to vertebrates. Our research has revealed substantial variability in toxin yields for different isolates of *K. micrum* (ca. 0.1 – 1 pg cell^{-1}). Moreover, samples collected during fish kills have contained 10-100 fold this amount (10-12 pg cell^{-1}). Both genera also contain high levels of the unusual fatty acid, 18:5n-3, in plastid galactolipids, which has been shown to be toxic to fish. Toxicity appears, as in many toxin-producing microalgae, to be controlled by environmental conditions, including nutrient and energy status as well as being strain dependent. We are conducting field and laboratory investigations to identify the toxicity of these algal taxa to eastern oysters and to understand the environmental conditions favoring expression of this toxicity. In addition, we are determining the abilities of different life-history stages of oysters to tolerate and recover from exposure to these harmful algae. Early findings have led to focused studies on the importance of carbon and phosphorus status of the cells in controlling fatty-acid composition and expression of different proteins. Our intention is to identify environmental characteristics that are likely to lead to toxic blooms of these dinoflagellates that could preclude success of oyster restoration efforts. This information will be useful to management of shellfish restoration by eliminating potential restoration sites with low probability of success and by providing information for retrospective analyses of oyster restoration sites following blooms of these dinoflagellates.

FISHERIES AND AQUACULTURE MANAGEMENT

XEL HÁ PARK FOR SUSTAINABLE MANAGEMENT OF QUEEN CONCH, *STROMBUS GIGAS* (Mollusc Gastropod) IN THE MEXICAN CARIBBEAN SEA. D. Aldana Aranda,[1] C.M. Sánchez,[2] A. Pinzón[2] and C. E. Baqueiro[3]

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The queen conch, *Strombus gigas*, is a large Caribbean Gastropod Mollusc which has been exploited for used as traditional food in all Caribbean countries. Its shell is used as music instrument, tourist curios and much more, and meat is a tourist attraction delicatessen. Since 1992, *S. gigas* is included in annex II of CITES (Convention for international trade of endangered species) as an endangered marine resource, due to over-fishing and destruction of its habitat. CITES is in charge of international traffic but not of local fisheries and trade. Each country is responsible for its protection and enforcement of protection regulation. However a lack of respect of the regulatory frame is the rule in most countries. Since November 2001, abundance, size frequency, spatial distribution and reproductive activity of *S. gigas* have been monitored in Xel-Há Park (Marine Protected Area in the Mexican Caribbean) showing different bottom and different condition of salinity, oxygen, and nutrients. Two sites were selected for this study: Bocana and Cueva de los Milagros. Bocana had a salinity of 35 ppm with 30% of sea grass coverage; Queen Conch population was constituted by juveniles (40 mm, shell length) to adults (320 mm, shell length). Cueva de los Milagros presented a muddy bottom, without sea grass coverage, with low salinity. At this site, Queen Conch population was made up principally of juveniles (80-150 mm shell length), juveniles less than 40 mm shell length and adults >220 mm shell length were scarce. In both sites, *S. gigas* showed recruitment from June to November, a good growth rate, and at Bocana the organisms presented a reproductive period from May to September, when egg masses where observed. Results of abundance, size frequency and reproductive activity showed that Xel-Há park contribute to protected and restore this species in the Mexican Caribbean region.

POPULATION STRUCTURE, DENSITY AND BIOMASS OF THE EASTERN OYSTER ON A NOVEL MODULAR ARTIFICIAL OYSTER REEF IN CHESAPEAKE BAY. R. Burke and R. Lipcius.

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Restoration efforts with native Eastern oyster, *Crassostrea virginica*, in Chesapeake Bay have been extensive. Restored reefs have generally experienced marginal success and require reseeding to sustain populations. Many restored reefs vary significantly from natural reefs in having: (1) limited vertical complexity, (2) low reef stability, (3) reduced substrate area for larval settlement, and (4) diminished reef community structure. We quantified population structure, density and biomass of oysters and mussels on a novel artificial concrete modular reef deployed subtidally in the Rappahannock River (Chesapeake Bay), with emphasis on predator-prey relationships and environmental stress. This reef offers significantly greater vertical complexity, reef stability and substrate surface area than many restored reefs and, thus, may be a more realistic mimic of natural oyster reefs. The modular reef was neither seeded artificially nor harvested. The reef was colonized heavily by native oyster and mussel larvae that recruited successfully and survived in a thriving oyster reef community for the 4.5 years since reef deployment in 2000. Oyster and mussel biomass and density values were among the highest recorded for natural and restored oyster reefs. Density and biomass differed significantly across four reef strata (top, bottom, sides, and interstices) with highest values in the more protected strata, which would provide greater structural complexity to alleviate predation pressure and provide protection from environmental stress such as siltation. We posit that restoration efforts with native oyster should utilize artificial reefs with the vertical structure and stability required to buffer environmental stress and predation pressure.

SEEDING THE SEED BEDS: ENHANCING OYSTER (*CRASSOSTREA VIRGINICA*) RECRUITMENT AND PRODUCTION IN DELAWARE BAY, USA. D. Bushek,[1] R. Babb[2] and J. Hearon.[1]

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Natural oyster production on Delaware Bay seed beds is close to collapse following five consecutive years of exceptionally low recruitment. Size frequencies have shifted toward larger oysters with few young oysters to replace those lost to fishing or natural mortality. Reasons for the low recruitment are unclear. Little settlement was observed on spat bags deployed biweekly during summer 2004 suggesting low larval abundance. During 2003 and 2004, unusually cool temperatures delayed spawning until late in the season, possibly reducing larval production or survival. Lack of suitable substrate may also be a problem as shell plantings have not occurred for many years. In contrast, consistently high settlement occurs in the lower bay inshore areas when suitable substrate is availble, but few oysters survive in this region. In summer 2003, spat were captured from the lower bay on surf clam shell (*Spisula solidissima*), then transferred to a primary seed bed in fall 2003 increasing early recruitment about 75-fold. Overwinter mortality during 2003-4 was relatively low and mean shell height increased from 26 to 48 mm during summer 2004. Overwinter mortalities measured in March 2005 were low and mean size was 52 mm by April 2005. Dermo disease in the transplanted oysters was equal to or lower than levels on surrounding beds. Growth, mortality, disease and density will be monitored during summer and fall 2005 to determine if oysters can reach market size at densities sufficient to justify expenses associated with planting and moving shell. Based on results to date, a sizeable portion of funds obtained for shellplanting efforts in Delaware Bay will be used to capture and transfer spat from high set – high mortality regions of the lower bay to the more productive, higher survival areas where extant seed beds exist.

CURRENT STATUS OF KOREAN SHELLFISH AQUACULTURE. K.S. Choi. (PLENARY TALK)

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Korea has three oceanographically distinct coasts where at least 23 commercially important shellfish species are cultured. In 2004, Korea produced 316,967 metric tons of shellfishes from aquaculture, which accounted for one-third of the total Korean aquaculture production. The Pacific oyster, *Crassostrea gigas* have been raised in an intensive manner along the south coast where there are numerous small enclosed bays and barrier islands. Korean oyster farming uses long-line suspended culture system and the production reached to 239,279 MT in 2004, which represented as 26% of the total aquaculture production and 75% of the shellfish production. Sea squirt, *Halocynthia rorentzi* are also commonly cultivated in the bays on the southern coast using long line hanging culture. Sea squirt landing in Korean has been decreasing for the past decade due to the unknown disease; in 2004, the landing was 6,349 MT, which was only 28% of the 1997's. Other commercially important molluscan aquaculture species on the south coast include the mussel, *Mytilus galloprovincialis*, the blood cockle, *Anadara broughtonii,* and *Anadara granosa*, and the abalone, *Haliotis discus discus*. The coastal area of Yellow Sea, on the weste coast, is characterized with high turbidity and productivity with well developed muddy tidal flats. Manila clams, *Ruditapes philippinarum* are commonly cultured on the tidal flats by sawing naturally harvested seeds and harvest 2 to 3 years after sawing. The clam landings have been declining since early 90's due to habitat destruction and disease-associated mortality; 27,570 MT of clams produced in 2004, which was only one-quarter of the clam production in 1993. Several studies have indicated that several types of pathogens are responsible for the mass mortality of clams including protozoan parasite, *Perkinsus olseni*, bacteria, *Vibrio tapetis* and trematod, *Cercaria tapidis*. On the east coast (the East Sea or Japan Sea), the giant scallop *Patinopecten yessoensis* has

been cultivated since early 90's using the suspended long-line system with several types of lantern nets and ear-hanging ropes. The scallop production has also been declining since 2000, due to degradation of water quality caused by high turbidity. In conclusion, shellfish landing in Korea has been declining for the past decade and the decrease is in part, associated with degradation of environmental quality and pathogenic organisms.

EXPLOITATION OF THE MARINE SHELLS IN THE LITTORAL ZONE IN SENEGAL: IMPORTANCE AND IMPACTS ON THE DURABILITY OF THE EXPLOITATION OF THE MARINE RESOURCES AND BIODIVERSITY OF THE MARINE ENVIRONMENT. H.D. Diadhiou and C. Crodt

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First sector economic of the country, the artisanal fishing multiplied by 15 its yearly production since years 50 while passing 22 000 to more than 340 000 t/yearns. It provides in value the quarter of the national exports with a progression of 23% from to 1998. The Senegalese fish production is very diversified. Besides pelagic and demersal fish, subsequent volumes of octopuses, cuttlefishes, shrimps, volutes, murex, and landed. Except the "volute" (*Cymbium* spp.), the marine shells were under exploited until recently. The development of commercial fishing initially related to fish and shellfish. The emergence of markets abroad led many fishermen to be interested in the exploitation of marine like marine molluscs exploitation as volutes and murexes. By way of example, one can mention the case of the murex whose unloadings strongly increased, passing from 805 in 2000 to 1931 tons in 2001. Its exploitation did not cease taking importance since. The different impacts (anthropic or natural) explaining the situation are analyzed in this article. Gillnets are used for the marine shellfish fishing. They are put on small funds where one meets a lot of algae playing an important role in trophic chain The net is moved from place to place as the catch per unit of effort is decreasing. On the "Petite Côte", the marine habitats located on the fishing grounds of marine shells are destroyed by the gears carrying important quantities of algae during fish operations. Coastal erosion also takes part by the transport of sediments in the stranding of the fishing grounds and the disappearance of the marine shells in the level of the coastal zone. In many fishing grounds, the resource has strongly decreased. The catches as well as the size of shells has decreased.

MANAGEMENT OF SHRIMP STOCKS IN THE SOUTH OF IRAN. A. Esmaeili.

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Iranian shrimp stocks are located in the northern Persian Gulf and Oman Sea. These stocks are important based on economic and biological criteria. Shrimp fisheries are often managed by minimum spawning stocks to prevent overfishing. In spite of this monitoring, shrimp capture has had large fluctuations in the south of Iran. The major problem currently facing the fisheries is the uncertain availability of shrimp and overfishing. The present study attempted to test influence of climate parameters on the shrimp stock and to determine the minimum sustainable and economic yields for shrimp fishery management. Surplus production bioeconomic model with climate parameters was used for determination of optimal harvest. It was found that temperature and rainfall had significant effects on optimum harvest. The management implication of this study is that the shrimp fisheries should be managed based on climate parameters before the opening of the fishing season.

TRENDS IN PINTO ABALONE (*HALIOTIS KAMTSCHATKANA*) ABUNDANCE IN THE SAN JUAN ISLANDS AND MANAGEMENT OF THE SPECIES IN WASHINGTON STATE. C. Friedman, D. Rothaus and Y.W.H. Cheng.

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Declining populations of pinto abalone (*Haliotis kamtschatkana*) have been monitored by the Washington Department of Fish and Wildlife (WDFW) in the San Juan Archipelago at ten index stations (1992, 1994, 1996 and 2003) which range in size from 135 m^2 to 378 m^2 (averaging 230 m^2). We documented a decrease in total abundance between 1992 and 1994 (n=351 to n=288) that, combined with additional anecdotal information, resulted in the closure of the fishery in 1994. Significant decreases in abalone densities were observed at five of the ten index stations between 1994 and 2003 ($p<0.01$). During 2003, mean abalone density at nine of the stations surveyed. was < 0.15 abalone/m^2. In addition, the mean animal length increased 12 mm between 1994 and 2003 when all data was examined ($p<0.0001$;100 mm / 1994 vs. 112 mm / 2003). These data combined with a lack of abalone <95 mm at five sites surveyed during 2003, are indicative of «Allee Effect» response to low population densities and corroborate the actions of WDFW (1996) to list pinto abalone as a «Candidate Species» and NOAA Fisheries (2004) to list Pinto abalone as a «Species of Concern». In response to these declines we have initiated a captive rearing program and the development of tools (mesocosms, real-time PCR test for larval quantification and recruitment modules) to better assess the dynamics of larval and juvenile pinto abalone.

A DEVELOPING FISHERY FOR COMMON WHELK, *BUCCINUM UNDATUM* IN NW IRISH WATERS: REPRODUCTIVE CONSIDERATIONS FOR STOCK SUSTAINABILITY. J. Hemer,[1] P. A. King,[1] O. Tully[2] and D. McGrath.[1]

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The Common whelk, *Buccinum undatum* is commercially exploited in the Irish Sea, where stocks indicate local exhaustion. Recent interest in expanding the fishery to include waters in northwest Ireland initiated a trial fishery in the region east of the Inishowen Peninsula, Republic of Ireland. Certain biological characteristics associated with the reproductive cycle of this species make it susceptible to over-fishing and localized extinction. Additionally, previous studies indicate a high degree of variability in biological parameters between different populations, suggesting that newly exploited stocks should be assessed independently of previous findings. Temporal and spatial variability in the size and age structure of the population, and the size at onset of sexual maturity for male and female Common whelks were investigated within the fishery and between five inshore populations around the Irish coast from May 2003 to May 2004. It was found that for male whelks in the region of the trial fishery, onset of sexual maturity occurs varies in size and age between the other investigated populations (72-94 mm total shell length and 8.25 years). Timing of the reproductive cycle was also determined within the region of the new fishery and cryostat was used to cut histological sections (5-7 μm) of the male and female gonads. Catch per Unit Effort (CPUE) and stock size were estimated for the trial fishery, and suggest that stocks may be of commercial value. However, landings per pot to the fishery vary significantly across the region. Results of analyses on sexual maturation and reproductive biology are presented and implications for the management of the fishery to ensure the sustainable harvest of the stock are discussed.

PRESENT STATUS OF SHELL FISHERIES WITH REFERENCE TO INTERTIDAL MOLLUSCS ON COAST OF MAHARASHTRA STATE (WEST COAST OF INDIA). B. Kulkarni, A. Jaiswar, P. Kerkar, B. Desai and K. Kulkarni.

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Maharashtra, located on west coast of India, is endowed with a coastline of 720 Km and 111512 sq. km of continental shelf. Inspite of rich source of molluscan like bivalve and gastropods, only 492945 tones of marine molluscs form a part of 3.9 million tones fishery production in India. On Maharashtra coast more importance is given for fin fisheries. Among shellfisheries only prawn and lobster fisheries are valued one whereas bivalve and gastropod fishery is neglected. At present, molluscs like clam and gastropods are largely harvested from coastal areas of Maharashtra. Among the bivalves, *Katelysia opima*, *Katelysia marmorata*, *Paphia textile*, *P. malabarica*, *Meretix casta*, *M. meretrix*, and *Perna viridis* forms a major share of clam fishery. Moreover blood clam of Arcidae family also contribute significantly to molluscan fishery. But blood clams are not relished like clams of Veneridae. Gastropod of Trochidae, Turbinidae, Neritidae, Littorinidae, Potamididae, Muricidae, Bursidae families contribute significantly to gastropod catch. However, most of these gastropods are not included as food item in Maharashtra state. At present coastal habitat in and around major cities are under deterioration due to increasing urbanization and industrialization. Intertidal Molluscan fishery in and around metropolitan like Mumbai is totally collapsed. However, molluscs are harvested on large scale from intertidal areas of Ratnagiri, Sindhudurg, and Raigad districts. But increasing level of pollution in intertidal areas of these coastal districts will certainly cause depletion in molluscan fishery. Therefore urgent measures are essential to protect these molluscan resources of Maharashtra coast.

THE ROLE OF CULTIVATION IN SHELLFISH RESTORATION. D. Mcleod. (PLENARY TALK)

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The concept of ‘restoration’ should be one of restoration to a food producing system, not a vanished eco-system of whatever mythic value. And such a restoration can involve new and different species, a revised biodiversity. There are two main methods by which the cultivation sector contributes to shellfish restoration and management of ‘wild’ stocks : Passive: - Contribution to settlement/recruitment outwith the concession areas; - Through reducing pressure on capture fishery supplies; Active: - Higher survival rate of seed; - More robust seed (hatchery selection); - Introduction of novel species. The commercial sector also contributes through involvement in ‘Integrated Coastal Zone Management’ (ICZM) - an increasingly important policy driver, as a rising percentage of populations inhabit the coastal littoral - and through participation in ecosystem-based resource management regimes. A major unresolved question is: What does industry gain from this? Are shellfish restoration enthusiasts any more than a marine equivalent of ‘tree huggers’? What is the realistic ‘Way Forward’ ?

SEA CAGE CULTURE OF SPINY LOBSTERS AND NATURAL COLLECTION OF LOBSTER POST – LARVAE (PUERULII) IN INDIA: – AN ALTERNATE EMPLOYMENT / ADDITIONAL SOURCE OF INCOME FOR COASTAL FISHERS. T. S. Murugan,[1] M.Vijayakumaran[1], R.Selvan[2], D. K. Jha[1], T.S.Kumar[1] and R.Venkatesan[1].

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The consistent depletion in catch in the coastal fishery has prompted the coastal fishers of India to seek alternate income generating endeavors in their nearby areas. True mariculture of fish/shellfish in sea cage is yet to be established in India and the coastal shrimp farming sector is too capital intensive for the poor coastal fishers to take up. They look to government aided programmes in the sea around them to generate alternate/ additional source of income. The sea cage fattening of lobsters introduced in the coastal villages of Tamil Nadu, India by the NIOT has opened up a new hope for the coastal fishers to take up mariculture. To preserve the lobster fishery in India, the government has

introduced ban on export of undersized lobsters (< 200 g size). But since lobsters are caught as bycatch in trawlers as well as by gill nets in traditional sectors, large numbers of juveniles/under sized lobsters are still being caught in India. The sea cage culture of lobsters to market size will help to increase its value upto 10 times in a short period of 3 – 5 months as has been successfully demonstrated by the coastal fishers of Tharuvaikulam, Tamil Nadu, India. The success of sea cage culture has induced fishers from other coastal villages also to take up lobster fattening in cages. An added attraction to this programme has been large scale settlement of lobster post – larvae (Puerulii) and early juveniles in and around cages. The survival and growth of these puerulii trapped in the cages has been very encouraging and the growth rate recorded is more than what is reported earlier. This paper describes the involvement of coastal fishers in successful adoption of sea cage farming of lobsters in India.

POPULATION DYNAMICS AND STATUS OF THE STOCK OF OYSTER (*CRASSOSTREA MADRASENSIS*) AND GREEN MUSSEL (*PERNA VIRIDIS*) IN THE COX'S BAZAR COAST OF BANGLADESH. S.M. Nurul Amin, A. Halim, M. Borna, M. Zafar and A. Arshad.

Marine Science Laboratory-IBS, Universiti Putra Malaysia, 43400 Serdang, Malaysia

Planning and management of mollusc resources requires knowledge of various population parameters and exploitation level (E) of that population in that location. Estimation of population parameters like asymptotic length (L,,f), growth-co-efficient (K), mortalities, exploitation level (E) and recruitment patterns of oyster (*Crassostrea madrasensis*) and green mussel (*Perna viridis*) in the Cox's Bazar coast of Bangladesh were studied using the length frequency based analysis of FiSAT software to evaluate the status of the stock. Asymptotic length (L,,f) was 20.88 cm and 19.43 cm and growth co-efficient (K) was 0.35/yr and 0.56/yr for *C. madrasensis* and *P. viridis* respectively. Total mortality rate (Z) was 1.35/yr for *C. madrasensis* and 1.44/yr for *P. viridis*. Natural mortality rate (M) and fishing mortality (F) rate was 0.99/yr and 0.35/yr for *C. madrasensis* and 1.38/yr and 0.06/yr for *P. viridis*. Exploitation level (E) of *C. madrasensis* and *P. viridis* was 0.26 and 0.04 that of the maximum allowable limit of exploitation (Emax) values were 0.37 and 0.38 respectively. These exploitation levels (< 0.50) indicated that while *C. madrasensis* is slightly exploited (E = 0.26) and the stock of *P. viridis* is virgin in the Cox's Bazar coastal area of Bangladesh.

INTERACTIONS BETWEEN THE ROCK CRAB (*CANCER IRRORATUS*) AND MUSSEL AQUACULTURE PRODUCTIVITY IN PRINCE EDWARD ISLAND, CANADA. M. Ouellette, L. Comeau and M. Hardy.

Fisheries and Oceans Canada, Gulf Fisheries Centre, 343 University Avenue E1C 9B6 Moncton, NB Canada

The rock crab directed fishery has evolved in the southern Gulf of St. Lawrence, over the past twenty years, with landings up to 3,715 mt in 2003. Concurrently, the mussel aquaculture industry has expanded considerably and now overlaps in many areas with the rock crab fishing grounds. Both of these activities are viewed as important in sustaining the economic viability of coastal communities. One of the important husbandry methods employed by growers to reduce the epifauna on mussel socks is to sink their longlines to the bottom. This periodic lowering of longlines enables the rock crab to climb onto the socks and feed on the epifauna and the second set of mussel spat, considered a nuisance. For a number of years, concerns have been raised by mussel growers as to possible impacts of the rock crab fishery within the cultivated areas on their industry. The main objective of this project is to examine whether there is a change in the abundance and structure of the rock crab populations on and under mussel lines during and following the directed fishery. The assertion that rock crabs are beneficial to mussel longline productivity will also be evaluated. Finally, the effects of the invasive green crab (*Carcinus maenas*) on the rock crab behaviour and mussel socks productivity will be investigated. Preliminary results will be presented from this first year of data collection. The results obtained could set a working base to improve the rock crab fishery management measures and thus ensuring that both industries can realize their full potential. This scientific investigation will thus contribute in applying coastal integrated management of human activities.

DESIGN OF ESTUARINE RESTORATION PROJECTS USING ASPECTS OF OYSTER PHYSIOLOGY AND ECOLOGY. M. Savarese, A. K. Volety, and S. G. Tolley.

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The design and effectiveness monitoring of U.S. federally sponsored estuarine restoration projects is governed by a formal protocol prescribed by the U.S. Army Corps of Engineers. The protocol is best exemplified by projects underway in the Greater Everglades, South Florida. We are using the American oyster, *Crassostrea virginica*, in numerous steps within the protocol: as a bioindicator of estuarine health, as a tool for establishing restoration targets, and as a measure of restoration effectiveness. This presentation reviews the protocol employed, demonstrates the utility of oyster biology and ecology to this process, and lastly illustrates its application by reviewing an Everglades restoration project (Picayune Strand) that awaits Congressional authorization. The adopted protocol consists of 9 steps: (1) defining restoration goals, (2) characterizing current conditions, (3) establishing the pre-alteration state, (4) designing alternative restoration scenarios, (5) establishing performance measures and targets, (6) modeling to evaluate each scenario; (7) designing a restoration monitoring plan, (8) implementing a restoration scenario, and (9) initiating adaptive management. Oysters and their reef communities are being used in steps 2, 3, 5, and 7. Various aspects of oyster physiology and ecology, including growth, standing stock, recruitment, susceptibility to disease, living density, the aerial distribution reefs, and the composition of the reef community, serve as bioindicators of estuarine health (step

2). These aspects are compared using a spatial homologue approach, whereby geomorphologically similar positions along the estuarine axis are compared among estuaries. Step 3 is achieved by comparing the present distribution of reefs with pre-alteration surveys. The same aspects of ecology are used to define targets and performance measures for restoration (step 5). Targets are defined for specific homologues using conditions in the neighboring, pristine estuary. Finally, restoration success can be gauged (step 7) by how close the system approaches a given target.

ESTIMATING THE RECRUITMENT OF *ARGOPECTEN PURPURATUS* (LAMARCK, 1819; PECTINIDAE) IN THE MARINE RESERVE OF LA RINCONADA (ANTOFAGASTA, CHILE). G. Thouzeau[1], M. Avendano[2] and M. Cantllanez[2].

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The chilean scallop, *Argopecten purpuratus*, is a species of major economic value in Chile. Scallop production in the past few years reached 20,000 metric tons, making Chile the third scallop producer in the world. Aquaculture production is mainly sustained by collection of wild spat on artificial collectors and subsequent on-growing of juveniles. However, overfishing of wild populations has led to dramatic decreases of natural stocks in the late 80's, making population restoration questionable in many areas. Past studies realised in the Rinconada Bay (Antofagasta, Chile) showed that continuous spat settlement from year to year in the Bay may compensate stock losses due to illegal fishing. In the years 2002 and 2003, major temporal variations were observed in benthic recruitment abundance, population size structure and spat abundance in artificial collectors. In particular, the total abundance of *A. purpuratus* stocks increased by 51.5% between May 2002 and May 2003, while mean individual size decreased from 75.8 mm in 2001 to 51.7 mm in 2003. The latter also resulted in the decrease of the abundance of harvestable individuals (minimum shell size: 90 mm), from 2.6×10^6 individuals in 2001 to 3.7×10^5 individuals in 2003. In both years of study, a major spawning event provided ca. 50% of the annual recruitment (50.9% in 2002 vs. 47,1% in 2003). A density-dependent relationship between spat abundance in collectors and recruit abundance on the bottom was observed in 2003, in contrast to 2002. The possible causes of these fluctuations are discussed in this talk.

GENETIC CONSIDERATIONS IN SHELLFISH RESTORATION.

GENETIC VARIATION AMONGST SCOTTISH POPULATIONS OF THE NATIVE OYSTER, *OSTREA EDULIS*, IN RELATION TO HUMAN-MEDIATED GENE FLOW. A. Beaumont, M. T. Garcia, S. Hoenig and P. Low.

University of Wales, Bangor, School of Ocean Sciences, Menai Bridge, Wales LL59 5AB UK.

Population genetic structure of *Ostrea edulis*, the native or flat oyster, in Scotland may be influenced by gene flow caused by natural larval dispersal, by human intervention or by selective processes. Identification of existing population genetic differentiation is an important part of the UK Biodiversity Action Plan for *O. edulis* and a precursor to the process of regeneration of oyster beds Samples of *O. edulis* were collected from 11 sites in Scotland, and from one site each in the Netherlands, Brittany and Norway. Samples were scored at up to 6 microsatellite loci and genetic variation identified as the number of alleles and observed heterozygosity per locus. Population data were tested for agreement with the Hardy Weinberg model and for population differentiation using F statistics and Nei's genetic distance measures. Mean numbers of alleles per locus ranged from 6.4 to 12.2 and observed heterozygosity per locus ranged from 0.59 to 0.79. These values indicate similar microsatellite genetic variation to other bivalve populations. Significant heterozygote deficiencies were evident at some loci most likely due to the presence of null alleles. Low genetic differentiation was detected within Scottish populations, with the exception of samples from the Ulva region, and the greatest genetic dissimilarity was between the Skye Norwegian sample and all others. The results are discussed in relation to historical data on human-mediated transfer of oyster stocks into Scotland.

VALIDATION IN COMMERCIAL CONDITIONS OF THE RESPONSE TO SELECTION OF THE EUROPEAN FLAT OYSTER *OSTREA EDULIS* FOR RESISTANCE TO *BONAMIA OSTREAE*. E. Bedier, A. Langlade, S. Angeri and R. Brizard.

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Since the outbreaks of the parasitosis with *Marteilia refringens* and *Bonamia ostreae* in the last 60's, the French production of the European flat oyster dropped from 20000 mT to less than 1500 mT currently, leaving the French shellfish farming in situation of virtually monoculture of the Pacific cupped oyster *Crassostrea gigas*. To sustain this traditional culture, Ifremer has developed, at the experimental level, a genetic selection for a better tolerance to *Bonamia ostreae* which led to an improvement of survivals. The transfer of these results to the business scale requires the control of the reproduction in hatchery and the adaptation of the cycle of production to the constraints of seedlings

in deep water as practised in Brittany (France). That's why a project, cofunded by Ofimer (1), and intended to evaluate the technical and economic feasibility of the commercial production of tolerant flat oyster spats, was led between 2002 and 2004 in partnership between Ifremer, a private hatchery (Vendée Naissain), the SYSAAF (2) and the SMIDAP (3). Spawning was obtained in 2002 by the Laboratory of Genetics and Pathology of Tremblade of Ifremer (Charente Maritime, France) from breeders descended from the experimental program of genetic selection. Average larval survival rate was 65% and the average settlement rate 40%. In experimental conditions, the contribution of the alga *Tetraselmis suecica* in larval phase led to an improvement of both survival and growth, which was not checked in commercial conditions. The pregrowing step is essential in the cycle of production of *Ostrea edulis* to obtain a sufficient size at seedling. This step, carried out in the Vendée Naissain facilities, does not seem to raise any specific problem, provided some decantation of water is met, if needed: the turbidity indeed is likely an element which blocks the growth in this species. The tolerance of the spat was assessed in both oyster bags in open water, and on the ground in deep water (8 m), as practised in the bay of Quiberon (Morbihan, France). Under these two conditions, the performances of the hatchery spat confirmed, after 2 years of breeding, the better tolerance acquired by the program of selection: the survival of tolerant oysters was 73,4% and 89,2% respectively on the ground and in bags, versus 33,6 and 39,8% for the wild collected spat. The *Bonamia* infestation rate was estimated to 0% for the tolerant spat versus 20% for the wild one, at the beginning of the 3rd summer of breeding. This project pointed out the bottlenecks still existing in the commercial production of spat of this species and drew up, according to acquired knowledge, which could be a technically feasible production in commercial hatchery. (1) Office National Interprofessionnel des produits de la mer et de l'Aquaculture (2) Syndicat des Sélectionneurs Avicoles et Aquacoles Français) (3) Syndicat Mixte pour le Développement de l'Aquaculture et de la Pêche en Pays de la Loire).

MONITORING BREEDING SUCCESS OF DEPLOYED OYSTERS WITH GENETIC MARKERS. J. Carlsson and K. Reece.

Virginia Institute of Marine Science, The College of William and Mary, P.O. Box 1346, Gloucester Point, VA 23062 USA

We report data from molecular genetic marker analysis of oyster recruits near reefs in Chesapeake Bay restored with native *Crassostrea virginica* in order to evaluate breeding success of deployed oysters. Oyster restoration efforts currently involve restoration or construction of suitable habitat followed by deployment of brood stock to boost recruitment. Several oyster stocks, including those derived from wild populations, as well as selectively bred strains, are being used in these efforts. As local native oysters and various previously deployed stocks may be present at deployment sites, it is important to be able to assign individual oysters to their strain or population of origin in order to evaluate the breeding success of deployed oysters. Due to inbreeding and intentional or unintentional selection, hatchery-reared stocks often have different allele or genotype frequencies that distinguish them from local wild oyster populations. Microsatellites are hypervariable nuclear genetic markers that have been successfully employed on a range of species to assign individuals to their population/strain of origin and are perhaps the most promising marker for oyster assignment tests. In addition, some selected strains that have been used in Chesapeake Bay deployments have unique mitochondrial profiles. We have developed a suite of markers, which includes both mitochondrial RFLPs and microsatellite loci that will be used to describe the genetic profiles of different strains used in restoration and of the local native oysters prior to large-scale deployments. This data will enable us to assign individual spat to either the local native population, to deployed oyster strains or to putative hybrid groups to help evaluate the breeding success of oysters used for restoration efforts.

FOOLPROOF OR FOOLHARDY? THE USE OF SELECTED AQUACULTURE STOCKS FOR LARGE-SCALE RESTORATION OF NATURAL OYSTER POPULATIONS. R.B. Carnegie, J. Carlsson, J.F. Cordes, E.M. Burreson and K. S. Reece

Virginia Institute of Marine Science Route, The College of William and Mary, 1208 Greate Road, Gloucester Point, VA 23062, USA

Diseases caused by parasites *Perkinsus marinus* and *Haplosporidium nelsoni* have limited expansion of *Crassostrea virginica* aquaculture along the east coast of the United States. Development of selected disease-resistant aquaculture lines, begun in the 1960's, has shown promise, and these lines find wide aquaculture use in the region today. One of these resistant aquaculture lines, the DEBY (for Delaware Bay) line that originated in collaboration between Rutgers University and VIMS, figures prominently in efforts to restore *C. virginica* populations in Chesapeake Bay. Large numbers of DEBY oysters are being deployed in small trap estuaries like the Great Wicomico River, in Virginia, which may serve as natural incubators for production of large amounts of oyster seed that may then be distributed throughout Chesapeake Bay. It is hoped that introgression of DEBY genes into wild stocks will confer disease resistance upon these wild stocks, thus "genetically rehabilitating" them. The use of genetically depauperate aquaculture stocks for large-scale restoration of natural populations raises numerous questions, however, which we can only begin to answer with existing data. Will outcrossing the selected line with wild stocks result in *decreased* performance, through disruption of co-adapted gene complexes that may underpin the resistance? Will introgression of the selected line with wild populations erode local adaptation that may have evolved in wild populations? Will it reduce the diversity of the wild populations, genetically *debilitating* them and leaving them potentially less resilient in the face of future challenges? Use of selected aquaculture lines for restoration may yield short-term gains in census numbers, but

possibly at a long-term cost in reef or population viability. A strategy balancing use of selected lines (increasing census numbers, and satisfying public demand for immediate progress) and wild stocks (to maintain natural diversity) may be a necessary compromise, however imperfect.

GENETIC DIVERSITY WITHIN AND AMONG NATIVE POPULATIONS AND HATCHERY STOCKS OF THE SUMINOE OYSTER *CRASSOSTREA ARIAKENSIS*. J.F. Cordes, J. Xiao, S.K. Allen Jr., and K. S. Reece.

Virginia Institute of Marine Science, The College of William and Mary, P.O. Box 1346, Gloucester Point, VA 23062 USA

Heavy fishing pressure, habitat degradation, and disease have severely impacted native oyster *Crassostrea virginica* populations along the US east coast. Even with proposed decreased harvesting and habitat restoration, it is feared that the native oyster will not rebound due to a number of diseases now prevalent in Chesapeake Bay waters and throughout the mid-Atlantic bight. Given the poor prognosis for native oyster populations, the states of Maryland and Virginia are considering the introduction of a fast-growing, disease-tolerant species of Asian oyster (*Crassostrea ariakensis*) for the purpose of establishing naturalized, self-sustaining populations. In its report on a 2003 workshop evaluating the risks and benefits of such an introduction the Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program identified a number of genetic concerns that should be addressed before any non-native oyster introductions took place. These include: 1) the importance of assessing the amount of genetic variation contained within and among *C. ariakensis* species across its native range in order to identify the best strain for introduction, 2) determining the genetic relationship between existing U.S. hatchery stocks and native populations of *C. ariakensis*, particularly with regard to the *C. ariakensis* strain that may ultimately be chosen for introduction, and 3) monitoring the amount of genetic variation in hatchery populations of *C. ariakensis* to avoid population bottlenecks and inbreeding. Currently we are using nuclear, mitochondrial, and microsatellite markers recently developed in our laboratory to address these concerns. Preliminary data will be presented on the geographic range of *C. ariakensis* in Asia, the amount of genetic variation within and among existing native populations, and the genetic relationship of current U.S. hatchery stocks of *C. ariakensis* to these native populations.

BETTER SHELLFISH RESTORATION THROUGH GENETICS? P. Gaffney. (PLENARY TALK)

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Genetics has come to play an increasingly important role in restoration ecology, including shellfish restoration. The two primary venues for the application of genetic methods are 1) development of selected strains for supplementation or restoration of debilitated populations, and 2) monitoring the success of restoration efforts through the use of genetic tags. The use of hatchery-propagated lines for enhancement programs has raised concerns about their potential genetic impact on resident populations, but this topic has not been adequately treated from a theoretical or practical perspective. Efforts to restore Atlantic populations of the eastern oyster *Crassostrea virginica* will be reviewed with attention to these topics.

