Département Océanographie et Dynamiques des Ecosystèmes
laboratoire : LER-MPL La Trinité-sur-mer

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Rapport de mission

14th International Conference on Shellfish Restoration, 23 - 27 août 2011, Stirling

Shellfish, our undervalued resource

Source : ***Gef Flimlin,*** *Professor/Marine Extension Agent, Rutgers Cooperative Extension, New Jersey USA*

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Résumé :

Cette conférence fait partie d'une série annuelle opérée depuis 26 ans, sous l'égide principalement de chercheurs et aménageurs de la côte Est des USA, sur le thème de la restauration des écosystèmes conchylicoles. Les Etats Unis et en particulier les Etats de la côte est ont en effet subi un effondrement drastique de la production conchylicole (huîtres, clams…), sous l'effet de la surexploitation et de la dégradation de la qualité d'eau (eutrophisation en particulier) : l'emblème de cet effondrement est la baie de Chesapeake, la plus vaste du pays (300 km). Des efforts financiers et humains considérables ont été engagés, au niveau fédéral et local, sans succès patent, ce qui témoigne de la difficulté intrinsèque à restaurer un écosystème dégradé et qui doit alerter sur l'importance d'actions préventives. La conscience des services écosystémiques rendus par ces gisements coquilliers notamment comme supports de biodiversité s'est étendue depuis, certains n'hésitant pas comparer l'enjeu de préservation de ces habitats coquilliers menacés à celui des récifs tropicaux ou même des forêts. C'est dans ce domaine des relations entre coquillages et environnement (clarification de l'eau et dénitrification, couplage entre compartiments pélagique et benthique, support d'habitat et de biodiversité…) que cette conférence fournit le plus d'informations d'intérêt.

Abstract :

The 14th International Conference on Shellfish Restoration (ICSR) comes this year to the United Kingdom for the first time in its 26 years history. The conference will be held at the University of Stirling in the heart of Scotland and its title and theme will be "Shellfish: our undervalued resource". The theme of the conference, "Shellfish: our undervalued resource", reflects the UK perception of shellfish as something that is good to eat, often in upmarket restaurants. Shellfish fisheries and aquaculture are indeed a very important part of the UK economy; shellfish reefs however form an ecosystem that provides myriad benefits ("ecosystem services") many of which have been lost through acute fishing pressures, disease, pollution and other factors. On a global scale, shellfish reefs are considered amongst the most threatened habitats. This conference hopes to change perceptions of the value of shellfish as a resource by bringing scientists from all over the world to discuss how we can learn from experience overseas, particularly in the USA, where there has been considerable investment and community-based efforts to restore and enhance shellfish populations.

Mots-clés : coquillages, restauration, récif, Chesapeake, Crassostrea, service écosystémique

Keywords :shellfish, restoration, reefs, Chesapeake, Wadden Sea, marine, *Crassostrea*

Commentaire : point de vue sur les services écosystémiques liés aux coquillages, et l'intérêt de préserver ou restaurer cette ressource

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Première partie : Identification de la mission

Objet : 14th International Conference on Shellfish Restoration, Stirling, 23-26 Août 2011 : *Shellfish: Our Undervalued Resource*

Dates : 23-26 août 2011

Lieu : Université de Stirling, Ecosse

Missionnaire : Joseph Mazurié

Programme : Projet Surmortalités, Action Risco A070209B

Confidentiel : Non

Organisme financeur : budget du projet (financement Région Bretagne)

Deuxième partie : rapport de mission

1. Résumé

Cette conférence fait partie d'une série annuelle opérée depuis 26 ans, sous l'égide principalement de chercheurs et aménageurs de la côte Est des USA, sur le thème de la restauration des écosystèmes conchylicoles. Les Etats Unis et en particulier les Etats de la côte est ont en effet subi un effondrement drastique de la production conchylicole (huîtres, clams…), sous l'effet de la surexploitation et de la dégradation de la qualité d'eau (eutrophisation en particulier) : l'emblème de cet effondrement est la baie de Chesapeake, la plus vaste du pays (300 km). Des efforts financiers et humains considérables ont été engagés, au niveau fédéral et local, sans succès patent, ce qui témoigne de la difficulté intrinsèque à restaurer un écosystème dégradé et qui doit alerter sur l'importance d'actions préventives. La conscience des services écosystémiques rendus par ces gisements coquilliers notamment comme supports de biodiversité s'est étendue depuis, certains n'hésitant pas comparer l'enjeu de préservation de ces habitats coquilliers menacés à celui des récifs tropicaux ou même des forêts. C'est dans ce domaine des relations entre coquillages et environnement (clarification de l'eau et dénitrification, couplage entre compartiments pélagique et benthique, support d'habitat et de biodiversité…) que cette conférence fournit le plus d'informations d'intérêt.

Mots clés : shellfish, restoration, reefs, Chesapeake, Wadden Sea, marine, Crassostrea

2. Cadrage

L'objectif

Cette conférence se tient annuellement depuis 26 ans. Elle repose sur le constat que les récifs de coquillages forment un écosystème qui procure une myriade de bénéfices («services écosystémiques »), dont beaucoup ont été perdus sous l'effet de la surpêche, de maladies, de pollutions ou d'autres facteurs. Au plan global, les récifs coquilliers sont considérés comme faisant partie des habitats les plus menacés. Cette conférence vise à changer les perceptions de la valeur de cette ressource en amenant les scientifiques de différentes parties du monde à partager leur expérience. La situation américaine est particulièrement instructive, car la destruction d'écosystèmes coquilliers a été massive sur la côte est, et des investissements considérables ont été engagés, assortis d'efforts de la communauté côtière dans son ensemble, pour restaurer et soutenir ces stocks coquilliers.

L'objectif général de cette mission était d'acquérir une vision plus large de ces services écosystémiques liés aux coquillages et des moyens de les préserver ou de les restaurer dans les sites dégradés. Plus concrètement, cette mission a permis de présenter et discuter d'un des volets du projet Risco (la restauration d'un bassin conchylicole en Baie de Quiberon) en rapport avec le thème général de la conférence, ceci sous un angle original

susceptible d'éveiller l'intérêt : l'aquaculture plutôt que les gisements naturels, et une pression naturelle liée aux prédateurs, plutôt qu'anthropique.

Enfin, toute participation à un colloque offre des opportunités de discussions et d'échanges susceptibles d'être valorisés dans le cadre de ses activités courantes à l'Institut.

Le déroulement

Les présentations sont consultables sur :

http://www.aqua.stir.ac.uk/shellfish2011/presentations

Elles se sont déroulées en 4 thèmes :

Theme 1: Evaluation of the habitat of restored and enhanced (artificial or man-made) shellfish reefs.

L'un des principaux services écosystémiques que procurent les assemblages denses de coquillages est la fourniture d'habitats, supports de nourriture, de nurserie et d'abris. En effet, l'abondance et la diversité d'organismes associés à ces habitats structurellement complexes excède souvent celles des habitats alentour constitués de sédiment mou. Des comparaisons de la faune associée entre récifs coquilliers et secteurs témoins permettent d'évaluer les bénéfices de la restauration et du maintien des habitats coquilliers. De telles évaluations sont présentées dans ce colloque.

Theme 2: Evaluation of ecosystem engineers in ecosystem restoration.

Cette session porte sur les aspects physiques de la restauration des récifs coquilliers, en termes de protection du littoral, modification de l'hydrodynamisme, accroissement de la sédimentation, et amélioration de la qualité de l'eau. Elle prend en compte différentes espèces de bivalves.

Theme 3: Restoration and management of mobile shellfish

Cette session traite plus spécifiquement des espèces mobiles telles que crabes, homards, coquilles St Jacques et crevettes, ainsi qu'éventuellement échinodermes et gastéropodes..

Theme 4: Focus workshop on oyster restoration in Europe – what can we learn from the USA experience?

Ce worshop sur les huîtres a inclu notamment les interactions entre *Crassostrea gigas* et *Ostrea edulis*, l'intérêt des actions entreprises par les communautés locales, ainsi que les risques de maladie : elle s'est appuyée en particulier sur les réussites et les échecs de l'expérience américaine.