GENETIC VARIATION FOR RESTORATION, SPECIES INTRODUCTIONS OR AQUACULTURE DEVELOPMENT: WHAT AMOUNT IS NECESSARY, SUFFICIENT OR IDEAL FOR EACH APPLICATION? K. Reece, J. Carlsson, R.B. Carnegie, J.F. Cordes and S.K. Allen Jr.

Virginia Institute of Marine Science, The College of William and Mary, P.O. Box 1346 Gloucester Point, VA 23062 USA

The decline of native *Crassostrea virginica* populations in the US mid-Atlantic states due to over fishing, habitat destruction, and disease is well documented. Continued heavy disease pressure has led to interest in using selected disease-tolerant stocks for reef restoration, as well as introducing a non-native Asian oyster, *C. ariakensis*, for aquaculture development, fishery resource enhancement and habitat restoration in the Chesapeake Bay region. Construction of artificial oyster reefs to catch natural spat fall of *C. virginica* and reefs stocked with hatchery seed from wild brood stock have had limited success, leading to more recent efforts to stock these reefs with selectively bred hatchery brood stock. Selectively bred oyster stocks have enhanced resistance to the local parasites *Perkinsus marinus* and *Haplosporidium nelsoni,* which have devastated the local wild populations. These stocks, however, have significantly reduced genetic variation compared to natural populations. Further, out-crossing resistant stocks with wild oysters can compromise resistance due to the deterioration of non-additive genetic mechanisms through recombination. Implications of restocking with disease-tolerant, genetically depauperate strains will be discussed. Additionally, most current proposals for introduction of the non-native oyster are focusing on a *C. ariakensis* strain that originated from a small accidental introduction to the US west coast over 40 years ago. This strain shows significantly reduced genetic variation compared to wild populations in Asia. We expect that genetic divergence of isolated hatchery-propagated stocks from their parent groups will accrue over time, although we have observed reduced genetic variability with *C. ariakensis* stocks brought to VIMS from China after just one hatchery generation. If introduction and/or aquaculture development is to be successful, it may be necessary to regularly supplement hatchery stocks with input from wild Asian populations to maintain genetically healthy stocks in US hatcheries, thereby avoiding inbreeding depression and the loss of genetic variability.

HISTORICAL CONSIDERATIONS IN SHELLFISH MANAGEMENT

MANAGEMENT OF SCALLOP (*PECTEN MAXIMUS* L.) FISHERIES IN NORTHERN BRITTANY. POPULATION PATTERNS UNDER TEMPERATURE EFFECTS AND CATCH CAPACITIES OF THE FISHING FLEET. S. Fifas and P. Arzel.

IFREMER - STH/UDPP, Centre de Brest - B.P. 70, Plouzané 29280 France

History of scallop fisheries of the North-East Atlantic is mainly regulated by two factors after the 2nd world war: (1) the hydro-climatic component: scallops may benefit significantly because of temperature increase and of global warming and (2) coastal and inshore fishing activities targeting these species have been characterized by deep changes (from generalized motorization of vessels to computer processing on board) for 50-60 last years inducing continuous increase of catch capacities. Even if scallops had got a more symbolic than commercial position before the 20th century, they were advantaged by favourable conjunction of both factors cited above. They became the most emblematical molluscs of European fisheries. Two scallop beds of Brittany (Bay of Brest, Saint-Brieuc Bay) are analysed. Both stocks present different features of demographic pattern as well as for fishery development. The Bay of Brest held the most advanced position during the first period, but it underwent not regulated mechanization. Fishing of young scallops (almost 30% at the age of one year) has been so strong nowhere else; furthermore, catch capacity had been developed whereas favourable population dynamics at the start of 50's kept from seeing that the stock had declined gradually. After the severe winter of 1963, the Saint-Brieuc Bay and the Channel fisheries took over because of good environmental conditions. More strict regulation has been attempted notably for selectivity of fishing gears and minimum market size. However, catch capacity grows continually and an irreversible status has just been avoided at the end of 80's. At present, traditional regulation policy seems to run out because of computing developments on board. Only strict limits on number of fishing hours are not enough. In biological regulation there is only a little profit possible, but economic overcapacity of the fleet was already reached.

HARD CLAM AQUACULTURE ON THE EAST COAST OF THE US AND ITS RELATION TO HABITAT ENHANCEMENT. G. Flimlin and J. N . Kraeuter. (PLENARY TALK)

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The culture of the hard clam or Northern Quahog, *Mercenaria mercenaria*, is practiced in almost every coastal state along the Atlantic Coast of the United States at some level. The growth of this aquaculture industry stems in part from the reduction of wild stocks in many states. Participation in this industry has fluctuated from its beginnings in the mid-1970's. Several states presently excel in cultured clam production, but prices have dropped although the market may not be fully exploited. The techniques for the hatchery phase and initial nursery phase are very similar from place to place, but growout technology and local regulations can be very different depending on the state and the site. The impact of *Mercenaria* culture has not been formally studied, however, many in the industry are quite convinced that their operations are beneficial to the local environment.

A CENTURY OF EVOLUTION OF THE SHELLFISH FISHING AND FARMING ECOSYSTEM IN MONT-SAINT-MICHEL BAY: FROM THE FISHING TO THE SHELLFISH CULTURE OR FROM THE APPROPRIATION OF THE RESOURCE TO THE APPROPRIATION AND THE MODELLING OF THE SPACE. P. Le Mao, C. Retiere and C. Le Bec.

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At the beginning of the last century, the only modes of shellfish exploitation in the Mont-Saint-Michel bay were the fishing of cockles *Cerastoderma edule* on the mudflats and the native oysters *Ostrea edulis* fishing by dredging on subtidal soft substrates, sometimes followed by a stocking on 110 hectares of parks on intertidal flats. After a period of decline and almost disappearance during the first half of the last century, the exploitation of shellfish restarted after the second world war and took very quickly a considerable dimension in the bay, with a very consequent development of the shellfish farming (native and pacific oysters, mussels). These practices led directly and indirectly a pronounced modification of the general functioning of the bay ecosystem with a massive occupation of the marine area of bathymetric levels included between 5 meters above and below the most low tide level, mainly in bay of Cancale. Not only the man monopolized and created new spaces by implanting shellfish structures (bouchots and oysters tables), but these activities induced the appearance in the bay of several invasive species: the slipper limpet *Crepidula fornicata* which now presents a biomass more than 7 times high as the cultivated shellfish, but also the manila clam *Ruditapes philippinarum* and the pacific oyster *Crassostrea gigas*. These modifications acted on the trophic structure and on the production potential of this benthic ecosystem. They also act on their physical (hydrosedimentology) and biological characteristics by modification and creation of habitats. This acts on the biodiversity of the Mont-Saint-Michel bay : appearance of bioherms of anthropological origin in a quasi-exclusively sedimentary environment."

THE NATURAL OYSTER BEDS OF FRANCE: EVALUATING POLICIES OF MANAGEMENT SINCE THE EIGHTEENTH CENTURY. O. Levasseur.

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French management of its natural oyster beds represents a particularly illustrative example of how relationships with marine resources began to change in the eighteenth century. In face of dwindling harvests, the perception grew that the resource would effectively be used up. The resulting alarm caused authorities to seek solutions that proved effective only in the short term. The authorities sought two logical resolutions to the crisis. These included protecting the natural oyster beds from overexploitation while at the same time seeking scientific solutions to eliminate the constraints imposed by the natural reproduction oysters through the implementation of artificial methods of production. Despite even these feeble efforts, as quickly as each crisis passed, pressure from various local interests caused disengagement by authorities. It would be precisely in this absence of long term interest that the principle problems would once again arise. Time and again, authorities waited for reoccurring crises before applying new methods of intervention. This paper seeks to highlight three different crises on France's natural oyster beds: the first between 1750 and 1790, where the first tentative efforts for management would appear; the second, a century later, during the scientific work of Victor Coste and the birth of modern oyster culture; and the third during the epizootic that decimated *Ostrea edulis* in 1920/21. Through the study of these periods, covering nearly two centuries, it is possible to follow the diachronic process involved in the construction of oyster management policy and measure both its short-term and the long-term impacts. Finally through study of both the successes and failures of management strategies, there will be an attempt to arrive at some conclusions as to the validity of any coherent policy during the entire period concerned.

A HISTORICAL PERSPECTIVE FOR DETERMINING CHANGES IN THE DISTRIBUTION OF OYSTER HABITATS IN SOUTHWEST FLORIDA, USA USING ARCHIVED MAPS AND CHARTS OF FEDERAL AGENCIES. J. Stevely.

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A key issue in oyster reef restoration and fisheries enhancement in southwest Florida, USA is to establish a historical baseline showing pre-development location and extent of oyster reef habitatwithin a bay system. Our project discusses the utility of using U.S. Army Corps of Engineers and U.S. Coast and Geodetic Survey cartographic source documents for delineating antecedent oyster reefs. Coupled with recent (2001) habitat mapping conducted by the Sarasota Bay National Estuary Program we were able to develop a picture of oyster reef evolution over 120 years. Our methodology includes scanning the source maps, identifying and digitizing oyster polygons, and creating GIS coverages. This historical information is compared with comtemporary conditions derived from interpretation of 2001 color aerial photographs to create a change analysis oyster reef map. Examples of the historical source maps are shown for Little Sarasota Bay, Florida, USA. This work has provided a valuable tool for planning oyster reef restoration programs.

THE KJÖKKENMÖDDEN FROM WESTERN MAURITANIA (7TH-2ND MILLENIA B.P.). P. Tous[1] and R. Vernet.[2]

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The sea-shells middens of the Mauritanian coast constitute an exceptional example of the use of coastal marine resources, under a dry tropical climate. During at least 6 millennia men lived on this shore, or visited it to fish or collect bivalves and gastropods. The study of molluscs remains, in their natural environment and other archaeological indices provide key information for the interpretation, on long time periods, of the variations of both the hydro-climate and the terrestrial climate, as well as about the fluctuations of the sea level, all factors which played a decisive role on the evolution of the way of life of the populations of the atlantic Sahara. Recently developed methods, based on isotopic analysis of the shells themselves, allow us to make very fine reconstitutions of the characteristics of littoral climates at different periods, and can contribute to better understanding of the links between the atmosphere and the ocean. Molluscs have been the bases of various Neolithic and Protohistoric Saharan and Sahelan societies, for use either as a food staple or ornamentation, or even for « industrial » purposes. This may remind us of some current exploitation systems in other regions of Western Africa. The diversity of the littoral ecosystems and their evolution, which can sometime be very fast and in some cases related to overexploitation of the resources, can be observed through these vestiges. Therefore they constitute a source of knowledge on the management of living coastal resources and the coastal zone.

IMPORTANCE OF HATCHERIES AND AQUACULTURE IN SHELLFISH RESTORATION

DISINFECTANTS USED IN MOLLUSC HATCHERIES AND NURSERIES. C. François and J. P. Pepin.

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Increasing development of aquaculture business has thrown up new requirements in terms of prevention and control of mollusc diseases. In closed structures, one way to reduce infectious risk is to make use of anti-infectives . Specific drugs like antibiotics should be used only for therapeutic purpose against identified agents. Less specific anti-infectives like disinfectants could be employed for preventive and also for curative goals against causal pathogens and opportunist agents. A critical analysis synthesizes the bibliography available on disinfection in mollusc hatcheries and nurseries. Physical and chemical tools are reviewed then selected depending on four criteria: (1) efficiency against most important pathogens of molluscs, (2) safety for animals, operator and environment, (3) ease of use regarding to the specificities of this rearing and (4) finally cost. Further developpements will also include experimental assays to assess this choice. First collected information suggest that disinfection should be more considered and could be integrated in a Good Practice Programme, including routine management procedures but also disinfection plan in the case of disease outbreak.

SETTLED MESH TRIALS OF THE SCALLOP *PECTEN MAXIMUS* IN SOUTH WEST IRELAND. D. Millard and F. O'Mahony.

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The availability of scallop seed is seen as the main problem hindering the expansion and success of scallop aquaculture in Ireland. After years of wild collection trials around the coastline, only one area, Mulroy Bay, Donegal, produces large quantities of natural scallop seed, but unfortunately this annual 'spat-fall' event is unpredictable, being a boom or bust scenario. For the last few years Cartron Point Shellfish Ltd. have been trying to produce seed from their hatchery in Clare to service the seed demand but due to biological and economic reasons have also been unable to produce seed for the Industry. In 2004 the pump ashore facility owned by Fastnet Mussels Ltd., Gearhies, Co. Cork, Irealnd was identified as suitable for a settled mesh trial. During 2004 over 400, 1000 micron mesh bags, containing four week old scallop larvae settled on a $1m^2$ of mesh were delivered to various sea sites, these resulted in over 100,000 30-50mm scallop for reseeding in 2005. In 2005 it is hoped to at least equal the number of bags put to sea but with improved handling techniques a higher survival rate. It is hoped that if this technology proves successful then it can be scaled up and replicated around the coastline.

PROTECTION OF BIVALVE LARVAL REARING BY BENEFICIAL MARINE BACTERIA. P. Miner and J. L. Nicolas.

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In the first step of this study, marine bacteria were collected from different biotopes along Brittany coast. The isolates were tested for their antibacterial activity by method of diffusion on agar against *Vibrio anguillarum*, *Escherichia coli*, *Pseudomonas areuginosa*, *Staphylococcus aureus* and *Candida albicans*. Only 54 out of 887 isolates showed an activity against one target at least. Then, three isolates (X6, X20, X129) were chosen among the most active bacteria and were characterized. All belonged to the species, Roseobacter gallaeciensis. Their antagonistic activity and the one of the reference strain, *Roseobacter gallaeciensis*, named here X34, were different against vibrio pathogenic to bivalves. The strain X129 and X34 were tested in bivalve larvae for their protective effect. In larval rearing X34 cultured in axenic microalgae, and distributed à 104 cell/ml (final concentration) increased growth of scallop (*Pecten maximus*) and oyster (*Crassostrea gigas*) larvae. It protected also oyster larvae against bad quality of sea water. The probiotic X129 cultured in Casamino Acid medium and added at 106/ml (final concentration) was efficient to limit the spontaneous mortality in scallop larval rearing. Finally X34 might stimulate the metabolism of larvae whilst X129 probably acted directly against pathogenic bacteria in sea water. However the defect of these probiotics is the lack of reliability and further experiments will be necessary to determine the optimal conditions allowing a better expression of antagonistic and stimulating effects. As soon as the effect will be stabilized it will be possible to replace antibiotic treatment necessary to scallop larval culture by these beneficial bacteria. Some different experiments were also performed with clay particles, essential oils, and antibacterial peptides. Unfortunately the molecules were more toxic on bivalve larvae than on bacteria. Clay particles improved the survival until before metamorphosis but did not protect the larvae after.

THE ROLE OF HATCHERIES IN STOCK ENHANCEMENT PROGRAMS IN THE REPUBLIC OF THE MARSHALL ISLANDS: THE IMPORTANCE OF STRIKING THE RIGHT BALANCE. M. Nair.

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Republic of the Marshall Islands (RMI) is a chain of island nation with rich and diverse marine resources. Shell and finfish resources form the major economy of this country. Due to extreme artisan and commercial fishing of these valuable resources like Giant Clams, ornamental shellfishes, pearl oysters etc., these resources have been over exploited causing environmental damage, stock depletion and threatening food and economic security. The Government of RMI in this regard has taken the immediate initiative to restock depleted reefs through its fisheries department Marshall Islands Marine Resources Authority (MIMRA) and also several organizations, funding agencies and programs like the USDA Land Grant, JICA- OFCF of the Japanese Government are involved in this program jointly and independently as the need maybe. Several species of Giant Clams, Black-Lip Pearl Oyster, White Cowry, Helmet Shell have all been sea ranched for stock enhancement in areas of severe depletion. There is also a ssustained effort in prioritizing which are the immediate candidate species required atoll- wise like Trochus shells in one Pearl Oysters or Triton Shells in another. However the most challenging and critical question for the program managers is the vital question of how much has to be sea ranched for a sustainable environment, stock replenishment and food security. The various shellfish stock enhancement programs undertaken with hatcheries and their immediate and long-term impact on the stock, environment and food security and the vital importance of striking the right balance will be discussed here.

HATCHERY TECHNOLOGY TO SUPPORT SHELLFISH RESTORATION, AND RECENT RESEARCH ON NEW ZEALAND ABALONE STOCK ENHANCEMENT. R. Roberts,[1] E. Keys,[2] G. Prendeville[3] and C. Pilditch. (PLENARY TALK)

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Abalone (Haliotidae) are highly prized marine snails fished and farmed in numerous countries. Several major abalone fisheries declined dramatically in recent decades, but New Zealand's *Haliotis iris* fishery remained stable until 1999. Since then commercial catch has been reduced by ~18%. To stem or reverse that decline, various management measures are being assessed. This paper describes experiments to assess the viability of stock enhancement by release of hatchery-reared seed. Five sites were seeded with 2600 to 20000 juveniles (mean 11 mm shell length (SL), range 6-19 mm), then surveyed 17 - 20 months later, near the end of the vulnerable juvenile phase. Survival across the five sites ranged from 1.7 to 25.1% (average 13.8%). Estimated survival to harvest (125 mm SL) ranged from 1.3 to 18.6% (average 10.2%) assuming 3 further years of mortality at M=0.1. Growth averaged 29.5 ± 1.7 (±SE) mm SL year-1 across the five sites. Substrate movement during storms appeared to reduce survival at the two poorest sites, highlighting the risk of using exposed locations with moveable (=sampleable) boulders. Boulder reefs (1 x 2 x 0.5 m) were constructed by placing natural boulders in wire baskets over sand or bedrock. These reefs allowed accurate census of small abalone for short term experiments relating to seed size (5 to 25 mm SL) and density (25 to 640 m^{-2} of seafloor). Growth and survival of 8-24 mm seed decreased with increasing density, but regressions were non-significant ($P>0.05$) due to variability among reefs. Densities as high as 300 m^{-2} gave good growth and survival (>40%) over 3 months. Survival increased with seed size up to an optimum of ~15 mm, and decreased for larger seed. Results suggest that reseeding is likely to be economically viable if careful selection of sites and habitat is exercised.

PATHOLOGY AND EPIDEMIC CONSIDERATIONS IN SHELLFISH RESTORATION

CONSIDERATION OF QUAHOG PARASITE UNKNOWN (QPX) DISEASE DURING HARD CLAM ENHANCEMENT PROGRAMS. B. Allam.

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Quahog Parasite Unknown (QPX) is a protistan pathogen that affects hard clams, *Mercenaria mercenaria*, in the Northeastern United States up to Canadian Maritime Provinces. Although the first observations of QPX were documented in the 1950's, the disease remains very poorly understood to date. This report summarizes some of our results that pertain to the consideration of QPX in hard clam enhancement programs. Our monitoring of QPX disease in wild hard clams showed that heightened prevalences occurred in areas with higher clam densities. Results also demonstrated a seasonal pattern in QPX prevalence, with a peak in early summer followed by a decrease in autumn that seems to be associated with the death of infected clams. In vitro investigations reveal that QPX isolated from New

York clams exhibited optimal growth at 23ºC, while pathogen isolated from Massachusetts clams had optimal growth at 20°C. Differences were also observed in tolerance to salinity of the above isolates, suggesting that these isolates represented two different strains of the pathogen. Laboratory and field transmission experiments suggest that susceptibility to this infection is a function of clam strain and the particular QPX isolate used during challenge. These results warrant a cautious approach to extrapolation of results obtained from one location using one clam strain onto other geographical areas. Hard clam enhancement programs often involve the transplant of spawner clams or the seeding of hatchery-produced juveniles. Our results emphasize the need for careful consideration of optimal periods of the year for clam collection in source areas to limit the risk of transplanting infected clams. Clam density in seeded areas must be cautiously managed to minimize potential for disease outbreak. Finally, current diagnostic techniques need to be improved in order to contend with the focal nature of sub-lethal QPX infections.

A HYPOTHESIS FOR LONG TERM POPULATION CYCLES IN THE FLAT OYSTER *OSTREA EDULIS* AND CONSEQUENCES FOR STOCK RESTORATION EFFORTS. C. Askew.

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It is known that there have been long-term historical cycles in stock of *O .edulis* in European waters. For example an 'oyster famine' was recorded in the 1630s and in the 1850s stocks were abundant around the British Isles. That was followed by a decline until the 1920s, for which no adequate explanation has been presented. Over-fishing and pollution are often quoted. Whilst over-fishing played an important part, the long-term damage may have been exerted by an indirect mechanism. Studies at Southampton Oceanography Centre by Hawkins and Hutchinson have shown that the immune system of *O. edulis* is compromised by high density stocking in cultivation, even at relatively low stock densities relative to practice with *C. gigas*. However, historically native oysters did exist in high density natural reefs. It is proposed that selective pressure at each generation, combined with higher chances of fertilisation between closely adjacent oysters within a reef, resulted in selection of oysters capable of surviving higher population densities. Once the high density reefs were lost, either through fishing or disease, this selective pressure was lost. Oysters survived at lower density, but the progeny were no longer subject to selection for the ability to survive high stock density. Within a few generations such ability may have been diluted. Under natural conditions in the absence of fishing, this could have been a mechanism driving long-term population oscillations, as a cycle would be established between stock density and the competence of the immune system. It is proposed that an experimental high-density oyster 'reef' be established and allowed to self-perpetuate, without fishing, providing a model for populattion dynamics studies.

A LONG TERM STUDY OF BONAMIOSIS IN QUIBERON BAY, SOUTH BRITTANY, FRANCE. I. Arzul, L. Miossec, E. Blanchet, C. Garcia, J. P. Joly and F. Cyrille.

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Bonamiosis was first reported in association with mass mortality of flat oysters, *Ostrea edulis*, in June 1979 in L'Ile Tudy, Brittany. The disease rapidly spread to all of the oyster farming areas in France but also in other European countries. The French flat oyster production, which already suffered from another protozoan disease, marteiliosis, decreased from 5500 mt in 1979 to less than 2000 mt after 1980. In 2001, about 350 French farms sell 1650 mt of flat oysters. This production mainly relies on natural spat collection which specially occurs in Quiberon bay. One third of this spat is transferred from South to North Brittany for further growth. Quiberon bay constitutes an interesting site regarding the surveillance of bonamiosis because of the simultaneous presence of spat and adult flat oysters. We analyze and present herein the long term series of data collected in this area. On the period 1980-2004 more than 30000 oysters were sampled for different purposes in Quiberon bay and were tested by histology and/or heart imprints for the detection of *Bonamia ostreae*. Detection frequencies presented some fluctuations including two peaks in 1994-1995 and 2000-2001. Disease frequencies recorded during the first period of this study (1980-1989) were lower than those reported later (1990-2004), probably related to the flat oyster mass mortality. Differences could be noted according to animal age and sampling season. Although the disease is enzootic in Quiberon bay since 1980, the production of flat oyster is still present in this area. One can wonder how environment and cultural practices can influence the evolution of the disease and the oyster defense mechanisms while the parasite appears to inescapably lead to the dead of the infected oysters.

USAGE OF CHEMOTHERAPEUTANTS TO MITIGATE DISEASE PRESSURE IN SHELLFISH: A REMEDY OR A DISASTER? F. L. Chu,[1] E. Lund[1] and P. Soudant[2]. (PLENARY TALK)

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A worldwide increase in the frequency and intensity of diseases has affected economically and ecologically important marine organisms. Various disease agents have been reported to be associated with the outbreak of diseases and subsequent mortality in many cultivated and feral populations of shellfish species. To counteract the diseases and to improve yields in cultivated species, research efforts have directed to development of novel chemotherpeutants to mitigate disease pressure and produce disease resistant strains. Various antibiotics and chemotherpeutants have been tested and used in controlling diseases in intensive aquaculture, including oxytetracycline, oxolinic acid, chloramphenicol, and cycloheximide. While usage of drugs appear successful in controlling disease and improving

survivorship in several economically important shellfish species, improper and extensive use of antibiotics has resulted in the development of antibiotic-resistant bacteria and persistence of antibiotic residues in the target organisms and in the environment. Thus, it is important to develop effective disease control dose while minimizing residues in target organisms and in the environment. Alternative approaches using antimicrobial peptides derived from the hosts and biological control in preventing and controlling diseases appear quite promising. Development of molecular and biochemical techniques to block active sites of pathogen's key proteins and interrupt the pathogen's metabolic pathways is forthcoming. Recently we targeted the lipid synthetic pathway of the parasite, *Perkinsus marinus*, which causes Dermo disease in the eastern oyster, *Crassostrea virginica*. We found that triclosan inhibits lipid biosynthesis and kills *P. marinus* at low concentrations (5-20μM) that have minimal effect on oyster hemocyte viability. Triclosan, a common antibacterial agent, has not yet been shown to have toxic effects to mammals. The tested concentrations are 1000 times lower than the allowed level by FDA in daily use hygiene products. Currently we are testing effects of triclosan in treating Dermo infection and its toxicity in oysters.

BONAMIOSIS IN IRELAND – CURRENT PERSPECTIVES. S.C. Culloty. (PLENARY TALK)

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The European flat oyster *Ostrea edulis* has been harvested in Ireland for many centuries and was the main oyster species produced in the country up to the 1980's. Oyster beds are concentrated along the North, west and south coasts of the country. In 1987 Irelands' disease free status ended with the discovery of the protozoan parasite *Bonamia ostreae* in flat oysters in Cork harbour on the south coast of Ireland. One of the main areas of production in the country, the beds were quickly decimated with up to 90% mortalities in older oysters. Since then the disease has spread to some of the other main oyster producing areas along the west coast and in recent months the disease has been diagnosed in Lough Foyle on the north coast. Though it is difficult to determine how the parasite was introduced to a particular area it is thought to be related to movements of infected oysters and contamination from equipment. Different strategies have been employed at different sites to try to combat the disease or to keep the areas viable including modified husbandry techniques, changing to the production of other species such as the Pacific oyster *C. gigas* and long term strategies such as breeding flat oysters for resistance to the disease. The outcome of these particular strategies will be discussed as well as the results of a number of studies comparing the relative susceptibility of oysters bred for resistance with other populations from Ireland and Europe. Results indicate that selective breeding from survivors over a number of generations reduces the susceptibility to infection. Another area that has caused difficulty for management of the disease has been uncertainties related to the life cycle of *B. ostreae*. It is known that the parasite can be transmitted directly from oyster to oyster. However, it has not been determined if another organisms may act as a secondary host or carrier species for the parasite. Also, in infected oysters, difficulties arise in trying to identify the parasite during the initial weeks post infection. During this so-called 'latent period' it is unclear if the parasite is localised within a particular tissue of the oyster or if another stage in the life cycle is present. The results of a current study looking at aspects of the life cycle of *B. ostreae* will be outlined. Several invertebrates have been found to be positive when screened by PCR for *B. ostreae* and the significance of these results needs to be interpreted in relation to the life cycle of the parasite. Screening and diagnosis of *B. ostreae* has implications for movements of oysters and for planning restocking and regeneration programs. The diagnosis of *B. ostreae* is conventionally carried out by examination of ventricular heart smears and/or histology. Molecular based techniques such as Polymerase Chain Reaction and *in situ* hybridisation are now available. Results of validation of the different methods would indicate that all techniques presently available have a certain margin of error and no one technique should be used in isolation when considering movements of oysters or when screening programs are being undertaken. Various aspects of the work carried out on *B. ostreae* in Ireland since 1987 will be discussed in relation to their implications for restocking and regeneration of oyster beds.

FROM A HOST TO THE OTHER: THE CRITICAL ROLE OF THE SHORT CERCARIAE STAGE. X. De Montaudouin,[1] C. Desclaux[1] and K. T. Jensen[2]

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Many shallow-water bivalves exploited for human consumption are intermediate hosts to a variety of trematode species, some of which may be pathogenic to the hosts and impact their population dynamics. For trematodes using bivalves as their second intermediate host, the processes determining emission rates of cercariae from their first intermediate host and transmission rates to the bivalve hosts are vital for an understanding of the development of trematode epizootics in bivalves. The present study analyses the required conditions to successfully infect the second intermediate host (the cockle *Cerastoderma edule*) by cercariae larvae (*Himasthla quissetensis*) emitted by the first intermediate host, the gastropod *Nassarius reticulatus*. Field monitoring and flume experiments demonstrated that the infection can occur even though cockles and parasitized *N. reticulatus* are allopatric because cercariae can be transported with currents. This free-living stage is short (ca 24 h) and infectivity is even shorter. Temperature is the most important factor for cercariae emission, cercariae lifespan and infection success in cockles. However, the appropriate temperature (around 19°C) has to be combined with a suitable cockle shell length. Consequently, cockle

growth rate, and all related factors, has to be integrated to understand parasite/cockle phenology. Finally, *in situ* survey and chronobiology experiments put in evidence the existence of a nyctemeral rhythm in cercariae emission. Recognizing the strong temperature dependence of parasite-host dynamics, climatic change may have significant consequences for the role of parasites on shellfish populations in the future.

BROWN RING DISEASE IN THE MANILA CLAM (*RUDITAPES PHILIPPINARUM*): A NUMERICAL MODEL. J. Flye Sainte Marie,[1] S.E. Ford,[2] E. Hofmann,[3] F. Jean,[1] J. Klinck,[3] C. Paillard[1] and E. Powell.[2]

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Brown ring disease, caused by the bacterial pathogen Vibrio tapetis, affects growth of the Manila clam and can induce high mortalities on the field. The developement of this disaese has been shown to be highly controlled by environmental factors, physiological status and phenotype of the host. In order to better understand the complex interactions between the environment, the clam and the pathogen, a numerical model is being developed. It incorporates the host (the Manila clam), the pathogen (*V. tapetis*) and is forced by the environment (temperature and food availability). The host physiology is modelled through an energy balance model that takes into account immunological variables. This host model is coupled to the pathogen development model. This model differs from previous bivalve models in that it is individually based. Rather than tracking a 'standard' host, the model follows an assemblage of individuals of differing phenotypes. Phenotypic variability of (1) assimilation rate, (2) hemocyte activity rate (number of bacteria phagocyted per hemocyte per day) and (3) calcification rate (a measure of the ability to recover by covering over the symptomatic brown ring deposit) are taken into account. The model can simulate the 'life story' of individuals with a combination of high, intermediate or low values of the three parameters. Model simulation indicate that the developement of brown ring disease is dependent on food supply (high being good for the clam) and on temperature (relativelylow being good for the pathogen). Such a model could be used as tool predict impact of environmental changes (long-term worming or eutrophication) on disease developement. This work is part of the MODELMAB project granted by Région Bretagne.

EFFECT OF *IN VIVO* POLLUTANT EXPOSURE AND PATHOGEN INJECTION ON PHAGOCYTOSIS GENE EXPRESSION IN THE PACIFIC OYSTER, *CRASSOSTREA GIGAS*. B. Gagnaire,[1] T. Renault,[1] H. Thomas-Guyon[2] and T. Burgeot.[3]

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Shellfish industry has developed in an important way in France. However, this activity is mostly realised in estuary zones, which are subjected to pollutions (pesticides, mercury) due to anthropic activities (agriculture, industry). The harmful effects of pollutants on species inhabiting these estuarine zones are poorly known. Bivalve molluscs and particularly Pacific oyster, *Crassostrea gigas*, may represent a model because they are sedentary, and they filter water intensively, which favour bioaccumulation of pollutants in their tissues. Among all physiological functions possibly disturbed by pollutants, defence mechanisms, assumed by circulating cells, the hemocytes, are poorly documented in bivalves. Moreover, animals presenting impaired defence mechanisms may be more sensitive to infectious diseases. In this context, effects of pollutants on hemocyte functions and disease susceptibility were tested in Pacific oyster, *Crassostrea gigas*. A pesticide combination (alachlor, metolachlor, atrazine, therbutylazine, glyphosate, fosetyl aluminium, carbaryl, diuron) at environmental concentrations (0.5 $\mu g.L^{-1}$ to 1 $\mu g.L^{-1}$) reported in Marennes-Oleron basin (Charente-Maritime, France) was tested *in vivo* during 7 days on Pacific oysters. Mercury chloride was tested *in vivo* at two concentrations (50 $ng.L^{-1}$ and 250 $ng.L^{-1}$) during 7 days on *C. gigas*. Total RNA were extracted from hemocytes in order to compare expression of 20 genes involved in phagocytosis between control and contaminated samples using real time PCR. Other experiments involved the same contamination processes followed by an injection of OsHV-1 (Oyster Herpes Virus type 1) or bacteria (*Vibrio*), infectious agents which could lead to mortality events. Total RNA were also extracted from hemocytes at 4 hours and 24 hours post-injection in order to compare gene expression between infected control and infected contaminated samples. Analysis of gene expression are still in progress. Results will allowed us to conclude about the potential role of contaminants in the sensitiveness to infectious diseases.

REPAMO: A SURVEILLANCE TOOL FOR MOLLUSC HEALTH. C. Garcia, I. Arzul, C. Bruno, F. Cyrille, J. P. Joly, L. Miossec and M. Robert.

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At the present time losses due to diseases are one of main factors limiting the aquaculture development. Unceasing increase of exchanges between different countries favours the risk of introduction and propagation of new pathogen agents. At the beginning of the 90's the European Union laid the surveillance of mollusc health inside each Member State in order to protect the safety of exchanges. Indeed few measures are available to protect molluscs from diseases. Only the prophylactic approach is possible; this approach is based on a zoosanitary surveillance of mollusc populations and/or a development of resistant populations against some diseases. Created in 1986, the French network for

surveillance and monitoring of mollusc health (REPAMO) ensures the survey of shellfish health status along French coasts according to the Directives 91/67/EEC and 95/70/EC. The missions of the network are: (1) the surveillance of notifiable diseases present in France (Bonamiosis due to *Bonamia ostreae* and Marteiliosis due to *Marteilia refringens*), (2) the surveillance of health state of cultured and natural populations of molluscs, (3) the study of abnormal mortalities and (4) the control of exchanges from European country or from Third country. Therefore, the aims of REPAMO network are to prevent the introduction and spread of exotic diseases inside the different areas of French production and to study the impact of pathogens already present and to survey their evolution.

INVOLVEMENT OF PATHOGENIC BACTERIA IN SUMMER MORTALITIES OF THE OYSTER (*CRASSOSTREA GIGAS*). M. Garnier, Y. Labreuche, C. Garcia and J. L. Nicolas.

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To explain the summer mortalities of Pacific oyster (*Crassostrea gigas*) a causal agent, bacteria, has been repeatedly invoked and occasionally reported. A study was conducted to investigate the involvement of bacteria in oyster mortalities during summer. Moribund and apparently healthy oysters were sampled during mortality events along the French coast and in rearing facilities, mainly when temperature reached 19°C or more and oysters were in the gonadal maturation phase. Hemolymph was aseptically withdrawn and submitted to bacteriological analysis. In healthy oysters, bacteria colonised hemolymph at low concentrations depending on season and location. In most moribund oysters, bacteria were present in hemolymph and other tissues. These bacterial populations were more often diversified in oysters from open sea than from facilities where animals were generally infected by a single type of bacterium. Only the dominant colonies were identified by phenotypic and genotypic characters (RFLP of GyrB gene and partial sequence of 16S rDNA). They belonged to a limited number of species including *Vibrio aestuarianus*, members of the *V. splendidus* group, *V. natriegens* and *Pseudoalteromonas* sp. The most frequently encountered was *V. aestuarianus* (56% of isolates) which was composed of several strains closely related by their 16S rDNA but diversified by their phenotypic characters. They appeared intimately linked to oysters. The species inside the *V. splendidus* group were less prevalent (25% of isolates) and more taxonomically dispersed. Certain dominant strains injected to oysters provoked mortality, whilst others appeared innocuous.

CHARACTERIZATION OF *VIBRIO* SPP. ISOLATED FROM VENERID CLAMS (*RUDITAPES PHILIPPINARUM*, *RUDITAPES DECUSSATUS*, *VENERUPIS AUREA*, AND *TAPES PULLASTRA*) AND CORKWING WRASSE (*SYMPHODUS MELOPS*) IN NORWAY. CAN PATHOGENIC BACTERIA BE TRANSMITTED BETWEEN CLAMS AND CORKWING WRASSE. K. Korsnes,[1] C. Paillard,[2] S. Mortensen,[1] P. LeChevalier,[3] C. Skår,[1] A. G. Eriksen,[1] L. Harkestad[1] and O. Bergh.[1]

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Bacteria identified as Vibrio tapetis has been isolated from both corkwing wrasse (*Symphodus melops*) and Manila clam (*Ruditapes philippinarum*) in Norway. An environmental survey was therefore initiated to evaluate a potential transmission of the pathogen *Vibrio tapetis* from introduced Manila clams, showing clinical signs of Brown Ring Disease, to native Norwegian clam species and corkwing wrasse *Symphodus melops*. Manila clams and native clams of the species *R. decussatus*, *Venerupis aurea*, and *Tapes pullastra* from the same site were collected. A targeted search for predominant *Vibrio* spp in the venerid clams was performed, with special emphasis on the pathogens *V. tapetis* and *V. splendidus*. Isolated strains where subjected to genetic characterization by sequencing partial sections of 16S rDNA, GyrB and Hsp60 genes. Based on the characterization results, a selection of strains was mad and used in experimental challenge of corkwing wrasse. The first series of challenge experiments indicate that different *Vibrio* species are pathogenic for clams and fish respectively. Challenge experiments with corkwing wrasse however indicate that this species is generally susceptible to vibriosis – a finding that complicates the studies, as well as the transmission hypothesis.

EFFECTS OF EXTRACELLULAR PRODUCTS FROM THE PATHOGENIC *VIBRIO AESTUARIANUS* STRAIN 01/32 ON LETHALITY AND CELLULAR IMMUNE RESPONSES OF THE OYSTER *CRASSOSTREA GIGAS*. Y. Labreuche,[1] P. Soudant,[2] M. Gonçalves,[2] C. Lambert[2] and J. L. Nicolas.[1]

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Vibrio aestuarianus strain 01/32 was previously shown to be pathogenic to *Crassostrea gigas* juveniles. To investigate virulence mechanisms of this pathogen, we studied the toxicity to oysters of its extracellular products (ECPs). ECPs displayed lethality to animals, with a LD50 value of 3.3 µg/g body weight. To determine the oyster cellular immune responses were induced by these ECPs, we further examined *in vitro* their effects on *C. gigas* hemocytes, using flow cytometric-based hemocyte assays. Treatment of hemolymph with ECPs caused a significant inhibition of hemocyte phagocytosis and adhesive capabilities. In contrast, the pathway of reactive oxygen species production was enhanced by higher ECP concentrations. Exposure of hemocytes to live bacteria induced no changes in hemocyte parameters. Together, these results suggest that *V. aestuarianus* strain 01/32 secretes one or more factors which may play an

important role in the pathogenicity of this microorganism, and which display immunosuppressant activities on hemocyte functions.

MODULATION OF REACTIVE OXYGEN SPECIES (ROS) PRODUCTION BY HEMOCYTES OF TWO AQUACULTURED BIVALVES, CLAM AND OYSTER, FACED TO PATHOGENIC *VIBRIOS*. C. Lambert,[1] P. Soudant,[1] M. Jegaden,[1] Y. Labreuche[2] and M. Rifi.[1]

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Last decades have seen emerging diseases affecting marine animals, particularly bivalves, leading to ecological and/ or economical disruptions. In Europe, bacteria belonging to the genus *Vibrio* have been shown to be pathogenic to adult bivalves: *Vibrio tapetis* on clam *Ruditapes philippinarum* and *V. aestuarianus* on oysters *Crassostrea gigas*. Capacity of reactive oxygen species (ROS) production by bivalve hemocytes is one major defense system against pathogenic bacteria. To study bacteria/ hemocyte interaction, a flow cytometric method has been recently developed in our laboratory to evaluate the in vitro capacity of hemocytes to produce ROS. As a result, alive *V. tapetis* as well as killed bacteria (heated) have been shown to drastically reduce the ROS production of clam hemocytes, even at low concentration (less than 5 bacteria per hemocyte). To a letter extent, *V. tapetis* showed inhibition capacity on oyster *C. gigas* hemocytes. Conversely, alive *V. aestuarianus* showed no effect on ROS production of oyster hemocyte even at 50 bacteria per hemocyte. However, extra-cellular products from this vibrio have been shown to strongly activate the ROS production of *C. gigas* hemocytes. These results question about the diversity of bacterial strategy against bivalves and show the importance of a better knowledge of host-pathogen interactions in sustainable aquaculture.

BROWN RING DISEASE LIKE-SYMPTOMS IN NATURAL POPULATIONS OF CLAMS IN GLÉNAN ARCHIPELAGO, SOUTH BRITTANY. P. LeChevalier,[1] C. Le Boulay,[1] H. Haberkorn,[2] K. Korsnes,[3,4] S. Mortensen,[3] C. Skår,[3] A. G. Eriksen,[3] L. Harkestad,[3] Ø. Bergh[3] and C. Paillard. [2]

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The Brown Ring Disease (BRD) is a vibriosis affecting a large number of bivalve species, and BRD signs have been reported from several clam species. General disease symptom is a brown deposit of the inner surface of valves. The process of shell formation is altered by the aetiological bacterial agent, *Vibrio tapetis*, originally isolated from the Manila clam, *Ruditapes philippinarum*. In the Glénan Islands, located in south of Brittany (France), BRD-like symptoms are detected in populations of natural clams. One strain was isolated from such clams and characterised by biochemical and genetic methods. Based on DNA:DNA hybridization with type strain CECT 4600, on characterization of gene segments of 16S, GyrB and Hsp60, we suggest this bacterium to be a new strain of *V. tapetis*. This strain differs from the type strain CECT 4600 by "fill inn". This is the first report of BRD signs in Glénan area, and the first isolation of *V. tapetis* from this area. The presence of BRD in Glénan archipelago will be discussed.

CULTURAL PRACTICES AND RISK OF SHELLFISH PATHOGEN EXCHANGES: THE OYSTER AQUACULTURE IN FRANCE. L. Miossec[1] and S. Girard[2]

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The first national census concerning shellfish culture in France was carried out in 2002. The main purpose was to provide accurate and comprehensive information on the number and structure of the companies using an in depth review of production factors (leases, plants, equipment's, labour and qualifications), and a survey of cultural practices up to the market level. Moreover, the census aimed to quantify the bivalve sales dedicated to consumption and to measure the livestock transfers among rearing shellfish production areas at different developmental stages: spat, intermediate products and fully grown marketable products. The French oyster production reached 109 000 metric tons in 2001. The main production was observed in Poitou-Charentes region (Southwest coast of France), including the Marennes-Oleron Bay, followed by Normandy and South Brittany regions, respectively. The other rearing areas represented less than 10% of the total landings. In 2000, spat production was estimated at 4.6 billions of units, of which 84% were produced using the traditional wild spat collecting operations. In contrast, only 15% resulted from hatchery production. More than 60% of the spat production was translocated the following year outside their native areas (Charente Maritime and Arcachon bay) for further growing, mainly in Normandy and South Brittany. Similarly, movements among rearing areas were precisely reported over the rearing cycle. Those exchanges were important between the Northern and Southern parts of Brittany, Poitou-Charentes, and Normandy, while limited for the other rearing areas. After investigation on the main economical factors driving bivalve translocations, we discuss the potential consequences of those cultural practices if exotic pathogens were to be accidentally introduced. We emphasise the necessity of these types of data set to further investigate epidemiological situation when outbreaks occur, to discuss time series data on pathogen occurrence and disease status, as well as to specify zoning and associated strategy when implementing a targeted surveillance programme.

DO DISEASES CAUSE SEVERE IMPACT ON WILD MARINE ANIMAL POPULATIONS? C. Paillard,[1] S. W. Feist[2] and S. Ford.[3]

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Over the past ten years, the emergence and intensification of marine diseases affecting ecologically and economically important species have provoked noticeable changes in marine ecosystems. Their intensification has been associated with warming trends and general ocean degradation due to anthropogenic activities. The disease impact on wild marine animal populations is not well known in comparison to the impact on cultivated and economically species. The aim of this presentation is not to give an exhaustive review but to point out some important cases of diseases which could have severe impacts at population level in invertebrates and vertebrates. The other objective is to evaluate the main factors (climatic change, over fishing, pollution, exchange with aquaculture stocks, etc) which could trigger disease in wild populations.

AN INTEGRATED APPROACH TO THE ENVIRONMENT-HOST-PATHOGEN INTERACTION STUDY: CASE OF VIBRIOSIS MODEL IN MANILA CLAMS. C. Paillard,[1] J. Flye Sainte-Marie,[1] G. Erauso,[1] F. Jean,[1] S. Ford,[2] E. Powell,[2] J. Klinck[3] and E. Hofmann.[3]

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The marine bacterium *Vibrio tapetis* is the causative agent of the brown ring disease affecting cultured Manila clams *Ruditapes philippinarum*, causing heavy economic losses in Europe. This shell disease was first observed in 1987 in Brittany, France and has spread along the Atlantic coast from Norway to Marocco. The highest prevalences are found along the North Atlantic coast. BRD symptoms have recently been identified in *R. philippinarum* in South Korea. Multiple approaches (ecological, physiological, cellular and molecular) have been developed to study BRD using both field and laboratory studies. Host-pathogen interactions modulated by environmental factors have been investigated experimentally in both the field and the laboratory, using repeated individual sampling, in vivo bacterial challenge and *in vitro* bio-assays. Recently, genetic tools have been developed to detect the pathogen and to help identify host-pathogen interaction mechanisms. To elucidate the potential functions encoded by *V. tapetis* megaplasmid, we have undertaken its complete genome sequencing. We propose here to integrate all these approaches in describing the background of the vibriosis model. The proposed multiple approaches to disease analysis could help different users (professionals, resource managers, political authorities, etc) to implement pertinent strategies in order to anticipate epidemic cases and to restore shellfish ecosystems.

REPORT ON THE OCCURRENCE OF *VIBRIO TAPETIS* IN KOREAN WATERS: CHARACTERIZATION AND ITS IMPACT ON CLAM HEALTH. K.-I. Park,[1] C. Paillard,[2] P. LeChevalier,[3] M.-J. Cho,[1] P. Soudant,[2] C. Lambert[2] and K.-S. Choi[1]

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Vibrio tapetis, a causative agent of brown ring disease (BRD), has been reported as the cause of mass mortality in the clam *Ruditapes philippinarum* and *R. decussatus* occurring on Atlantic coasts of France, Spain and England. In the present study, *V. tapetis* was isolated from the Manila clam *Ruditapes philippinarum* distributed on Anmyoendo Island, the west coast of Korea. *V. tapetis* grow at 4 and 18 °C but not at 30 °C. Fatty acid composition, amino acid composition and protein profile of *V. tapetis* were very similar to *V. tapetis* (NCIMB 13622). In addition, partial 16S rRNA gene sequences of *V. tapetis* showed 99.48-99.63% similarity to LP2 and 99.71-99.85 % similarity to CECT4600, respectively. These results suggest that *V. tapetis* isolated from the Manila clam in Korea is the same species or taxonomically close to *V. tapetis* reported from Europe. Prevalence of BRD in the present study area was 47% and most of the infected clams showed early phase of the infection (conchiolin deposit group I). Infection intensity of BRD was negatively correlated with condition index of clams ($p<0.05$), suggesting that BRD has negative impacts on the host clams.

DEVELOPMENT OF GENUS-, SPECIES-, AND STRAIN-SPECIFIC MOLECULAR PROBES FOR *PERKINSUS* SPP. AND *BONAMIA* SPP., AND THEIR USE FOR EPIZOOTIOLOGY STUDIES AND RISK ASSESSMENTS IN USA. J. A. F. Robledo, W. T. Pecher, M. R. Alavi, E. J. Schott, K. Saito, S. Tasumi and G. R. Vasta

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During the past few years the native *C. virginica* have been reduced to such low numbers in the Chesapeake Bay by parasitic diseases such as "Dermo", that the introduction of a presumably disease-resistant species (*C. ariakensis*) is being considered by the industry, and state and federal agencies. The establishment of in vitro culture methodology in the early 1990s facilitated the genetic characterization of the parasite and the development of PCR-based diagnostic

assays. We selected regions within the intergenic spacer (IGS) of the rRNA gene for the design of species-, and strain-specific PCR primers for the development of sensitive diagnostic assays for *P. marinus*, *P. andrewsi* and *P. olseni*. The strong conservation of IGS sequences close to the 5'end of the SSUrRNA in all the abovementioned Perkinsus species enabled the design of genus-specific diagnostic primers. We are currently using PCR-based diagnostic methods to investigate the epizootiology of Perkinsus species in shellfish along the East Coast of USA (from ME to VA), and to assess the potential risk for *C. ariakensis* to harbor and transmit shellfish parasites and pathogens. *C. ariakensis* maintained in a fully contained aquaculture facility were monitored for *P. marinus*, *P. andrewsi*, *P. olseni*, *Haplosporidium nelsoni* (MSX), and *Bonamia ostrae* infections during a 15 week period. Prevalences of *Perkinsus* spp. and *B. ostrae* (66% and 3%, respectively) were maintained or increased during the experiment. MSX was not detected in any of the animals tested. Experimental assessment of the capacity of *C. ariakensis* hemocytes to kill or inhibit proliferation of *Perkinsus* spp, suggested that similarly to *C. virginica*, *C. ariakensis* is unable to kill all infecting *P. marinus* trophozites, and that under stressful conditions *P. marinus* infection intensity and prevalence may increase. [Supported by awards from ODRP/NOAA-MDSG, NRAC/USDA, and the MD DNR].

FUNCTIONAL GENOMICS (EST) AND GENOME SEQUENCING OF THE PROTISTAN PARASITE *PERKINSUS MARINUS*. J. A. F. Robledo,[1] E. J. Schott,[1] M. J. Gardner,[2] J. Kissinger[3] and G.R. Vasta[1]

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Perkinsus marinus is a protistan parasite that causes "Dermo" disease in the eastern oyster *Crassostrea virginica*, along the Gulf and Atlantic coasts of USA. Taxonomically related to apicomplexans and dinoflagellates, this parasite has been subject to intense research for over five decades. Approaches for control of the disease include early detection to restrict transport of infected stocks, selective breeding of disease-resistant oysters from populations naturally or experimentally exposed to the pathogen, and treatment with antiparasitic agents. In recent years genomic approaches have proven to be valuable methods for gene discovery in pathogens. An EST initiative is underway in our laboratory aimed at (a) dissecting the biological basis of infectivity and pathogenesis of this parasite, and (b) identifying genes encoding potential targets for treatments. The study consisted in 2,513 EST derived from two *P. marinus* trophozoite Lambda ZAP cDNA libraries: (1) trophozoites cultured in standard conditions and (2) trophozoites cultured in standard conditions supplemented with oyster serum. Several EST sequences aligned with genes currently investigated as potential targets for therapy in other protozoan parasites, such as, cathepsins, metacaspase, panthothenate synthetase, aldolases, HSP 70, glycerophosphodiesteras, and methionin aminopeptidase. Comparison of the data sets from both unexposed and serum-exposed parasites revealed sequence clusters and singletons that may be specific to the serum exposure. EST from both treatments contained a high number of sequences with match to apicomplexan parasites and with no match in the Genbank database. The complete sequence of the *P. marinus* genome, recently initiated in our laboratories and TIGR will yield a complete, annotated genome sequence, a physical map of the genome, additional ESTs (a total of 12,000), and a *P. marinus* Gene Index. Information resulting from both genomic projects should facilitate future hypothesis-driven research on this ecologically and economically important parasite [Supported by awards from ODRP/NOAA-MDSG, and NSF-USDA.

ANTIOXIDANT ACTIVITIES IN THE PROTISTAN PARASITE *PERKINSUS MARINUS*. E. J. Schott, J. A. F. Robledo, W. T. Pecher and G. R. Vasta

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Perkinsus marinus, a parasite of the eastern oyster, *Crassostrea virginica*, is becoming an increasingly useful organism for the study of mechanisms of intracellular survival and virulence. Viable *P. marinus* trophozoites are engulfed by oyster hemocytes, but suppress chemiluminescence normally associated with phagocytic activity, leading to the hypothesis that the parasite prevents reactive oxygen species (ROS) production or accumulation by enzymatic means. In vitro, cultured trophozoites are resistant to superoxide (O_{2^-}) and hydrogen peroxide (H_2O_2). We previously described two Fe-type SODs from *P. marinus*, which have the potential to convert O_{2^-} to H_2O_2, but the mechanism(s) for H_2O_2 removal has not been identified. *P. marinus* trophozoites lack detectable catalase activity, and instead possess an ascorbate dependent peroxidase activity (APX). Partial purification of *P. marinus* APX revealed a 35 kDa protein on SDS-PAGE, which, upon partial sequence analysis, confirmed similarity to plant APX. Two putative APX cDNAs (PmAPX1 and PmAPX2) that differ in their predicted N-terminal regions. Immunofluorescence studies suggest that APX1 and APX2 are targeted to different subcellular locations. Identification and partial characterization of several phosphatase-like genes from *P. marinus*, included a protein phosphatase (PP) 2B- and two PP2C-like genes, that show high similarities to putative protein phosphatases and hypothetical proteins of apicomplexan parasites. Soluble iron is a critical factor for virulence, and most parasites have developed efficient mechanisms for iron acquisition from their hosts. We identified and characterized in *P. marinus* the divalent cation transporter Nramp (Slc11a), and obtained partial sequence of the *C. virginica* homologue. The biochemical, structural, molecular and functional analysis of SODs, APXs, and PPs and Nramps may provide further insight into the mechanisms underlying the intracellular survival of *P. marinus*, and disease susceptibility of its host. [Supported by awards from ODRP/NOAA-MDSG, and NSF]

SPATIAL HETEROGENEITY AND TRANSMISSION ECOLOGY OF TREMATODE PARASITES IN BIVALVES ON TEMPERATE TIDAL FLATS. D. W. Thieltges.

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Trematode parasites have been shown to exert a variety of negative effects on marine mollusc hosts. However, little is known on the spatial structure of infections and the transmission ecology of marine trematodes. This presentation reports on field studies on the spatial structure of infections of trematodes utilizing bivalves as second intermediate hosts in blue mussels *Mytilus edulis* and common cockles *Cerastoderma edule* from the temperate tidal flats of the Wadden Sea (Germany). In addition, results of field and laboratory experiments on different aspects of the transmission ecology potentially underlying spatial structures will be presented. The investigations revealed a strong spatial heterogeneity in trematode infections on large (between sites) as well as small (within sites) spatial scales. Multiple regression analysis showed the presence of first intermediate hosts to be the strongest predictor for infection intensity on a large spatial scale. On a smaller spatial scale, infection intensities were modified by habitat features (e.g. tidal height of site or residual water at low tide) and host features (e.g. density and size of hosts). Hence, the observed spatial heterogeneity in infections results from a complex interplay of abiotic and biotic factors. Knowledge of these factors allows singling out hotspots for trematode parasitism on tidal flats.

PURIFICATION AND ANTIGENIC CHARACTERISTICS OF THE RICKETTSIA-LIKE ORGANISM FROM THE OYSTER, *CRASSOSTREA ARIAKENSIS* GOULD. X. Wu,[1,2] J. Sun,[2] W. Zhang[2] and B. Wen.[3]

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Rickettsia-like organism was suggested as an etiological agent infecting the oyster, *Crassostrea ariakensis* Gould heavily. Because of the lack of molluscan cell line for *in vitro* culture of specific intracellular prokaryotes, antigenic analysis of the rickettsia-like organism has been limited by the inherent difficulties of purifying them. In this report, we describe the use of different speed centrifugation and renografin density gradient centrifugation to purify the rickettisa-like organism directly from the infected tissues of the oyster. The purity and integrity of purified prokaryotes were verified by electron microscopy. Specific polyclonal antiserum of the mouse was prepared for serological characterization of the RLO. Thirteen major constitute proteins were electrophoretically identified by silver staining, their molecular weights are ranging between 99 and 17 KD and only eight major proteins were identified with the Coomassie blue R. The percentages of RLO proteins were analyzed by scanning apparatus. The antiserum above was used in an immunoblot of proteins from purified prokaryotes and identified three major antigens. The present results have further our knowledge of the protein antigens of the RLO and identified several proteins potentially useful for diagnostic assays or for production of experimental vaccines.

PURIFICATION AND IDENTIFICATION WITH 16S RDNA AND *IN SITU* DNA HYBRIDIZATION OF THE RICKETTSIA- LIKE ORGANISM FROM OYSTER, *CRASSOSTREA ARIAKENSIS* GOULD. Z. Yang[1] and X. Wu[2].

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Oyster samples *Crassostrea ariakensis* (Gould) aged 2-3 years were collected from YangXi, Guangdong province in China in October 2004. In this area, a mass infection of an obligate intracellular prokaryotic, Rickettsia-like organism (RLO) has been found. After taken back living oysters were cleaned and random divided in two groups and raised in water tank with aspiration. One group (n=10) were raised in high temperature (30 °C) with high salinity (28 °C-32 °C), the other (n=10) in low temperature (20 °C) with low salinity (18 °C-20 °C). During the two months culture, the oyster in high temperature with high salinity were dead all, while those in low temperature with low salinity dead only three. When oyster was found dying, it was taken out and gill was fixed in Davidson's fixation and 4% neutral paraformaldehyde. Then they were embed in paraffin and sectioned for histological staining and *in situ* DNA hybridization. Other parts of dead oyster was frozen in –70 °C to be used for purification of RLO. The gill and the other part of oyster were separately homogenized and RLO was purified by renografin discontinuous density gradient centrifugation method described before. After purification, two groups of prokaryotes purified from different tissues were both confirmed to be RLO by electric microscope. Then the DNA of prokaryotes was got and 16S rDNA of bacteria was amplified by PCR. After that, partial 16S rDNA amplified from RLO in gill was synthesis to be DIG-labeled probe and used to detect clones with 16S rDNA sequence of RLO amplified from other part of oyster tissues by southern dot blot. The clone used in southern blot was T-vector inserted sequence of RLO amplified from other part of dead oyster tissues. In 66 dots, we got eight strong reaction dots. Five of the strong reaction clones were sequenced and two of five are never reported but with the same sequence. By NCBI BLAST analysis we knew this is a new kind of bacteria belong to gamma subdivision and similar to *Piscirickettsia salmonis* but the similarity is only about 91%. We used specie- specified sequence as probe to detect these bacteria by in situ DNA hybridization. Together with H&E and Giemsa staining, we confirmed the sequence is the sequence of prokaryotes that we call Rickettsia-like organism in oyster.

SHELLFISH FITNESS CONSIDERATIONS IN SHELLFISH RESTORATION

ESSAY OF THE SEDIMENT DISTURBANCE IMPACT IN THE BIVALVE RESOURCE EXPLOITATION (BASQUE COUNTRY, NORTHERN SPAIN). J. Bald,[1] A. Borja,[1] I. Muxika[1] and J. Murua.[2]

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In the Basque Country (northern Spain) the Mundaka Plentzia and Txingudi estuaries, show exploited populations of clams (*Ruditapes decussatus*), by both professional and recreational shellfishers, being the main responsibles of the low stock and biomass in some of these estuaries. However, not only the shellfishing activity, but also the disturbance of the sediment can explain these low biomasses. Several authors have highlighted the negative effect of the removal of high quantities of sediments on clam juveniles due to their exposition to predators and also to the burial to an excessive depth of these juveniles. In order to determine the effect of this practice, at the request of the Department of Fisheries of the Basque Government, in 2001 the Marine Research Division of the AZTI-Tecnalia developed a research project in the Mundaka estuary. The project consists on the seeding of juvenile clams in 9 lines of 12 cages (46 cm x 14 cm x 35 cm; length x high x width) protected with a 7 mm net in the surface. A number of 50 clams were seeded in each cage. Monthly, between March 2001 and July 2002, the sediment of three lines was disturbed simulating the shellfishing activity, other three lines were trample on simulating a high affluence of shellfishers, and three lines were maintained as control. Each month 3 cages of each treatment lines were taken away and their content was sieved. For each treatment and month, the number, length and dry weight of the clams obtained in each cage was measured and the length-weight relationships were calculated. Also, in collaboration with the laboratory of the School of Ocean Sciences, of the Gales-Bangor University (UK), the measurement of the internal microgrowth bands, in the clam shell, was used to estimate the effect of treatments disturbance. The results obtained demonstrate the impact of sediment disturbance on the allometric relationships of juvenile clams, leading to a negative allometric growth of clams. Other factors like growth rate, mortality, weight, etc. did not show significant differences between treatments.

COMPARISON OF IMMUNE PARAMETERS, DISEASES, BIOCHEMICAL COMPOSITION AND CONDITION INDEX OF THE MANILA CLAM *RUDITAPES PHILIPPINARUM* COLLECTED FROM FOUR LOCATIONS AROUND ANMYEON-DO ISLAND, KOREA. K.-S. Choi,[1] K.-I. Park,[1] H.-S. Park[2] and Y.-J. Park[3]

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In order to develop techniques for evaluation of health of the Manila clam, *Ruditapes philippinarum* collected from four tidal flats (Nudong, Gonam, Hwangdo and Bangpo) on Anmyeon-Do Island, Korea, immune parameters, disease burden, biochemical composition and condition index (CI) of the clams were measured. Anmyeon-Do Island lies about 25 km from north to south and 5 km from west to east with distinctive environmental differences. The largest hemocyte counts were observed in the clams from Gonam, followed by Hwangdo, Nudong and Bangpo ($p<0.001$). Phagocytosis rate and hemocyte mortality of Goanm and Nudong clams were higher than those of Hwangdo and Bangpo clams ($p<0.001$). Infection intensity of the protozoan parasite *Perkinsus olseni*, metacercaria and brown ring disease (BRD) were higher in the clams from Hwangdo compared to other areas, whereas Bangpo clams were the most lightly infected with the pathogens studied ($p<0.001$). Carbohydrate concentration of Hwangdo clams was significantly lower than that of other clams. Lower CI was observed in the clams from Hwangdo and Bangpo than that of Gonam and Nudong. In addition, *Perkinsus* and BRD infections were negatively correlated with CI of Hwangdo clams ($p<0.05$). Our study indicates that clams from Hwangdo were physiologically weaker than other clams due to pathogens. Indeed, mass mortality of the Manila clam has occurred recently in Hwangdo where high eutrophication and low water current exist. Accordingly, it is believed that our investigations well represented the health status of the Manila clam.

EVALUATION OF VARIABILITY OF IMMUNE PARAMETERS IN OYSTERS *OSTREA EDULIS* DERIVED FROM DIFFERENT POPULATIONS AND CULTIVATED IN THE RÍA DE AROUSA (GALICIA, NW SPAIN). M. Da Silva, A. Villalba and J. Fuentes.

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The protozoan *Bonamia ostreae* causes high mortality of the European oyster *Ostrea edulis*. A study to assess variability through *O. edulis* populations for interesting characters and to identify favourable populations was performed as a stage previous to a selective breeding programme for disease resistance. This presentation includes results of the evaluation of immune parameters of oysters from various origins. Four oyster populations were chosen in Greece, Ireland, and Galicia (Ortigueira and Coroso). Oysters from those populations were used as brood-stock to

produce 4 - 5 spat families from each origin. Spat of 19 families were cultivated in the Ría de Arousa and surveyed monthly. Three haemocyte types were distinguished: granulocytes (Gr), large hyalinocytes (LHy) and small hyalinocytes (SHy). A seasonal pattern of variation of the total haemocyte count (THC) and the differential haemocyte count in the haemolymph was recorded. The Galician oysters showed higher THC and % Gr than foreign oysters, although differences were not significant. Significant differences in % Gr and % SHy between families under Irish and Greek origins were recorded. High % Gr likely enhanced tolerance to disease and survival. Progression of *B. ostreae* infection induced a significant increase of THC, especially of LHy that, seemingly, is the most favourable haemocyte type for parasitic division in its cytoplasm. Sixteen hydrolytic enzymes were detected in the haemocytes and 14 in the plasma of *O. edulis* and 14 enzymes in the haemocytes and the plasma of *Crassostrea gigas* with the kit API ZYM. Differences in occurrence or concentration of some enzymes were detected between *O. edulis* origins, between *O. edulis* and *C. gigas*, and between infected and non-infected oysters by *B. ostreae*. The extra enzyme activity in the infected oysters could be due to enzymes produced by the parasite or to haemocyte production induced by the parasite.

RESPONSES OF PACIFIC OYSTER *CRASSOSTREA GIGAS* POPULATIONS TO ENVIRONMENTAL STRESS IN DIFFERENT ESTUARIES ALONG THE ATLANTIC COAST OF FRANCE. E. David,[1] A. Tanguy,[2] J. Laroche[1] and D. Moraga[1]

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World-wide, accidental and chronical pollutions constitute major threats for coastal marine ecosystems. Moreover, eutrophication and chemical contaminations are currently associated to hypoxia as a direct or indirect effect. Benthic sedentary filter organisms are specifically exposed to these stressors. Patterns of differential gene expression associated with hypoxia stress in aquatic invertebrates remain unknown. Therefore, in this study, we looked at the response of the Pacific oyster *Crassostrea gigas* to hypoxia in experimental design. A suppression subtractive hybridization (SSH) method was used to identify specific hypoxia-up- and down-regulated genes, in gills, mantle and digestive gland, after 7-10 days and 24 days of exposure. Among the 615 EST identified, we analysed the expression of potentially regulated-genes by RT-PCR in different tissues at different sampling time over the time course of hypoxia. The genes retained for this study are implicated in different physiological pathways such as energetic metabolism (glycogen phosphorylase, carbonic anhydrase), protein regulation (BTF3), lipids metabolism (delta-9 desaturase). Then we investigated expression of the same genes in natural populations of *Crassostrea gigas*. Populations of three highly contaminated French Atlantic estuaries were considered (the Vilaine, Loire and Gironde) and compared to the Belon estuary, used as a reference site because of its relatively low level of contamination. The comparison of expression patterns between the different estuarian populations, coupled with polymorphism analysis will help us to appreciate genetic adaptations in molluscs species to disrupted environments.

GROWTH AND SEASONAL CHANGES IN BIOCHEMICAL COMPOSITION FOR THE BIVALVE *CRASSOSTREA GIGAS* FROM BIZERT LAGOON, TUNISIA. S. Dridi,[1] M. S. Romdhane[2] and M. Elcafsi[1]

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Growth and seasonal variations in biochemical composition of the bivalve *C.gigas* was studied from February 2002 until January 2003. Separate analyses were made of gonad-visceral mass. Seasonal changes in body weight and biochemical composition are associated with the processes of reproduction, growth, storage utilization of reserves and environmental parameters, especially food availability. Separation between oysters in the two phases of gametogenic cycle demonstrated that during sexual repose, correlation between the different parameters of growth modals is closer then those determined during the gonadal activity. Variation in biochemical composition was about 1,33 % ± 0,61 of fresh weight in glycogen, 3,36% ± 0,23 of fresh weight in protein and 16,86 % ± 2,55 of fresh weight in lipids. Maximum concentrations of glycogen and lipids occurred during the resting phase or initial gamatogenesis to play a central role in energetic and metabolic supply during gametogenesis and corresponding with minimum concentrations of protein. During this phase of reproductive cycle, condition indices (CI) reveal high levels caused by phytoplankton abandance which induce gross biochemical component accumulation and increase of tissues dry weight. On the other hand, minimum concentrations of bothes glycogen and lipids occurred at maturity when protein reached maximum concentration. During this phase, oysters spent most of their energy reserves in gametogenesis, therefore (CI) levels decrease essentially in june, jully and September which corresponds to spawning.

SEASONAL VARIATIONS OF IMMUNE PARAMETERS IN DIPLOID AND TRIPLOID OYSTERS, *CRASSOSTREA GIGAS*. M. Duchemin,[1] M. Auffret[1] and M. Fournier[2]

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Since the last two decades, triploids oysters have been artificially obtained and introduced in aquaculture in order to enhance growth versus reproduction. Several field and lab studies have shown a strong relationship between the immune status of diploid bivalve molluscs and the health status of the ecosystem. These sedentary, filter-feeders are very dependent on the environmental parameters of the water column such as nutritive particles, temperature, salinity

but also pollution. The present study aimed to compare immune parameters in individuals with different cytogenetic status reared in the same conditions. For 15 months (May 2003 to August 2004), diploid and triploid oyster batches have been sampled (n = 10 individuals/sample) from a French producing site (Belon, Britanny, France) representative of estuarine conditions. Several immune parameters investigating haemocyte integrity and immunocompetence were analysed each month by flow cytometry. Histological observations were made in gonads to discriminate gender and gametogenesis stages. Results indicate that immune parameters in both diploid and triploid oysters exhibited marked seasonal variations. Taken as a whole, alterations observed in maturing individuals corresponded to a low immune status in late spring, at a time corresponding to the spawning period. Furthermore, sex grouping of individuals revealed uneven immune alterations among males and females. These observations demonstrated a clear correlation of seasons with variations of immune parameters in these oysters, independently of their cytogenetic status. Such effects should be considered as confounding factors when immunomodulation by environmental stress would be examined, i.e. in monitoring studies.

ENVIRONMENTAL MONITORING OF STRESS INDUCIBLE GENES AT THE TRANSCRIPTIONAL LEVEL IN THE BIVALVE *CRASSOSTREA GIGAS*. E. Farcy,[1-2] B. Fievet,[2] C. Voiseux,[2] A. Serpentini[1] and J. M. Lebel.[1]

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Aquatic organisms such as marine molluscs are exposed to multitude of stressors that are either natural or anthropogenically introduced into the environment. In this context, stress molecular markers may be investigated to evaluate the effects of pollutants on organisms. At protein level, biomarkers such as Heat Shock Protein or Metallothionein often fluctuate with physical and chemical environmental parameters. The question arises about the regulation mechanisms of these molecules and gene transcription is a first possible answer. The recent technique real time PCR allows quantifying the relative number of transcript of one specific gene. This study reports on the environmental monitoring of transcript level of stress-inducible genes in *Crassostrea gigas*. Changes in gene expression with seasons and sites were investigated in four locations along the French coasts. Finally, naturally observed levels are compared with transcript level obtained after an acute, though ecologically relevant, thermal stress.

FITNESS DIFFERENCES IN THE MUSSEL *MYTILUS GALLOPROVINCIALIS* CULTIVATED IN FANGAR BAY (EBRO DELTA, NE SPAIN). E. Galimany, M. Ramón and M. Fernández.

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The bays of the Ebro Delta can be considered as estuaries with very peculiar characteristics (high daily temperature oscillation with variations up to 4ºC, summer temperatures reaching up to 30ºC, seston concentrations from 25 to 70 mg/l, etc.). The main purpose of the study was to compare the development of the mussel culture in Fangar Bay with two different seed sources: a coastal zone (Maresme) and the bay itself, both of them with different environmental features. The shell length growth, weight and mortality were analysed as the main environmental parameters that directly affect the cultures (temperature, salinity, oxygen concentration and seston) were studied too. The results showed that, at the end of the culture cycle there were no significant differences between the adult length of both seed sources Fangar and Masnou. But it was also observed that there were differences on the dried weight of mussels, being superior the ones coming from Fangar. The mortality of mussels remained under the 10% all along the growth period (october 2002-july 2003). Nevertheless, at the beginning of august 2003, mortality became significantly higher in mussels which seed came from Masnou and increased, in both origin seeds, from surface to bottom. The water bay reached temperatures up to 28ºC and even higher on surface from mid july and at the bottom from the beginning of august. Due to these extreme temperatures, at mid august the mortality became the 100% in all depth levels and affected all mussel sizes (adults and young). It was the first time of the mussel culture history in the area that all the production that was at the time in the water and the seed to begin with the new cultures were completely lost.