L'agenda

Agenda at a glance

Tuesday 23 August 2011	
Throughout day	Golf or fishing can be organised
15.00-18.00	Arrival and Registration
18.30 –19.30	Whisky tasting provided by WoodWinters-£10pp-optional
19.30	Dinner served at the Abbey Craig Restaurant (for extra guests or those in chalet accommodation the cost for dinner is £24.00)
Wednesday 24 August 2011	
07.30 to 09.00	Registration
09.00 to 09.10	Opening Ceremony
9.10 to 10.30	**Theme 1: Evaluation of the habitat of restored and enhanced shellfish reefs.**
10.30 to 10.50	Coffee
10.50 to 12.30	Theme 1 continued
12.10 to 14.00	Lunch at the Abbey Craig Restaurant
14.00 to 15.40	**Theme 2: Evaluation of ecosystem engineers in ecosystem restoration.**
15.40 to 16.00	Tea
16.00 to 17.20	Theme 2 continued
18.00 to 19.00	Welcome drinks reception at Crush Hall, Pathfoot Building with Provost of Stirling.
19.30	Dinner served at the Abbey Craig Restaurant (NB Reserve a place for £24 if not already booked through conference at MC, or at ACD and AS Halls)
Thursday 25 August 2011	
07.30 to 09.00	Registration
9.00 to 10.40	**Theme 3: Restoration and Management of mobile shellfish**
10.40 to 11.00	Coffee
11.00 to 12.40	Theme 3 continued
12.40 to 14.00	Lunch at the Abbey Craig Restaurant
13.45	Field trip by coach and boat on the Firth of Forth. Or free to explore sites of Stirling
19.30	Dinner served at the Abbey Craig Restaurant
21.00 2nd coach leaves 17.15	Optional excursion into Edinburgh for the Military Tattoo provided bookings (£40 per person are made) (limited numbers). Free coach will leave straight from Boat Trip and return after event.
Friday 26 August 2011	
07.30 to 09.00	Registration
09.00 to 10.40	**Theme 4: All about oysters**
10.40 to 11.00	Coffee
11.00 to 12.20	Theme 4 continued
12.20 to 14.00	Lunch at the Abbey Craig Restaurant
14.00 to 15.40	Theme 4 continued
15.40 to 16.00	Tea
16.00 to 17.20	Theme 4 continued
19.00	Scottish gala conference dinner and ceilidh
Saturday 27 August 2011	
10.00	Check out

3. Bilan

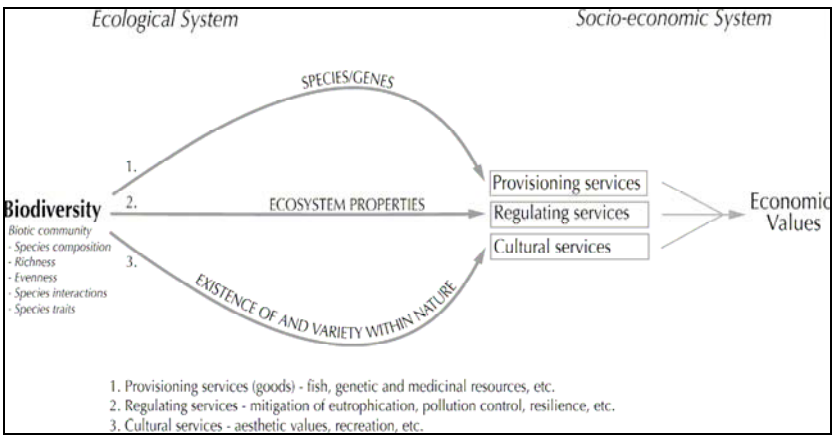
3.1. Les services écosystémiques liés à la présence des coquillages

Cette approche est issue du Millenium Ecosystem Assessment. Elle a été centrale durant ce congrès, dans la mesure où l'existence avérée de ces bénéfices à l'échelle écosystémique et pas seulement à l'échelle de secteurs de production (pêche et conchyliculture) est la justification-même des mesures de maintien ou de restauration des gisements ou élevages de coquillages. **Mark Spalding**, de l'Université de Cambridge (s'appuyant notamment sur Kirby, 2004 et Airoldi et al. 2007) a dressé un constat alarmant de la situation mondiale des récifs coquilliers (85% d'entre eux seraient en danger), comparable à celui les récifs tropicaux ou des forêts, et a plaidé pour une meilleure reconnaissance des services écosystémiques rendus. La perte d'habitats structurellement complexes, particulièrement en zone tempérée, tend à passer inaperçue, car le référentiel de chaque observateur se limite à quelques décennies : «the coastal and marine world is getting flatter» (Airoldi et al. 2008)

http://www.nature.org/ourinitiatives/habitats/oceanscoasts/explore/shellfish-reefs-at-risk.xml *(the Nature Conservancy)*

Ronnback et al. 2007 rappellent la distinction habituelle entre :

- services de production de biens (alimentaires…)
- services de régulation (de l'eutrophisation…)
- services culturaux (aesthétiques, récréatifs…)



Mel Austeen *(Plymouth, Angleterre)* met en avant, au titre des services écosystémiques, la nourriture (poissons et coquillages), la régulation des contraintes climatiques (séquestration de nutriments), les ressources génétiques, les technologies marines, la fertilisation, la protection des côtes, la détoxification (bio-remédiation) de certains polluants, le contrôle des maladies et de nuisances biologiques, des opportunités en faveur du tourisme et des loisirs. Les coquillages favoriseraient aussi la faune endogée et les bioturbateurs du sédiment. Des services indirects, non marchands et de non usage sont à ajouter. Les interactions entre différentes activités devraient être prises en compte.

D'autres auteurs mettent l'accent sur certaines de ces fonctions :

Farinas Franco *(Roy. Uni)* : développement de la biodiversité et notamment de la faune endogée, lié aux biodépôts des moules (*Modiolus modiolus*)

Lisa Kellogg *(USA, Virginie)* : fonction de dénitrification (N) et de séquestration des nutrients, en lien avec l'évolution des biodépots, particulièrement intéressante dans les sites eutrophes. Cerco et Noel (2010) évaluent à 14%- 40% pour le carbone, 11%- 23% pour l'azone, 37%- 84% pour le phosphore, la diminution de concentration sous l'effet des bivalves, dans certains secteurs de la baie de Chesapeake (Cerco et al. 2010). Piehler et al. (2011) ont évalué le potentiel de dénitrification selon les habitats.

C.Guy *(Irlande)* **:** diversité d'épibiontes sur les huîtres : 50 espèces ont pu être recensées (différentes pour *C.gigas* et *O.edulis*)

Luca Van Duren *(Pays Bas)* : rôle des coquillages, notamment épibenthiques en tant qu'architectes des écosystèmes (« ecosystem engineers »). Ainsi, les Pays-Bas s'intéressent-ils aux capacités des huîtres creuses à prévenir l'érosion des côtes, les risques d'inondation, et la perte de sédiment dans le détroit de l'Escaut (Oosterschelde).

Différents auteurs : clarification des eaux liée à la filtration : la production primaire (micro-algues) en est favorisée, malgré la diminution de la biomasse algale. L'effet serait dépendant de l'échelle considérée (micro-meso-macro). **Karin Troost** *(Pays-Bas)* souligne cependant la surexploitation du phytoplancton dans le détroit de l'Escaut, dont l'ensemble du volume est filtré en 7 jours. La baie de Chesapeake, filtrée autrefois 47 fois durant le temps de résidence, ne l'est plus qu'une fois aujourd'hui.

Dara H.Wilber *(USA)* décrit les effets négatifs de la sédimentation sur les récifs, sur les communautés résidentes, en particulier les crabes de vase et les moules.

Brenda Walles *(Pays Bas)* : montre l'intérêt de récifs d'huîtres creuses pour la stabilisation du sédiment et la défense contre l'érosion côtière.

Andreas Waser et **J.M. Jansen** *(Pays Bas)* : les gisements de moules favorisent l'alimentation des oiseaux (eiders, goélands, huîtriers-pie…) et des crabes : entre 5% et 50% des moules (selon les gisements) seraient ainsi la proie des oiseaux. Cette fonction entre en concurrence avec le prélèvement de jeunes moules opéré par la mytiliculture (35000 tonnes par an), aujourd'hui remis en question.

Robert Rheaut *(USA)* résume ces services : réduction des sels minéraux en excès (via dénitrification et séquestration de nutriments), amélioration de la qualité et transparence des eaux, richesse des habitats et biodiversité (soutien notamment des pêcheries de poissons).

P.Kingsley-Smith *(USA)* met en avant la fonction d'habitat au profit d'organismes nectoniques (nageurs), tels que crabes, crevettes et poissons, résidents ou de passage.

Steven Scyphers (Alabama) présente la contribution très significative de plusieurs types de récifs à l'augmentation de biomasse de différentes espèces : +297% pour les crabes bleux, +108% pour le « while red drum », +79% pour le flet…

Mark Spalding *(Roy. Uni)* développe ces évaluations chiffrées : 0.2 à 3.5 kg d'N dénitrifié par ha et par jour ; 2600 kg de poissons non récifaux par ha de récifs coquilliers.

3.2. Espèces et zones géographiques concernées

Les présentations les plus nombreuses ont porté : pour les USA sur les baies de la Côte Est ainsi que du Golfe du Mexique ; pour l'Europe, sur la Wadden Sea (Pays-Bas, Allemagne) et le Royaume Uni.

- **USA côte Est et Golfe du Mexique** :
  Crassostrea virginica

2/3 des eaux côtières seraient eutrophisées aux USA.

Baie de Chesapeake : Geret de Piper (USA)**,** présente le cas bien connu de la baie de Chesapeake, la plus grande baie des Etats Unis (Etats de Maryland, Virginie et Washington), frappée d'eutrophisation, avec une « zone morte » alarmante.

Louisiane : la pêcherie d'huîtres (7000 t, soit 40% des USA) est en déclin (Earl Melancon), du fait notamment des prédateurs, de la perte des zones humides, de la diversion de fleuves. Une restauration des stocks en zone intertidale vise aussi à contrôler l'érosion côtière particulièrement forte dans cette région.