CHARACTERIZATION OF GLUCIDIC METABOLISM OF PACIFIC OYSTER, *CRASSOSTREA GIGAS* AS A WAY TO STUDY THE RESERVES MANAGEMENT. A. C. Hanquet-Dufour,[1] C. Heude,[1] K. Kellner,[1] H. Bacca[2] and M. Mathieu[1]

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The glycogen contained in the storage tissue of the oyster, *Crassostrea gigas*, is the major source of energy supporting general metabolism and gametogenesis. Storage and mobilization of glycogen occur in specialized cells of this tissue, the vesicular cells. The metabolism of these cells varies during the annual reproductive cycle, with two metabolic switches between storage and mobilization stages, suggesting the occurrence of a strict regulatory pathway. The effect of trophic conditions on glucose uptake and glycogen synthesis was investigated using cellular and molecular approaches applied on dissociated cells: In vitro measurement analysis of a radioactive tracer (14C D-Glucose) led us to determine the kinetic of glucose transport (a saturation at high substrate concentration), the effect of glucose

concentration (Km and Vmax) and the impact of hexose transport inhibitors, like cytochalasin B and phlorizin. Furthermore the expression of SGLT (Na+/glucose transporter) was quantified by Realtime PCR. The effect of a preincubation of dissociated cells in various extracellular glucose concentrations (*in vitro*) was evaluated by glucose uptake and SGLT expression measurements. Moreover the impact of environmental factors on reserve management was confirmed using experimental trophic conditioning: oysters were maintained in two opposite trophic level (fast or abundant diet (Syndicat Mixte de l'Equipement du Littoral)) at different periods of their reproductive cycle. The metabolic properties in term of storage associated to reproductive events of oysters' families (Resistant and Susceptible strains issued from Morest selection) were compared.

AMYLASE POLYMORPHISM AFFECTS GROWTH IN THE CUPPED OYSTER *CRASSOSTREA GIGAS*. A. Huvet, M. Prudence, F. Jeffrov, S. Pouvreau, J.-Y. Daniel, C. Quéré, P. Boudry, E Bédier, M. Ropert, A. Van Wormhoudt, J. Moal and J.-F. Samain.

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The better understanding of physiological and environmental factors that determine optimal food conversion efficiencies is of major interest for the cupped oyster *Crassostrea gigas* for which the strong increase of aquaculture has been correlated in France with a decrease in productivity due to competition between aquatic species for limited food supplies at grow-out sites. To investigate the non-neutrality of the polymorphism of amylase, a key enzyme for carbohydrate assimilation, in oyster physiology, we report in the present paper the growth and survival measurement of amylase genotypes within five bi-parental *C. gigas* families, bred to be polymorph at the two PCR-RFLP amylase markers, and reared over one year under standard culture conditions in two French aquaculture areas. For growth, amylase genotypes within three families have shown differences of total weight and meat wet weight mainly significant in one location. The amylase polymorphism affects *C. gigas* growth and we can assume that differences of growth between genotypes are expressed depending on the environment. Considering that no differences of survival were observed between genotypes within family, this variability of growth can lead to a gain of yield. For biggest differences between genotypes within family, enzymatic parameters were analyzed. The specific amylase activity appeared significantly different between the genotypes within one family and positively correlated to differences in weights. Specific amylase activity was therefore affected by amylase polymorphism and may partly explain growth difference observed between amylase genotypes in this experiment. The correlation between amylase polymorphism and growth in the cupped oyster *C. gigas* has suggested the interest of using the amylase markers for selective breeding program in oyster.

STRATEGY OF AQUACULTURE OF *RUDITAPES DECUSSATUS* BASED ON HIGH BIOCHEMICAL COMPOSITION OF THE POPULATIONS TO REPOPULATE LAGOONS AND BAYS OF MOROCCAN COASTS. A. Kamara,[1] N. Rharbi,[1] M. Ramdani[2] and A. Berraho.[3]

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The european clam is more required in the Moroccan lagoons and estuaries because of its important commercial value. The anarchistic daily collecting of the shells by the residents threatened this species which becomes increasingly rare. To this end, the present study contributes to develop a technique of aquaculture based on the selection of the best parents using biochemical analyses of the energy reserves of the various sampled populations, during an annual cycle, in 3 Moroccan sites: the lagoon of Nador on the Mediterranean, the lagoon of Oualidia on the Atlantic coast and the bay of Dakhla in the south of Morocco. The evolution of the index of condition, the gonadic index, the biochemical composition of the gonad was followed monthly, for the 3 populations, from September 2002 to December 2003. The results show the reproduction of this bivalve closely related to the trophic conditions and of temperature of the site. The gametogenetic activity is spread out March at November, period during which the lagoons undergo two important phenomena, namely spring and aestival phytoplanktonic bloom, followed by the autumnal picoplanktonic bloom. *Ruditapes decussatus* has a short period of sexual rest with the bay of Dakhla and from December to February in the two other lagoons. During this period, trophic and thermal conditions of sites are very unfavourable with the reproduction. The biochemical composition of the gonad shows that the latter is richer in lipid with variable contents during the year, with a maximum in August and October. The glucids and the proteins are also variable during the cycle of reproduction and the strong contents are noticed at the individuals resulting from bay of Dakhla. A comparative study between the various populations studied, concerning the gametogenetic activity, the index of condition and the biochemical composition, indicates the population of bay of Dakhla is characterized by an important performances to make a success of the clam aquaculture in the upstream part of the lagoon of Oualidia.

GROWTH OF *CRASSOSTREA GIGAS* SPAT AND JUVENILES UNDER DIFFERING ENVIRONMENTAL CONDITIONS. J. King, J.W. King, S. K. Malham and M. W. Skov.

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Crassostrea gigas spat (10-12mm), purchased as a single cohort from a hatchery, were placed on trestles at three on-growing sites in North Wales at two densities (600 oysters/bag and 1000 oysters/bag). The sites had varying

environmental parameters such as exposure to air, temperature, nutrients and phytoplankton. Growth and mortality was assessed over 4 months in the summer of 2003. All sites and densities produced variations in tissue dry weight (mg), shell length (mm) and shell dry weight (mg) but little variation in protein or glycogen content (mg/ml dry weight). Shell length (mm), shell dry weight (mg) and tissue dry weight (mg) were found to be low where oysters were immersed for the whole tide and highest where the animals were exposed for at least 1 h/tide and were kept at the lower density. Condition indices were similar at two sites but very different at the third. At this site the temperature was high and phytoplankton was abundant although there was very little tidal water flow across the trestles. Results are discussed in relation to the environmental causes of the variation observed and how these data may assist in the choice of oyster growing sites.

THE DYNAMICS OF SULFIDE AND AMMONIUM IN SEDIMENTS OF OYSTER PRODUCTION ZONES: AN ESTIMATE OF BENTHIC FLUXES AND WATER-COLUMN INVENTORIES. J. Knœry,[1] A. Cozic[1] and E. Bédier.[2]

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It has been proposed that sediment may play a role in seasonal oyster mortality. In order to investigate the possible role of the sediment, a study aimed at characterizing the seasonal dynamics of sulfide and ammonium in the immediate vicinity of oyster beds was conducted. These compounds are byproducts of organic matter remineralization and are known to occur in coastal sediments at varying depths below the sediment-water interface (SWI). The study was designed to examine i) the potential for release of sulfide and ammonium from the sediment using an experimental and modeling approach, and ii) the dynamics of sediment-released sulfide and ammonium in the overlying water. The sudy has been conducted at several sites along the French coastline. These sites were on a north to south gradient along the French coastline: Baie des Veys, Normandy; Bay of Quiberon and Rivière d'Auray, southern Brittany; and Marennes Oléron, Charente. At each of the five sites, sediment cores were repeatedly collected throughout 2004. The porewaters of the top 10 cm were extracted and analyzed for dissolved sulfide and ammonium. At two sites (Rivière d'Auray and Bay of Quiberon), water-column dissolved sulfide concentrations were likewise determined in 2005. At Marennes Oléron, benthic foraminifera populations were followed. Preliminary assessment of the data collected so far reveals the expected seasonal cycling of reduced substances in the sediment, and shows a maximum potential for their diffusion in the water column at times of oyster mortality. Superimposed on this seasonal signal is superimposed on evidence for inter-annual variability in the sediment. Computed fluxes and experimentally quantified inventories will be presented. Early results show rather low sulfide and ammonia concentrations. In 2005, two sites of the five sites are examined for a second year in a row and we will be able to better describe the relationship, if any, between the possible release of sedimentary reduced substances and oyster mortality.

MOLECULAR IDENTIFICATION AND EXPRESSION STUDY OF DIFFERENTIALLY REGULATED GENES IN THE PACIFIC OYSTER *CRASSOSTREA GIGAS* IN RESPONSE TO TEMPERATURE CHALLENGE. A. L. Meistertzheim, M. T. Thebault and D. Moraga.

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In the context of a global warming of the planet, geographical distribution of numerous species is changing (colonization of new habitats due to higher temperatures for example). These opportunist species first become resident and then can invade this new habitat. The Pacific oyster, *Crassostrea gigas*, marine bivalve of economic interest was the subject of volunteer introductions in the course of the end of the 19th century and progressively invaded the intertidal beds of French coasts, developing in a group various environmental terms. As described for many species, populations introduced into new environments showed a strong power of adaptation. Study of the genetic adaptation's process of *C. gigas* according to the temperature is therefore of a particular interest since the Pacific oyster becomes an invasive species in temperate areas. In this aim, we investigated the molecular response of *C. gigas* exposed to two temperatures (13°C and 25°C) in experimental conditions. A suppression subtractive hybridization (SSH) method was used to identify specific regulated (over-expressed and inhibited) temperature-regulated genes. The expression of genes involved in temperature variation regulation was analysed by RT-PCR in different tissues over the time course of experimentation to verify that tissue-specific patterns of expression would reflect the different metabolic roles of tissues during the thermal challenge. Specific stress proteins (HSP70) level will be also investigated using ELISA test.

OYSTER MORTALITIES AND BIO-DEFENSE MECHANISMS. K. Mori and K. G. Takahashi

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Oysters are cultured widely around the world due to their commercial importance. Seed production systems and intensive culture techniques of oysters have been established. As a result of the increases in areas and production associated with intensive culture, mass mortalities of oysters caused by a wide variety of agents have became a serious problem. In larval and juvenile oysters, infectious diseases caused by marine vibrios, designated larval vibriosis or bacillary necrosis, result in mortalities exceeding 90% within 24 h of infection, leading to the limitation of hatchery production. In adult oysters, the main causative agents are protozoan parasites. For example, *Bonamia ostreae*, *Perkinsus marinus* (Dermo), *Haplosporidium nelsoni* (MSX), and *H. costale* (SSO) have brought about epizootic mortalities of oysters in the USA. It is well known that oyster hemocytes can phagocytose *P. marinus* cells, but cannot

degrade them, whereas oyster hemocytes do not phagocytose live *H. nelsoni* cells. On the other hand, exposure of marine molluscs including oysters to various environmental chemicals may produce manifestations of the toxicity toward their bio-defense mechanisms. This would imply that such exposure should make these organisms less resistant to agents of disease and potential pathogens. In recent years, the association between pollutant-stress and enhanced incidence of diseases of oysters has been investigated. An antifouling agent tributyltin (TBT) has been shown to cause greater mortality and greater intensity of infection by *P. marinus* in *Crassostrea virginica*. Copper treatment markedly suppresses immune response in *Crassostrea gigas* and increases susceptibility to infection of vibrios. In this presentation, we will describe several major infectious diseases of oysters and organismic responses to these diseases. We also touch on the bio-defense mechanisms and interactions between defensive factors in oysters and microbial agents, protozoan parasites, or chemical pollutants.

MAIN RESULTS OF THE 2001-2004 "MOREST" PROJECT ON SUMMER MORTALITY IN THE PACIFIC OYSTER (*CRASSOTREA GIGAS*). J. F. Samain and MOREST collaborators (PLENARY TALK)

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The Morest project on *Crassostrea gigas* oyster summer mortality was focused on the complex interactions between environment, oysters and pathogens. A temperature over 19°C appeared the first necessary condition in France, but was not sufficient to produce mortalities. This temperature is associated to the ultimate reproductive stage of gonadogenesis, when the energy storage and as scope for growth are at the minimum level. It is an optimal temperature for vibrio (*V.estuarianus* or *V.splendidus*) division rate as well as for anaerobic production of H2S and NH4+ from accumulated organic matter in the sediment which is considered as one of the major stressing factors in the environment. Trophic level is a second critical parameter as it controls reproductive effort in priority. Hemocytes number decreased during the gonadogenesis period, whatever the food supply. Phagocytose capacity decreased with food level and reproductive effort. Infection challenges or natural infection in these conditions led to mortality rates related to this decrease. However, some stress was necessary to induce mortality when temperature and reproduction were in the risky window. A simple transfer of oyster induced mortality. Sediment proximity appeared a reproducible detrimental factor, in relation to organic matter content, as well as to the annual fresh water run-off from watersheds.A genetic component evidenced by divergent selection in two generations was confirmed. Sensitive (S) and resistant (R) oysters in the same area or in controlled experimental conditions showed a difference in reproductive strategy faced to similar food conditions. Molecular studies comparing these two phenotypes are now focused on glucose metabolic pathways and immune mechanisms. None of these different factors can separately induce summer mortality, and all of these conditions seem necessary to reproduce the event. According to these interactions, strategies to forecast and prevent the risk are elaborated.

THE OYSTER MORTALITY IN CHINA. G. Zhang.

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About more than 20 species of oysters are distributed along the coastal China from Bohai Sea to South China Sea. Four species of oysters are cultured. Pacific oyster *Crassostrea gigas*, sengmao oyster *C. cuccullata* and jinjiang oyster *Crassostrea rivularis*. Jingjiang oyster has divided 2 species, *C. hongkongensis* (white meat) and *C. ariakensis* (red meat). Pacific oyster aquaculture occurred in north China Sea including Shandong and Liaoning peninsula, with total 638,326 tones at less in 2000, Sengmao oyster is in Fujian and part of Zhejiang, Jinjiang oyster is in South China Sea. Total output of oysters in China is 2,988,649 tones in 2000 and 37.64% in total output of mariculture in same year. *C. gigas* is the main oyster cultured in Dalian, Liaoning and died massively in the late June to late September in 1997. The mortality in some sea such as Hongxing was reached 70-80% and not harvest. Death occurred not only the two-years age oyster, which is spawning group, also the one-year group, which is not spawning individual. The possible seasons were that spawning oyster is sensitive to the worse environment due to the high density of farming poor nutrition, red tidal harm, high temperature stress, sudden change of environmental factor and the pollution. Two-year age oysters died first and made the environment worsen and then resulted in 1-year oysters mortality, which were mixed cultured with 2-year age oyster. The transparency of Hongxing sea in the early September when oysters died massively was over 5 meters, phytoplankton was seldom and the dissolved oxygen was less than 5ml/L. Other oyster mortality was found in different seas and due to different seasons. Most of mortality was relative to high density of farming and the sudden change of environmental factors. *C. rivularis* (most of white meat oyster) in Guangdong province appeared large-scale mortality in 80-90% in some seas and the rickettsia was found.

SHELLFISH-ECOSYSTEM LINKAGES

BIOCENOTIC CHARACTERIZATION AND SHELLFISH ABUNDANCE IN A NATURALLY PRESERVED AREA OF KERKENNAH ISLAND (TUNISIA). N. Aloui-Bejaoui,[1] S. Gana[1] and M. Le Pennec[2]

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The Kerkennah islands are located in the Mediterranean sea, in the south east of Tunisia, about 12 miles away from Sfax. They are positioned on a continental shelf with shallows waters extended all around. This ecosystem is considered among the most ecologically preserved in Mediterranean sea, due to the absence of harmful human activities, with an important marine biodiversity. Macrobenthos fauna is very diversified. Flora is largely dominated by *Cymodocea nodosa* and *Posidonia oceanica*, the mediterranean endemic phanerogam which is known by the high specific richness that it includes. In order to evaluate the biodiversity level in this area, fauna samples were collected in 10 stations on soft bottom and *Posidonia rhizomes* and leefs. A total of 78 species were collected: 34 molluscs, 10 crustaceans, 8 echinoderms, 7 porifera, 7 tunicata, 6 polychaetes, 3 cnidaria, 2 bryozoans and 1 sipunculida. Molluscs represented 44% of the total fauna abundance. Similarity and multivariate analysis (MDS) allowed us to discriminate the stations with respect to their benthic assemblages in order to estimate biotic conditions that could explain the place of molluscs in each of the four identified cluster. The higher similarity value involving molluscs was obtained with echinoderms, tunicata and polychaetes (45.5%). However, if bivalves were considered separately this similarity level reached 60.7%. Furthermore, these bivalves showed a particular similarity, in terms of abundance, with echinoderms (80.7%). It also appeared that the higher levels of similarity involving bivalves were obtained in stations with high density of phanerogams beds, *Posidonia oceanica* (stations 2, 4, 6, 7, 8) and *Cymodocea nodosa* (station 3). A complementary multidimensional scaling analysis, performed by considering all species explicitly, confirmed that these six stations were clustered in two groups, 2-3-4 in one hand and 6-7-8 in the other hand. These two clusters were those where the highest biodiversity was observed.

A MODEL FOR BIOACCUMULATION OF METALS IN *CRASSOSTREA VIRGINICA* FROM APALACHICOLA BAY, FLORIDA. D.A. Apeti, E. Johnson and L. Robinson.

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Kinetics of bioaccumulation of the trace metals (Cd and Zn) by *C. virginica* were investigated in this study. A computer program, Oyster Bioaccumulation Model (OBM), was developed to simulate the accumulation of the metals from both dissolved (water column) and particulate (food) phases by *C. virginica*. The model is based on two main attributes: (1) the oyster biological characteristics such as gill morphometry, feeding growth rate, respiration rate and lipid composition, and (2) the physicochemical properties of metals, which include aqueous diffusivity and partition coefficients. For some data from Chesapeake bay, simulation results compared well with field results. Predicted Bioaccumulation Factor (BAF) parameters (5.5×10^2 for Cd and 3.0×10^4 for Zn) for Apalachicola Bay show that elemental concentrations in *C. virginica* are up to 3 orders of magnitude greater that that of the water column. Furthermore, the model is shown to be flexible enough to be utilized in other estuaries.

MODELLING VARIABILITY OF SHELLFISH PRODUCTION IN RELATION WITH ENVIRONMENTAL CHANGES IN THAU LAGOON (FRANCE). C. Bacher[1] and A. Gangnery.[2]

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Bivalve aquaculture is an important economic activity in Thau lagoon and depends on environmental conditions and farming strategy. In order to assess the sensitivity of cultivated oyster production to environmental changes, a model of oyster population was linked to a bioenergetic equation of individual growth and reproduction based on the Dynamic Energy Budget (DEB) concepts. Analysis of different scenarios allows to assess the effect of changes of environment (temperature, primary production) on shellfish production. They are discussed in relation with the nutrient inputs from the watershed and interannual variability of meteorological forcing and primary productivity.

A GENERIC MODEL OF THE GROWTH AND REPRODUCTION OF THE PACIFIC OYSTER *CRASSOSTREA GIGAS*: FIRST RESULTS. Y. Bourles,[1] S. Pouvreau,[1] S. Lefevbre,[2] D. Maurer[3] and M. Alunno-Bruscia[4]

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Bioenergetic models of the growth and the reproduction of the Pacific oyster (*Crassostrea gigas*) are already available in the literature. But most of them exhibit two recurrent limits: (1) they do not allow to simulate growth and reproduction of *C. gigas* over time; (2) they cannot be applied to other shellfish culture areas or ecosystems without any significant changes. Thus, it appears as an evidence that a generic model which could go beyond these two limits is

lacking. The new model presented here is built on the basis of a Dynamic Energy Budget (DEB) theory, which describes quantitatively the energy flows through an animal (Kooijman 2000). Successfully applied on different species (e.g. Van Haren and Kooijman, 1993; Van der Veer *et al*., 2001), this model simulates for an organism the energy allocation to storage, structural volume, reproductive compartment and maintenances according to food densities and temperature. Values of the model parameters were estimated on the basis of physiological data taken from the literature and from personal experimental data (see review in Van der Veer *et a*l., 2006). The data used for the model validation came from three long term growth experiments (> 5 months) performed on Pacific oyster under several controlled conditions. The validation of the model was successful in the two first experiments, showing the good suitability of the model to capture the quantitative aspects of growth and reproduction in the Pacific oyster. In the last experiment, the good fitting between simulations and observations was satisfying, except at the beginning. After some refinement of the model, the next step will be to investigate its suitability to simulate growth and reproduction of *C. gigas* in the field under several environmental conditions. New simulations obtained recently for oysters growth in Arcachon bay (France) are shown preliminary here as first results.

ECOLOGICAL CONSEQUENCES OF FOOD COMPETITION BETWEEN BIVALVES AND ZOOPLANKTON. J. Cloern.

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Benthic and pelagic suspension feeders capture and ingest phytoplankton cells as a primary source of energy and essential dietary components such as unsaturated fatty acids. As a result, secondary production is often correlated with indices of algal food supply such as chlorophyll biomass or primary production. Competition for the algal food resource between benthic and pelagic consumers intensifies when mollusk biomass increases as a result of aquaculture or invasion by alien species such as: *Crepidula fornicata* in the rade de Brest, Dreissena polymorpha in the North American Great Lakes, *Potamocorbula amurensis* in San Francisco Bay, and *Corbicula fluminea* in freshwaters throughout Europe and North America. Many of these invasions were followed by significant declines in zooplankton biomass, presumably because of enhanced food competition as mollusk biomass and ingestion grows. Redirected energy flow from pelagic to benthic consumers has led to declining stocks of pelagic fishes, so the balance between benthic and pelagic secondary production has impacts that propagate to top-level consumers. Why are bivalves so successful at outcompeting crustacean zooplankton, and why are food webs disrupted radically when mollusk biomass increases? Here I present results from a simple food web model to explore the hypothesis that the competitive advantage of mollusks derives from their ability to tap two pools of organic matter that are largely unavailable to crustaceans: dissolved organic matter and micron-sized plankton. If this hypothesis is correct, then differences in feeding mode and efficiency between bivalves and crustaceans have ecosystem-scale consequences that must be considered as we translocate species and expand culture of mollusks in coastal waters around the world.

HIGH RESOLUTION REGIONAL HABITAT MAPPING FOR EVALUATING ENVIRONMENTAL INTERACTIONS WITH BIVALVE AQUACULTURE. P. Cranford[1] and J. Grant.[2]

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The long-line culture of mussels (*Mytilus edulis*) has expanded rapidly in eastern Canada and a high proportion of the surface area of many coastal embayments in Prince Edward Island (PEI) is leased for mussel aquaculture. Environmental interactions with shellfish clearly place limits on aquaculture profitability and the capacity for continued resource growth. A variety of oceanographic tools (e.g. manual water samplers and moored electronic sensors) have been employed in attempts to detect aquaculture induced changes in the suspended particulate food supply. Unlike water sampling, moored in situ environmental sensors are able to sample at a sufficiently high frequency to quantify temporal environmental variability. However, the inability to adequately quantify spatial variability has a tendency to mask the interactions between a dynamic environment and the cultured resource. A towed undulating vehicle (BIO-Acrobat) was developed containing a suite of environmental sensors (CTD, optical plankton counter, chlorophyll fluorometer, transmissometer, and oxygen) to provide the intensive horizontal and vertical sampling needed to rapidly characterize environmental variations over spatial scales relevant to whole bays. The BIO-Acrobat was used to map environmental conditions in Tracadie Bay, one of the more extensively leased aquaculture embayments in PEI. The data are being used to support biophysical modelling efforts designed to address a broad range of questions regarding sustainable mussel exploitation, food particle depletion, system productive capacity, aquaculture/land-use interactions, and ecosystem health.

MODELLING BIVALVE CARRYING CAPACITY IN COASTAL ECOSYSTEMS. J. Grant.

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Natural and cultured populations of suspension-feeding bivalves are well known to affect particle dynamics in estuarine ecosystems via grazing and biodeposition. Due to the imposition of bivalve culture on coastal environments, and possible conflict with other resource users and stakeholders, there is continued interest in prediction of carrying capacity and culture management. Eastern Canada has well developed shellfish culture in some regions and many areas with potential to support bivalve farming. Research efforts have thus been directed to modelling studies of carrying capacity as well as field work in support of models. Most modelling is anchored in hydrodynamics to incorporate

exchange of particles and dissolved materials into a diffusion/advection framework. Beyond this foundation, trophic-based models that include bivalve populations have been constructed at varying levels of complexity including single box, multiple box, and GIS models. Each type of model has specific data requirements, and management uses. In general, 'what if' scenarios are used to examine the response of environmental performance standards to various levels of cultured biomass. This paper evaluates the types of models, examples of their use, and remaining research questions in their implementation. Research sites in Canada, China, South Africa are used to demonstrate model development, including advances in physical-biological coupling, role of GIS, use of optimization routines in model prediction.

A MULTIDISCIPLINARY STUDY OF A COASTAL ECOSYSTEM SUPPORTING MUSSEL CULTURE: OBSERVATIONS AND MODELLING FOR A SUSTAINABLE MANAGEMENT. T. Guyondet,[1] J. Grant,[2] V. Koutitonsky,[1] S. Roy,[1] G. Tita[1] and A. Trottet[1]

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Lagoons and other coastal systems around the world are subject to increasing threats due to an increase in population densities, industrial activities, resource exploitation and global warming. A research project whose objective is to understand the interactions between the Great-Entry Lagoon ecosystem (Magdalen Islands, Canada) and the mussel culture is presented. Its outcome should lead to a wise carrying capacity assessment and a sustainable management of the lagoon resources. Previous carrying capacity studies have come to the conclusion that an integrated approach is best suited to make a complete analysis of the effects of bivalve culture on the aquatic ecosystem. This ecosystem approach should address the hydrodynamics as well as the biogeochemical processes of the system and adress the different temporal and spatial scales inherent to the ecosystem dynamics. Hence, a multidisciplinary approach was initiated by collecting field data on the major components of the ecosystem, hydrodynamics, biochemical parameters of the water column and the sediments and ecophysiology of farmed mussels. Sampling was designed to address the temporal and spatial variability of the parameters and serve as the basis for the development of a suite of integrated ecosystem numerical models. Two different models are considered. The first is an ecosystem box model representing the pelagic NPZD system and the mussel growth at a coarse spatial scale (boxes). These boxes were determined by a 3D hydrodynamic modelling study of the water renewal inside the lagoon. A user friendly version of this model will be transferred to the mussel growers to help them with their farm management. The second model is a coupled 3D hydrodynamic-ecosystem model describing in more details the hydrodynamics, the pelagic and benthic biochemical processes and the mussel ecophysiology. This model addresses the ecosystem response at various spatial scales and should lead to our understading of the mussel/environment interactions.

DOES SPATIAL HETEROGENEITY OF THE TROPHIC ENVIRONMENT FOR THE PACIFIC OYSTER OCCUR IN THE BAIE DES VEYS? INSIGHT FOR SPATIAL DIFFERENCES IN OYSTER BIOLOGICAL PERFORMANCES. S. Lefebvre, F. Jouenne, B. Véron, J.C. Marin-Leal, F. Orvain, K. Grangeré, K. Costil, J. Royer and M. Ropert.

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The Baie des Veys is a macrotidal and intertidal ecosystem of 37 km² influenced by four rivers. Potential food sources for filter feeders bivalves in this system (cultivated oyster and mussel populations, natural cockle population), are hence phytoplankton, microphytobenthos (MPB) and detritical organic matter from marine or continental sources. Spatial differences in biological performances of the Pacific oyster, *Crassostrea gigas*, were regularly observed at a middle spatial scale (few kms distance). The aim of this study was to state if a spatial heterogeneity of the trophic environment can occur in this system leading to differences in the oyster biology. The analysis of the spatial heterogeneity was undertaken through the synthesis of four different approaches: (i) study of the stable natural isotopic composition (C,N) of food sources and of oyster populations (ii) hydrodynamical modelling to state for the influence of continental freshwater in the bay (iii) study of structure and biomass of the phytoplankton community and finally (iv) spatial structure of the microphytobenthos biomass in the sediment. The study focused on the comparison between north and south parts of the cultivated area. No difference was evidenced by the phytoplanktonic biomass as measured by chla. However, phytoplankton community structure could sometimes differ, aggregatives structure of the MPB biomass was shown in this area and results from the model simulation showed that the influence of the continental freshwater could impact differently this system. Finally, differences in stable natural isotopic composition were observed for oyster populations located in the north and the south of the cultivated area. Therefore, it is assumed that spatial heterogeneity can occur in such system possibly due to local resuspension of sediment organic matter (MPB and detritical) and/or inputs of continental detritical organic material. These results will be discussed according to the biology of oysters (growth, reproduction and survival).

METAPOPULATION SOURCE-SINK DYNAMICS AND RESTORATION OF OYSTER REEF NETWORKS. R. Lipcius,[1] S. Schreiber,[2] D. Schulte,[3] H. Wang[1] and R. Burke.[1]

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Various marine species have experienced significant declines in multiple populations. In the Eastern oyster, population collapses have been sequential and driven by identifiable common causes including overexploitation, habitat destruction, intense predation and disease. A comprehensive analysis of these declines indicates that a diverse suite of ecological forces is limiting the ability of populations in decline to recover, among them predation, degraded habitat quality, susceptibility to disease, decreased alternative prey availability, diminished metapopulation connectivity, and altered population states. In particular, we investigated the role of metapopulation connectivity in the Eastern oyster, and demonstrate that the spatial structure of oyster reefs is critical to metapopulation recovery. We conclude that an ecosystem-based approach incorporating metapopulation structure is critical to the recovery of Eastern oyster metapopulations.

TROPHIC INTERACTIONS OF CULTIVATED OYSTER AND ITS POTENTIAL COMPETITORS AS ANALYZED BY NATURAL ISOTOPE COMPOSITION (C, N) AND LIPID BIOMARKERS (FATTY ACIDS AND STEROLS) IN TWO ECOSYSTEMS OF NORMANDY (FRANCE): PRELIMINARY RESULTS. J. C. Marin -Leal, S. Dubois, F. Orvain, A. Ourry, M. P. Henry, D. Barillier, J. Ledauphin, B. Véron, R. Galois, J. L. Blin, M. Ropert and S. Lefebvre

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Food sources for marine cultivated bivalves are generally not well identified although they are essential for the sustainability of such activities together with a better understanding of coastal ecosystems. Besides the well-known phytoplankton, other sources of organic matter as microphytobenthos (MPB) and detritus (continental or marine origins) can contribute significantly to the growth of marine bivalves. The aim of this study was to identify the potential food sources and to estimate their contribution to the growth of the Pacific oyster and its suspected competitors in two shellfish ecosystems: the Baie des Veys and the Lingreville area. Each of these coastal zones are characterised by different biological performances of the cultivated species. The consistent methodology used was based on the analyses of the food sources simultaneously to the animals by coupling two techniques: stable natural isotope composition (C, N) and lipid biomarkers (Fatty acids and sterols). A field study was undertaken for 2 years since may 2004 every two months. The sampled food sources were suspended organic matter from marine and continental origins, MPB, detritical organic matter from the sediment and macroalgae. Besides, bivalves (*Crassostrea gigas*, *Mytilus edulis*, *Cerastoderma edule*), gastropod (*Crepidula fornicata*), and annelids (*Lanice conchilega*, *Sabellaria alveolata*) were sampled at the same time. Significant interspecific variations of both stable isotope ratios and fatty acid composition of these suspension-feeding species suggested that there are a variety of pathways by which organic matter reaches invertebrates at lower trophic levels of the community food web. Preliminary results on natural stable isotope ratios showed that the contribution of these different sources to the animal growth differed depending on the ecosystem, the period of the year and the considered species. From all evidence, nitrogen stable isotope should be more discriminating than carbon. None of the organisms could be related to a unique food source although MPB was one of the primary contributor to the assimilated food of suspension feeders but POM (mostly phytoplankton) was a significant source anyway. These results are supported and completed by lipid biomarkers analyses that revealed specific fatty acids in the animal tissues as indicators of food items. For example, the roles of epiphytic bacteria or eukaryotic microorganisms are discussed. Combination of stable isotope ratio analysis and lipid markers has rarely been used and appears to be a useful tool for analysing trophic relationships in shellfish ecosystems.

ASSESSMENT AND INTERPRETATION OF TEMPORAL OR SPATIAL DIFFERENCES IN SHELLFISH PRODUCTIVITY OF VARIOUS FRENCH ECOSYSTEMS. J. Mazurié, P. G. Fleury, M. Ropert, P. Soletchnik, D. Maurer and A. Gangnery.

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Monitoring of *Crassostrea gigas* performances, from two year-classes, during 12 years, in various French shellfish farming areas have revealed great inter-annual and inter-sites differences in reproduction, growth, mortality or quality of oysters (meat content, *Polydora* infestation...). The presentation attempts to highlight how a comparative analysis of existing temporal or spatial data on molluscs, water quality, geography or meteorogoly may help to better understand and manage shellfish ecosystems. The range of hydrobiological conditions (food availability, turbidity, temperature...) recorded at national, pluriannual scale, in relation to shellfish performances, enlarges the base of such relationship. However, undirect causative factors, either natural (geography, meteorology) or human (cultured stocks, densities), may present advantages in terms of accessibility, determinism (closer to source) and management : - the observed «site-effect» on growth and mortality is not clearly linked to geographical traits (morphology, oceanic exposure, island protection...). More significantly, the vicinity of fluvial nutritive fluxes (Gironde, Loire...) determines nearby shellfish production but also a higher variability (year-site interaction): oyster growth fluctuates more through successive years in south-Brittany than in north-Brittany, probably in closer response to climatic and fluvial variations. Fluvial inputs in excess during rainy years seem to increase mortality risk (Over-mortality of one-year oysters in Brittany in 1995 and 2001; of two-years old oysters in a Normandy bay). - meteorological conditions influence oyster production at different stages : rainy springs and hot summers for instance favor oysters reproduction (at Arcachon), but impair one year spat survival, the same year. - According to sites, growth limitation and increased mortalities may occur from stock excess,

at different densities and different scales from local (Baie du Mont Saint Michel) to global (Marennes-Oléron). However, physical limitations (farming limited to banks in rias...) or social ones (shellfish leases regulated in Thau laguna...) may have prevented overexploitation.

MACROALGAL GROWTH ON BIVALVE AQUACULTURE NETTING PROVIDES HABITAT FOR MOBILE INVERTEBRATES AND JUVENILE FISH. M. Powers[1] and C. Peterson.[2]

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Destruction and degradation of biogenic habitats contribute to declining yields in coastal fisheries worldwide. We tested the hypothesis that macroalgal growth on protective bottom mesh used in bivalve aquaculture substitutes for seagrass as habitat for mobile invertebrates and juvenile fish. Macroalgal biomass, mobile invertebrate densities, and fish densities were sampled bimonthly from August 1997 – June 1999 in habitats provided by two types of hard clam (*Mercenaria mercenaria*) aquaculture leases and compared to two natural habitats, a seagrass bed (*Zostera marina* and *Halodule wrightii*) and unvegetated sandy bottom. The biomass of macroalgae was significantly greater on aquaculture mesh than on the sandflat but did not differ significantly from the seagrass meadow on most sampling dates. Community structure of mobile invertebrates and juvenile fish utilizing clam leases was more similar to that of seagrass than sandflat habitats. Community similarity among the structured habitats (the seagrass and two lease types), was greater than the similarity between night and day within any given habitat. Total numbers of mobile invertebrates summed over all 11 dates were 75 times greater in the seagrass than in the sandflat habitat, whereas the biogenic habitat of the leases provided a 44-fold enhancement of invertebrates over sandflat. Utilization by juvenile fish was 3 times greater in seagrass and 3 – 7 times greater in clam leases than on the sandflat. Thus, the biogenic habitat provided largely by macroalgal growth on protective bottom mesh of clam leases supports elevated densities of mobile invertebrates and juvenile fish similar to that of natural seagrass habitat, thereby representing a previously unrecognized and valuable ecosystem benefit of bivalve aquaculture.