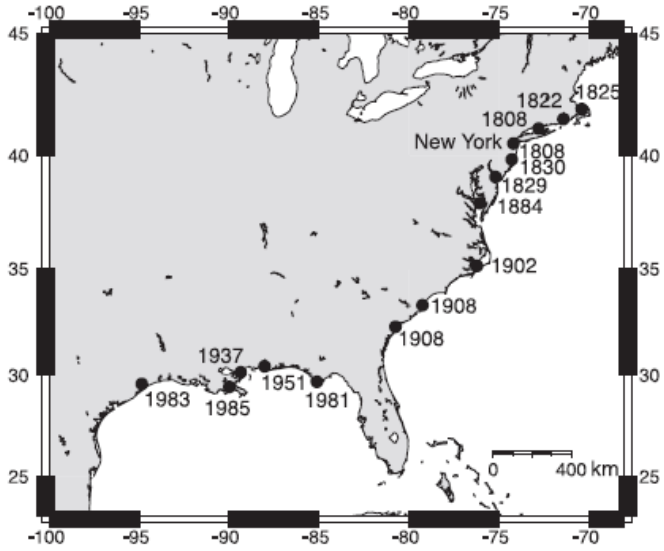


Fig. 2. Map showing linear expansion of exploitation of oyster reefs along eastern North America. Individual estuaries are labeled with the earliest date for reef degradation, as derived from landings data (peak in landings), earliest importation of nonendemic oysters to restock each estuary, and earliest use of dredges. The major urban center driving this exploitation is shown.

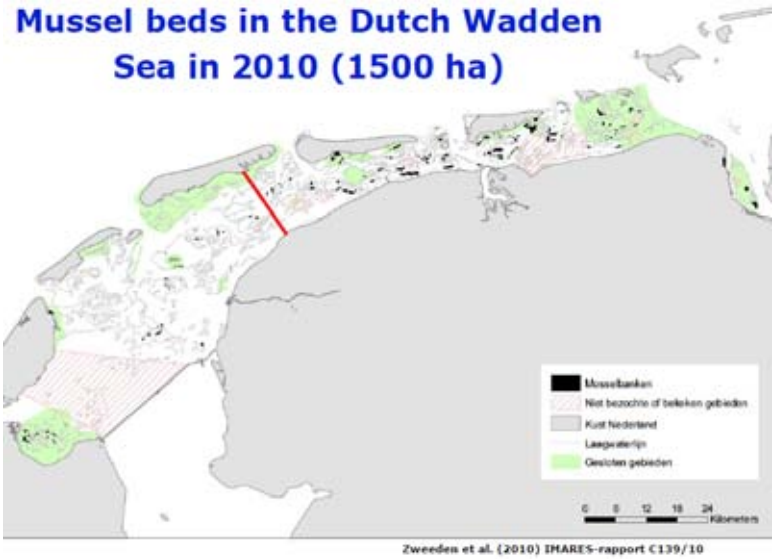
Source : M.X.Kirby, 2004 : http://www.pnas.org/content/101/35/13096.full.pdf+html

- **Europe** :
  Mytilus edulis, Modiolus modiolus, Crassostrea gigas, Ostrea edulis

  - **Pays-Bas** : *Mytilus edulis, Crassostrea gigas*

Les gisements de moules de **Wadden Sea** ont décliné entre 1930 (3000 ha ; taux naturel de couverture est de 2-4%) et 1990, où ils ont quasi disparu, pour remonter ensuite (1500 ha en 2010, représentant une biomasse de l'ordre de 60 000 tonnes) : les principales causes de déclin sont l'effort de pêche, la prédation (aviaire majoritairement), et les mortalités hivernales. Le réchauffement des eaux de 2°C, observé dans ce secteur a pu induire une prédation accrue par les étoiles de mer. Contrairement aux craintes, il a été montré que l'espèce invasive *C.gigas* ne se substituait pas aux moules, mais au contraire fournissait de nouveaux substrats propices à leur extension. Les études se développent notamment sous l'égide de la Wadden Academie.

Les fonctions de défense contre l'érosion côtière sont particulièrement appréciées aux Pays-Bas en particulier dans la région de l'Oosterschelde, qui héberge aujourd'hui 50 000 tonnes de moules indigènes et 300 000 tonnes d'huîtres invasives.



  - **Irlande du Nord :**

Essai réussi de construction de récifs surélevés, à base de Coquilles de pectinidés, afin de favoriser le recrutement de *Modiolus modiolus* (« horse mussel »), dont les effets bénéfiques sur la biodiversité ont été établis.

  - **Grande Bretagne :**

En Ecosse, la primauté est donnée à l'espèce indigène *Ostrea edulis*, au travers du « native oyster species action plan ». Des mesures d'estimation de la ressource, de nettoyage des anciens gisements et d'immersion de supports pour le captage sont entrepris dans le Loch Ryan. L'introduction de stocks résistants au Bonamia est envisagée (notamment à partir du captage opéré dans les bassins ouverts de Rossmore (Cork, Irlande). En Angleterre, une pêcherie d'huîtres plates autrefois très active, dans le Solent, au nord de l'île de Wight, fait l'objet d'études de restauration : la croissance est devenue très lente et la reproduction semble perturbée (proportion de femelles de moins de 20%, sans explication claire). Sarah Culloty rappelle l'histoire du déclin de l'huître plate suite aux épizooties, et des efforts de relance entrepris à l'échelle européenne (programme Oystercover)

- **France :** *Crassostrea gigas, Ostrea edulis, Mytilus edulis & galloprovincialis…*

En France, grand pays de conchyliculture en comparaison des pays nordiques ou anglo-saxons, ces enjeux de restauration de récifs coquilliers sont beaucoup moins présents. Comme ailleurs, les gisements côtiers de coquillages indigènes (huître plate par exemple) ont fait ou font d'objet de surexploitation. Mais ces stocks surpêchés ont été remplacés par des stocks en élevage, principalement de l'espèce introduite *C. gigas*. Qui plus est, cette espèce introduite s'est mise à proliférer, initialement aux abords des parcs d'élevage, puis plus largement. On peut alors considérer que « nos récifs coquilliers » sont les poches ou les suspensions d'huîtres et les bouchots à moules : peut-être leurs services écosystémiques mériteraient-ils d'être mieux évalués.

3.3. Méthodes de restauration

Plusieurs méthodes ont été testées, souvent à grande échelle, mais avec semble t'il un déficit d'évaluation scientifique, qui rend difficile une estimation précise des effets.

3.3.1. Limitation des captures

Mesure primordiale si le nombre de recrues apparaît limitant, appliquée par exemple dans la pêcherie d'huîtres plates en déclin du Loch Ryan (Ecosse) : capture maximale de 5% du stock.

- Reconstitution d'habitats

Quand le recrutement semble limité par les supports de captage, l'introduction de collecteurs additionnels (notamment de coquilles de bivalves) est la mesure la plus simple et la plus efficace. Ceci est pratiqué à grande échelle aux USA, à la fois sur estran et en zone subtidale. Des essais couronnés de succès ont été entrepris ailleurs, par exemple en Irlande, en support à la modiole. Les habitats en 3 dimensions (s'élevant au-dessus du sol) semblent les plus efficaces.

- Introduction de géniteurs et amélioration génétique

Jens Carlsson et Ryan Carnegie rappellent les difficultés rencontrées dans la tentative d'introduire une souche de *Crassostrea virginica* (souche DEBY) sélectionnée pour sa résistance au MSX (haplosporidie) et Dermo (Perkinsus) : les gènes sélectionnés semblent s'être très peu répandus dans les stocks naturels (moins de 2% ?). En Nouvelle Zélande, un programme de réintroduction de géniteurs et de juvéniles d'*Haliotis iris* vise à soutenir la pêcherie d'ormeaux, avec une évaluation des effets génétiques sur la population sauvage

- Introduction de juvéniles

Steven Allen (USA Maryland) et K.T. Paynter ont présenté les actions pluriannuelles de semis de naissain de *C. virginica* indemne de maladies, dans une partie de la baie de Chesapeake : 3 milliards de naissains ont déjà été introduits, et 2 milliards par an sont prévus au cours des années prochaines. Les sites sont identifiées par des campagnes de caractérisation des fonds au sonar latéral et en plongée. Pour que la proportion de femelles atteigne un niveau suffisant (20% à 1 an, 60% à 5 ans), le stock de géniteurs

doit être maintenu en place plusieurs années. En Nouvelle-Zélande, des introductions de juvéniles d'ormeaux *Haliotis iris* sont en cours.

- Interdiction ou développement de l'aquaculture

Aux Pays-Bas, les protecteurs de la nature et les mytiliculteurs se sont mis d'accord pour une réduction progressive de la capture de juvéniles de moules sur les gisements de Wadden Sea (transférés pour l'élevage dans l'estuaire de l'Escaut), afin de préserver la source alimentaire des oiseaux.

Dans plusieurs Etats américains, l'aquaculture est aujourd'hui perçue comme une alternative à la restauration des gisements naturels,.

S.M.Ray *(Texas, USA),* devant les difficultés de restauration des stocks sauvages (Etat du Maryland) préconise l'approche aquacole qui a montré quelque succès en Virginie.

Robert Rheaut, président de l'association des conchyliculteurs de la côte Est des USA (ECSGA), déclare que les coquillages cultivés fournissent pour l'essentiel les mêmes services que les coquillages de gisement. Selon lui, les cages d'élevage qui miment l'habitat de poissons en attireraient autant que les herbiers. Il rappelle en outre que la conchyliculture est l'une des sources de protéines qui impactent le moins l'environnement. Il plaide pour le paiement de ces services écosystémiques aux éleveurs, ou au moins pour que ces services favorisent l'octroi de concessions (aujourd'hui très difficile). Par rapport aux gisements naturels inexploités, l'aquaculture procurerait des bénéfices additionnels tels que (1) extraction pérenne de matière organique et minérale, au moment de la récolte : une huître = 0.1 à 0.5 g N et 0.02 à 0.16 g P : 300 kg d'huîtres extrairaient la production azotée d'une personne par an ; (2) absence d'investissement public et (3) fourniture d'emplois et de nourriture.

- Implication du public

Gef Flimlin (New Jersey) a illustré par de multiples exemples la manière dont le grand public, les scolaires, des volontaires… ont été impliqués dans des opérations locales de réhabilitation de l'environnement et de soutien à différentes espèces (clams, pectinidés, huîtres…) autrefois florissantes : contrôle de la qualité de l'eau, pose de collecteurs, implication dans les nurseries publiques, opérations de communication (exemples en couverture)…

- Rétribution des services écosystémiques, marché des nutriments

Doug Lipton (Maryland, USA) signale qu'à partir de la réglementation instaurée en baie de Chesapeake, sur la charge maximale de rejets en nutriments, une réflexion s'est engagée dans les Etats riverains, pour ouvrir un marché des nutriments et une rétribution éventuelle des services écosystémiques au profit notamment des conchyliculteurs.

3.4. Projets et efforts financiers de restauration

Quelques exemples :

Aux USA, dans les Etats de la Côte Est et du Golfe du Mexique (Louisiane, Alabama), des efforts considérables sont engagés pour implanter des barrières récifales, intertidales (25 M dollars en Louisiane pour disposer des structures à la côte) ou pour restaurer des gisements subtidaux (baie de Chesapeake). Pour la restauration de cette seule baie, on a dénombré 3487 meetings. Cependant, peu de projets ont des objectifs clairement établis. Des estimations des fonds engagés ont été fournies par M.Spalding : NOAA : 53 millions $, US Army : 20 millions $, ONGs (centaines de volontaires…) ; American Recovery and Restoration Act 2009.

Aux **Pays Bas** 20 « bed programs » sont engagés pour mieux connaître l'évolution des gisements de moule de Wadden Sea et leur lien avec les peuplements aviaires.

En **Nouvelle-Zélande**, un effort de repeuplement en ormeaux *Haliotis iris*, est opéré, à partir de juvéniles d'écloseries, pour soutenir la pêcherie (C.A. annuel de 50 millions de dollars).

3.5. Discussion : effets uniquement positifs ?

On note dans cette conférence, un parti pris nettement favorable aux coquillages, dont la présence n'aurait que des effets positifs sur les écosystèmes. Pourtant, selon Cranford et al (2011, in press), la culture des mollusques bivalves et les structures d'élevage associées ont le potentiel d'impacter l'environnement, de différentes manières, à la fois positives et négatives. L'effet positif essentiel sur l'environnement serait de soutien à la biodiversité lié à l'ajout de structures biotiques et abiotiques et à la capacité des bivalves de clarifier la colonne d'eau. Par contre, la consommation de particules en suspension particulièrement le phytoplancton, les modifications de la dynamique des nutriments liées à l'excrétion azotée et le recyclage de déchets organiques, et les effets liés au transfert de matière en suspension du compartiment pélagique au compartiment benthique, sont classées au rang d'effets négatifs. En réalité, le caractère positif ou négatif de ces effets dépend largement de l'écosystème où il s'exerce et en particulier des facteurs qui contrôlent la consommation de nourriture (intensité de l'élevage…) et la production de déchets (facteurs physiques tels que l'hydrodynamisme).

Le point soulevé par Cranford et al. (2011) sur l'intensivité des élevages apparaît comme la cause essentielle de différence de perception entre écosystèmes sous-peuplés (surpêchés…) où l'addition de coquillages a d'abord des effets positifs et écosystèmes surpeuplés en coquillages, où les effets négatifs peuvent l'emporter.

Quelques affirmations émises lors de cette conférence mériteraient donc d'être relativisées :

(1) « En consommant le phytoplancton, les filtreurs suppriment l'accumulation de matière organique dans les estuaires…, qui peut les prédisposer à l'hypoxie, les efflorescences d'algues toxiques, les maladies parasitaires, et autres symptômes de détérioration environnementale » (Michael Xavier Kirby, 2004).

Commentaire : certes, mais la matière organique soutirée de la colonne d'eau tend à s'accumuler sur le fond (dépendant des courants), avec de possibles effets négatifs

(2) Selon la société « Aquaculture Carbon Limited » (Nouvelle Zélande) (http://www.aquaculturecarbon.com), l'aquaculture des mollusques et des crustacés induit une séquestration de Carbone.

Commentaire : pourtant, en vertu de la réaction de calcification rappelée ci-dessous, la calcification se traduit par une libération de CO_2 dans la colonne d'eau. Dans les conditions actuelles, la libération CO_2 est de 0.6 mole par mole de CaCO3 précipité (Gattuso, 1994). $Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$

3.6. Références

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4. ANNEXE

Technical Programme

Aims and Themes

The overall aim of the conference is to highlight the wider value of shellfish in the environment and we have sought papers that reflect this greater value of shellfish resources and their ecosystem services.
Conference sessions will focus on the following four programme theme areas;

Theme 1: Evaluation of the habitat of restored and enhanced (artificial or man-made) shellfish reefs.

One of the principal ecosystem services supported by dense assemblages of shellfish is the provision of habitat that provides food, nursery and shelter. As such the abundance and diversity of organisms associated with these structurally-complex habitats often exceeds that of surrounding soft sediment habitats. Comparisons of associated fauna can therefore be used as a metric of the success and value of restored and enhanced shellfish habitats. Such studies that include the evaluation of these fauna and reef types will be presented here.

Theme 2: Evaluation of ecosystem engineers in ecosystem restoration.

This session will focus on the physical aspects of shellfish restoration in terms of shoreline protection, altered hydrodynamics, increased sedimentation and improvements in water quality. Shellfish restoration, enhancement and management in this session will include a number of different species of bivalves.

Theme 3: Restoration and management of mobile shellfish.

This session will focus on the more mobile shellfish such as crabs, lobsters, scallops and shrimp. However, papers will also be accepted for echinoderms and gastropod molluscs.

Theme 4: Focus workshop on oyster restoration in Europe – what can we learn from the USA experience?

The oyster workshop will take a broad view including possible interactions between *Crassostrea gigas* and *Ostrea edulis* (or their equivalents), the value of community actions, and disease risks but will cover some of the benefits and pitfalls from the US experience.

Schedule of Presentations and Activities

Tuesday 23 August 2011	
15.00-18.00	Arrival and Registration
18.30-19.30	Whisky tasting arranged by WoodWinter £10pp in Management Centre (optional)
19.30	Dinner served at Abbey Craig Restaurant (For extra guests or those in chalet accommodation the cost for dinner is £24.00)
Wednesday 24 August 2011	
07.30-09.00	Registration and full Scottish breakfast; in Management Centre or Pathfoot for those in halls
09.00 -09.10	Opening Ceremony
Session 1	**Theme 1 Evaluation of the habitat of restored and enhanced shellfish reefs.**
9.10-9.50	**Keynote Speaker Melanie Austen** Ecosystem services – adding value to shellfish resources.
9.50-10.10	**Doug Lipton** Payment for Ecosystem Services From Shellfish Restoration: Examples From Chesapeake Bay.
10.10-10.30	**Earl J. Melancon** The Importance of Constructed and Natural Intertidal Oyster Reefs to the Future of the Subtidal Oyster Fishery in Louisiana, USA, as it Relates to Coastal Wetlands Restoration.
10.30-10.50	Coffee
10.50-11.10	**Jose Fariñas-Franco** Temporal changes in biotic communities on artificial reefs deployed for the regeneration of *Modiolus modiolus* biogenic reefs in Strangford Lough, Northern Ireland.
11.10-11.30	**Rayner Piper** Shellfish populations within the Eastern English Channel Dredging Licence Areas. Confounding factors 5 years on.
11.30-11.50	**Lisa Kellogg** Bivalve restoration and aquaculture: The role of associated organisms in enhancing ecosystem services
11.50-12.10	**Dai Roberts** The world is their oyster: Differences in epibiota on sympatric populations of native (*Ostrea edulis*) and non-native (*Crassostrea gigas*) oysters.
12.10-12.30	**Michelle Price-Hayward** Sanitary surveys in the Scottish context – a tool for informing site selection and optimisation of water quality.
12.30-14.00	Lunch at the Abbey Craig Restaurant
Session 2	**Theme 2 Evaluation of ecosystem engineers in ecosystem restoration.**
14.00-14.40	**Keynote Speaker Luca van Duren** Shellfish as ecosystem engineers: small-scale processes and large-scale consequences.
14.40-15.00	**Norbert Dankers** The wane and wax of intertidal mussel-beds in the Dutch Wadden Sea.
15.00-15.20	**Jasper Donker** Predicting survival chances of mussel beds using hydrodynamical models calibrated by field measurements.
15.20-15.40	**Dara H. Wilber** Sedimentation impacts on restored intertidal oyster reefs in South Carolina, US and the implications for secondary consumers.
15.40-16.00	Tea
16.00-16.20	**Brenda Walles** The use of an ecosystem engineer in coastal defense.
16.20-16.40	**A.M. Waser** The role of littoral mussel beds of different size and age for birds and shore crabs.
16.40-17.00	**Jeroen M. Jansen** The fate of ephemeral structures in the Wadden Sea: exploitation, protection and reconstruction of sublittoral musselbeds.
17.00-17.20	**Karin Troost** Changes induced by expansion of the ecosystem engineer and invasive species *Crassostrea gigas* in continental NW European estuaries.
18.00-	Welcome drinks reception at Crush Hall, Pathfoot Building with Provost of Stirling.
19.30	Dinner at Abbey Craig restaurant (NB Reserve a place for £24 if not already booked through conference at MC, or at ACD and AS Halls)