INCREASING BIODEPOSITION BY INVASIVE SUSPENSION FEEDERS: IMPLICATIONS FOR THE BIOGEOCHEMICAL CYCLE OF SILICON AND PHYTOPLANKTON DYNAMICS. O. Ragueneau,[1] L. Chauvaud,[1] B. Moriceau,[1] A. Leynaert,[1] G. Thouzeau,[1] A. Donval,[1] F. Le Loc'h,[1] F. Jean,[1] G. Laruelle[2] and P. Regnier.[2]

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Biodeposition is a process that strongly affects physical, chemical and biological properties near the sediment-water interface, and bivalve mollusks have been shown to influence the cycling of many biogenic elements through this process. In the Bay of Brest ecosystem, the benthic suspension feeder *Crepidula fornicata* has been proliferating for 50 years, and its influence on phytoplankton dynamics at seasonal scale, via its role on a coastal silicate pump, has been suggested by Chauvaud *et al*. (2000) and tested successfully by Ragueneau *et al*. (2002). Building on this idea, we explore further, at annual scale, the role of biodeposition in the annual Si cycle of the Bay of Brest. We show that annual biodeposition of Si can represent up to 84% of river Si inputs. We also show that preservation of biogenic silica in *C. fornicata* mats is very good (27%), leading to an annual retention of Si representing 23% of river inputs. We suggest that this high retention is essentially controlled by the biodeposition mechanism, which is directly under the control of the proliferation of the exotic suspension feeder. Increasing biodeposition in an ecosystem could thus represent a third route in the so-called «silica depletion hypothesis», beyond eutrophication and dam building. We believe that such a hypothesis should be tested in the many areas of the coastal ocean submitted to the proliferation of such exotic species that modify sedimentation of biogenic matter, as it may have important implications for the functioning of coastal ecosystems seaward of the invasion. Cores have been taken in the Bay of Brest and first profiles of biogenic silica accumulation rates below *C. fornicata* mats are presented.

THE ROLE OF SHELLFISH CULTURE IN ECOSYSTEM MANAGEMENT. A.C. Smaal. (PLENARY TALK)

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Bivalve filter feeders play a dominant role in estuarine and coastal ecosystems. They are an important prey for many wader birds and diving ducks, form habitat structures and process a lot of material. The filtration of particles from the water column, the deposition of detritus on the bottom and the subsequent release of inorganic nutrients forms a shellfish mediated feedback in the ecosystem that stimulates productivity and stabilizes the system.
Shellfish culture generally results in an increase of shellfish growth and a decrease in mortality, hence a higher biomass, in comparison with pristine systems. Harvesting of marketable cohorts results in a relatively young and productive population of the exploited species. However, harvesting also removes biomass and habitat structures from the system. The management of ecosystems is in many cases defined by the management objectives, and these differ for different systems. Shellfish culture often occurs in clean and relatively undisturbed ecosystems that are nowadays also important for nature conservation. This has resulted in conflicts between shellfish culture and nature management.
A better understanding of the role of shellfish in the ecosystem is the key to manage shellfish culture in such a way that both the economy and the ecology can profit from shellfish culture.

This thesis will be discussed with shellfish culture in the Dutch Wadden Sea as a case study.

GIS MAPPING OF CUMULATIVE EFFECTS OF MUSSEL FARMING ON BENTHIC SUSPENSION FEEDERS. J. Stenton-Dozey, S. Ude and S. Crai.

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A large proportion of mussel farming in New Zealand is concentrated along the coastal ribbon in sheltered to semi sheltered areas within the Marlborough Sounds. Mussels (*Perna canaliculus*) are grown on dropper lines suspended from floating long lines that make up individual farms of 1 to 5 ha at depths between 15 to 30 m close to inshore beds of scallops and horse mussels. Cropping is usually rotated on the longlines providing a mixture of newly seeded (30-50 mm) to harvest crop (90-100 mm) mussels. With this crop mixture, a 5ha farm would represent a «water processing rate» by mussels of 17940 m^3 /hr and biodeposition of 29 kg/d of faeces and pseudofaeces. The area of biodepoeition is critical to the sustainability of the benthic scallop and horse mussel beds. To quantify the spatial extend of the benthic zones of influence (BZI), biodeposition area was defined by the Benthic Deposition Parameter (BDP) which describes trajectories of faecal material released by the farm and where it is distributed. In this study we use one bay in the Sounds with 40 coastal farms as an example of applying GIS mapping of BZI. The BDP is distributed from the farm boundary outwards. Data was assembled within a GIS (ArcGis 8, ESRI, 1992) where it was modelled to obtain a number of raster layers (10x10m pixels) from which the «water processed» and «benthic deposition» maps were produced. The first raster layer modelled was the current velocity. A single value of velocity was assigned to each location where an ADP had been moored. Velocity contours were then constructed using a Kriging (Universal) technique available within the GIS. This surface was subsequently used as a factor in modelling «water processed» and BDP. A benthic distribution zone was modelled as: Lb= Up x Ts + 2* sqrt(KhxTs) (m) where Lb is the lengthscale, Up the current magnitude (m s^{-1}), Kh is horizontal diffusivity (m^2 s^{-1}.), Ts the sinking timescale calculated as Ts = d1/Us where d1 = H-ld/2 and H = water depth at farm (m), ld = dropper length (m), Us = faecal sinking speed (m/s) set nominally to 0.05 m/s and where a nominal dropper length for each farm, ld, is calculated as two-thirds of the water depth at the farm centroid. An ArcInfo AML script was written to process the data for each farm. Individual layers of BDP were calculated from the length scale. The length scale was used as a parameter to produce a buffer around farm outlines to produce the «zone of influence». The effect of cumulative biodeposition of all farms within a bay on the longterm sustainability of scallop and horse mussel beds is discussed.

HABITAT SUITABILITY INDEX MODEL FOR THE AMERICAN OYSTER, *CRASSOSTREA VIRGINICA*: IMPLICATIONS FOR RESTORATION AND ENHANCEMENT OF OYSTERS IN SW FLORIDA ESTUARIES. A. K. Volety,[1] T. Barnes,[2] L. Pearlstine,[3] and F. Mazzotti[3]

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Alterations in freshwater inflow resulting from watershed development and water management practices have impacted salinity and water quality within southwest Florida estuaries impairing oyster *Crassostrea virginica* abundances in the Caloosahatchee Estuary compared to historic values. Altered hydrology including unnatural high and low water deliveries to the estuary have been identified as key stressors. In concert with changes in ecosystems related to the "Comprehensive Everglades Restoration Plan" (CERP), an adaptive assessment strategy is being developed to ensure ecological integrity of the Caloosahatchee estuary. The key component in adaptive management in the Caloosahatchee estuary is the focus on water quantity, quality, timing and duration of freshwater flows into the estuary. In order to better understand how alterations in the watershed impact oyster populations, we are engaged in an integrative approach of adaptive management in developing a Habitat Suitability Index for oysters. Each stressor metric is being portrayed spatially and temporally across the Caloosahatchee Estuary and is incorporated into a GIS to facilitate policy decisions. New monitoring / experimental sites are being established in areas of high uncertainty to improve overall model predictability. For the stressor response model for the American oyster, a larval component index (LCI) and adult component index (ACI) are being examined. Spat recruitment, mean salinity, temperature, and inflow of freshwater comprise the LCI. The ACI is comprised of densities of living oysters, disease intensity of *Perkinsus marinus*, spat recruitment, salinity, temperature and frequency of killing floods. The Habitat Suitability Index of oysters is calculated as LCIw * ACIw, where w = 1 / number variables. The weight can take on different values for different variables; however, the sums of the weights must be equal to one. Areas that show high HSI from this model are being targeted for restoration and enhancement of oysters in the Caloosahatchee Estuary.

SOCIO-ECONOMIC, POLICY, OUTREACH AND EDUCATION ASPECTS OF SHELLFISH/HABITAT RESTORATION

SOCIO-ECONOMIC EVALUATION OF THE SCALLOP RESTOCKING PROGRAM SOCIO-ECONOMIC EVALUATION OF THE SCALLOP RESTOCKING PROGRAM IN THE BAY OF BREST. F. Alban,[1] J. Boncoeur[1] and J. P. Carval.[2]

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In the midst of the XXth century, the bay of Brest (France) was an important scallop (*Pecten maximus*) fishery. Following a collapse of the stock in the 60', a recovery plan was set up, including a restocking program that has progressively turned into a sea-ranching program. This program is based on the production of juveniles by a hatchery-nursery unit, together with a fishery management plan including a marine reserve. Part of juveniles coming from the restocking program is sown extensively on natural beds, and part is sown intensively in an area closed to fishing for 2 or 3 years. The location of the reserve changes through time, its management being based on a crop rotation system. Fishing on natural beds is controlled through fishing effort, while the harvesting of the crop in the reserve is based on individual quotas. After a trial-and-error period, this program has made a significant move towards economic sustainability in the 90'. It is now self-financed by fishermen, through an individual yearly contribution. This paper estimates the net benefits of the restocking program and associated management system of the fishery. It also analyses the way this program is perceived by fishers. The results of simulations provide a basis for a discussion of alternatives concerning the future of the fishery. The question of the role of the reserve, and of its links with individual fishing rights is particularly addressed.

CARIBBEAN EDUCATION PROGRAM FOR SUSTAINABLE MANAGEMENT OF THE QUEEN CONCH, *STROMBUS GIGAS*. D. Aldana Aranda,[1] L. Frenkiel,[2] M. Sanchez Crespo,[3] C. S. Pérez[3] and M. Rolon.[4]

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The queen conch, *Strombus gigas*, is a large Caribbean Gastropod Mollusc which has been exploited for food and many other purposes since pre-Columbian times. It was also used during slavery for remote communication. It is still used as traditional food, and a tourist attraction delicatessen, its shell is used as music instrument, tourist curios and much more. Now, it is an endangered marine resource mainly because of over-fishing, but probably also because of destruction and pollution of its natural habitat. It is included in annex II of CITES (Convention for international trade of endangered Species). However CITES is in charge only of international traffic but not of the local fisheries and trade. Each country is responsible for its protection and enforcement of protection regulation. However a lack of respect of the main regulations is the rule in most countries. Research workers at academic level, from Guadeloupe (French Caribbean),Yucatan (Mexico) in cooperation with the education group of the private marine park of Xel- Ha in Quintana Roo (Mexico) and with the support of the Caribbean Fisheries Management Council (CFMC) from Puerto Rico have joint their efforts to produce a whole set of documents at school and general public level. The documents, edited in English, French and Spanish, comprise a booklet, a diaporama and a large set of games accessible on 4 internet sites and in CD edition, distributed for free at the Gulf and Caribbean Fisheries Institute (GCFI) meetings and through the Strombus net site. They may be used for school and public information; they may be reproduced, used to produce paper booklets and cardboard plays. They are designed to be adapted in each country to popularize the idea that *Strombus gigas* is a common nature cultural and economic heritage of all the Caribbean people and that children have to be involved in its protection.

HENDERSON INLET COMMUNITY SHELLFISH FARM, WASHINGTON STATE, U.S.A. D. Barth and B. Peabody.

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The Puget Sound Restoration Fund (PSRF) is a non-profit organization in Washington State, U.S.A. PSRF's mission is to achieve on the ground restoration of habitat and native species in Puget Sound by focusing on action, not politics. PSRF's goal is to mobilize resources from a varity of sources to complete priority projects. These habitat and restoration projects include, but are limited to, community based habitat restoration projects, community shellfish farms, native oyster restoration projects and their associated monitoring, reporting and regulatory compliance. To this end PSRF has established two community shellfish farms in Washington State. The farms are born from the concept that local community support for clean water, pollution abatment, and habitat restoration can influence local and state governments to accomplish needed objectives. In the Henderson Inlet of southern Puget Sound the community shellfish farm brings together residents, students, elected officials and volunteers of all disciplines to seed, maintain, and soon

harvest shellfish. The Hendersun Inlet demonstration farm is host to various environmental education outreach activities with schools, conservation groups, and governmental agencies. Volunteers are the key to its success, and the farm is envisioned to expand and become a centerpiece for shellfish restoration in Washington State. The farm is co sponsered by the Pacific Coast Shellfish Growers Association (PCSGA). This joint industry/conservation organization project has been the focus of media attention and should be shared with others.

SHELLFISH RESTORATION ON PRIVATELY LEASED OR OWNED SUBMERGED LANDS IN THE UNITED STATES: A CATALYST FOR PARTNERSHIPS AND ECOSYSTEM BASED MANAGEMENT. R. Brumbaugh, M. Bortman, C. LoBue, J. White, B. Lyons and M. Beck.

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Populations of many commercially important species of bivalves have declined dramatically during the past century in temperate marine and estuarine systems throughout the United States. Until very recently, restoring shellfish populations has been motivated by commercial and recreational harvest objectives, with landings being the primary metric for success or failure. However, ecosystem services such as water filtration and provision of habitat for species associated with robust shellfish populations are increasingly invoked as justification for shellfish restoration. Measuring these services has proven challenging, however, in part because many restoration sites are ultimately opened to harvest and other activities that can affect their ecological function. The Nature Conservancy (TNC), working with the NOAA Community-based Restoration Program, has developed a network of shellfish restoration projects at TNC priority sites across the U.S. which provides a means of engaging the public directly in restoration across a national stage. Several of these restoration sites occur on submerged lands that are leased or owned outright by TNC. These sites present opportunities to establish longer-term monitoring programs to facilitate the measurement of ecosystem services provided through restoration, and help to bring together diverse groups of stakeholders including managers, scientists and fishers and to formulate ecosystem-based restoration objectives.

A STRATEGIC MAINFRAME FOR SHELLFISH RESTORATION MANGEMENT: THE ENFORCEMENT OF THE LAW OF THE SEA THROUGH THE ENVIRONNEMENTAL EC POLICY. O. Chantrel.

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The seas are the main regulator of the biosphere, receiving all the pressures of development. The law of the sea can found a universal juridical order, forming the basis of the law of development concerning the ways of managing sustainability. The universal necessity to protect the marine environment and a wide approach con-cerning the precaution in risk management for waters under jurisdiction or responsibility of any state are inte-grated into any activity to witch it control. This universal environmental competitiveness regulator also concerns the WTO which has sustainable development as its objective. The EC is an international organisation which forms part of the UNCLOS. The EC is also bound to the main objective of sustainability. The variability that the EC has acquired, the solidarity it promotes within its member states surpasses the co-operations promoted by UNCLOS. So, EC may be admitted as international organisation with competence in all areas related to UNCLOS. The European maritime geography, the juridical regional network and a sufficient variability allows to use the law of the sea to found a paneuromediterranean regional identity for development and security©. The EC is reforming the administrations in the purpose of obtaining a coherent risk management understood in the emerging of a sustainable development. This system encompasses a significant area. Article 6 of the EC introduces the law of the sea into all policies and actions which affect the marine environment, from conception to application. The integrated management of coastal zones contributes to a coherent management and control of public policies affecting the sea, and might strengthen the EC's environmental policy. This strategy needs a network made up of a regional maritime agencies system(c) to obtain a new approach of maritimity©.

A COMMUNITY BASED APPROACH TO DELAWARE INLAND BAYS SHELLFISH RESTORATION AND WATER QUALITY MONITORING. J. Ewart, J. Farrell and E. Whereat.

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Delaware's three coastal or «inland» bays (Rehoboth, Indian River and Little Assawoman) are part of series of contiguous coastal lagoons that range along most of the eastern seaboard of the United States. The estuary has been experiencing the impacts of chronic eutrophication and sediment erosion resultant from several decades of sustained nutrient input and development from within the surrounding watershed. The cumulative impact of these inputs has degraded water quality and has reduced the diversity and abundance of various species of fishes, invertebrates and submerged aquatic vegetation (SAV). Other adverse environmental impacts include habitat loss, increased turbidity, episodic hypoxic and anoxic conditions, macroalgal and potentially hazardous phytoplankton blooms. The Delaware Center for the Inland Bays (CIB) was established as a nonprofit organization by the Delaware Legislature in 1994 to facilitate a long-term community based approach for the wise use and enhancement of the estuary. Maintaining healthy populations of bivalve shellfish (American oyster *Crassostrea virginica* and the hard clam *Mercenaria mercenaria*) for their ecological, recreational and commercial value to Delaware's coastal bays is a priority of the Center's Comprehensive Management Plan. Applied field research and demonstration work to evaluate the efficacy of using aquaculture methods for shellfish and habitat restoration has relied extensively on a private-public sector partnership.

Local community involvement has played an integral role by providing policy guidance, materials, in-kind and other services, access to facilities and equipment, volunteers and the participation of local municipalities. Inland Bays shellfish restoration activities including a newly initiated effort in the Little Assawoman Bay are reviewed and discussed highlighting citizen volunteer water quality monitoring, oyster gardening and public education and outreach programs.

LEARNING FROM THE PAST: CHALLENGES IN MANAGING NEW ZEALAND'S NEW SHELLFISHERIES. A. Frazer.

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New Zealand has a number of established commercial shellfisheries, but relatively few new shellfisheries. This is due, in large part, to a moratorium on fishing permits for new species, which constrained development of new shellfisheries throughout the 1980s and 1990s. A time series of historical catches for New Zealand's shellfisheries is presented. The scene has been set for development of a new suite of shellfisheries in New Zealand by the recent expansion of the Quota Management System (QMS) to include 13 new shellfisheries, and by the removal of the permit moratorium for new species. Commercial fishers are now able to target new shellfish species with commercial potential, with a trigger for QMS entry where active management is required and sustainability and economic benefit is evident. Challenges in managing these new shellfisheries are discussed. New Zealand's experience, from established shellfisheries such as paua (abalone), oysters and scallops, is that considerable effort is often required to maintain the long-term viability of shellfisheries due to: susceptibility to disease and habitat degradation · uncertainty in terms of appropriate sustainability targets high market value (which attracts a race for catch and illegal fishing). However, the QMS provides a sound platform to meet these challenges. Stakeholder-led initiatives in terms of enhancement and sustainable harvesting practises are outlined. The way in which this experience has been taken into account in management settings for new QMS shellfisheries is discussed. It is expected that quota holders will work to address multi-sector issues and invest in research prior to further development of these shellfisheries. This is already occurring to some extent. Barriers to progress include insufficient initial catch to warrant investment and inadequate governance structures.

STRATEGIES OF SHELLFISH FARMERS TOWARDS THE UTILIZATION OF THE MARITIME PUBLIC GROUNDS: THE EXAMPLE OF OYSTER CULTIVATION IN CHARENTE MARITIME (FRANCE). S. Girard, J. Pérez and R. Mongruel.

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The aim of this paper is to analyse the strategies of the French oyster producers to manage land access rights, at individual and collective level. The main sources used come from data of the first national census in shellfish farming and from local qualitative surveys. We focus on the Marennes-Oleron sector, as the main oyster cultivation region in France and the national area for fattening activity. Unlike rearing concessions, located in maritime public grounds, oyster fattening takes place in wetland ponds, in private grounds. This final process providing oysters with extra value-added enables the local firms to better valorise their products and hold commercial supremacy. At individual level, the typology of oyster farming firms, based on structural indicators shows the role played by the «land» (i.e the set of concessions) in classifying the enterprises. The typology highlights different strategies as regards the utilization of oyster farming concessions in public or private grounds: integration, specialization (spat production/ growing/ fattening) or (and) geographical diversification. These strategies have to be analysed within the context of the current national management system and of the environment. Particular attention will be paid to side effects resulting from the shortcomings of enforcement of management rules. Interactions with other users, mainly agriculture and tourism, are also considered insofar as they influence the stakeholders' behaviour.

SUMMER RESEARCH OPPORTUNITY FOR MIDDLE SCHOOL STUDENTS: THE GEOBIOLOGY OF OYSTER REEFS. D. Henry, J. Kakareka, A. N. Loh and M. Savarese.

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The Summer Research Opportunity (SRO) at The Whitaker Center of Florida Gulf Coast University (FGCU) immerses students in various science disciplines to stimulate interest and appreciation for the sciences. The SRO is a two-week program designed for forty middle school students. During Thomas Alva Edison Regional Science and Engineering Fair, students were awarded the opportunity to participate in the SRO. Students are introduced to a variety of science disciplines by participating in research endeavors, scientific discussions and demonstrations. SRO students actively participate in a research project designed to expose them to both field and laboratory based research. The project culminates in a research presentation of the study results. Southwest Florida's estuaries are critical to the health of the coast and adjacent ocean. Within the collection of ecosystems present, the system of greatest productivity is oyster reefs. The reproduction and growth of the American oyster, *Crassostrea virginica*, is typically concentrated in localized areas within the well-mixed regions of our estuaries. The oysters congregate and create a three-dimensional architecture that then supports a great deal of associated life. Despite this importance to estuarine ecology, oysters are highly sensitive to subtle changes in water quality. Managers, like those at Rookery Bay NERR, monitor the physiology of oysters and the ecology of their reefs to document human effects. This information is then used to design restoration efforts – the health of oysters is used to determine how water flow to an estuary should be improved. Although oyster reefs have been used extensively for environmental management and restoration, little work has been done to

characterize the environmental conditions under which they thrive. In addition, little is known about how variable those environmental conditions can be. SRO students and faculty developed a research plan to characterize the geobiology of oyster reefs from a range of salinities.

RETURN OF THE NATIVE – IS EUROPEAN OYSTER (*OSTREA EDULIS*) STOCK RESTORATION FEASIBLE? I. Laing,[1] P. Walker[2] and F. Areal.[3]

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Throughout much of the UK and in Europe generally, the native oyster is in a severely depleted state in the wild. In order to address and potentially to reverse this situation *Ostrea edulis* was designated as a named species in the UK Biodiversity Action Plan as part of a national commitment to the International Convention on Biodiversity. Amongst other initiatives, which will be summarised in this paper, a feasibility study was carried out to evaluate all the factors, including an economic assessment, relevant to a programme of stock restoration. The study showed that there is a considerable body of data on the biology, ecology and distribution of *Ostrea edulis* to inform restoration projects. Appropriate legislation is already in place to allow for restoration. Non-marketable costs and benefits were estimated. They provide an idea of the high value that may be placed on biodiversity aspects. Nevertheless, this study also shows that stock restoration can be commercially viable if fishery prices and yields are sufficiently high, although sustaining a fishery at the historical harvest level is unrealistic. Restoration efforts and associated studies elsewhere have shown the potential for success of native oyster stock regeneration, especially in disease-free areas. For these, there is a very strong element of re-creating and conserving an ecological resource. The relaying of cultch is seen as an essential component of a successful oyster restoration programme and the use of sanctuaries is generally considered beneficial. The loss of the standing stock is a limiting factor and re-stocking is an effective strategy. There is a basic genetic similarity of wild European *O. edulis* populations such that the source of stocks is not critical. There are some problems with hatchery rearing from these, but using breeding ponds or importing part-grown oysters are viable alternatives.

SHELLFISH RESTORATION: TOWARDS AN INTEGRATED AND CONCERTED APPROACH. T. Landry. (PLENARY TALK)

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Shellfish restoration has been justified and focused on ecological, economical and subsistence benefits. In Atlantic Canada, this activity dates back to the pre-colonization era, mainly for food subsistence and ceremonials purposes. Over the past century, shellfish restoration has mainly supported the oyster industry in several key bays. Recently, this activity has been linked to ecological benefits, and more specifically to mitigation and compensation goals. Despite the value of the underlying justifications, the success and efficiency of shellfish restoration in a given coastal ecosystem requires an integrated approach in order to maximize the benefits of all users. This approach is presently the basis of scientific investigations being conducted in Atlantic Canada. Preliminary results already suggest that a concerted approach will be more beneficial.

SHELLFISH RESTORATION PROJECTS IN THE CONTEXT OF SOCIAL, POLITICAL AND ECONOMIC FACTORS: OBSERVATIONS OF A CHANGING LANDSCAPE. S. Macfarlane. (PLENARY TALK)

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Shellfish restoration projects, as designed by entities involved principally in the growing of shellfish may have a positive effect on shellfish populations. However, unless consideration is given to factors other than shellfish growth and survival, project success may be elusive. Social, political and economic factors often play a pivotal role in the success of projects. Changes in attitudes, priorities, funding and leadership over time may impact the long-term success of restoration projects where shellfish populations take years to rebound. Changes in land use and water use may result in habitat and/or water quality degradation rendering a shellfish restoration site inhospitable for the effort or worse, resulting in major mortalities of shellfish planted in the area. Documented habitat changes have occurred when coastal area populations increased. Changes can be dramatic or subtle as will be shown in multi-decadal observations. It is often cumulative effects that are not only difficult to quantify but are ones that can lead to the greatest challenges for shellfish managers primarily because the action takes place on the land but the result is evidenced in the estuary. «Fixing» land use problems to «save» shellfish is often not perceived as being cost-effective and we, as shellfish managers, need to do a better job of articulating the ecological importance of shellfish in a broader context. Recently, though, community efforts at the grass roots level have served to emphasize the importance of shellfish enhancement, citizen monitoring programs and resource management plans as a function of ecosystem restoration.

BIOECONOMIC SIMULATIONS OF MANAGEMENT MEASURES CONTRIBUTING TO RESTORATION OF A CRUSTACEAN SHELLFISH STOCK: THE CASE OF THE *NEPHROPS* IN THE BAY OF BISCAY. C. Macher, O. Guyader and C. Talidec.

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Trawling for *Nephrops* in the Bay of Biscay endangers biodiversity and habitats but this activity is especially characterized by the high level of discards of many species. This generates a waste as well for the stock as for the fleet. *Nephrops* trawlers discard about half of their *Nephrops* catches in numbers, and a third in weight. It explains the stakes of improving the selectivity of the fishing gear to restore this stock. A better exploitation pattern through an increased selectivity would enable to reduce discards and so to attend a more sustainable situation with a better valorisation of the production potential. After describing the economic importance of the Nephrops fishery of the Bay of Biscay and its management measures, the paper analyzes the biological and economic consequences of different scenarios of technical measures. Six theoric scenarios of improving selectivity and two scenarios of adoption of a *Nephrops* grid are simulated. The potential impacts of these scenarios on *Nephrops* biomass, landings, discards and economic indicators like rent are analyzed and discussed. When taking the dynamic of fishing effort into account, we show that the rent generated by technical measures may be reduced. The need to complete technical measures like selectivity by mechanisms of access regulation to adjust fishing capacity to production potential of the stocks is underlined. Technical measures contribute to discards reduces and, as a consequence, to restoration of the stock and limitation of impacts on biodiversity. However, these measures are still insufficient to ensure the sustainability as they don't include limitation of the impacts on habitats and modifications of the trophic relations.

FROM A "HIDDEN MARKET" TO A "HYPOCRITICAL MARKET": UNINTENDED EVOLUTION AND UNEXPECTED EFFECTS OF THE FRENCH ALLOCATION SYSTEM FOR SHELLFISH FARMING CONCESSIONS. R. Mongruel, J. A. Perez Agundez and S. Girard.

Ifremer/DEM, Centre de Brest, BP 70, 29820, Plouzané France

The legal status of the land dedicated to shellfish farming activities in France is based on a concept of «temporary access authorization to the Public Maritime Domain»: individual and delivered by the Administration, the concessions can not be neither appropriated nor sold. Nevertheless, two practical reasons led to the generalisation of concessions commercial exchanges: the anteriority of the user and the value accumulation. This paper analyses how the spontaneous emergence of this quasi-rights market was followed rather than regulated by the global evolution of the law. In 1915-1919, a first adaptation of the law allowed for the designation of the future user of a concession by the former one, initially in order to facilitate the inheritance of shellfish farms by the descendants, which conduced to an unintended development of bilateral negotiations. These negotiations became also financial, even when the Administration was not informed of the price paid for the successions registered: concessions were exchanged on a hidden market. In 1983, a legal reform tried to eradicate the market by restricting the right to choose the successor to the case of family transmissions only, but after professional pressure on the government, the law changed again in 1987. In addition to the restoration of the right to choose a successor, the actual law considers now the payment for the concession transmission as a legal indemnity for the «improvement of the productivity potential» realized by the former user: the hidden market has became a hypocritical one. Formally ignored by the Administration, the market can not be regulated and generates therefore unexpected effects: the value of the rights raises problems of equity, excessive concentration and access to the sector for new comers, and speculative behaviours try to benefit from institutional change in the shellfish farming area management, like restructuring or opening of new zones.

RESTORING DYNAMICS TO UNPRODUCTIVE RIGHTS WHEN RESTRUCTURING THE MONT ST. MICHEL SHELLFISH FARMING AREA: THE EXAMPLE OF NON DESIRABLE EFFECTS OF LAND USE RIGHT MARKETS. J. A. Perez Agundez, R. Mongruel and S. Girard.

Ifremer/ DEM, Centre de Brest, BP 70, 29820 Plouzané, France

The French shellfish farming industry is based on an allocated system of temporary use rights of maritime spaces. Those rights are exclusive and revocable under the legal principle characterising the state property as non privatizable. The reason for creating a quasi-right market of shellfish farming concessions in the 80's was basically the need to establish general rules allowing a better adjustment of enterprises to the dynamic of the sector. Within this context, the aim of this paper is to analyse the management strategies of shellfish farming enterprises related to their needs of land use rights. This paper will focus how the modification in regulation of the land use rights transfer system towards a more liberal structure has driven to particular strategies of enterprises according to the economic theory. The case study selected will particularly analyse the modification of the shellfish farming cadastre on the Mont Saint Michel bay (North Brittany) led at the end of the 90's and explained by the decrease of the local ecosystem productivity. The silting up of the Western zone of the Mont Saint Michel shellfish farming area has driven to its closing and to its parallel transfer towards the East. The allocation rights system in this restructuring operation has transformed the former rights of the closed area in equivalent rights of the new more productive zone. This particular type of exchange rights regime combined with passivity of management by the local administration may have caused unexpected effects which will be explored in this paper.

HALIEUTIC AND ECONOMIC CHARACTERISTICS OF THE EXPLOITATION OF JAPANESE CLAM IN THE GULF OF MORBIHAN (BRITANY). I. Péronnet,[1] F. Daures,[2] M. Salaün[1] and J. Diméet.[1]

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The exploitation of the Japanese clams (*Ruditapes phillipinarum*) started in 1991 on the managed natural clam-bed of Sarzeau located in the gulf of Morbihan (Brittany) and plays today a very important economic role for this place. In addition, this activity is carried on a particularly sensitive ecosystem, where coexist large stakes: economic stakes between professional fisheries and other uses, environmental stakes because of existence of remarkable natural habitats which oblige to take into account these environmental constraints in the management measures. Indeed, the gulf of Morbihan shelters the second eelgrass meadow (*Zoostera noltii*) of the French littoral (2000 ha) and is also a wintering area of the Brent goose, (*Branta bernicla*). This species is an herbivorous goose which subsist, in winter, on sheets and rhizomes of eelgrass (*Zoostera noltii* and *Zoostera marina*). Trampled down by fishermen eelgrass meadow could be damaged and human presence constitutes a sufficient disturbance to be incriminated in the local decline in this population of birds. This activity requires to establish the most adequate management according to the objective of sustainable exploitation and environmental constraints and is framed by a specific regulation measures (system of licences and quota, monitoring by a water bailiff, allowance of areas to each category of fishermen, protected areas of eelgrass, undisturbed wintering areas for geese. It also requires a minimum information on the fishing fleets involved in this fishery. The aim of this article is to put in light the clams fishing activities from halieutic and economic point of view. Indeed, this activity concerns approximately 305 sailors, and can be practised either by hand or by ship with a dredge. The level of specialisation of each fleet varies and goes from 5 «metiers» on average (metier= a specific fishing activity) for the fishermen using a ship with a dredge to only 2 «metiers». for the fishermen by hands. The clam's turnover represents the most important part of the turnover of the Gulf of Morbihan fishing fleets.

THE LANDSCAPE APPROACH: IMPORTANCE OF ALTERNATIVE PREY FOR EFFECTIVE SHELLFISH RESTORATION. R. Seitz and R. Lipcius.

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A landscape approach to restoration requires consideration of habitat quality and connectivity, and the impact of alternative prey on survival of oyster reefs facing heavy predation. We assessed abundance of benthic prey at proposed oyster restoration sites on the Lafayette and York Rivers, Chesapeake Bay. Oyster reefs are used as refuge by crabs, which can feed heavily on juvenile oysters. Given this predator-prey relationship, oyster reef restoration is unlikely to succeed in areas with high crab abundance, unless there is sufficient alternative prey. We quantified bivalve diversity, density, and biomass in deep and shallow (< 1.5 m), unvegetated subtidal habitats and also examined differences among developed shorelines. Bivalve diversity, density, and biomass were significantly higher in shallow than deep benthic habitats. Benthic abundance and diversity were higher in subtidal habitats adjacent to Natural Marsh than those adjacent to Bulkhead and were intermediate in Rip-Rap shorelines, depending on landscape features. Predator density and diversity were also highest adjacent to Natural Marsh. There is thus a crucial link between natural marshes, food availability for predators in subtidal habitats, and predator abundance. We conclude that if alternative infaunal prey abundance is adequate, restoration of adjacent oyster reefs would be likely to succeed. Given high bivalve abundance, biomass, and diversity in marsh-fringed habitats, we recommend integrated salt marshes and shallow oyster reefs in restoration efforts. We therefore propose that marsh habitats be created and oyster reefs be restored in the adjoining shallows of the coastal marsh zone for an integrated landscape approach to restoration.

THE ECONOMIC IMPACT ASSOCIATED WITH THE RECREATIONAL SCALLOP SEASON IN CITRUS COUNTY, FLORIDA, USA. D. Sweat[1] and C. Adams.[2]

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A recreational bay scallop (*Argopecten irradians*) season was established on the Gulf coast of Florida in 1994. In 1995, the recreational season was limited to a more restricted region – the area north and west of the Suwannee River. Due to a number of factors, including efforts to re-establish bay scallops through stock enhancement activities, the recreational season was re-opened during 2002 in the region between Aripeka and the Suwannee River. Within this region, the highest concentration of scallops, and thus recreational scalloping activities, is near the mouths of the Homosassa River and the Crystal River, in Citrus County. The recreational scallop season runs from 1 July to 10 September of each year. During this time period, local businesses experience increase business volumes as recreational scallopers arrive in large numbers attempting to harvest daily bag limits. Anecdotal evidence and reports suggest that the recreational scallop season provides a significant boost to the local economy, as recreational scallopers purchase fuel, food, supplies and lodging accommodations during their stay. In addition, many of these recreational scallopers come from outside the area, thereby bringing in new dollars to the local economy. The purpose of this study was to estimate the economic impact associated with the 2003 recreational scallop season in Citrus County, Florida. This information would help resource managers and county business representatives better understand the economic and social implications of ensuring a sustainable recreational harvest of bay scallops. Interviews were conducted with representatives of a variety of business types in the area. The business types included fishing guides and dive shops, restaurants, lodging accommodations, convenience stores and gas stations, and retail shops. As a result of this survey, the total economic activity associated with non-resident expenditures on recreational scalloping activities during 2003 in Citrus County, Florida was determined to be $1.6 million.

ASSESSING THE IMPACTS OF HARMFUL ALGAL BLOOMS ON A COMMERCIAL FISHERY: THE CASE OF THE WEDGE CLAM (*DONAX TRUNCULUS*) FISHERY IN THE BAY OF DOUARNENEZ – FRANCE. O. Thebaud,[1] S. Fifas,[2] A. Menesguen,[3] E. Nezan[4] and G. Veron[2]

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The commercial fishery for wedge clam, or telline (*Donax trunculus*) in the bay of Douarnenez in France started in the early 1980ies. During twenty years, the activity has developed, from an opportunistic fishery, into a regular fishing enterprise for 36 fishermen, who derive from it most, if not all, of their revenue. The fishery is nowadays strictly regulated. It is subject to natural variations in the productivity of clam stocks, in relation with meteorological conditions which can strongly affect the stocks. The bay of Douarnenez has been experiencing regular blooms of harmful algae, both of species leading to shellfish poisoning for human consumption, such as *Dinophysis* (Diarrhoeic Shellfish Poisoning) and *Pseudo-nitzschia* (Amnesic Shellfish Poisoning), and of species leading to mortalities of marine animals, such as *Karenia mikimotoi*. It has been suggested that the occurrence of these blooms can be related to hydrological phenomena, leading to limited exchanges between the bay's waters and the open sea, and to thermal stratification of the water column in summer. The blooms can lead to slowed growth, as well as increased mortality of clams. Toxins accumulated in the clams also create risks for human consumption, which regularly lead to temporary fishing bans in the bay, in application of national and European health safety regulations. The aim of the paper is to analyse the consequences of these harmful algal blooms on the wedge clam fishery. The dynamics of the blooms having an impact on the fishery are described. The potential impacts of these blooms on clam biology, as well as their consequences on the economic status of fishermen, are analysed. In particular, the economic impacts of temporary fishing bans are discussed, taking into account their potential consequences on markets, and the adaptation strategies of fishermen The analysis allows identification of further research needs to better evaluate the impacts of harmful algal blooms on the biology and harvesting of clams. Current hypothesis on the determinants of these environmental perturbations, in particular the amplifying role of nutrients of human origin, are also discussed.