Schedule of Presentations and Activities continued

Thursday 25 August 2011	
Session 3 Theme 3 Restoration and Management of mobile shellfish Chair Dai Roberts	
9.00-9.40	**Keynote Speaker Robert Rheault** Ecosystem services rendered by Shellfish Aquaculture.
9.40-10.00	**Tom McCowan** Genetic Approaches to Reseeding in New Zealand's Blackfoot pāua (*Haliotis iris*)
10.00-10.20	**Christopher Hepburn** Pathways to fisheries restoration: community management, science and traditional Ecological Knowledge
10.20-10.40	**Posters session** Introductions to the poster presentations; two minutes to explain why your poster has to be seen!
10.40-11.00	Coffee
11.00-11.20	**Peter Kingsley-Smith** The role of oyster reefs in the provision of habitat for diverse assemblages of nektonic organisms with varied life history strategies
11.20-11.40	**Steven Scyphers** How does oyster reef design and setting affect fish community structure in the Northern Gulf of Mexico
11.40-12.00	**Bruno Ens** Bird Predation on intertidal mussel beds
12.00-12.20	**Alvares G. F. Benga** Traditional exploitation and wise skills' management of a bivalve: *Anadara senilis* L. (1758) in the Saloum Delta.
12.20-12.40	**Iratxe Menchaca** Subtidal edible sea urchin (*Paracentrotus lividus*) populations in the Basque Country (Northern Spain). Facing the future exploitation.
12.40-14.00	Lunch at the Abbey Craig Restaurant
13.45	Departure for field trip by coach and boat on the Firth of Forth, discussions, or free to explore sites of Stirling.
17.15	Departure of coach for collecting delegates from field trip and delivery to Edinburgh for tattoo.
18.15	One coach leaves from South Queensferry to Stirling and one coach takes us to Edinburgh
19.30	Dinner at Abbey Craig Restaurant for those not going to Tattoo
Evening see timings above	Optional excursion into Edinburgh for the Military Tattoo provided bookings £40 per person are made (limited numbers). Free coach will leave straight from Boat Trip and return after event.

Schedule of Presentations and Activities
continued

Friday 26 August 2011	
Session 4 Theme 4 All about oysters Chair Peter Kingsley-Smith	
9.00-9.40	**Keynote Speaker Mark Spalding** Rediscovering baselines and rebuilding reefs – understanding the challenges of ecosystem-scale restoration in North America.
9.40-10.00	**Mark Luckenbach** 20 years of oyster restoration in the Chesapeake Bay USA What we have learnt and where we go from here?
10.00-10.20	**Steven Allen** Large scale Hatchery based oyster restoration in the Maryland portion of the Chesapeake I: Overview and goals
1020- 10.40	**Kennedy Paynter** Large scale hatchery based oyster restoration in the Maryland portion of the Chesapeake II: Results and Progress.
10.40-11.00	Coffee
11.00-11.20	**Sammy Ray** Shellfish reef restorers: adjusts goals to current, not by-gone conditions.
11.20-11.40	**Francis O'Beirn** Environmental factors that influence the local establishment of Pacific oysters: modeling occurrence data from a coordinated sampling programme.
11.40-12.00	**Tristan Hugh-Jones** Loch Ryan oyster beds (*Ostrea edulis)* Scotland
12.00-12.20	**Lisa Kamphausen**, Restoration potential of a wild *Ostrea edulis* fishery with a very low proportion of female phase oysters
12.20-14.00	Lunch at the Abbey Craig Restaurant
Session 5 Theme 4 continued Chair Mark Luckenbach	
14.00-14.40	**Keynote Speaker Sarah Culloty** Conservation of the Native European Oyster *Ostrea edulis* through control of its main pathogen *Bonamia ostreae*
14.40-15.00	**Jens Carlsson** The use of genetics in oyster restoration
15.00-15.20	**Ryan Carnegie** Confronting disease in oyster restoration: the case of *Crassostrea virginica* in Chesapeake Bay, USA.
15.20-15.40	**Kimberley Reece** Genetic Monitoring of Selectively Bred oysters deployed for broodstock enhancement in a Chesapeake Bay Tributary
15.40-16.00	Tea
16.00-16.20	**Hein Sas**, Spreading and ecological function of the Pacific oyster *(Crassostrea gigas)* in the Dutch Wadden Sea.
16.20-16.40	**Joseph Mazurie** Towards restoration of endangered oyster aquaculture in a French subtidal bay through control of predators.
16.40-17.20	**Closing Keynote Speaker Gef Flimlin** Putting the Bight in Shellfish
19.00	Drinks served prior to dinner
19.30	Scottish gala conference dinner and ceilidh. Abbey Craig Restaurant
Saturday 27 August 2011	
08.00 to 10.00	Full Scottish Breakfast at the Abbey Craig restaurant or Pathfoot for those in campus accomodation
10.00	Check out

Abstracts of plenary speaker talks in alphabetical order

Steven Allen*[1], Kennedy T. Paynter Jr. [2,3], Stephan Abel[1], Don Meritt[4]
[1]Oyster Recovery Partnership, Annapolis, MD, USA, [2]Department of Biology, University of Maryland, College Park, MD, USA, [3]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD, USA, [4]Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, MD, USA

Large Scale Hatchery Based Oyster Restoration in the Maryland portion of the Chesapeake I: Overview and Goals

With oyster populations in the Maryland portion of the Chesapeake Bay at critically low levels, restoration activities have been undertaken to rebuild reefs with hatchery-produced seed. Since 1994, the Oyster Recovery Partnership (ORP) has worked together with its partners to steadily build Maryland's oyster restoration capabilities and capacity. As a result since 2000, the Maryland has produced and planted nearly 3 billion spat on shell on over 1,400 acres. With the announcement of President Obama's Executive Order 13508, an expanded effort for restoration is underway. Working with our partners both State, Federal and academic agencies, as well as not for profit groups, Maryland watermen and volunteers, we constantly refining our methodology to improve the efficiency and effectiveness of oyster recovery efforts. Relying on past methods and coupling them with state of the art technologies, we are now gleaning a better understanding of our recovery efforts and their ecological and economic ramifications and learning from both our successes and failures.

Alvares G. F. Benga
Geography Department, Université de Ziguinchor, Associated researcher / Biogeography Laboratory, Geography Department, Université Cheikh Anta DIOP de Dakar

Traditional exploitation and wise skills' management of a bivalve: *Anadara senilis* L. (1758) in the Saloum Delta

In the Saloum Delta, live the islander people called niominka. Centuries passing by, women of this farmers fishermen community have conceived unsuspected techniques of exploiting and valorizing mollusks. Owing to its availability, *Anadara senilis* L. (1758) is the most exploited This activity is a real source of financial income for them in the sense that it plays an important role in the cultural and socio-economic levels in a country characterized by a multidimensional crisis. A certain specificity characterizes the collecting of the bloody cockle. Unlike many living resources which exploitation is regulated by the law on state property, the collection of this resource demands an expertise. It is practiced in an area where the traditional system on property is still in force.

The crisis of agrarian systems consequence of the climatic changes has imposed new realities which have generated the development of new practices. The demographic boom, the wind of migration and the economic crisis have increased the pressure on the tidal reservoirs in search of *A. senilis* L. (1758) to the extent that many authors fear an overexploitation in view of the extraction rate. Yet, unlike the appearances, certain fundamental natural, cultural and economic determining factors combine to control discreetly but surely the exploitation of this resource. They could make it possible to demolish these pessimistic arguments and lead to their relativization. These reasons do not also prevent initiatives for biological rest to support the production.

Ryan B. Carnegie
Virginia Institute of Marine Science, College of William & Mary, P.O. Box 1346, Gloucester Point, VA 23062, USA

Confronting disease in oyster restoration: the case of *Crassostrea virginica* in Chesapeake Bay, USA

Diseases frequently loom as impediments to restoration of natural oyster populations. Overcoming disease is a fundamental restoration challenge. Recently in the Chesapeake Bay region of the eastern USA, where parasites *Perkinsus marinus* and *Haplosporidium nelsoni* infect oyster *Crassostrea virginica*, consideration has been given to introducing a non-native oyster species, and to the restoration application of domesticated, disease-resistant native oyster lines, to avoid disease effects. Significant drawbacks to both strategies led to their abandonment. More recently, it has been suggested that restoration efforts should focus on reefs in lower salinities, which inhibit diseases. It has been assumed that reproduction by oysters in low-salinity refugia supports oyster populations in disease-intense waters of higher salinity, where oysters are thought to be too diseased to reproduce.

Mounting evidence suggests, however, that oysters in disease-intense waters are increasingly resistant to *P. marinus* and *H. nelsoni*, fully reproductive, and probably more important than oysters adapted to low-salinity waters for maintenance of the populations as a whole. This argues for specifically focusing restoration in waters where disease pressure is greatest, in recognition of the reproductive value of oysters in these waters and to promote the deepening of disease resistance. This strategy is increasingly being advocated and adopted.

Jens Carlsson, Tom F Cross, Sarah C Culloty
School of Biological, Earth and Environmental Sciences/Aquaculture and Fisheries Development Centre, University College Cork, Distillery Fields, North Mall, Cork, Ireland

The use of genetics in oyster restoration

Many of the world's shellfish stocks have been severely impacted by overfishing, diseases and habitat degradation. For instance, overfishing and fishing methods (altering habitats) and, more recently, diseases have devastated the native Eastern oysters (*Crassostrea virginica*) and the associated industry in the Chesapeake Bay and elsewhere along the US eastern Seaboard. Similarly, the native flat oyster (*Ostrea edulis*) stock in Europe has experienced a collapse in census numbers across its native range, caused by disease and overfishing, and now the industry is severely hampered. The severely depleted stocks of shellfish have led to a number of research projects and restoration efforts, ranging from disease mitigation to habitat, fisheries and stock restoration. Genetics is a valuable tool that can help elucidating causes for diseases including detecting genetic differences among strains/populations in disease causing organisms and agents and for disease diagnostics (real time PCR and species/strain/population identification). In addition, genetics is the only available tool for inferring population structure, which enables identification of management/conservation units. Many of the restoration efforts are focused on restoring census number through supportive breeding of native strains of wild origin or deployment of aquaculture selected "disease tolerant" strains/lines. Genetics is an invaluable tool for monitoring how these strains/lines are performing (e.g. survival and growth in the wild environment), and is the only available tool to ascertain if deployed shellfish are reproducing in the wild and enables

Abstracts of plenary speaker talks in alphabetical order—continued

estimations of reproductive success. Here we outline how genetics has been and can be used in shellfish restoration efforts with specific focuses on the American Eastern oyster and the European flat oyster.

Jan F. Cordes and **Kimberly S. Reece**
Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA, USA 23062

Genetic Monitoring of Selectively Bred Oysters Deployed for Broodstock Enhancement in a Chesapeake Bay Tributary

One strategy employed for oyster restoration in Chesapeake Bay, USA is the addition of selectively-bred or wild-derived oysters produced in hatcheries onto reefs to serve as spawning stock. During 2005-2006 there was a large-scale deployment of oysters selectively bred for resistance to parasitic diseases to a bare, historic oyster reef in the Great Wicomico River, Virginia. Previous genetic studies conducted using both mitochondrial and nuclear genetic markers suggested that these oysters contributed little to the genetic make-up of spat collected in 2007 at sites surrounding the deployment reef. There are several possible reasons for this relatively low genetic contribution including predation (low survival), poor adaptation of the hatchery stocks to the natural environment (low reproductive/recruitment success), or insufficient temporal sampling following the deployments (experimental error). Therefore, we undertook additional analyses including determination of persistence of deployed oysters on the restored reef, an estimation of the number of oysters on neighboring reefs derived from deployed animals, and additional sampling of adults and sub-adults at a later time (2009) at more distant sites to determine the longer-term recruitment contribution to the system. Approximately 40% of deployed animals persisted on the restored reef. Analyses of the additional oysters collected from surrounding sites and from throughout the system are ongoing and results of these analyses will be presented.

Norbert Dankers, Frouke Fey, Jeroen Jansen, Arno Kangeri (Imares) and Jaap van der Meer
(Royal NIOZ), Texel

The wane and wax of intertidal mussel-beds in the Dutch Wadden Sea; *hypothesis development for an integrated research project*

Intertidal musselbeds almost completely disappeared in 1991. Several attempts were undertaken in order to restore them, but these failed. Some good spatfalls increased the area of beds again to above 2000 hectares but in recent years the area is decreasing again. The low acreage is most prominent in the western part of the Wadden Sea.

Before new attempts for restoration are undertaken the factors which are responsible for survival have to be clear. The beds have been studied since the earliest development in the 1990ties. From all (more than 100) beds general information (areal size, biomass, location) is available for a period of 15 years. For a limited number very detailed information on size, exact boundary, location, percentage cover and population and community characteristics is available for the same period. The data will be presented and hypothesis developed on the major factors which influence survival of beds of different ages. Results are available of beds ranging in age between 1 and 17 years. They indicate that about half of the area of seed beds disappears in their first year. After the first year the decrease in area slows down and many beds maintain themselves by spatfall within the bed, even in years when spatfall outside the bed is minimal. In general, beds deteriorate further until a major spatfall rejuvenates them. Patch formation is prominent, and older beds show a clear pattern of hummocks rising well above the surrounding area or channels draining the bed. It is hypothesised that storm events, build-up of substrate and predation are the major factors responsible for deterioration.

Based on the hypotheses an integrated research project has started in which physical factors (wave and currents), biological characteristics (mussel population dynamics, byssus strength, substrate characteristics, patch formation) and predation pressure (by birds and crabs) will be studied

Jasper Donker, Maarten van der Vegt, Piet Hoekstra
Department of Physical Geography, Utrecht University

Predicting survival chances of mussel beds using hydrodynamical models calibrated by field measurements.

The Mosselwad project, studies the stability and opportunities for restoration of mussel beds in the Wadden Sea. In this context we seek to predict mussel bed stability with respect to hydrodynamic forcing. To make accurate predictions with models, field experiments are needed to determine relevant processes and to establish representative estimates for model parameters. To determine these parameters a six week campaign was performed on a relatively young mussel bed in the Wadden Sea. During this period wave height, period, propagation velocity, dissipation and currents were measured. From these measurements the wave energy dissipation rate is determined, which is subsequently used to estimate the bed-shear stress and friction parameters. Results show that bed friction, due to the absence of wave breaking, is the dominant process for wave dissipation. The bed friction parameter is found to be 5 times larger than on an uncovered flat. Results of the field experiments are used to calibrate a wave model (SWAN). The calibrated model is subsequently used to make predictions of bed-shear stresses on mussel beds during stronger wind conditions than observed. Model results show that area's where mussels have disappeared were subjected to the largest bed-shear stresses.

Bruno J. Ens[1], Jaap van der Meer[2], Andreas Waser[2]
[1] SOVON [2]NIOZ

Bird predation on intertidal mussel beds

Around 1990, intertidal mussel beds were heavily overfished and disappeared almost completely from the Dutch Wadden Sea. A new fishery policy in 1993 restricted fishery on intertidal mussel beds and as a result the beds gradually reappeared. However, restoration of intertidal beds was mostly restricted to the eastern part of the Dutch Wadden Sea and very few beds reappeared in the western part of the Dutch Wadden Sea. As part of a major project on mussel bed restoration, called "Mosselwad", we investigate the probable cause of this discrepancy. In particular, we investigate the hypothesis that bird predation on mussel beds is much higher in the western part of the Dutch Wadden Sea compared to the eastern part of the Dutch Wadden Sea. To this end we review the literature on mussel predation by birds and the processes governing the intensity of predation. For Oystercatchers, we can employ a model that calculates predation pressures on different stocks of shellfish on the basis of Oystercatcher counts, data on tide and weather, and Wadden Sea wide shellfish surveys. Finally, we will present the first results of measurements on bird predation under current conditions.

Abstracts of plenary speaker talks in alphabetical order—continued

Jose M. Fariñas-Franco[1], D. Roberts[2], D. Smyth[3], A.M. Mahon, E. Gorman[1], and L. Kregting[1]
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Temporal changes in biotic communities on artificial reefs deployed for the regeneration of *Modiolus modiolus* biogenic reefs in Strangford Lough, Northern Ireland

In 2009 the MRRG constructed an experimental artificial reef in Strangford Lough, Northern Ireland as part of trials to regenerate biogenic reefs of the horse mussel, *M. modiolus*, which had been impacted by dredging. The aim of the study was to test the hypotheses that the artificial reef would accelerate succession, enhance natural recruitment of *M. modiolus* spat, and that these effects would be greater on elevated cultch. The reef was constructed using king scallop *Pecten maximus* shell as cultch and adult *M. modiolus* collected locally were re-laid over experimental plots within the reef. Experimental plots consisted of elevated and non-elevated cultch; mussels re-laid on unmodified substratum served as controls. After six months dive monitoring surveys revealed high survival rates in the translocated mussels which formed tight clumps in the different treatments. Pseudo-faeces and sediment accumulated in the crevices increasing habitat complexity and attracting numerous species to an otherwise barren area within the historic range of *M. modiolus*. This presentation provides a progress report on the experiment describing the effect of elevation on mussel survival, faunal assemblage succession and natural recruitment.

Christopher Hepburn[1], Stephen Wing[1] Henrik Moller[2], Nigel Scott[3]
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Pathways to fisheries restoration: community management, science and Traditional Ecological Knowledge

A multidisciplinary, cross-cultural approach was used to inform a strategy for how to restore the black-foot abalone or pāua (*Haliotis iris*). This is a 'cultural keystone' species for Māori (New Zealand's Indigenous people) and provides a significant commercial and recreational fishery. An alarming collapse of readily available abalone on the intertidal and shallow subtidal zones has led to changes in local community-led fishery closures and reduced catch limits. Some customary abalone fisheries will likely be unable, or slow to recover without reseeding with juvenile abalone raised in aquaculture facilities. Proposed reseeding programmes will be focussed on key local areas and rely on an understanding of the ecology of juvenile abalone stages from a combination of Traditional Ecological Knowledge of Māori, marine science and state-of-the-art technology to raise pāua and test the efficacy of different reseeding techniques. Targeted reseeding programmes where the fishery is managed at scales more appropriate to abalone life history and to local management of stocks could play a major role in restoring abalone fisheries in New Zealand for all stakeholders.

Tristan Hugh-Jones
The Loch Ryan Oyster Fishery Co Ltd, The Thatched Cottage, Penberth, St Buryan, Penzance, Cornwall, TR19 6HJ

Loch Ryan Oyster Beds (*Ostrea edulis*), Scotland

The Loch Ryan Oyster Beds, in South West Scotland, have been actively farmed since they were presented to the Wallace family by King William III in 1701. The oyster beds have had a "boom and bust" history, from about 110,000 dozen (130,000Kg) harvested in 1910, to being closed due to over fishing in 1958. Since 1996, the Loch Ryan Beds came under the control of David and Tristan Hugh-Jones who have been actively restoring them using aquacultural techniques developed over the last 32 years.