THE FINANCIAL VIABILITY OF POLYCULTURE: EVIDENCE BASED ON DATA FOR SALMON-MUSSEL AND SALMON-MUSSEL-MACROALGAE PRODUCTION SYSTEMS. D. Whitmarsh,[1] E. Cook,[2] M. Kelly[2] and C. Sanderson.[2]

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Integrated production systems have a role to play in ensuring the sustainability of aquaculture and in mitigating the environmental impacts of fish farm effluent. Particular interest has recently focussed on the prospects for integrating finfish production with bivalves and seaweed, given that in both cases there are potential economic benefits arising from enhanced growth of these organisms when grown in close proximity to mariculture activity. A key question concerns financial viability, since the adoption of 'sustainable' technology involving polyculture will not occur unless there is a reasonable prospect of earning a positive return on capital. Previous investigations have demonstrated the commercial potential of integrated salmon-mussel production systems, though whether (and how quickly) this form of polyculture is adopted will depend on the expected trend in the prices of salmon and mussels (Whitmarsh, Cook and Black, in press). The present paper extends the previous work on this topic by comparing the profitability of polyculture based (i) salmon and mussels with (ii) salmon, mussels and macroalgae. The latter builds on recent studies that have shown that the commercially valuable red seaweed *Palmaria palmata* will absorb fish farm dissolved farm nutrients and undergo enhanced growth when grown in close proximity to salmon cages situated on the West coast of Scotland. A capital budgeting model is used to evaluate the profitability of investment, with results presented in terms of net present value (NPV) and internal rate of return (IRR), while sensitivity analysis is used to test the effect on profitability of changes in key parameters. The paper also includes an examination of the prices for these farmed species in the light of emerging market conditions. Reference Whitmarsh, D.J., Cook, E.J. and Black, K.D. (2005, in press). Searching for suatainability in aquaculture: an investigation into the economic prospects for an integrated salmon-mussel production system. Marine Policy (forthcoming).

POSTER PRESENTATIONS

ASSESSMENT OF SHELLFISH HABITAT AND RESOURCES

THE RESOURCES OF THE EDIBLE TURBAN SNAILS TURBO SPP. ALONG THE COAST OF HENGCHUN PENINSULA, SOUTHERN TAIWAN. M. Chen.

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Many of the world's fish population are overexploited, and the ecosystems that sustain them are degraded. For example, reduced stocks of herbivorous animal and added nutrients from land-based activities have caused ecological shifts from the original dominance by corals to a preponderance of fleshy seaweed in coral reef of many regions. Turban snails are conspicuous members of shallow coral reef habitats where they graze on algae. They were valued as food and ornamental items in the Indo-Pacific region. Recently, the resources of some species of turban snails have been considerably diminished, and the need to restore these resources has been proposed in some regions. The history of utilizing turban snails by indigenous people can be traced back to three thousand years in Hengchun Peninsula, southern Taiwan, but there was very few information about exploitation of these resource. The present study was monitoring these resources by surveying the abundance and estimating the CPUE of turban snails in field. The following results were found in this study: (1) The density of snails range between 0 to 10 individuals per 100 m^2 in field; (2) The CPUE was decreased belong the time, from 6 to 0.5 Kg per hour. These results suggest that the over-exploitation of turban snails was happen, and the marine protect area was need to conservation of this resource.

SPAT SETTLEMENT OF PECTINIDAE AND MYTILIDAE IN THE NORTHERN ADRIATIC SEA. A. Chinellato, M. Bressan[1] and M. Pellizzato.

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Some species of bivalves of the families Pectinidae (*Chlamys varia* (L.), *Proteopecten glabra* (L.), *Aequipecten opercularis* (L.)) and Mytilidae (*Mytilus galloprovincialis* Lmk) are important fishery products in the Northern Adriatic Sea. From December 2003 to November 2004 a research project on the larval settlement was carried out in an area located 2 nautic miles offshore the Venetian coasts, using three types of experimental collectors for bivalve spat harvesting («pegs», «chinese caps» and «bags»), suspended at 2 and 10 m depth. The study revealed the periods and density of settlement, as well as the bathymetric preferences of the various species. Pectinidae species, present during the whole study period, were mostly abundant in summer (up to 267 ind m^{-2} day^{-1}) and showed a higher settlement on «bags» and «chinese caps» at 10 m depth. *M. galloprovincialis* exhibited a seasonal trend with peaks in spring (up to 21 ind m^{-2} day^{-1}) and a preference for a more superficial depth; other not commercial species of Mytilidae showed different patterns and preferences. Moreover, a calendar of the settlement was assessed, which may be useful for the shellfish producers, in order to define a suitable spat harvesting strategy throughout the different year periods.

SHELLFISH MONITORING NETWORK IN THE SOUTHERN GULF OF ST. LAWRENCE. L. Comeau,[1] T. Landry[1] and J. Davidson[2]

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In the southern Gulf of St. Lawrence, the commercial farming of shellfish has expanded rapidly over the past two decades, and is currently an important rural industry. In 1996, a standardized Shellfish Monitoring Network (SMN - https://www-dev.gfc.dfo.ca/sci-sci/smn-rmm/index-e.jsp) was launched in order to better understand the naturally-occurring variability (both spatial and temporal) in shellfish growing conditions. The SMN is similar to the "REMORA" monitoring network developed in France. The SMN is kept simple in order to extend its geographic coverage and promote its long-term viability. The protocol essentially consists of deploying juvenile blue mussels (*Mytilus edulis*) and American oysters (*Crassostrea virginica*) at fixed stations across the southern Gulf in the spring; their growth and meat content is thereafter monitored until the onset of winter. Since the objective is to detect growth patterns that are reflective of natural changes in the environment, the monitoring stations are located outside the farm boundaries, where food supply is less likely to be influenced by farming operations. This poster presents an overview of the SMN technique and SMN results.

EFFECT OF SHELLFISH FARMING TO A UNIQUE BIOGENIC HABITAT: OYSTERS ALTER SABELLARIID REEFS IN THE BAY OF MONT-SAINT-MICHEL, FRANCE. S. Dubois,[1] J. A. Commito,[2] F. Olivier[3] and C. Retière[3]

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The polychaete *Sabellaria alveolata* is an important foundation species whose reef structure adds topographic complexity and high levels of biodiversity to the otherwise low-relief, soft-bottom environments in the Bay of Mont Saint-Michel, France. In this bay, commercial farming of shellfish (oysters *Crassotrea gigas* and mussels *Mytilus edulis*) is an important and expanding industry. Numerous studies have demonstrated a variety of effect of shellfish farming activities on the benthic marine environment. We tried here to investigate the impacts of colonization of oysters from nearby aquaculture farms on the *S. alveolata* population and reef community structure. In addition, we compared effects of oysters – permanent epibionts – with ephemeral effects of green algae, known to be a consequence of rapid urbanization and/or coastal agriculture. Univariate and multivariate comparisons of macrofauna were conducted for five reef types: controls (no epibionts), low oyster density, high oyster density, green algae, and oyster and green algae. Results showed that all three reef types with oysters had significantly higher species richness and diversity values than control and algae-only reef types. Pairwise ANOSIM and SIMPER comparisons of controls versus the four reef types with epibionts revealed that all three of the reef types with oysters were significantly different from controls, but there was no significant difference between controls and algae-only reef types. A striking feature of the reef comparisons is that no single species in this species-rich system contributed more than 8.86% to the dissimilarity between reef types. Thus, k-dominance curves for species abundances were not effective in revealing differences among reef types. Our results demonstrate that recent anthropogenic inputs of oyster and algal epibionts affect the reef species assemblage. In addition, epibionts, especially green algae, alter *S. alveolata* population structure, causing a reduction in new recruits that over the long run may cause significant damage to the reef structure itself.

SPACE COMPETITION STUDY BETWEEN THE CLAM *RUDITAPES DECUSSATUS* AND TWO ASSOCIATED SPECIES: *CERASTODERMA EDULE* AND *SCROBICULARIA PLANA*, IN MOULAY BOUSSELHAM LAGOON, MOROCCO. N. Elmousaoui,[1] A. Berraho,[1] A. Orbi[1] and H. Labbardi,[2] M. Ramdani.[3]

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Space competition study was carried out in the lagoon of Moulay Bousselham during the period June 2002-June 2003, between the clam *Ruditapes decussata* and the two associated: *Cerastoderma edule* and *Scrobicularia plana*. Nets of breeding jointly containing the clam and *Cerastoderma edule* were installed downstream from the lagoon and other nets jointly containing the clam and *Scrobicularia plana* were put upstream. These species were divided into 3 classes of size; gross (> 30mm), middle (20-30 mm) and small (< 20mm). The studied parameters are mainly the death rate and the linear growth. The results showed that the death rates are more important at *Cerastoderma edule* and *Scrobicularia plana* that in the clam: * for the hull:100% at the end of 6 months for all the classes of size; * for *Scrobicularia plana*: 85-100% according to the sizes and the seasons; * for the clam: 0,16-10% in downstream area and 0-10% in upstream area. The linear growth is followed for the clam only owing to the fact that it has very low death rates. The growth of this species is normal with respect to the two other species. It is faster in downstream area than in upstream area (k=0.31; 0.13 and 0.06 downstream, and 0.05; 0.001 and 0.004 upstream respectively for small, middle and large sizes.

CHARACTERIZATION OF OYSTER SUMMER MORTALITIES ACCORDING TO THE FRENCH IFREMER/REMORA MONITORING NETWORK; WITH INPUT FROM PHYTOPLANKTONIC (IFREMER /REPHY DATABANK) AND METEOROLOGICAL DATA (MÉTÉO-FRANCE DATABANK). P.-G. Fleury, J. Mazurié, M. Ropert and P. Soletchnik.

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The wide range of data from the French Ifremer/REMORA network, collected since 1993 allows a global characterization of mortalities of 1-year old and 2-year old cupped oysters *Crassostrea gigas*, that are cultivated in the main French oyster areas, and thus a better understanding of the causes of these mortalities (Ifremer project MOREST). The average annual mortalities on intertidal sites range from 10 to 20%. Most of the mortalities take place in Spring and Summer. 1-year oyster mortalities occur in Marennes and several sites in Brittany whilst 2-year oyster mortalities occur in the same sites and in baie des Veys (Normandy). In addition, 2-year oyster mortalities appear more variable according to different annual surveys. Internal (physiological) factors and external (environmental) factors have been considered successively. A Principal Component Analysis (PCA) on seasonal mortalities, growths and gonad maturations showed that, at the time scale of the REMORA monitoring (seasonal data), no strong correlation can be set up between mortalities and growth or maturation. 2-factors ANOVAs (Sites and Years) on the Spring+Summer mortalities differentiated the variance weights of these factors according to the year-class of animals: the site effect was slightly higher (51%) for the 1-year class, whereas the year effect was higher (74%) for the 2-year class. This was

reinforced by the result of another PCA that included meteorological and environmental data such as rain, sun, air and water temperature and chlorophyll a, which showed that the 1-year oyster mortalities were the most correlated (even if not significantly) with chlorophyll a and temperature (which are site dependant), whereas the 2-year oyster mortalities had a closer correlation to the rain (year dependent). In conclusion, this survey reveals more clearly the effect of external factors than internal ones on oysters mortalities. It also reveals that the causes of mortality may be somewhat different for 1-year oysters (preponderance of geographical factors) than 2-year oysters (meteorological factors).

OYSTER RESTORATION IN AN URBAN LANDSCAPE: TECHNIQUES FOR INITIAL EFFORTS TO CHARACTERIZE A BASIN-WIDE OYSTER POPULATION IN THE LYNNHAVEN RIVER, VIRGINIA, USA. P. Ross, M. Luckenbach and A. Birch.

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Historically in the Chesapeake Bay estuary, USA, (states of VA and MD), quantitative evaluations of oyster reef restoration efforts have focused on subtidal reefs. Furthermore, assessment, usually in the form of fisheries-based metrics (e.g. abundance of market-sized, ~76 mm, oysters), has typically occurred only after restoration efforts have been implemented. There are few instances of coordinated data collection before, during and after restoration activities. Beginning in 2006, a large-scale oyster restoration effort, including habitat and brood stock enhancement (utilizing disease resistant oyster strains), is planned for the Lynnhaven River Basin, a small and relatively closed tidal tributary of the lower Chesapeake Bay. In contrast to most other restoration sites in this region, the Lynnhaven Basin is heavily urbanized, with extensive portions of the shoreline covered with stabilization structures such as wood or metal bulkheads and granite or concrete rubble. Much of the intertidal portion of these structures supports oyster populations. Though oyster restoration efforts within the tributary are focused primarily on subtidal reefs, evaluating the impacts of this effort will require basin-level assessments of the oyster population. Techniques for accomplishing this on traditional oyster reefs are fairly standard. However, the urban character of the shoreline has resulted in many «non-traditional» habitats that are supporting many live oysters that will significantly contribute to overall population estimates. Accounting for and rigorously sampling such habitats is important to accurately describing the oyster population in this system. We present our techniques to map and quantify the total oyster population in the Lynnhaven Basin, including: sub-meter accuracy Global Positioning Systems (GPS) integrated with an ArcView-based Geographic Information Systems (GIS), digital video and still image processing and in situ biological oyster data collection. Our assessment followed three iterations of increasing data resolution, with each phase providing feedback into the sampling design for subsequent phases.

PRACTICAL CONSIDERATIONS FOR SUCCESSFUL INTERTIDAL OYSTER REEF BUILDING IN NEW JERSEY,USA. S. Tweed.

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Successful creation of sustainable oyster reefs, for restoration, enhancement or harvest, is dependent on physical site conditions and larval ecology, and should be measured by reef persistence and development of sustainable natural oyster populations. Fringing intertidal oyster reefs, common in the southern US, allow for easy assessment of successful reef structure and biological processes on oyster reefs. While no longer common in New Jersey, intertidal reefs can be built and evaluated to determine the potential for oyster restoration at numerous New Jersey locations. Fringing intertidal and shallow water oyster reefs were the first reefs to be harvested and depleted. Sediment records, larval ecology and the hydrodynamics of estuaries suggest that fringing intertidal reefs could still be successful in New Jersey. To guarantee success, practical siting concerns such as substrate, exposure, winter damage, sedimentation, and larval recruitment must be considered during reef building. A successful reef, built on the Cape Shore of Delaware Bay in 1990 from naturally recruited native oysters, has been used to assess the physical and biological potential for other intertidal reefs sites in Delaware Bay. This small reef, approximately 30 square meters, has survived for over 15 years and supports an adult oyster population of about 400 oysters per square meter. Approximately 20 percent of these oysters are market size and some are over 4 inches in height. Other reef sites in Delaware Bay are compared to the Cape Shore reef in terms of substrate, exposure, recruitment and their potential to sustain populations of the native oyster. Results of these comparisons are used to calculate the ecological and economic contributions of creating intertidal oyster reefs in New Jersey.

ENVIRONMENTAL QUALITY MONITORING AND IMPROVEMENTS

EFFECTS OF EXPERIMENTAL CONTAMINATED SEAWATER ON PHYTOPLANKTON PRODUCTION USED IN HATCHERY AND OYSTER EMBRYO-LARVAL STAGE DEVELOPMENT. G. Arzul,[1] C. Leturque,[1] J. Benoît,[1] F. Barloy,[1] C. Le Balle,[1] G. Durand,[2] D. Hureau[2] and F. Quiniou.[1]

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When the hatchery is close to agricultural areas it is difficult to avoid the contamination of seawater by runoff from cultivated lands. Runoff can carry concentrations of pesticides at levels deleterious to the production of forrage microalgae, as well as for the growth and survival of bivalve larvae. The present work aims to determine the effects on phytoplankton growth and oyster (*Crassostrea gigas*) embryo larval development, of seawater experimentally contaminated by pesticides detected in coastal seawater of Brittany (France). Among the two algal species tested, the diatom *Chaetoceros gracilis* was more affected in growth rate than the prymnesiophyte *Isochrysis galbana*, when cultivated in presence of four herbicides, dimethenamide, nicosulfuron, sulcotrione and glyphosate, and the insecticide chlorpyriphos-ethyl. Obviously the commercial formulations were more potent toxicants that the pure active molecules. According to the effective concentration producing 50% attenuation of the algal growth rate (CE50), it was possible to determine an increasing toxicity of the formulations: For *C. gracilis*: sulcotrione formulation (Mikado) was more potent toxicant than glyphosate (Roundup), nicosulfuron (Milagro) and dimethenamide (Frontière). For *I. galbana*: dimethenamide (Frontière) was more toxic than nicosulfuron (Milagro). According to abnormal oyster embryo development a similar classification gave nicosulfuron (Milagro) more toxic than chlorpyriphos-ethyl (Dursban). The pesticides can modify the algal production and induce embryo abnormalities at much lower concentrations. Calculated EC10 and the pesticide concentrations recorded in coastal seawater are in the same range and show that hatchery functioning can be affected by contaminated seawater.

EFFECT OF AN EXPERIMENTAL PESTICIDE CONTAMINATION ON NATURAL COASTAL PHYTOPLANKTON COMMUNITIES AND POSSIBLE CONSEQUENCES ON THE SECONDARY PRODUCTION. G. Arzul,[1] P. Malestroit,[2] C. Videau,[3] F. Quiniou,[1] G. Durand[3] and D. Hureau.[3]

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Marine coastal phytoplankton communities can be affected by the pesticide contaminations. Not only the toxicants modify quantitatively the chlorophyll concentration, but also the specific composition of the populations can be changed. This is due to the differences in sensitivity to the toxicants, of the algal species. In normal conditions, species succession and herbivory occurrence are in accordance, and several authors pointed out the role of some phytoplankton species in the success of bivalve larval development. Our experiment was based on seawater sampled in subsurface layer nearby two shellfish production areas. Sub-samples were contaminated by a mixture of pesticides that can be occasionally detected in coastal marshlands releases. The no-contaminated (control) and contaminated samples were incubated in indoor mesocosms under controlled temperature and alternated light/dark conditions. The biomass in term of chlorophyll concentration presented a general decrease during the first part of the experiment in the contaminated samples, and conversely an increase in the control. In the same time the percentages of potentially noxious phytoplankton cells (*Karenia* sp., *Alexandrium* sp., *Pseudonitzschia* sp.) was more elevated in the contaminated samples than in the controls. With reference to the published data concerning *Prorocentrum* and *Chaetoceros* species favorable to zooplankton reproduction, our results showed that both were less represented in the contaminated samples, while less favorable diatoms (*Skeletonema* sp., *Thalassiosira* sp., *Navicula* sp.) sometimes could be more important in contaminated than in controls. These results support the hypothesis that pesticides can be indirectly involved in the decrease of natural shellfish production.

ENVIRONMENT AND IMMUNOMODULATION: EFFECTS OF SOLUBLE FRACTION OF NORWEGIAN HEAVY FUEL ON IMMUNE SYSTEM OF SEA BASS, *DICENTRARCHUS LABRAX*. A. Bado-Nilles,[1] C. Quentel,[2] S. Le Floch,[3] M. Auffret,[4] B. Gagnaire,[5] T. Renault,[5] J. Arzel[3] and H. Thomas-Guyon[1]

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Bay of Marennes-Oleron is an important French area of reproduction for sea bass, *Dicentrarchus labrax*. This area is often subjected to many pollutions due to anthropic activities, including pesticides and polycyclic aromatic hydrocarbons (PAH) which cause adverse effects in aquatic organisms. The harmful effects of such contaminants on fish immune system leading to a decreased resistance against pathogens begin to be described, but remain poorly known. In this context, influence of micropolluants, like PAH, on the defense mechanisms developed by sea bass was tested. Fish were exposed five days to a soluble fraction of PAH with environmental concentration (760 ng/L). At the end of the contamination, fish were transferred to non contaminated sea water and a kinetic study of blood immune

parameters was assessed during one month. The effects of HAP were compared to those observed in a control group kept in non contaminated sea water. Leucocytes viability and activities were analyzed by flow cytometry. Plasmatic alternative pathway of complement activity and lysozyme concentration were performed. Dosage of PAH in fish tissues was carried out. Just at the end of the contamination, a significant increase of the cellular mortality was observed in contaminated fish compared to control fish. No difference neither on forward and side scatter profiles of blood cells population nor on phagocithic activity was found between the two groups whenever they were sampled. In contaminated fish, from day 3 to day 9, a significant higher haemolytic activity of complement, was noted. These results will be discussed.

ENVIRONMENT AND IMMUNOMODULATION: EFFECTS OF SOLUBLE FRACTION OF NORWEGIAN HEAVY FUEL ON IMMUNE SYSTEM OF PACIFIC OYSTER, *CRASSOSTREA GIGAS*. A. Bado-Nilles,[1] M. Auffret,[2] C. Quentel,[3] S. Le Floch,[4] B. Gagnaire,[5] T. Renault,[5] J. Arzel[4] and H. Thomas-Guyon[1]

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Bay of Marennes-Oleron is the first French area of oyster production, especially Pacific oyster, *Crassostrea gigas*. This area is often subjected to many pollutions due to anthropic activities, including pesticides and polycyclic aromatic hydrocarbons (PAH) which cause adverse effects in aquatic organisms. The harmful effects of such contaminants on animals inhabiting these estuarine zones are poorly known, although many studies begin to be developed. Most of this studies use bivalve molluscs as biological indicators: these animals can bioaccumulate pollutants within their tissues by filtration. Moreover, they are sedentary so they cannot escape in case of chronic or sudden pollution. In this context, influence of micropolluants, like PAH, on the defense mechanisms developed by Pacific oyster was tested. Adult oysters were exposed nine days to a soluble fraction of PAH with environmental concentration (760 ng/L). At the end of the contamination, oysters were transferred to non contaminated sea water and a kinetic study of haemolymph immune parameters was assessed during one month (four sample dates). Effects of HAP were compared to those observed in a control group kept in non contaminated sea water. Haemocytes viability and activities were analyzed by flow cytometry. Phenoloxidase activity and lysozyme concentration were performed by spectrophotometry. Just at the end of the contamination, a significant decrease of the phagocithic activity was observed in contaminated oyster compared to control oyster. No difference either on haemocytes mortality nor on serum lysozyme concentration was found between the two groups whenever they were sampled. In contaminated oyster, on day 14, a significant higher mitochondrial activity and hyalinocyte percentage were noted. These results will be discussed.

USE OF THE BLUE MUSSEL, *MYTILUS EDULIS*, AS AN ECO-SENTINEL TO ASSESS ECOTOXICOLOGICAL PHENOMENA IN POLLUTED COASTAL WATERS. T. Bataille,[1 2] M. Duchemin[2] and M. Auffret.[2]

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Risk assessment in polluted, coastal ecosystems requires a joint monitoring of physico-chemical data and biological signals. The immune system of bivalve molluscs, including mussels, is known to be sensitive to chemical contaminants and several immune alterations are now recognized as "effect biomarkers" in ecotoxicological surveys. A diagnostic of immunotoxic effects was applied to blue mussels, *Mytilus edulis*, transplanted for 10 weeks at three sites within the military harbor of Brest where high levels of chemical contaminants, including heavy metals, have been reported in the sediments. Two cages per site were positioned either at the mid-tide level or 50 cm above the sediment surface. To explore the role of contaminant bioavailability, an experiment was conducted in the laboratory during a 6-week period where mussels were exposed to various levels of dissolved metals and particulate contaminants associated to sediments collected in the harbor. The exposure scenario was based on physical and chemical measurements in situ for dissolved cadmium, copper and lead concentrations, total suspended matter and mussel clearance rate. No acute cytotoxic effects were observed in the laboratory or in the field. Phagocytosis was found to be stimulated in the laboratory. Conversely, at one site, a significant inhibition of phagocytosis was observed after 10 weeks of exposure for mussels caged near the bottom compared to those maintained at the mid-tide level. The observation of such immunomodulatory effects suggested chronic immunotoxicity. Furthermore, the difference of responses observed at this site depending on the distance from the bottom, where contaminants are trapped, allows the suggestion of a chemical risk mainly due to contaminant transfer from sediments.

***IN SITU* MICROCOSMS FOR THE EVALUATION OF THE PESTICIDE IMPACT ON PHYTOPLANCTON D. De La Broise and S. Stachowski.**

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Experimentations on the impact of xenobitics on natural environments are usually set up in microcosms or mesocosms. However, physical, chemical and biological conditions in such systems are often far from natural conditions. In phytoplancton microcosms, a bloom is often observed that would not occur in the original sea water. Then, conclusions from experiments in such systems are often difficult to extend to the natural environment. The main challenge in microcosm studies is then to create and maintain conditions that mimic as close as possible the natural environment.

We tested a phytoplankton microcosm system in 2 liters bottles, including a liquid and a gas phase. A set of 36 bottles is maintained 4 meters underwater on a stainless steel structure. Renewal of a part of the liquid phase can be made every 2 to 4 days. Comparison of two weeks old microcosms and natural surrounding sea water were based on the phytoplankton pigments analysis (assessed by HPLC of pigments). Results showed that such microcosms can be usefull as tools for xenobiotic impact evaluation. Applications were run on low concentrations of agricultural pesticides.

PENIS SHAPE VARIATION IN THE FEMALE OF *HEXAPLEX TRUNCULUS* AFFECTED BY IMPOSEX FROM TUNISIA COASTLINE. Y. Lahbib, N. Trigui El Menif and M. Boumaiza.

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The assessment of TBT pollution by imposex incidence was studied in many stations of the Tunisian coastline. Results showed that imposex indices were high in sites frequented by big boats such as Bizerta Channel, fishing harbor of Sfax, NPK factory of Sfax, Shkira and Adjim Channel. Otherwise, microscopic observations of the female genital system showed a varied shape of the penis. It is bent in Gargour resembling to a parrot beak ended by a flagellum, in this site imposex was 93% and the VDSI 3,27. In the fishing harbor of Sfax, 100% of imposex and a VDSI of 4,21 were recorded. The female penis showed two aspects; a long strip with a flagellum shape tip and a slender or a papilla shape large penis with flagellum resembling to the male penis shape. In the fishing harbor of Gabes characterised by an imposex frequency of 51,5% and a VDSI of 1,8, the slender penis was straight with a flagellum and sometimes showing excrescences at the base. Finally, in Bizerta channel, the most affected site by TBT pollution as indicated by imposex frequency of 100% and a VDSI of 4,23, the penis shape was similar to the one of the male penis with a large base and a long flagellum at the tip. These results showing variable shapes of the penis in impoxed females seems to be related to the organotin pollution of the marine environment as well as to the sensibility of females to the pollutant.

TESTING POLLUTANTS IMPACT ON MARINE SPECIES IN EXPERIMENTAL FACILITIES. S. Le Floch, J. Arzel, F. Merlin and P. Richard.

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In spite of many past accidental marine pollution incidents, there is still only limited information on sub-lethal pollutants effects on many marine species, and little information on the actual significance of stress indicators in such circumstances. For that reason, Cedre built in 2003 a 160 m^2 experimental greenhouse specifically equipped to expose marine animals to various concentrations of chemicals, including oil products. The facility, presently unique in Europe, was constituted by two rows of tanks: • the first row includes 4 square plastic exposure tanks (capacity of 3m^3) supplied by a pollutant/water mixing tank; • the second row includes 2 sets of tanks equipped each with a cylindrical plastic exposure tank (capacity of 500 l) and supplied by an independent pollutant/water mixing tank. The development of this experimental unit was decided in the aftermath of the wreckage of the chemical tanker Ievoli sun, after emergency experiments on crab (*Cancer pagurus*) and mussel (*Mytilus edulis*) had to carried out in a makeshift, improvised facility, to determine the toxicity of styrene and its olfactory detection threshold, in cooperation with Ineris and Ifremer. The unit is now fully operational and thorough studies on the impact of a heavy fuel were carried out on: • turbot (*Psetta maxima*) to study physiological parameters, morphology of gill epithelium, gill ATPase and EROD activity, growth and metabolism performances, in collaboration with the University of occidental Brittany; • on seabass (*Dicentrarchus labrax*) and oyster (*Crassostrea gigas*) to study the immune system, mitochondrial damage, mortality and phagocytose cells, lysozyme activity, histological changes on liver and gills, in collaboration with the French Agency for food safety (AFSSA) and La Rochelle University. Those experiments and their results are briefly described here. They show the possible response of the facility to queries of decision makers in the context of an operational urgency, combining the respective capacities of different, complementary institutions, with experience ranging from advisory services to fundamental research.

ESTABLISHING BASELINES FOR RECOVERY OF OYSTER (*CRASSOSTREA VIRGINICA*) POPULATIONS IN SOUTHEAST FLORIDA, USA. M. Parker and W. S. Arnold.

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Along the Atlantic and Gulf coasts of Florida, oysters occur in nearly all estuarine and nearshore waters. Many of these waters, especially along the southeast coast of Florida, have experienced altered patterns of water delivery and quality as a result of water management practices related to the St. John's River and Kissimmee River basins, Lake Okeechobee and the Everglades. Alterations in freshwater flow have reduced or eliminated many oyster reef areas and impacted both the timing and extent of oyster reproduction. The Comprehensive Everglades Restoration Program (CERP) is being implemented as a means of reinitiating natural freshwater flow to coastal waters on both coasts of south Florida. Because of its wide distribution and essential habitat value, the eastern oyster is included in this program as a target species for monitoring and restoration. Changes in oyster distribution and abundance, reproductive development, disease incidence, and juvenile recruitment and growth are being monitored at several sites along the southeast coast of Florida including the St. Lucie estuary, the Loxahatchee River, Lake Worth Lagoon and Biscayne Bay. Oyster populations in Tampa Bay, Mosquito Lagoon and the Sebastian River are also being monitored as a background for comparison because these are outlier populations not affected by CERP water management practices. In January 2005, study sites were established within each estuary and monthly sampling of recruitment, reproductive

development and disease incidence was initiated. Adult surveys using 1-m^2 quadrats also were conducted at each study site to determine oyster distribution and abundance. Adult surveys will be continued twice per year, once in the winter and once in the summer. Preliminary results indicate that the pattern of degradation of oyster populations among estuaries is rather chaotic while the pattern within an estuary is more predictable.

BIOMARKERS IN *CRASSOSTREA GIGAS* LARVAE IN A FIELD EXPERIMENT. F. Quiniou,[1] G. Damiens,[2] M. Gnassia-Barelli,[2] X. Caisey,[1] A. Geffard,[3] C. Mouneyrac,[4] H. Budzinski,[5] E. His[1] and M. Roméo.[2]

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Early embryo-larval stages of bivalve molluscs are frequently used in marine exotoxicology laboratory studies, however, cannot accurately simulate natural conditions. Field experiments can eliminate artefacts resulting from artificial laboratory conditions affecting the real toxicity and bioavailability of contaminants. Two field experiments were conducted (July 2002 and June 2004) in which fertilized gametes from *Crassostrea gigas* were placed into a special container (device patented by Ifremer). Embryos kept in the containers were immersed into two sites of Arcachon harbor (A: entrance of the harbor and P) for 48 h (field temperature 21 °C, salinity 31.5). The containers were ballasted so as to keep them at a depth of 1 meter under the surface. Larvae were collected and biomarkers (acetylcholinesterase AChE, catalase CAT, glutathion S-transferase GST activities, Thiobarbituric reactive substances TBARS, metallothionein concentrations) determined in the samples as well as metal and PAH (polycyclic aromatic hydrocarbons) concentrations in larvae and sediments collected under the containers. The results show that GST activity and TBARS levels are significantly higher in P than in A. MT and copper concentrations in larvae tend to increase from A to P whereas AChE activity shows a trend to be lower in P. Organics in larvae show a tendency to be higher in A than in P. The sediments are richer in copper in P than in A whereas the contrary is true for organics. In P, larvae seem to be submitted to an oxidative stress inducing lipid peroxidation of the membranes (shown by TBARS and GST activity), this stress may be caused by copper present in the surrounding environment. Larvae caged in A (entrance of the harbor) where water masses flow, seem to be affected by low molecular weight PAHs such as naphtalen e which are soluble (contrary to high weight compounds). Moreover, the percentage of abnormal larvae is higher in A (40 %) than in P (60 %) suggesting that A is less exposed to pollutants than P. Nevertheless both sites may be considered as submitted to anthropogenic influence. As conclusion, tranplantation of larvae together with chemical and biomarkers measurements constitute an "active biomonitoring" providing early warning signal of pollution.

THE USE OF MICROBIAL SOURCE TRACKING TO DETERMINE BACTERIAL POLLUTION SOURCES IN COASTAL WATERSHEDS USING MULTIPLE ANTIBIOTIC RESISTANCE AND COLIPHAGE ANALYSIS. G. I. Scott,[1] M. H. Fulton,[1] B. C. Thompson,[1] L. F. Webster,[1] A.K. Leight,[1] J. Stewart,[1] J. Gooch,[1] D. Chestnut,[2] R. F. Van Dolah,[3] and H. Kelsey.[4]

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Sewage treatment plants (STPs), septic tanks, confined animal feeding operations (CAFOs), urbanization and wildlife pollution sources are significant environmental hazards that may adversely affect estuarine water quality in coastal waters, causing impairments of intended uses (swimming and shellfish harvestability). Most shellfish closures in the result from urbanization including human, domestic animal or wildlife sources. Development of methods for differentiating human versus wildlife coliform bacterial sources are needed to properly manage bacterial pollution emanating from different sources. Several methods for differentiating human and wildlife coliform bacterial sources were evaluated including Multiple Antibiotic Resistance (MAR) and coliphage. Water samples were collected from several river and estuarine watersheds in the southeastern US and selected pollution sources (STPs, CAFOs and septic tanks). Samples were enumerated for fecal coliform bacterial densities (MPNs or MF) and *E. coli* were isolated by API biotyping. Samples were then analyzed by MAR and coliphage. Results indicated that the % of *E. coli* comprising the coliform group and MAR was highest at sewage treatment plants and in CAFOs and urban areas with septic tanks or influenced by sewer discharges. Wildlife areas had negative MARs or resistance to a single antibiotic and a lower % of *E. coli*. Coliphage results proved useful in differentiating human versus animal and wildlife sources.

NEW MORPHOLOGICAL ASPECTS OF IMPOSEX DEVELOPMENT SCHEME IN *HEXAPLEX TRUNCULUS* (GASTROPODA: MURICIDAE) FROM TUNISIAN WATERS. N. Trigui El Menif,[1] Y. Lahbib,[1] M. Le Pennec[2] and M. Boumaiza.[1]

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The imposition of male sexual characteristics in some neogastropod females, or imposex, was used as a very reliable bioindicator for evaluation of sea water contamination by tributyltin paintings. Our objective was to examine individuals of *Hexaplex trunculus*, of different sizes, living in various sites of the Tunisian coasts. New morphological

aspects of the expression of this abnormality were observed on females collected in less contaminated sites. In most of these individuals a portion of a vas deferens canal, took place at the middle part, separating the penis site and the vaginal opening. This was the first sign of the beginning of the imposex phenomenon. This vas deferens portion could progress, in a first case, toward the proximal side, together with the development of an incipient penis and then, progressively, the penis duct joined the vas deferens. In the second case the evolution occurred in the two senses leading to the penis site and the vulva.

EXOTICS/INVASIVE/INTRODUCED SPECIES CONSIDERATIONS

GAMETE SURVIVAL AND FERTILIZATION EXPERIMENTS WITH *CRASSOSTREA VIRGINICA* AND *CRASSOSTREA ARIAKENSIS*. D. Bushek, X. Guo and G. DeBrosse.