In 1996 a programme of only harvesting the largest 5% of the crop was started, and the smallest 95% of the crop were re-laid densely into small areas, to explore the growth rate variations in the Loch and also to improve fertilisation rates. A study was undertaken to determine the potential benefits of different cultch types to facilitate capturing the larvae, with sites examined over the entire Loch. Dredge and dive surveys have been carried out to determine the stock densities and the benthic type, which has enabled better management. Over the last 15 years a much better understanding of the hydrography of the Loch has been obtained, which explains both the growth rates and the larval retention. Loch Ryan Shellfish was a finalist in the, "Crown Estate Aquaculture Awards, 2009", and was the winner of "Scotland's Best Native Oyster, 2010" This paper will outline the history of the Loch Ryan Oyster Beds, and will explore the ways in which the beds are being managed and restored back to their former productive days, with the challenges that are being met on the way. The presentation will focus on the need to be able to sustain a population by being financially viable, so that both the restoration needs of the oyster, and the financial stability for the business can both be met.

Jeroen M. Jansen[1*], Norbert Dankers[1], Aad Smaal[1], Antonio Aguera[1], Frouke Fey[1], Tim Schellekens[1], Sanjeevi Rajagopal[2], Marnix van Stralen[3] and Kees Kersting[4]
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The fate of ephemeral structures in the Wadden Sea: exploitation, protection and reconstruction of sublittoral musselbeds.

Musselbeds are considered important ecological structures in the Wadden Sea. Inhabiting numerous invertebrate species and benthic fishes, benthic biodiversity increases when the associated communities develop over time. Sublittoral musselbeds in the Wadden Sea are of economic value as well. Fisherman harvest from natural seedbeds to stock their culture lots. Annual recruitment events result in the formation of new seedbeds in the Wadden Sea that become visible during summer. Due to external forces, such as storms or swarming starfish populations, young seedbeds may disappear again before or during their first winter. Sensitivity to storms and seastar predation-risk are expected to be largely site-dependent, but not very well understood.

Several research projects join forces to unravel musselbed development and survival in relation to external and internal variables. The common aim of these studies is to develop a model that predicts the faith of a newly formed seedbed, based on the beds' location, time of the year, mussel density and predation pressure.

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Since fisherman, NGO's and the government agreed on a transition from fishing on wild seedbeds to the use of suspended seed collectors, part of the sublittoral seedbeds is closed for fisheries every year. Predicting where seedbeds will survive may hold the key to successful sustainable aquaculture in the Wadden Sea, since it will determine how efficient musselbed restoration in the sublittoral will be.

Lisa Kamphausen, Antony Jensen, Lawrence Hawkins
National Oceanographic Centre, University of Southampton, UK

Restoration potential of a wild *Ostrea edulis* fishery with a very low proportion of female phase oysters

Between 1972 and 2006 the Solent contained Europe's largest self sustaining *Ostrea edulis* fishery, supporting a local fleet of around 60 boats. From the 1980's onwards there was a slow decline in the population but since 2006 this decline has accelerated because of recurrent recruitment failures. Without a successful spatfall, the commercial extinction of the population in the coming years is likely.

To inform potential restoration strategies we studied the reproductive processes in the population, and discovered a very low proportion of female phase oysters (13.4-14%).

The reproductive status of 362 individuals sampled in 2009 and 2010 was determined by histological and visual examination. In both years significantly more male phase oysters than females were found (chi-squared, $p < 0.001$). Monthly analysis of gonad development between June 2008 and September 2009 showed that despite the skewed sex ratio the reproductive development in each gender was as expected and animals were developing and spawning sperm and eggs, peaking towards the end of June.

This skewed sex ratio has important implications for restoration efforts, and shows that examination of population reproductive processes is a vital component of assessing restoration potential.

Lisa Kellogg
Virginia Institute of Marine Science, College of William & Mary

Bivalve restoration and aquaculture: The role of associated organisms in enhancing ecosystem services

Many studies have demonstrated that both bivalve restoration and aquaculture can provide habitats that enhance the abundance and diversity of macrofauna and, in some cases, flora. Fewer studies have examined the role that these associated organisms play in enhancing the ecosystem services provided by these habitats. Data from recent studies in Chesapeake Bay, U.S.A., reveal that macrofaunal organisms associated with a restored oyster reef enhance nutrient sequestration, denitrification and filtration. Though they account for only 14% of total biomass on this reef, the non-oyster reef residents sequester 37% and 35% of the nitrogen and phosphorus, respectively. A review of current knowledge of the role that associated organisms can play in enhancing ecosystem functions illustrates gaps in current knowledge and suggests directions for future research.

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The role of oyster reefs in the provision of habitat for diverse assemblages of nektonic organisms with varied life history strategies.

Once primarily viewed as a fishery resource, since the 1990s oyster reefs have been more widely appreciated as "ecosystem engineers" that create and modify habitat and support a number of critical ecosystem services. Such ecosystem services include the improvement of water quality through filter-feeding, enhanced benthic-pelagic coupling and denitrification, shoreline protection and reduced erosion, and the provision of habitat for finfish, crustaceans and other invertebrates. Indeed within the southeastern United States, the South Atlantic Fishery Management Council (SAFMC) has designated oyster reefs as essential fish habitat (EFH). Data presented here will demonstrate two main themes in this regard: 1) oyster reef habitats support more abundant and more diverse assemblages of nektonic organisms (defined as those organisms capable of moving independent of currents primarily, finfish, swimming crabs and shrimp) than soft sediment habitats; 2) finfish species frequently found in close association with oyster reefs vary considerably in their life history strategies, such that oyster reefs are important to estuarine-dependent, marine-migratory, freshwater-migratory and diadromous species. Data will be derived both from recent graduate student work comparing nekton utilization of different reef types and also from long-term SCDNR monitoring efforts that target recreationally and commercially important species.

Doug Lipton[1], Geret DePiper[1], Stephan Abel[2] and Matt Parker[3]
[1] Department of Agricultural & Resource Economics, University of Maryland, College Park, MD 20742, [2] Maryland Oyster Recovery Partnership, Annapolis, MD 21401, [3] University of Maryland Extension, Glen Burnie, MD 21061

Payment for Ecosystem Services from Shellfish Restoration: Examples from Chesapeake Bay

The current situation in the Chesapeake Bay demonstrates the opportunities and challenges in monetizing ecosystem services provided by shellfish. Due to violating the provisions of the Clean Water Act by having impaired waters, the Chesapeake is under a regulatory regime known as a Total Maximum Daily Load (TMDL). The TMDL sets a cap on the annual loadings of nitrogen and phosphorus from the watershed. In addition, all the major jurisdictions impacted by the TMDL have established or are in the process of establishing nutrient trading systems. These two components, cap and trade, provide the necessary ingredients for either aquaculture operators or oyster restoration activities to receive payment for nutrient removal and sequestration. However, there may be legal challenges to allowing trading between land-based (pre-discharge) sources and waterbased (post-discharge) nutrient removal. An alternative is to anticipate the recalculation of the TMDL in future years and establish a market for shellfish production and restoration that increases assimilative capacity of the ecosystem leading to a higher TMDL. We calculate examples of what likely payments would be for ecosystem services of Chesapeake oysters, and give examples of how municipalities might be willing to pay for oyster ecosystem services to allow growth and development.

Mark Luckenbach
Virginia Institute of Marine Science, College of William & Mary

20 Years of Oyster Restoration in the Chesapeake Bay, U.S.A.:What have we learned and where do we go from here?

Efforts to reverse the depletion of oyster populations and

Abstracts of plenary speaker talks in alphabetical order—continued

enhance oyster fisheries in the Chesapeake Bay and other U.S. estuaries date back over a century. Only within the past few decades have these efforts been expanded to include the explicit goal of recovering the ecological functions provided by oysters and the biogenic reefs they form. Oyster reef restoration in the U.S. generally involves one or more the following activities: (1) restricting harvest, (2) planting of shell or other substrate as a base for natural recruitment, (3) planting hatchery-produced oysters and (4) introducing a non-native species. In the Chesapeake Bay, following a decade of deliberation, a decision was made not to introduce an exotic oyster species and to focus instead on ecological restoration and aquaculture development with the native oyster. While oyster aquaculture is expanding rapidly, restoration practices have advanced little beyond fisheries enhancement approaches. Theoretical and empirical underpinnings for guiding restoration goals, approaches, and evaluation remain underdeveloped. A coherent approach to restoring ecological functions provided by oysters will require clarification of the relationships between (*i*) structural and functional parameters, (*ii*) monitoring results and management decisions, and (*iii*) one -time and recurring costs and benefits for both wild populations and aquaculture.

Joseph Mazurie[1], Jean-Yves Stanisiere[1], Jean-François Bouget[1], Aimé Langlade[1], Emilie Leclerc[1], Gilles Herve[2], Ika Meidy[3], Evelyne Goubert[3]
[1] IFREMER LER-MPL La Trinité-sur-mer, [2] IFREMER LER-PAC, Toulon, [3]UBS Vannes

Towards restoration of endangered oyster aquaculture in a French subtidal bay (Baie of Quiberon) though control of predators

A research programme, devoted to restoration of oyster culture in a subtidal bay (Baie of Quiberon, South Brittany, France) was undertaken, after 5 years of abnormal mortalities. This study ("Risco"), implicating both industry, socio-economic experts and biologists, was funded by the Regional Council of Brittany, for 3 years (2010-2012).