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A proposal to introduce reproductive populations of the Asian oyster *Crassostrea ariakensis* into Chesapeake Bay is receiving considerable attention. The proposal is an effort to restore oyster production where populations of the once abundant native oyster, *Crassostrea virginica*, have been decimated by over fishing, habitat loss/degradation and disease. As a result, there is a Federal requirement to develop a comprehensive environmental impact statement (EIS). One question is the degree to which gametes from the native and introduced species will interact if both species end up co-inhabiting the same habitats. Previous studies have indicated that hybrid larvae can be formed, but do not survive beyond 7 or 8 days. This creates the possibility for a negative interaction via a gamete sink. To begin to evaluate the potential for a gamete sink, experiments on gamete longevities and frequencies of hybridization and fertilization under varying densities and distances are being examined in the laboratory. Results obtained during summer 2005 will be presented.

IMPACT OF THE CURRENT PROLIFERATION OF THE ALIEN *CREPIDULA FORNICATA* ON SHELLFISH HABITAT AND RESOURCES IN THE BAY OF BREST (FRANCE). L. Guérin,[1] J. M. Guarini[2] and G. Thouzeau[1]

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In a context of coastal zone management, the approach associating the monitoring of environmental parameters together with the monitoring of pelagic and benthic populations helps to understand ecosystem functioning. The ecological monitoring undertaken for more than 20 years in the Bay of Brest highlighted a new ecological (and economical) risk: the proliferation of an exotic benthic suspension feeder and potential scallop competitor, the slipper limpet *Crepidula fornicata* (L.). The mechanisms of its proliferation are still unknown in the Bay, particularly the reasons of the recent acceleration (15-20 years) of the invasive process. A multidisciplinary approach allowed studying the slipper limpet population dynamics in the Bay together with natural fluctuations of the hydroclimate and anthropogenic disturbances (like eutrophication). The impacts of the current proliferation of the slipper limpet on the ecosystem structure and functioning were specified: among them, the suspension feeders would exert a major feed-back on primary production (through filtration and biodeposition activities). Today, this invasive species would be a key element in ecosystem structuring and functioning. In addition to estimate the slipper limpet stock in the Bay in the year 2000, this study provides new data on the distribution of the benthic megafauna associated with, or excluded by, the invader. Future evolutions are considered and recommendations are made to limit its extension and to maintain the scallop fishery in the Bay of Brest (integrated coastal zone management).

PROLIFERATION OF *CRASSOSTREA GIGAS* (THUNBERG) IN THE BAY OF BREST: FIRST ESTIMATIONS OF THE STOCK AND ITS IMPACT ON THE GLOBAL FUNCTIONING OF THE ECOSYSTEM. M. Lejart and C. Hily.

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Introduced in the middle of the sixties in France, the Pacific oyster, *Crassostrea gigas*, now reproduces naturally in the Bay of Brest. This phenomenon, first punctual occurred near oyster beds in the east of the bay, has been recently inclined to take more important proportions. Firstly, the set up of a sampling campaign (82 sites) combined with the utilization of geographic information system permitted us to put the wild Pacific oysters stock in the bay at 6514 tons (total dry weight) distributed over 3 km^2. The mean oysters density is 84 ± 97 $ind.m^{-2}$ and can reach up to 780 ± 343 $ind.m^{-2}$ at some sites (Moulin-Mer). Altough the density is greater in the south of the bay, the high recruitment rate (53,16 ± 20,54 %), especially in the north of the bay, points to a large dynamic in proliferation. The second objective of the study was to estimate the Pacific oyster's impact on the global functioning of the ecosytem by on the one hand its

filtration and biodeposition activities, and on the other hand biocalcification. Estimation of stock and general equations supplied by the literature have permitted us to put mean annual production at 736 g $CaCO_3$ m^{-2} reaching 6257 g $CaCO_3$ m^{-2} on the more colonized sites and this surpasses tropical coral reefs estimates. Net production of CO_2 due to $CaCO_3$ production plus oyster's respiration and minus measurements of shell dissolution undertaken in the laboratory is put at 147 g CO_2 m^{-2} yr^{-1}. The volume of water filtered by oysters in the bay ($6{,}19 \times 10^9$ l d^{-1}) and the increase of the Si/C ratio by a factor 2,5 between the phytoplankton and the faeces, make oysters an important actor in the trapping of silica in the sediments hence preserving the bay from toxic blooms in the summer.

DENSITY-DEPENDENT GROWTH, COMPETITION AND REEF-FORMING CAPABILITY IN *CRASSOSTREA ARIAKENSIS*. M. Luckenbach and A. Curry.

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Consideration is currently being given to the intentional introduction of the non-indigenous oyster *Crassostrea ariakensis* into Chesapeake Bay, U.S.A. Enthusiasm for such an introduction has been fueled, in part, by rapid growth rates of this species in aquaculture trials with sterile triploids. Little is known, however, about how this species would grow in high-density assemblages, how it might interact with native oysters or its ability to form biogenic reefs. We conducted experiments using *C. ariakensis* and native *C. virginica* set on ceramic tiles and grown in a quarantined, flow-through seawater system to assess (1) the density-dependence of growth rate, (2) intra- and inter-specific competition for space and (3) the growth form of each species at varying densities. Total densities of 1, 2, 10, 20 & 50 oysters per tile in proportions of *C. virginica*:*C. ariakensis* of 100:0, 90:10, 50:50, 10:90 & 0:100 were established on ten replicate tiles for each combination of density and species, and oysters grown for six months. At termination all oysters were removed from the tiles, identified to species, and shell- and soft tissue-growth measured. The results revealed (1) a pattern of negative density-dependent growth for both species, (2) lower growth rates for *C. ariakensis* than for *C. virginica* under conditions of intra-specific competition for space, (3) superior performance by *C. virginica* under inter-specific competition for space, (4) a stronger effect of inter- compared to intra-specific competition on growth for both species and (5) a greater propensity for *C. virginica*, compared to *C. ariakensis*, to grow vertically under conditions of space limitation. These findings shed light on potential interactions between *C. ariakensis* and *C. virginica* should the former be introduced into the Chesapeake Bay.

BEHAVIOR AND SUBSTRATE SELECTION IN *CRASSOSTREA ARIAKENSIS* PEDIVELIGER LARVAE. M. Luckenbach,[1] S. Bonniwell[1] and M. Tamburri.[2]

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In response to historically low abundances of native oysters (*Crassostrea virginica*) in the Chesapeake Bay the U.S. states of Maryland and Virginia are considering introducing the Asian oyster (*C. ariakensis*). However, it is widely recognized that our current understanding of the biology and ecology of *C. ariakensis* is insufficient to predict how and where this species would become established if introduced. Among the gaps in our knowledge about this species are the factors that influence settlement and metamorphosis. The behavior of native *C. virginica* pediveligers has been studied for many years and it is well established that they use a variety of habitat characteristics when selecting a site for colonization. We conducted a series of experiments in a quarantine facility using two *C. ariakensis* strains («south China» and «west coast») and *C. virginica* to investigate the effects on settlement of (1) various natural (shell and granite) and man-made (fiberglass, PVC and steel) substrates, (2) natural biofilms, (3) adult chemical cues, (4) hypoxia and (5) sedimentation. Our results to date indicate that both species settle preferentially onto oyster shell (with no distinction between the species of the shell), but that *C. ariakensis* exhibits a greater propensity to settle on PVC and fiberglass than *C. virginica*. Natural biofilms have a strong positive effect on settlement by both species, while a weaker positive effect of congeneric adult chemical cues is observed for both species. Ongoing studies should clarify the effects of hypoxia and sedimentation on settlement by *C. ariakensis* and identify any difference between it and the native oyster.

RESPIRATION, CALCIFICATION AND EXCRETION OF AN INVASIVE SPECIES, *CREPIDULA FORNICATA* L.: IMPLICATION FOR C AND N FLUXES IN IMPACTED AREA. S. Martin, G. Thouzeau, J. Clavier, L. Chauvaud and F. Jean

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The invasive gastropod, *C. fornicata*, colonizes more than half of the benthic surface of the Bay of Brest (France) with high densities at depths from 10 to 35 m. This non indigenous molluscs' proliferation is associated with modifications of biogeochemical fluxes at the sediment water interface. Carbon and nitrogen flux changes are thus related to the gastropod respiration, calcification and excretion processes. Respiration induces carbon dioxide production, calcification indirectly generates carbon dioxide and excretion results in ammonium release. Respiration, calcification and excretion of temperate molluscs change according to intrinsic factors such as body size and external factors, i.e. temperature and food availability. The purpose of this study was to assess, through physiological characteristics of this limpet, its impact on the ecosystem carbon and nitrogen fluxes considering both seasonal variations and individual size. *C. fornicata* respiration and calcification increased with temperature. Carbon dioxide fluxes resulting from respiration

ranged from 1 in winter to 45 µmol g^{-1} AFDW h^{-1} in summer. Calcium carbonate fluxes increased from -4 to 44 µmol g^{-1} AFDW h^{-1} corresponding to carbon dioxide fluxes from -2 to 26 µmol g^{-1} AFDW h-1. Ammonium excretion varied from 0.7 to 3 µmol g^{-1} AFDW h^{-1}. Maxima, measured in spring, were related to trophic resource availability. Respiration, calcification and excretion rates were more important for the small size individuals. Relating to a mean value of 1,500 individuals m^{-2} in sites displaying high densities of *C. fornicata* in the Bay of Brest, total carbon and nitrogen release by the invasive molluscs in high colonised sites were ~300 g C m^{-2} y^{-1} and ~30 g N m^{-2} y^{-1}.

MANAGEMENT STUDY AND SURVEY OF *CREPIDULA FORNICATA* (SLIPPER LIMPET) IN THE FAL, CORNWALL, U.K. M. Syvret,[1] C. Leverton[2] and A. Brigden[3]

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The Fal (South Cornwall, U.K.) was once a major source of native oysters. In the early 1900's 500 dredgermen earned their living from this fishery. Today, due to previous over fishing, pollution, disease and most recently exotic species introductions, the fishery is only worked by approximately 30 dredgermen. The fishery is unique in that it is the last oyster fleet that is known to operate under sail. This remains the case today in an effort to help limit the level of fishing effort. Pollution and over fishing have now largely been addressed but the effects of exotic introductions such as the slipper limpet (*Crepidula fornicata*) are increasingly causing concern for the continued sustainability of the fishery. In 2005 therefore the Port of Truro Oyster Fishery Management Committee secured FIFG funding for a 3 year project to look at this problem. Building upon previous baseline studies this project has two main aims: • to monitor the numbers/population structure of the slipper limpets and their possible effects on oyster numbers, using dredge sampling (to be carried out by CEFAS). • To investigate what actions have been tried to limit the damage, or reverse the effects of slipper limpets, on other fisheries. We will also seek to research new ways of removing the slipper limpets, or alternatively, methods by which they can be made into a marketable product (with input from the Shellfish Association of Great Britain). As part of this project we are keen to find out about other experiences around Europe in dealing with this exotic introduction. The Management Committee would therefore invite delegates to share their experiences in this respect. Anybody providing input would be offered the option of receiving a copy of the final report (e-mail: m_syvret@seafish.co.uk).

COMPLEX IMPACTS OF INVADERS - THE AMERICAN SLIPPER LIMPET *CREPIDULA FORNICATA* IN EUROPEAN SEAS. D. W. Thieltges.

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Introduced species are often accused to severely affect native biota. However, actual data on impacts are rare and impacts do not have to be only negative. This poster presentation exemplifies the complex nature of impacts of introduced species with experiments on impacts of the epizootic American slipper limpet *Crepidula fornicata* on its major basibiont in northern Europe, the blue mussel *Mytilus edulis*. In two field experiments of 12 weeks, epigrowth by *C. fornicata* resulted in a four to eight fold reduction of survival of mussels equivalent to a mortality of 28 and 30 %, respectively. Shell growth in surviving mussels with attached *C. fornicata* was 3 - 5 times lower compared to unfouled mussels. However, a laboratory experiment also showed sea star (*Asterias rubens*) predation on mussels with limpet epigrowth to be three times lower than in unfouled mussels. Hence, although negatively affected by *C. fornicata* in one way, this epigrowth is beneficial for fouled mussels in another. This indicates that the actual impact of an introduced species is a complex interplay of positive and negative effects which may only be revealed experimentally.

FISHERIES AND AQUACULTURE MANAGEMENT

MEXICAN MARINE PARKS AS A MANAGEMENT TOOL FOR RESTORING THE QUEEN CONCH *STROMBUS GIGAS*. D. Aldana Aranda,[1] E. Baqueiro Cárdenas[2] and S. M. Naim.[3]

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Strombus gigas is a species of primary economic importance to all Caribbean countries. Its importance comes from the high exploitation levels ought to local demand for inner consumption, tourist market and international trade. In 2002, its catch volume was 3020 tons with a value of 3 million $US. It has been placed as a commercially threatened species under CITES (Appendix II). In 2003, *S. gigas* was indexed at SPAWN trade and in 2003, CITES did not authorize imports of Queen conch from the Dominican Republic, Haiti, and Honduras. *S. gigas* populations have been depleted in many areas and seriously diminished in others, where exploitation is still taking place due to its limited distribution range and accessibility, in low energy grass and algal beds. In Mexico, different measures have been taken to regulate

exploitation, which include minimum size, lip thickness, and catch quotas, temporal and permanent fishing bans and marine parks as a measure to preserve reproductive stocks. The level of protections in the different marine parks of Mexico goes from a total fishing ban with high reinforcement, to controlled exploitation with little or no reinforcement. The impact of the marine parks on the populations of *S. gigas* is variable as the number of parks. Density of populations is an indicator used to know the exploitation levels for this species. In this study are presented data of density for *S. gigas* at Xel-Há, Cozumel Parks, Chinchorro Bank and Alacranes reef versus the measures taken at each NPA (Natural Protected Area) in order to know if these NPA haven contributed to the conservation of *S. gigas* stock as a source of juveniles and adults for the rehabilitation of areas under no commercial exploitations and low commercial exploitation sites, respectively.

MODELLING THE MANAGEMENT OF CLAM (*RUDITAPES DECUSSATUS*) EXPLOITATION IN THE PLENTZIA AND MUNDAKA ESTUARIES (BASQUE COUNTRY, NORTHERN SPAIN). J. Bald and A. Borja.

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Some of the estuaries of the Basque Country (northern Spain) present exploitation areas of clam populations, both by professional and recreational fishermen. There is a possibility of overfishing and, therefore, the Department of Fisheries of the Basque Government needs to: (a) understand the situation relating to these populations; and (b) provide a tool to establish the most adequate management for the exploitation of clams. In order to simulate different alternatives for the exploitation, based upon scientific data on the population, a system dynamics model is being used. Here the VENSIM® model was employed, utilising data on clam populations: stock and biomass in the Plentzia and Mundaka estuaries between 1998 and 2005; the area occupied by the species; the length and weight class distribution; the number of fishermen; average biomass captured by the fishermen; natural mortality by length class; maturation; fertility rate; etc. This study improves previous experiences in modelling clam exploitation in the Plentzia and Mundaka estuaries. Following validation of the model, after running it for 1 and 10 years, some cases were simulated. This analysis was undertaken in order to establish the effect in the resource evolution of modifying the number of fishermen, the aperture-close season of captures, the minimum sustainable biomass, the exploitation area and the minimum legal length for shellfishing. This approach tries to establish the sustainable exploitation of the clam populations in the Basque Country. According to model results, the best management measure in order to achieve a sustainable exploitation of clam resource is the reduction of the shellfishing effort.

SUSTAINABLE AQUACULTURE IN NEW BRUNSWICK, CANADA. S. Doiron.

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Sustainable Aquaculture in New Brunswick, Canada: Until the late 1990s, the oyster industry in New Brunswick has been practiced by locals in a traditional way common to the region. Oysters were raked from the bottom with thongs and dredges. Modest landings came from public fishing grounds and a few privately own beds. The face of the industry significantly changed at the beginning of the new millennium. A new growing technique was introduced and the farming of oyster expanded to another level, creating jobs, incomes and interest in New Brunswick rural communities. As marine biologists hired by the New Brunswick Department of Agriculture, Fisheries and Aquaculture, we implemented a monitoring program to assess de development of this rising industry. Oysters are now grown into floating vexar bags at the surface of the water reducing the production cycle by almost its half. The end result presents an oyster of greater quality, selling for a better price and getting to market size in a shorter time period. The monitoring program's goal is to evaluate the geographic trends along the east coast of NB and to acquire data on survival, growth and quality. Observations of the presence of fouling organism and occurrence of disease outbreak are also items being monitored. In addition to this data acquisition, the monitoring program consists in a tool offering legislators a mean to assess industry activities, site productions, and manage the allocation of aquaculture sites.

ANALYSIS OF SEASONAL FISHING STRATEGY AND TACTIC OF *DONAX TRUNCULUS* (BIVALVIA, DONACIDAE) IN THE BAY OF DOUARNENEZ (BRITTANY, FRANCE). APPROACH BY STRUCTURAL MODELLING. S. Fifas, G. Veron and O. Thebaud.

IFREMER, Centre de Brest, B.P. 70, 29280 Plouzané France

The exploited French molluscs beds undergo to a fishing pressure characterized by high seasonality because of regulation system. Targeted species are usually protected during period of reproduction by applying close season. Otherwise, in some cases as for the *Donax trunculus* population of the Bay of Douarnenez external factors (tourist season of July and August in the same areas than dredging) bring about forbidding fishing activities. Apart from that, high concentrations of toxic micro-algae induce supplementary closing period with starting interval and duration changing from year to year. Those constraints cause anticipation of fishing pressure before periods of high closing risk (mainly in spring). This study involves analysing the seasonal optimising strategy including biological characteristics of species. The theme is developed by structural modelling of yield per recruit put forward Beverton and Holt model of dynamics of exploited populations and by taking into account seasonal component of the individual growth of *Donax* (sinusoid term added to the Von Bertalanffy's approach). Different model scenarios are presented under the hypothesis

of constant fishing effort during the whole year. It is deduced that anticipation of exploitation during spring do not optimise fishing strategy whereas autumnal increase of fishing effort could bring a more significant result.

ESTIMATION OF WATER RENEWAL TIMES AT AQUACULTURE SITES IN COASTAL LAGOONS. V. Koutitonsky, G. Tita and T. Guyondet.

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Shellfish aquaculture sites in coastal lagoons must be selected with considerations given to several factors. One of these is the water renewal rate at the site, as a faster rate will ensures an adequate supply of organic matter (food) to the shellfish and flush away any release of organic detritus (biodeposits). Water renewal rates depend on bathymetric steering, tidal and other sea-level fluctuations at the lagoon entrance, local wind stress and river inflow, each contributing at different spatial and temporal scales of variability. Thus, an accurate estimate of water renewal time cannot be provided by the classical tidal-prism method but must rely on a more objective approach. This work presents a method to estimate the water renewal rate at selected aquaculture sites in a coastal lagoon. Field data and three-dimensional coupled hydrodynamic and tracer-transport numerical models are used to estimate the local and integral renewal times. The method is applied to Grande-Entrée lagoon in the Magdalen Islands, Eastern Canada and results are validated with sea-level time series and 17 month long *in-situ* observation of mussel growth rates across a mussel farm. The growth rates are found to be greater where estimated local renewal rates are faster.

STOCK ENHANCEMENT OF GREENLIP ABALONE (*H. LAEVIGATA*) IN AUSTRALIA: EFFECT OF DENSITY-DEPENDENCE ON SURVIVAL, GROWTH AND IMMUNITY. S. Huchette,[1] C. Dixon,[2] R. Day,[2] S. Shepherd,[3] M.A. Travers[1 4] and C. Paillard.[4]

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Seeding of hatchery-produced abalone has the potential to enhance or maintain wild populations and ensure the viability of fishing grounds, but survival of out planted juveniles has been poor or unreliable in many previous seeding experiments. In our study hatchery produced *Haliotis laevigata*, age 18 months with a mean size of 28 ± 3 mm, were released at 8 sites in South Australia. Six reefs were established at each site, each with two boulder layers and approximately 6 m^2 in area. Juveniles were anaesthetized prior to individual tagging and then given 5 days to recover on settlement plates within cages. The cages were transported in cool boxes, opened and placed between boulder layers by divers within six hours of leaving the hatchery. Juveniles were seeded at 6 different densities at each site. High and low density juveniles were sampled after 18 months in order to evaluate their immunity status. Estimated minimum survival ranged from 0 to 57% after 9 months (mean = 38%). Empty shell collections accounted for 10% of seeded juveniles during this period. These results compare very favorably with previous seeding experiments, particularly considering the range of sites seeded and the number of reefs within each site. This was probably due to careful site selection, careful handling of seeded juveniles and the provision of a suitable, cryptic environment to reduce mortality. A strong density-dependent growth was observed in all seasons. The effect of seeding density and growth on the immunity status of the juvenile is discussed.

QUALITY CHARACTERISTICS AND QUALITY CHANGES DURING REFRIGERATED STORAGE OF MUSSELS (*MYTILUS GALLOPROVINCIALIS* LAMARCK) REARED IN TWO TUSCANY EXPERIMENTAL SITES. G. Parisi, G. Giorgi, A. Messini and B.M. Poli.

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The Italian mussel production was 92219 t in 2002, corresponding to 50% about of the national aquaculture production. High consumption and discontinuous offer along the year open the perspective to expand in new geographical areas the mussel culture, actually irregularly distributed along the coasts of the Country. Tuscany, a region sited in Central Italy and faced to the Tyrrhenian sea, for their characteristics may be a new candidate area for mussel cultivation. Objective of this work was to evaluate the quality characteristics and quality changes during the refrigerated storage of mussels reared in two Tuscany experimental sites (open sea and Orbetello lagoon), both classified in A class. Mussels (*Mytilus galloprovincialis* Lamarck) from the same population (initial length: 30.3±8.3 mm) were utilized to prepare mesh («reste»), transferred in the two sites for the suspended culture rearing. After 3 months, every 40 days about, mussel samples were monitored for biometric characteristics and chemical composition. After 10 months from the transfer, the mussels were harvested and specimens of a sub-sample were analyzed on the day after for: total length and weight, shell and soft part weight. In mussel specimens stored at 4 °C, the following parameters were then monitored in different days (1, 3, 7, 10) from harvesting: weight/length ratio; incidence of specimens without intervalvare liquor; liquor turbidity; soft part pH, ATP and related catabolites content. Total viable count, coliforms, *Pseudomonas* spp. and lactic acid bacteria were also determined on the edible part. Mussels from the two sites showed marked differences in growth (higher in lagoon than in open sea) and in biochemical composition, presenting evident changes during the storage for almost all the analyzed parameters. The behavior of the parameters considered during the storage seems to reveal a poor quality in the lagoon mussels, particularly during the first period of the refrigerated storage.

ALABAMA OYSTER REEF RESTORATION PROGRAM. S. Powers and R. Shipp.

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In 2002, the University of South Alabama, USA initiated a multi-year, multi-disciplinary program designed to restore and enhance oyster reef habitat in the state of Alabama coastal waters. The three principal goals of the Alabama Oyster Reef Restoration Program are (1) to develop the scientific understanding necessary to direct current and future oyster restoration and enhancement in Alabama coastal waters, (2) to assist in the development of a long-term strategy for sustained productivity of Alabama's oyster resources and the associated ecological benefits that accrue from healthy oyster-based habitat and (3) to provide this information to state and federal management agencies, the fishing industry and the general public through outreach activities. The program is funded by grants from the National Marine Fisheries Service and consists of large-scale reef creation activities performed in cooperation with the Alabama Department of Conservation, targeted research projects and outreach and education activities. Targeted individual research projects fit into one of five areas: ecological benefits, fisheries benefits, oyster biology, environmental/site-specific studies, and socioeconomic analyses. Several of these individual research projects utilize oyster reefs created under the large-scale reef creation component, whereas others have proposed the creation of smaller scale oyster reefs. Here, we present major accomplishments of each of these five areas.

MAPPING LIVING AND BURIED OYSTER REEFS USING HIGH-RESOLUTION SIDESCAN SONAR AND SEISMIC SUB-BOTTOM PROFILING IN THE CAPE FEAR RIVER, SOUTHEASTERN NORTH CAROLINA. K. Rodriguez, N. Grindlay, L. Abrams, T. Alphin and S. Artabane.

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Eastern Oysters (*Crassostrea virginica*) are filter feeding organisms that settle in dense aggregates and have positive impacts on water quality. They provide a series of ecosystem functions including habitat for other organisms and habitat stability. The United States Army Corps of Engineers (USACE) has been dredging North Carolina's Cape Fear River since the early 1900's to create navigable waterways. The dredged material was discarded as dredge spoil islands throughout the lower 20 km of the river. These activities have altered water flow and increased sedimentation rates, which in turn has reduced the amount of hard substrate available for oyster spat settlement and growth. Currently there is a relatively small amount of hard substrate remaining in the lower river that routinely experiences high overspat events, followed by high mortality from a combination of competition and high sedimentation. During the winter and spring of 2005, sidescan sonar and sub-bottom profiling systems were used to map four areas within a 15 km long section of the lower Cape Fear River to locate living and buried oyster reefs. The southernmost area contains living oyster populations, whereas the three northern areas have no living oysters, are along dredge spoil islands, and potentially contain buried oyster reefs. In the northern areas, water quality is suitable for oyster growth and larval supply does not seem to be a major issue. Using the hypothesis that oysters should be able to grow in locations where they once thrived, these data will be used to guide placement of oyster cultch. If these sites prove suitable for new oyster cultivation, this geophysical technique has important implications for the success of future oyster restoration projects in southeastern North Carolina.

WHEN AQUACULTURE RESTORES AND REPLACES AN OVERFISHED STOCK: THE CASE OF THE SCALLOP *ARGOPECTEN PURPURATUS* (LAMARCK, 1819) IN NORTHERN CHILE. G. Thouzeau[1] and M. Avendano.[2]

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The Chilean scallop *Argopecten purpuratus* is found in shallow bays from Paita, Peru to Valparaiso, Chile. Life span of this fast-growing species is about 4-5 years and commercial size in Chile (90 mm) is reached in 18 months. The Tongoy, Guanaqueros, Rinconada and Mejillones banks were the most important scallop banks to be exploited in the 1980's. These last two populations contributed up to 80% of the annual landings at that time. Economic exploitation of *A. purpuratus* in Chile in recent years has been primarily based on aquaculture, as the species was banned from harvesting on natural banks in 1988, due to severe overexploitation. The scallop fishery has been closed for many years, but natural scallop beds are still in jeopardy because illegal harvesting continues. Since intensive culture began in the 1980's, Chile has become the world's third largest scallop producer. The scallop wild stock in 1998 was estimated to 10-15% of the total stocks of the species in Chile, with most of the individuals being kept in sea farms. The domestication process of cultured species leading to genetic impoverishment, scientists concluded that it was urgent that selected natural beds be protected in order to preserve *Argopecten* genetic diversity. A protected marine reserve was created in 1997 in the Rinconada Bay (Antofagasta). This population was selected because previous studies on biometrics and enzyme polymorphism suggested that it would be the most appropriate to be used in future aquaculture attempts. Scallop management studies have been carried out within the reserve, the objectives of which included development of a program for artificial collection of scallop spat to be used both in repopulation of wild stocks to historic population levels and in support of mass culture activities in Chile. The results of these past and on-going projects will be discussed in this talk.

GENETIC CONSIDERATIONS IN SHELLFISH RESTORATION

ASSESSING GENETIC VARIABILITY IN THREE INVERTEBRATES FROM THE ASTURIAN COASTS IN THE NORTHERN SPAIN. Y. J. Borrell, J. A. Sánchez and E. Vázquez.

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The main role for genetics in exploited invertebrates is in the identification of groups of interbreeding individuals as the basis for a sustainable fishery. In Asturias, where exits an ancient culinary tradition of consumption of barnacles, sea urchins, etc, there are not previous data about the identification of breeding units for these species that have been under commercial exploitation for decades. In a preliminary approach we have sampled three zones in the western, centre and eastern of the Asturian coasts (Punta la Cruz, Moniello, and Tereñes) for sea urchins (*Paracentrotus lividus*), common limpets (*Patella vulgata*) and barnacles (*Pollicipes cornucopia*). We conducted sequencing of the mtDNA control region of 59 individuals (45 sea urchins and 14 barnacles) and also sequencing of the 12S gene of 40 limpets. Our results showed a high level of nucleotide and haplotype diversity for the three species under study. Higher genetic heterogeneity was found for the limpet specie, whereas sea urchin and barnacles showed low levels of genetic differentiation among zones. Management of these exploited invertebrates in Asturias should take into account the real possibility of the existence of different stocks.

STUDY OF THE REPRODUCTIVE POTENTIAL OF TRIPLOID OYSTERS *CRASSOSTREA GIGAS* (THUNBERG). J. Normand, P. Boudry, F. Cornette and C. Ledu.

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Reproduction was studied in triploid *Crassostrea gigas*, by crossing gametes from diploid and triploid parents. Triploids are able to produce viable gametes and their resulting progeny consisted in diploids, aneuploids and polyploids. Gametes from triploid parents frequently led to abnormal polar body formation, even before caryogamy occurred. A high frequency of aneuploids was observed, related to the missegregation of chromosomes during meiosis in triploids. This might be due to the observed incomplete synapsis in triploid eggs during Prophase I. The proportion of aneuploids decreased during larval development, reflecting differential mortality between ploidy levels. Due to limited gonadic development and high larval mortality rates, the reproductive potential (up to the pediveligere stage) of triploids was about 5.44% (female 2n x male 3n) and 1.47% (female 3n x male 2n) relative to crosses between diploids. Interestingly, polyploid larvae were mostly found in female 3n x male 2n progenies. Our results will be discussed from biological and environmental points of view.

IMPORTANCE OF HATCHERIES AND AQUACULTURE IN SHELLFISH RESTORATION

STUDY OF THE PROBIOTIC EFFECTS IN SHRIMP BY MEANS OF BIOTEST PERFECTED WITH *ARTEMIA SALINA*. S. Frouel,[1] D. Pham,[2] and J.-L. Nicolas.[3]

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The rapid expansion of the shrimp farming industry is accompanied by the emergence of bacterial diseases affecting shrimp survival and growth. Antibiotic treatment is generally applied during larval stage or growing stage in the ponds to limit the bacterial diseases. With the damaging impact of antibiotic on the environment and the development of resistant bacteria, alternative methods have been investigated. Among the solutions studied to control and to replace antibiotic treatment, probiotic appear promising. However the used bacterial strains and the method of distribution are often determined of empirical manner. In this study, a commercial product including 2 strains, *Lactobacillus rhamnosus* and *L farciminis*, inactivated by heating, was tested on larvae and post-larvae of the shrimp *Litopenaeus stylirostris*. Preliminary results displayed a stimulating effect of growth (better than control batch with antibiotic) or on survival (equal to the control batch with antibiotic) when probiotic was added to sea water tank at 107cell L^{-1}. In order to improve the distribution, to isolate the active fraction and to understand the mechanism of stimulation a test has been perfected with the crustacean, brine shrimp *Artemia salina* which exhibited a similar response at the addition of probiotic preparation . Effect of probiotics on performances was first measured on 4 day sold *Artemia* and then

physiologic parameters; in particular, the enzymatic activities of digestive metabolism (trypsin and alpha-amylase) were dosed. These enzymes were chosen because there was a good correlation between larval development and their activities. Although these enzymes were stimulated or repressed by the concentration and composition of diet, the probiotic effect differed from a simple nutritive effect, especially from the skimmed milk added at the same concentration. The biotest is performed in 3 ml wells of cell culture plate in which about 50 individuals aged of 4 days are distributed. In these conditions probiotics stimulate in a few hours the endogenous synthesis of the enzymes. The first results show that trypsin activity is only stimulated by active commercial product whereas amylase is stimulated by active form as well as inactive form of the probiotic product. Progress in purification of active fraction or compound and in understanding of stimulation mechanism should make it possible to improve the effectiveness of probiotic treatment in shrimp.

CULTURE OF WHITE CLAM *SPISULA SOLIDA* LARVAE FOR RESTOCKING PROPOSES: PRELIMINARY RESULTS. S. Joaquim,[1] D. Matias,[1] M. Gaspar[1] and W. S. Arnold[2]

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Exploitation of *Spisula solida* constitutes one of the most important bivalve fisheries all over the Portuguese Coast. However, in the last decade, bivalve stock showed large annual fluctuations and therefore endangering the sustainability of these fisheries. The reasons for the failure of the recruitment of these bivalve populations are mainly due to natural and anthropogenic causes. Shellfish aquaculture can support the development of restocking programs and therefore the enhancement of bivalve stocks. One of the possible methods to perform bivalve restocking is larval injection since it is designed to circumvent the natural spawning process by introducing larvae produced in hatchery directly into the water column. For this purpose we attempt to develop/improve aquaculture techniques in order to produce high quality larvae of *S. solida* for restock programs. As a first step we it was investigated the effect of five temperatures (15, 17º, 19º, 23º and 25ºC) on eggs incubation. The hatching rate was determined at 24, 31, 48 and 55 h in order to establish the embryonic chronogram of the species. The results suggest a relationship between temperature and the chronology of larval development, showing that D larvae appear above 24h after fertilization at 19 and 23ºC and over 48h at 15ºC. However, the precocious appearing of D larvae at 19 and 23ºC did not imply a greater hatching rate. The greater survival rate of D larvae (60%) was found at the lower temperatures (15 and 17ºC) showing an inverse relationship between the hatching success and the temperature of incubation. At 25ºC the eggs incubation was not viable. These results suggest that to obtain a higher *S. solida* D larvae quality, eggs incubation should be performed between the temperatures of 15 and 17ºC.

EFFECT OF THE ANTIMALARIAL DRUG, QUININE, ON THE VIABILITY OF THE EASTERN OYSTER PARASITE *PERKINSUS MARINUS*. C. Panko, V. Encomio and A. Volety.

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Perkinsus marinus is a lethal oyster parasite causing over 80% mortality of infected oysters in estuaries along the eastern seaboard of the U. S. Typical approaches to parasite prevention or mitigation include relaying oysters to lower salinity conditions in the field or through particle filtration and UV or ozone disinfection to treat potentially pathogen-laden seawater under hatchery conditions. However, some of these prevention techniques may be expensive long term or ineffective at certain stages in the rearing process. Furthermore, most of these techniques are strictly utilized to treat seawater and not particularly to treat infected oysters. Development of a chemotherapeutant specific for treating oysters infected with *P. marinus* may be an additional measure to prevent physiological strain on aquaculture brood stock before spawning. Currently no anti-protozoal drug therapy exists in aquaculture to effectively treat *P. marinus* infected oysters. Given the taxonomic proximity of *P. marinus* to apicomplexans such as the malarial parasite, the antimalarial drug, Quinine, was screened for drug sensitivity of cultured *P. marinus*. Following an acute challenge with varying concentrations of Quinine HCl, the viability of one strain of cultured meronts isolated from Laguna Madre, Texas oysters was determined using a dye reduction method. The assay was composed of a tetrazolium compound, MTS, in tandem with an electron coupling reagent, PMS. Only viable cells reduce MTS to a soluble color developing product formazan. The amount of formazan measured by absorbance at 490nm is directly proportional to viable cell activity. After a three hour exposure, the highest concentration tested, 50µg/ml, had the most significant effect ($p=0.000$) on parasite viability. The optimal sensitivity range was between 25 and 50µg/ml Quinine HCl. Following assay optimization, seven regionally different *P. marinus* isolates (ranging from Connecticut, New Jersey, Maryland, Virginia, Louisiana, and Texas) were exposed to 50µg/ml Quinine HCl to evaluate differences in susceptibility. The viability of all isolates significantly decreased after Quinine exposure. Maryland and New Jersey strains were more susceptible to treatment than the other isolates. The results of this study indicate the importance of examining the use of quinine in mitigating *P. marinus* infections under in vivo conditions.

A HATCHERY EXPANDS TO HELP RESTORE BAY SCALLOP, *ARGOPECTEN IRRADIANS IRRADIANS*, POPULATIONS AND FISHERIES IN NEW YORK. R. Michael. Patricio.

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The near total collapse of bay scallop populations, and the historic fishery it supported, on eastern Long Island, New York has prompted funding of a large scale restoration program. This four year effort will require raising production levels from 1 million to 10-20 million animals, annually. Although the hatchery has been in operation since 1991, this project will necessitate considerable expansion of all aspects of production. The hatchery has been using batch algae culture for many years, however, to meet the demands of our restoration project, a continuous algal production system was put in place. A Seasalter Continuous Algal Production Systems (SeaCAPS), system was installed to provide the volume of algae needed to increase the hatchery's production. This sysytem was chosen because it could provide not only the volume needed for the project, but also a constant supply of higher quality algae compared to the batch culture system. An expanded post-set growing facility was built to provide enough space for scallops that range from 250 microns to 2 mm. Juvenile scallops are placed on downweller sieves and receive coarsely filtered water which is free from macroplankton; a rotary drum filter was utilized to provide filtered (<100 micron) seawater. Scallops (>2 mm) will be placed in spat bags for continued growth up to 10 mm. A portion of the 10+ mm scallops will be free-planted, while the rest will continue to grow in lantern nets to be used the following year as spawner sanctuary stock. It is expected that the expansion and improvement of our facility will meet the needs of the restoration program and help return the scallop fishery to eastern Long Island.

NUTRITIONAL VALUE OF SIX PAVLOVOPHYCEAE FOR MOLLUSC LARVAE. R. Robert and E. Ponis.

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The nutritional value of the haptophyte *Pavlova lutheri* for molluscs has been widely debated while its poor food value for *Crassostrea gigas* larvae has been recently proved. In this study four unidentified strains of Pavlovophyceae and two known species (*Pavlova pinguis*, *Rebecca salina*) selected from the Algobank-Caen microalgal culture collection of the University of Caen were characterized (productivity, size, dry weight, ash, gross composition, fatty acids, sterols) and their nutritional value evaluated on *C. gigas* and *Pecten maximus* larvae. Despite a well balanced biochemical profile, particularly in PUFA content, these microalgae exhibited poor food value for *C. gigas* larvae; two of these species (*P. pinguis* and *R. salina*) did not sustain any growth, a result similar to that obtained with starved larvae. Clearance experiments showed that both species were weakly ingested while an additional feeding trial excluded the possibility of toxicity of cellular exudates. In contrast one of the new strain concerned by this study (*Pavlova* sp. AC250) supported growth greater than the control for *P. maximus* larvae, while the other tested species led to poor development. This study clearly indicates that cultures of members of the genus *Pavlova* are not suitable for feeding of *C. gigas* larvae. In contrast, a new species has been identified for the rearing of *P. maximus* larvae. Further investigations on its productivity in operating conditions (perspex cylinders, polyethylene bags) should be performed in order to develop its use in commercial hatcheries.

INFLUENCE OF PHYTOPLANKTON ASSEMBLAGES ON LARVAL DEVELOPMENT AND SETTLEMENT OF *CRASSOSTREA GIGAS*. B. Rico-Villa,[1] C. Mingant,[1] J. R. Le Coz,[1] M. Le Pennec[2] and R. Robert[1]

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Microalgae commonly used as feed for bivalves, *Pavlova lutheri* (P), *Isochrysis affinis galbana* (T) and *Chaetoceros calcitrans* forma *pumilum* (Cp), were evaluated on Pacific oyster *Crassostrea gigas* to assess their nutritional value for larval development and metamorphosis during two feeding trials. Monospecific, bispecific and trispecific diets were firstly evaluated during 3 weeks from D larvae to young postlarvae. Then bispecific diets, based on different T and Cp proportions, were performed during a similar period. Compared to the other assemblages, bispecific diet TCp induced the best larval growth performance (13.2 µm. d^{-1}) and a high larval survival (98%). In contrast, monospecific diet P produced detrimental effects on larvae with low growth and low survival, not significantly different from that observed in the unfed condition. On the other hand, TCp did not result in higher metamorphosis (72%) compared to the other multispecific combinations, except PT. The best growth, high survival (99%) and high metamorphosis (87%) were induced with the combination 50T/50Cp but not very different from those observed at 75T/25Cp and 25T/75Cp. Unbalanced diets (95T/5Cp and 5T/95T) led to the worst larval performances (*e.g.* survival 69%) with no settlement. In addition, grazing experiences showed preferential consumption of microalgae with Cp>>T>>P. For mixed diets, except PT, three main feeding periods can be established: a first phase (8-10 days) with a weak daily consumption (<10 000 microalgae per larvae) followed by a second phase (next 8-10 days) with a sharp increase and regular intake, reaching 90 000 microalgae per larvae per day. Finally a marked drop (40 000 microalgae per larvae) was observed at the beginning of metamorphosis from day 20 to 21. A clear relationship between larval performances and grazing was shown while biochemistry content of larvae did not bring any further information.

PATHOLOGY AND EPIDEMIC CONSIDERATIONS IN SHELLFISH RESTORATION

PERMANENT ADVISORY NETWORK FOR DISEASES IN AQUACULTURE (PANDA). I. Arzul,[1] E. Ariel[2] and B. Hill.[3]

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The PANDA project aims to establish a permanent network of aquatic animal health specialists (researchers and diagnosticians) to provide a forum for the debate of issues concerning diseases in European aquaculture, and to communicate the results of these discussions to the European Commission with provision of advice on EU policy and legislation for aquatic animal health. PANDA consists of five scientific work packages: risk analysis, epidemiology, diagnosis, environmentally safe strategies for disease control, training in research and diagnostics. These work packages are lead by PANDA consortium members, supported by small task force of specialists, with wider input from experts registered in the PANDA network. Focused workshops and ongoing online discussions on subjects related to aquatic infectious diseases are being held for exchange of scientific information and opinion. Progress and outputs • A project website has established, and 200 worldwide experts have joined the network. • A simple hazard scoring system was used to identify and prioritize the most significant exotic, emerging and re-emerging disease hazards for European aquatic animals. • A prototype database of epidemiological characteristics of the identified disease hazards has been developed, information is being collated and entered onto it. • An assessment of the current best methods for rapid and accurate detection was undertaken for the main aquatic disease hazards and will help to identify requirements for improvements, standardization and validation. • Disease treatment strategies and their known or likely impact on the environment were reviewed and discussed. • A links based database of training opportunities for aquatic animal disease research and diagnosis is under development, and can be viewed on the website. Further details are available on the website (www.europanda.net) where you can register on the expert database to keep abreast of progress, contact other experts in your field, and contribute to the discussions and debates.

PARASITE COMMUNITIES IN COCKLES (*CERASTODERMA EDULE*) ALONG A LATITUDINAL GRADIENT (NORTH AFRICA TO SCANDINAVIA): PATTERN AND PROCESSES. X. De Montaudouin,[1] M. Baudrimont,[2] H. Bazairi,[3] M. Cottet,[1] L. Dabouineau,[4] C. Desclaux,[1] M. Gam,[3] P. Gonzalez,[2] K. T. Jensen,[5] F. Jude,[1] M. Krakau,[6] G. Lassalle,[1] S. Pina,[7] N. Raymond,[1] K. Reise,[6] F. Russell-Pinto,[7] D.W. Thieltges[6] and C. Paillard[8]

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Cockles (*Cerastoderma edule*) are important shellfish resource in the northeast Atlantic shallow water ecosystems. Their population sizes are highly fluctuating between years, so the standing crop in Europe is estimated to vary from 30 to 90 000 mt per year (FAO, 2005). Among factors involved in the population dynamics of cockles, digenean parasites can play an important role. Cockles are infected by free-swimming propagules (miracidia or cercariae larvae) through the bivalve ventilation current. Infection success and kinetics are closely related to host dynamics (especially growth rates) and to environmental parameters (especially temperature). With respect to the wide latitudinal distribution of this bivalve, this parasite/host system is an excellent model for studying role of climatic factors in controlling spread of vector borne pathogenic organisms and for predicting future epizootics in marine organisms as a result of climate change. Cockle dynamics, parasite species richness, parasite infection kinetics and environmental parameters have been surveyed since March 2005, focusing on the same cockle cohort (2005). This monitoring is concomitantly performed in Moulay Bousselham (Morocco), Aveiro (Portugal), Arcachon (France), Saint-Brieuc (France), Sylt (Germany) and Skallingen (Denmark). Comparisons of the different parasite/host systems point out the best parasite strategies and assess the plasticity of these biotic interactions.

SURVEY OF BROWN RING DISEASE IN CLAMS FROM NORTHERN LAGOONS IN TUNISIA. M. El Bour,[1] C. Paillard,[2] C. Sintes[2] F. Lakhal,[1] H. Attia[1] and A. Jacq[3]

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Since its first description by Paillard *et al.,* 1987, the brown ring disease (BRD) till spread in Mediterranean coastal areas. In Tunisia, first investigations for this clam's disease shown that prevalence rates still very low and the highest rate achieved was 20% in some areas. Here we reported, investigations results obtained for BRD in clams *Ruditapes decussatus*, for the period 2000 – 2004. As etiological agent of the BRD disease is *Vibrio* P1 or *Vibrio tapetis*, phenotypic characterization tools including isolation, biochemical and serological tests failed in identifying the pathogen. Using molecular method (SSCP – PCR) we characterized one strain named CH797-V2 isolated from clams *R. decussatus* affected by BRD, that incubate at 30°C and seems to be close to *V. tapetis*. Nevertheless, experimental infestations assays with this strain dealt both in Tunisia - (INSTM, standart conditions, 18°C) and France (IUEM, standart conditions, 14°C) failed to reproduce the BRD disease in clams. It seems that incubation temperature probably influence virulence features of bacteria *V. tapetis*.

***CERCARIA PLUMOSA* (DIGENEA, FELLODISTOMATIDAE) PARASITIZING *TAPES DECUSSATUS* AND *DONAX TRUNCULUS* HARVESTED IN THE NORTH AND IN THE SOUTH OF TUNISIA. L. Gargouri Ben Abdallah,[1] N. Trigui El Menif[2] and F. Maamouri.[2]**

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Cercaria plumosa is a parasite belonging to the family of the Fellodistomatidae. At the adult stage, it appears in the marine fishes. At first, this parasite was discovered, in the Black sea at *Syndosmya alba* then in the coastal ponds and in the Languedoc littoral (Mediterranean sea), at *Abra ovata*. In Tunisia, this parasite was harvested at *Tapes decussatus* in some areas: Bizerte and Tunis lagoons and Sfax sea. The same parasite was also detected at *Donax trunculus* in the Kalaat El Andalous sea. Contrary to the other trematodes, that present generally a strict specificity to the first intermediate host, this parasite presents a large specter of hosts. The bag- shaped sporocysts of *Cercaria plumosa*, containing cercariae are essentially located in the gonads and digestive gland of the mollusc. In the North East of Tunisia, these sporocysts were collected in the summer and autumn with global prevalence of 0.32 % at *T decussatus* and 0.12 % at *D. trunculus*. However, in the south of Tunisia, these sporocysts have been observed at *T. decussatus* in the spring and autumn, with a rate of global parasitism of 4.83%. This parasite is more frequent in this last biotope. In order to palliate this weak rate of parasitism, this parasite is gifted by a very important multiplication power. In fact, inside of the sporocyst of the first generation, there is the second generation of sporocysts that are going to give cercariae. These cercariae come out by the sporocyst's rupture. They present a positive phototropism. In perpetual agitation, these cercariae move through a rotator tail's movement. These movements allow vertical displacements between the bottom and the surface of water. The body of the cercaria does not take any part in the locomotion. After its exit from the mollusc, the cercaria can survive few hours in the petri-dishes. However, the increase of the temperature (28°C) shortens its longevity and drags its death in 15 minutes. These larval stages that exhaust their host's energizing reserves to assure their development and their multiplication can be harmful for these Molluscs because they would provoke the castration or even their host's death.

CO-INFECTION OF TWO SYMPATRIC BIVALVES, THE MANILA CLAM (*RUDITAPES PHILIPPINARUM*) AND THE COCKLE (*CERASTODERMA EDULE*) ALONG A LATITUDINAL GRADIENT. G. Lassalle,[1] C. Paillard,[2] P. Soudant,[2] X. De Montaudouin,[1] P. Lebleu[1] and E. Ferré [2]

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Manila clams and cockles are two major exploited bivalves of the north-eastern Atlantic coast. Both species undergo severe mortalities with different causes. Parasitism has been identified as a possible contributive factor, with potential actors like *Perkinsus olseni*/*atlanticus* (protozoan) and *Vibrio tapetis* (bacteria) for the clam, or digeneans for the cockles. The role of temperature in the development and the infection process of these parasites is admitted and it is consequently probable that a latitudinal gradient structures parasite communities. The cockle is often considered as a reservoir for digenean parasites but data lack for bacteria or protozoans. The Manila clam is known to shelter *P. olseni*/*atlanticus* and *V. tapetis*, but its status of introduced species supposes a light digenean infection. In January 2005, a sampling campaign was performed between Landeda (North Brittany) and Arcachon (South Bay of Biscay). Sympatric manila clams and cockles were collected to measure parasite load in each individual in term of *P. olseni*/*atlanticus*, *V. tapetis* and digeneans. *P. olseni*/*atlanticus* burden was very low (<40 cells g^{-1}) in cockles but occurred in the five stations and exhibited a clear southward increase with up to 85000 cells g^{-1} in Arcachon Bay. As already observed, there was an opposite trend for *V. tapetis* in clams, with a maximum prevalence in Landeda (33%). Surprisingly, *V. tapetis* prevalences in cockles and clams were not correlated to each other. Digenean abundance was

much lower in clams than in cockles, in all sites. Digenean communities differ between sites, certainly in relation with the presence of the other potential hosts of the parasite life cycle. The different correlation between each parasite load and the latitudinal gradient will be discussed in order to assess the role of the temperature for the global infection and to estimate whether a type of infection can exacerbate (or inhibit) another.

ECOLOGY OF *VIBRIO AESTUARIANUS*, PATHOGEN OF THE CUPPED OYSTER *CRASSOSTREA GIGAS*: PRELIMINARY STUDY BY EXPERIMENTAL INFECTIONS IN MICROCOSMS. V. Lefebvre, M. Garnier, Y. Labreuche, and J.-L. Nicolas

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Over the last decade, the Pacific oyster *Crassostrea gigas* has been the subject to important summer mortality outbreaks, occurring in the field and in hatcheries. In this context, bacterial strains were recently isolated from moribund *C. gigas* juveniles, sampled during summer mortality events. These strains were identified by phenotypic and genotypic methods as *Vibrio aestuarianus*. Currently, little is known on the ecological aspects of this pathogenic bacterium. Indeed its ecological niche as well as its relationships with *C. gigas* remain poorly understood. To deal with these questions, sensitive and specific detection techniques such as colony blotting were developed, and experimental infections in microcosms were subsequently performed. To localise more easily the pathogen, a plasmid encoding the green fluorescent protein (GFP) was introduced into *V. aestuarianus*. Several experimental conditions were tested to determine the relationships between the different compartments of the environment (i.e. seawater, sediments, oysters). According to this study, we confirmed the strict pathogenic character of the strain. We demonstrated that *V. aestuarianus* was able to pass from seawater to the oysters, but also from seawater to sediments and conversely. Nevertheless, the transmission in seawater appeared transitional, because the bacterium did not remain in this compartment. We also showed that the dying oysters constituted reservoirs where *V. aestuarianus* can multiply and from where the bacterium can go back to the seawater and then infect the oysters around. Finally, we showed that different strains of *V. aestuarianus* may cooperate during infection.

RECOMMENDATIONS FOR EVALUATION OF THE HEALTH STATUS IN CULTURED AND WILD SHELLFISH: *PERKINSUS OLSENI* INFESTATION IN CLAMS AS AN EXAMPLE. L. Miossec,[1] I. Arzul,[1] C. Garcia[1] and P. Soudant.[2]

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Infectious diseases in exploited shellfish population cause economical problems world-wide. The characteristics of the disease in the population -i.e. origin, frequency, distribution, development- need to be well known to set up appropriate measures for protection and restoration of shellfish population health. The investigation of disease in a population is the basis of epidemiology. Quantitative investigations include studies, survey, surveillance with specific sampling strategies according to the objectives. European clams (*Ruditapes decussatus*) and Manila clams (*Ruditapes philippinarum*), two commercially valuable species, are infected by the protozoan *Perkinsus olseni*. This pathogen has been associated with epizootic outbreaks involving in heavy mortality of shellfish, including clams. In Europe, the parasite was detected in Italy (the Veneto region), Portugal (Ria Formosa, Ria do Alvor, V.N. Milfontes, Aveiro, Lagoa de Obidos), Spain (Galicia) and France (Chausey Island, Golfe of Morbihan, Marennes-Oleron, Arcachon bay, Leucate and Thau lagoon). We analysed published and unpublished data on *Perkinsus olseni* infestation in wild and cultured clams collected in Europe, from the English Channel to the Mediterranean coast. Results obtained from these studies clearly demonstrate the detection of *Perkinsus olseni* in all sampling sites albeit with different intensities. We discuss these disease frequencies according to 1) objective, 2) targeted population, 3) methodological design, 4) quality of diagnostic tests and 5) characterisation of the pathogen. We emphasise the need for a relevant sampling strategy to measure occurrence of the disease.

DIPNET, A EUROPEAN PROJECT TO EVALUATE INTERACTIONS AND PATHOGEN EXCHANGES BETWEEN FARMED AND WILD AQUATIC ANIMAL POPULATIONS (FISH, SHELLFISH AND CRUSTACEANS). L. Miossec[1] and A.H. Garseth.[2]

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DIPNET (Disease Interaction and Pathogen exchange Network) is a co-ordination action funded under the UE Framework programme 6 priority 8 Scientific Support to Policy (SSP). The principal objective of DIPNET is to increase scientific knowledge of the potential transfer of pathogens and diseases between wild and farmed fish and shellfish populations. DIPNET started in October 2004 and is a 2 year project. The project is organized in four work packages. Work package (WP) 1 is focused on a literature review of disease interactions and pathogen exchange between farm and wild aquatic animals. This analysis includes both published and unpublished literature. The work

covers a wide range of habitats and species within Europe and, where relevant, world-wide. WP1 is divided into 4 sub-groups, covering successively the North Atlantic Scenario, the Continental European Scenario and the Southern European Scenario for fish, and the Shellfish Scenario for crustaceans and mollusks. Risk assessment and modeling studies in the area of aquatic health are critically reviewed in WP2. In particular, studies of disease interaction are scrutinized to determine how risk assessment or modeling contributed to the analysis of disease interaction. In WP3 a review critically examines the currently used methods in monitoring and surveillance activities on farms, rearing areas and harvested and wild stocks in Europe. An optimized epidemiological methodology will be proposed taking recent advances in the surveillance of terrestrial diseases into consideration. Two seminars will be organized later in the project targeted at potential users, one on risk assessment methods, the second on epidemiological methods. WP4 is focused on network building and knowledge dissemination. Newsletters are published twice a month and are available at the following address (http://www.dipnet.info/). WP5 is devoted to the scientific project co-ordination and liaison with the policy-makers of the European Union.

PRELIMINARY RESULTS ON RECRUITMENT AND GROW-OUT OF MUSSELS (*MYTILUS GALLOPROVINCIALIS* LAMARCK) ON AN EXPERIMENTAL HORIZONTAL AND SUSPENDED NET PLACED IN THE TYRRHENIAN SEA (TUSCANY, ITALY). G. Parisi and G. Giorgi.

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Simplified and less time-consuming rearing systems are indispensable to favorite the mussel production, reducing the production cost and promoting the mussel culture diffusion in new geographical area, characterized by environmental parameters favorable to the rearing. Objective of this work was to experiment and to evaluate the performance for recruitment and grow-out of a horizontal suspended net, utilized for all the rearing phase, from the spat collection to the grow-out of mussels until the commercial size. A prototype of polypropylene net (100m long, 0.40m wide; mesh: 5x5cm) was placed in open sea, at 2 miles from the coast line of Porto Ercole (Tuscany, Italy), suspended at 3-5m of depth. Recruitment and growth of the collected spat were monitored for 16 months in three different sectors of the net (the central one and the laterals ones). At each sampling date, the number of animals collected in a sampled area (200cm^2 for each sector) was counted and the analysis of biometric characteristics (length, width, thickness, total weight, shell and soft part weight) of the mussels was performed. The merchantable traits of commercial size mussels were also examined. The number of the spats collected by the net sampled area resulted 380 individuals on average, after 6 months from the placing of the rearing structure. By the spat counts and by the analysis of the length class distribution of mussels, subsequent recruitments were remarked. Differences in mussel recruitment and growth were observed among the different sectors of the net. After 19 months from net placing, this rearing system, without selective interventions, produced a yield of 25 kg/m of mussels, the 44.38% of which of commercial size, corresponding to 18.67% of the individuals present in the sampled area. The soft part incidence showed marked variations during the examined time, corresponding to the seasonal changes in environmental parameters.

COCKLE'S PARASITISM BY DIGENEAN TREMATODS AND BACTERIA: A POSSIBLE INTERACTION. N. Raymond, F. Jude, L. Bourasseau, Q. Balducchi, M.C. Sajus and X. de Montaudouin.

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Among factors inducing fluctuations of benthic mollusc populations, the combined effect of parasitism by digenean larvae and bacteria has rarely been studied. The cockle (*Cerastoderma edule*), an exploited infaunal bivalve of the Northwestern Atlantic coast, can experiment mass mortality. Before death, cockles often migrate at the sediment surface. Considering that the digenean load alone does not explain this abnormal migration, the role of bacteria was also investigated through a monthly sampling monitoring at Banc d'Arguin (Arcachon Bay, France). In a preliminary study, digenean and bacterial loads were compared for both positions (buried and unburied cockles). Digenean burden was assessed after dissection and the bacterial load was based on a quantification of the viable and culturable aerobic heterotrophic bacteria (VCHB) in flesh and intervalval liquid (FIL). The mean bacterial concentrations in buried cockles ($1.31x10^7$ bacteria/100 mL of FIL) was significantly lower than that in unburied individuals ($34.80x10^7$ bacteria/100 mL of FIL). To elucidate whether the higher bacteria load was a cause or a consequence of the cockle migration, buried cockles only were analyzed, with a comparison between cockles infected by the pathogenic digenean Labratrema minimus and cockles free of it. The quantification of VCHB was completed with the estimation of the total bacterial flora load, performed with microscopic epifluorescence counting (Live/Dead viability kit). Both VCHB and total bacterial flora were significantly higher (x1.3) in parasitized than in L. minimus free bivalves, suggesting a synergetic action of digenean and bacteria in cockle migration and death. Finally, a genotypical identification of the bacterial strains isolated from the «healthy» and infected cockles, based on 16S RNA sequences and phylogenetic analysis, will give a qualitative approach (bacteria community comparisons).

INFECTION OF POLYDORA SP. DURING REPRODUCTIVE CYCLE OF BLOOD CLAM *SCAPHARCA SUBCRENATA*. N. T. Thu Thao,[1] K.S. Choi[2] and T. P. Nguyen.[1]

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An annual gametogenic cycle of the blood cockle, *Sacapharca subcrenata* was investigated from specimen collected from Busan, Korea. Histological examination of the gonad indicated that S. subcrenata initiated gametogenesis as early as March when water temperature reached to 13°C. In June, most female clams became sexually ripe, exhibiting fully mature eggs in the follicles. In July, some clams displayed partially depleted ovary and individual eggs in the oviduct, suggesting that they were in spawning. Histological observation suggested that spawning activity of the clams in Busan was highly synchronized from July to August with one spawning peak during this period. The clams were in resting phase from September to February. Shell burrowing polychaete, *Polydora* sp. was frequently observed on the surface and the inner shells with its highest prevalence in November (63.3%). Distribution of *Polydora* sp. is depend on the area of the shell surface; high prevalence along the foot area (zone 1, 76.1-79.5%), low prevalence in middle area of shell (zone 2, 20.5-23.8%) and no prevalence in area that opposite to the foot (zone 3), regardless of the origin of the valve. Shell damages were detected from Polydora-infected clams, however the condition index and the gonad index was not significant difference between infected and non-infected clams (P>0.5). This is the first record of burrowing worms in the shell of *S. subcrenata*.

THE STUDY ON THE PROLIFERATION OF RICKETTSIA-LIKE ORGANISM PARASITIZING IN THE OYSTER, *CRASSOSTREA ARIAKENSIS* GOULD, IN BALB/C MOUSE. J. Sun,[1] X. Wu,[2] B. Wen,[3] M. Chen[3] and W. Zhang[1]

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The BALB/c mice were infected with Rickettsia-like organisms purified from the gill tissues of *Crassostrea ariakensis* Gould. The BALB/c mice were divided into four groups: (1): direct inject the RLOs; (2): inject the RLOs treated with penicillin; (3): inject the RLOs treated with penicillin and Cyclophosphomidum (CP) at the same time; (4): the control group, inject the sterilized PBS. The infection study involved three generations of the mice. The infected mice were anatomized at different times and RLOs were detected using histological section with staining technique and transmission electron microscope. RLOs were found in the spleens of the three generations of mice. It has been found that RLOs were more in 3 rd group mice. Present study suggested that RLO is innoxious or low virulent to the BALB/c mouse and is penicillin resistant. RLOs may propagate in the mouse bodies, but RLOs can propagate much more in the mouse that is inhibited the immunity function. In this study, the animal model for proliferation of Rickettsia-like organism parasitizing in *Crassostrea ariakensis* Gould was successfully set up, and the culture method of RLOs from marine mollusks in the terrene animal is significant to solve the problem about animal model for propagating RLOs to further research the molecular immunology and molecular biology, and provide the pathological model for researching the pathogenic mechanism of RLO.

SHELLFISH FITNESS CONSIDERATIONS IN SHELLFISH RESTORATION

STRUCTURAL AND FUNCTIONAL CHARACTERIZATION OF A MEMBER OF THE GLYCOSYL HYDROLASE FAMILY 18 INVOLVED IN GROWTH, DEVELOPMENT AND IMMUNITY OF THE OYSTER *CRASSOSTREA GIGAS*. F. Badariotti, M. Kypriotou, C. Lelong, M-P Dubos, P. Galera and P. Favrel.

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To understand the molecular processes underlying the physiological control of growth and development in Lophotrochozoans, genes encoding potential new mitogenic factors displaying homologies with members of the glycosyl hydrolase family 18 were investigated in the pacific oyster *Crassostrea gigas*. A cDNA encoding a member of the glycosyl hydrolase family 18 named *C. gigas* Chitinase-like protein 1 (CgClp1) was characterized. Expression profiles of this transcript monitored by real time quantitative RT-PCR in different adult tissues and during development support the involvement of CgClp1 in the control of growth and development in *C. gigas*. In addition, increased levels of this transcript in hemocytes, observed as a result of bacterial lipopolysaccharide or chitin stimulation plead for a role in immunity. Recombinant CgClp1 produced in both procaryotic and eucaryotic cells demonstrated a strong affinity for chitin but no chitinolytic activity. Moreover, transient expression of CgClp1 in primocultures of rabbit articular chondrocytes established that CgClp1 induces chondrocyte proliferation and regulates the synthesis of extracellular matrix components such as glycosaminoglycans and collagen. These observations together with the fact that CgClp1 gene organisation strongly resembles that of its mammalian homologues argue for an early evolutionary origin and a high conservation of this protein at both the structural and functional levels.

OBSERVATIONS ON GONADS AND OUTPUTS OF WILD AND CULTIVATED MUSSELS (*MYTILUS GALLOPROVINCIALIS* LMK) FROM THE LAGOON OF VENICE, ITALY. L. Da Ros,[1] A. Baù,[1] F. Meneghetti,[1] V. Moschino,[1] C. Losso[2] and A. Volpi Ghirardini.[2]

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This study reports on the results of histological gonad observations and of simultaneous fertilization tests carried out in wild and cultivated mussels collected from two populations settled nearby, in an area of the Lagoon of Venice closed to the sea inlet. Samplings were performed bimonthly in winter-spring 2003, during the main spooning season. The histology of reproductive tissue aimed at evaluating several parameters, i.e. oocyte maturity, size, number, and percentage of degenerated /reabsorbed ones. The main goal of the fertilization tests was to assess the quality of outputs. As a whole, the results achieved from the two study populations indicate worst oocyte and outputs conditions in the cultivated mussels than in the natural ones.

EFFECTS OF SEDIMENT LOAD AND TYPE ON THE PHYSIOLOGICAL CONDITION OF THE OLIGOHALINE CLAM *RANGIA CUNEATA* – IMPLICATIONS FOR FRESHWATER RELEASES AND DREDGING ACTIVITIES. V. Encomio, C. Panko, S. Martin and A. Volety.

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Hydrologic alterations in the Caloosahatchee River in southwest Florida have significantly impacted water quality in this estuary. Upstream freshwater releases from Lake Okeechobee result in dramatic reductions in salinity, adversely affecting bivalve populations. Less studied are the effects of sediment loading on bivalves in this estuary. High sediment loads may result from resuspension of sediment as a result of increased freshwater flow or dredging activities. Increased sediment loads may interfere with filter feeding causing adverse effects on the condition of bivalves. The physiological effects of sedimentation on oysters have been part of ongoing projects examining the impact of watershed alterations on the Caloosahatchee River. The use of oysters as a sentinel organism, however, only covers the mesohaline (10-30 parts per thousand, or ppt) regions of the estuary. Few, if any studies have examined changes in water quality on bivalves in the oligohaline (<10 ppt) portions of the Caloosahatchee estuary. The clam Rangia cuneata is found extensively in brackish regions of the Caloosahatchee and may be used as a bivalve indicator of those areas. The effect of sediment exposure (duration and sediment size) on physiological condition in Rangia was examined in lab experiments. Clams were exposed for thirty days to clay (< 4 μM grain size) and silt (40-60 μM) at 0, 1 and 2 grams/clam 3 days/week. At 0, 10, 20 and 30 days clams were sampled for condition index (dry tissue weight : dry shell weight), glycogen, lipid (total lipids and lipid class composition) and protein content. Condition index decreased significantly over time ($p=0.017$) but not with sediment type and sediment levels. Biochemical parameters are currently being analyzed and will be compared with changes in condition. Examining the effects of sedimentation on Rangia cuneata will be important in understanding the effects of hydrological alterations along the entire estuarine gradient.

WHITE CLAM *SPISULA SOLIDA* POPULATION RESTOCKING. S. Joaquim,[1] M. Gaspar,[1] D. Matias[1] and W. S. Arnold[2]

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Nowadays, populations of commercially important bivalve molluscs of the Portuguese continental coast became depleted due to a variety of natural and anthropogenic causes. In order to reverse this negative trend it is of utmost importance to adjust the fishing effort and to enhance bivalve stocks. In this presentation we show the results of a study designed to establish the most ecologically and economically feasible approach to restore white clam *Spisula solida* populations. Clams were transplanted from natural clam beds to a closed fishing area. With this purpose, local fishermen caught 4000 *S. solida* clams using a commercial dredge. The clams were equitably partitioned into two length groups: adults (> 25 mm) and juveniles (< 24 mm) and then transplanted into two 50 m^2 areas with a density of 40 clams per m2 in a presently closed but previously overfished area. Transplanted clams were sampled after two weeks and again after three months, in order to estimate their survival rate. The condition index, biochemical composition and reproductive condition of transplanted clams were compared with the same parameters of individuals from natural beds (control). Generally the physiological condition of clams was not affected by the transplanting method. Three months after transplanting, survival was significantly high. The differences found in mean survival rate between juveniles and adults (61% and 51%, respectively) suggest that juvenile transplantation can be more successful. These pilot experiments demonstrated that transplant could be a feasible and a successful strategy for enhancing *S. solida* populations. The increase of the local abundance of mature clams may lead to the success of fertilization and thus increase the residual reproductive value of each clam relatively to its pre-transplant value. Spawner transplant and seeding of juveniles will be used in Bivalve Restocking Programs, which, in conjunction with the establishment of closed areas, will contribute to the sustainability of *S. solida* fishery.

MOLECULAR CLONING OF A MOLLUSCAN GONADOTROPIN-RELEASING HORMONE RECEPTOR ORTHOLOGUE SPECIFICALLY EXPRESSED IN THE GONAD. F. Rodet, C. Lelong, M.P. Dubos, K. Costil and P. Favrel.

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Despite their economic importance, only very little information is available regarding (neuro) endocrine mechanisms of reproduction in bivalve molluscs. To gain insights into the molecular control of gonadic development of these animals, G protein-coupled receptors expressed in the gonad of the pacific oyster *Crassostrea gigas* were investigated. One such receptor was cloned by RT-PCR using oligonucleotide primers derived from consensus sequences of various vertebrate (neuro) peptide receptors. This receptor named Cg-GnRH-related receptor (Cg GnRH-R) exhibits 35%-27% of amino acid sequence identity with both vertebrate GnRH receptors and insect AKH receptors. A phylogenetic tree obviously exhibits two distinct groups: the vertebrate group and the protostomian invertebrate group, which suggests that there was only one ancestral receptor encoding gene before the divergence between Protostoma and Deuterostoma. In the protostomian lineage, Cg-GnRH-R clusters with the insect AKH receptor subgroup. Determination of tissue distribution of Cg-GnRH-R mRNA by real time quantitative RT-PCR shows a specific expression of Cg-GnRH-R in both male and female gonads during the reproductive cycle. In *C. gigas* gonad, Cg-GnRH-R mRNA displays a differential pattern of expression between male and female, with a higher expression in male gonads compared to female gonads at all stages of gametogenesis. The pattern of expression of Cg-GnRH-R in both sexes, similar to those observed for GnRH-R transcripts in various vertebrate gonads, suggests that Cg-GnRH-R cognate ligand achieves functions similar to those of vertebrate GnRHs as paracrine and autocrine regulators of vertebrate gametogenesis. Deorphanization of Cg-GnRH-R via the application of reverse endocrinology/pharmacology approaches will provide the first key regulatory (neuro) peptide coordinating the reproductive cycle in bivalve molluscs. Recently, two other GnRH-R-related members were identified in oyster. Screening of a genomic library pointed out that the three oyster GnRH-R related members are encoded by a single gene, which is alternatively spliced to generate these three receptors.

MORPHOLOGICAL AND FUNCTIONAL CHARACTERIZATION OF THE HAEMOCYTES OF THE SCALLOP, *CHLAMYS FARRERI*. W. Zhang,[1] X. Wu,[2] J. Sun[1] and D. Li[1]

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Light, transmission and scanning electron microscopical studies were carried out to characterize the haemocytes of the scallop *Chlamys farreri* (Jones & Preston). Five types of haemocytes were recognized according to cell size, granular features, and some structural and functional characteristics: type I small hyalinocytes, size of 2.44 ± 0.11μm, percentage of 45%-50%; type II large hyalinocytes, size of 4.83 ± 0.28μm, percentage of 15%-20%; type III small granulocytes, size of 4.07 ± 0.15μm, percentage of 15%-20%; type IV middle granulocytes, size of 7.20 ± 0.26μm, percentage of 20%-25%; type V large granulocytes, size of 13.87 ± 0.73μm, percentage of 3%-5%. Granulocyte types showed larger sizes and smaller N/C ratios than hyalinocytes. The mean haemocyte concentration of haemolymph was about 3.03 ±0.11 10^7 cells ml^{-1}. Different haemocyte counts identified that the haemocyte population contained 42.6% granular cells and 57.4% agranular cells. Three types of granules were distinguished: type I, with high electron-dense, type II,with low electron-dense and type III, with middle electron-dense. It was hypothesized that the type I granules might be phagocytosed foreign materials or internal waste materials; the type II granules might be primary lysosomes, probably originating in the Golgi complex or endoplasmic reticulum; and the type III granules might be secondary lysosomes, formed by fusion of two kinds of type II and type II granules. Both granulocytes and hyalinocytes showed phagocytic response to the two strains of bacteria, *E. coli* and rickettsia-like organisms. The phagocytic ability of granulocyte with 30%-40% was significantly higher than that of hyalinocyte with 4.8%-14%.

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