In parallel to environmental characterisation of this bay (3000 of concessions exploited by 80 enterprises), including bottom video images, the effort in 2010 was oriented towards an experimental protocol for rearing performances evaluation on 2 age-class oysters, *Crassostrea gigas* : this protocol was applied on 15 spatial stations, for discriminating (1) mortalities on-bottom and off-bottom, (2) mortalities from predators or not. Concerning adult oysters mortalities, the most harmful in this bay where spat seeding is not much practiced, the predominant cause was identified as predators : starfish (*Asterias rubens* and *Marthasterias glacialis*) in North-East sector, and boring snails (*Ocenebra erinacea* and *Pterophora inornata*, former *Ocinebrellus inornatus*) in South-Centre area. This spatio-temporal distribution remains to be understood ; on the other hand, cost effective control methods have to be developed with experienced oyster farmers (2011, 2012).

Tom McCowan[1], Gerard Prendeville[2] and Neil Gemmell [1]
[1] Centre for Reproduction and Genomics, Department of Anatomy and Structural Biology, University of Otago, Dunedin, New Zealand, [2]Paua Mac 7, 30 Boons Valley Road, Waikawa Bay, Picton, New Zealand.

Genetic Approaches to Reseeding in New Zealand's Blackfoot pāua (*Haliotis iris*)

New Zealand's Blackfoot Abalone or pāua (*Haliotis iris*) is a fishery of significant commercial, recreational and customary value. High fishing pressure and poaching of this species has caused a decline in stocks, raising concerns over the long-term sustainability of this resource. Reseeding has been trialed with promising outcomes in pāua. We are currently investigating how genetic approaches can be used to improve pāua reseeding management practices. We have undertaken a reseeding trial in Tory Channel, Marlborough Sounds, New Zealand where comprehensive genetic surveys using a panel of ten microsatellite markers have been made of hatchery broodstock and juveniles, of adults and juveniles from the wild target population, and from recaptured hatchery and wild pāua. This has provided a means for overcoming two challenges inherent in reseeding programs: 1) Tracing survival rates of released hatchery stocks, and 2) Monitoring genetic compatibility between hatchery and wild stocks. Further, our approach will allow for conclusions to be made regarding recruitment relationships existing in the wild population, the understanding of which is central to reseeding management strategies. These methods can ultimately be used to ensure the viability of reseeding programs and to monitor downstream genetic effects on wild populations.

Earl J. Melancon,
Professor, Department of Biological Sciences, Nicholls State University, Thibodaux, Louisiana, 70301.

The Importance of Constructed and Natural Intertidal Oyster Reefs to the Future of the Subtidal Oyster Fishery in Louisiana, USA, as it Relates to Coastal Wetlands Restoration.

Oysters, *Crassostrea virginica*, are a significant presence in the northern Gulf of Mexico state of Louisiana. From a commercial perspective, the fishery has produced annually over the past 40 years about 40% of the domestic supply for the United States. The fishery is a subtidal fishery, but much recent ecological focus has been on its intertidal populations as a living buffer to marsh loss through shoreline erosion reduction. This intertidal focus has become a central topic only in the last decade here in Louisiana because of the historical dominance of the commercial fishery and the more recent documentation of coastal land loss.

The juxtaposition of the subtidal fishery with its intertidal population is becoming increasingly important to document as Louisiana addresses coastal marsh loss. Currently, Louisiana has 30% of the total coastal marsh in the United States but accounts for 90% of the nation's annual loss. Proposed government coastal restoration strategies could have significant influence on the existence of the oyster's habitats. In this presentation, we focus on the ecological needs of the intertidal oyster population, the importance of where to strategically construct intertidal reefs, and how such populations may have a bearing on the future of the subtidal fishery.

Iratxe Menchaca and Juan Bald
AZTI-Tecnalia/Marine Research Division, Herrera kaia portualdea z/g. 20110 Pasaia (Gipuzkoa), Spain.

Subtidal edible sea urchin (*Paracentrotus lividus*) populations in the Basque Country (Northern, Spain). Facing the future exploitation.

The purple sea urchin *Paracentrotus lividus* (Echinodermata: Echinoidea) is widely distributed in the Mediterranean Sea and along the North-eastern Atlantic coast, from Scotland and Ireland to southern Morocco. This sea urchin lives on rocky substrates and in seagrass meadows, from shallow waters down to about 20 m depth. It is a species of commercial importance, with a high market demand for its roe, particularly in the Mediterranean Basin and more recently

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The purple sea urchin *Paracentrotus lividus* (Echinodermata: Echinoidea) is widely distributed in the Mediterranean Sea and along the North-eastern Atlantic coast, from Scotland and Ireland to southern Morocco. This sea urchin lives on rocky substrates and in seagrass meadows, from shallow waters down to about 20 m depth. It is a species of commercial importance, with a high market demand for its roe, particularly in the Mediterranean Basin and more recently

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engineer and invasive species *Crassostrea gigas* in continental NW European estuaries

Since the 1960s, the Pacific oyster *Crassostrea gigas* has been introduced for mariculture at several locations within NW Europe. The oyster established itself everywhere and expanded rapidly throughout receiving ecosystems, forming extensive and dense reef structures. It became clear that the Pacific oyster induced major changes in NW European estuaries. The case of the Pacific oyster in NW European estuaries is only one example in an increasing series of biological invasions mediated by human activities. This presentation shows how invasions by ecosystem engineers, that sometimes appear a threat, can also contribute to ecological complexity.

Changes induced by the Pacific oyster are mainly related to its ecosystem engineering activities, its relative lack of natural enemies and high filtration rate. Development of oyster reefs may compensate for habitat loss and biodiversity loss in estuarine environments that were caused by human activities in previous decades. Oyster reef development may also lead to a reduced carrying capacity for bivalve filter feeders in general, with cascading effects on other trophic levels. Induced effects differ between ecosystems with different characteristics. Case studies of the Oosterschelde estuary and Dutch Wadden Sea will therefore be presented.

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The use of an ecosystem engineer in coastal defense

Ecosystem engineers, are organisms that change the abiotic environment by physically altering structure. As a consequence they often, have effects on other biota and their interactions, and on ecosystem processes. The physical ecosystem engineering concept interconnects a number of important ecological and evolutionary concepts and is particularly relevant to environmental management. In this study the use of ecosystem engineers (Pacific oysters), for the reduction or prevention of tidal flat erosion in the Oosterschelde estuary, is investigated.

The application of oyster reefs is mostly needed in places subjected to severe erosion. As most of these places lack natural oyster reefs, artificial reefs can be constructed, using empty oyster shells, which provide suitable substrate for natural oyster settlement. The use of such artificial reefs as coastal defence will be successful when the reefs become living and self-sustainable structures and stabilize tidal flats. Therefore, artificial oyster reefs have been constructed in the Oosterschelde to monitor and evaluate the effectiveness of the concept.

First results show that artificial reefs indeed can reduce erosion and provide suitable substrate for oyster larvae, but the success of these reefs will depend on local environmental conditions. This study is part of the innovation programme Building with Nature (www.ecoshape.nl).

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The role of littoral mussel beds of different size and age for birds and shore crabs

Blue mussel beds are important ecological communities on the tidal flats of the Wadden Sea. Under favourable conditions individual beds become very old and may persist over decades. In the Dutch part of the Wadden Sea nowadays several hundreds of mussel beds occur. They differ in age, size and shape, in the associated benthic species diversity and in the size spectrum of the mussels. These different bed characteristics highly influence the predator abundance and the composition of the predator community. In this context, we initiated a semi-annual monitoring programme on a selection of mussel beds, spread out over the entire area of the Dutch Wadden Sea. Additionally, the numbers of birds foraging on the same beds at low tide are monitored six times per year. A combination of both data sets will give insights about the prevailing predation pressure on each of the mussel beds. The role of the mussel bed age for the predation success of shore crabs was experimentally tested under laboratory conditions, where crabs were allowed to prey upon simulated mussel patches. In this contribution, first results of the monitoring programme as well as of the laboratory experiments will be presented.

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Sedimentation impacts on restored intertidal oyster reefs in South Carolina, US and the implications for secondary consumers

Resident faunal densities and sedimentation (digitized percent surface coverage) were used as assessment metrics on five community-based oyster restoration sites constructed in South Carolina, US. By three years after reef construction, the associated community of resident crabs and mussels was well established at all five sites, however oyster population development among sites varied considerably. Average sedimentation coverage at the five sites ranged from 4 to 60% and was negatively correlated with both crab and mussel abundances. At a site with light sedimentation (samples ranging from 1 to 30% coverage), percent sediment cover was not related to the abundances of any associated resident fauna. The site with the highest sedimentation (samples ranging from 42 to 77% coverage) exhibited a negative correlation with mussel density and no significant correlations involving crabs. Negative relationships between sediment cover and resident crab distributions were most evident at sites with intermediate sediment cover. Resident crabs and mussels are important prey items for a diverse array of secondary consumers, therefore sedimentation of oyster reefs can be quantitatively linked to reduced food availability for these higher trophic levels. These results can be used to more completely quantify biological impacts caused by sedimentation on oyster reefs from activities such as dredging, vessel traffic, and coastal development.

PRESENTATION IFREMER : à suivre

Towards restoration of endangered oyster aquaculture in a French subtidal bay (Baie of Quiberon) through control of predators

Joseph MAZURIE, Jean-Yves STANISIERE, Jean-François BOUGET, Aimé LANGLADE, Emilie LECLERC, Gilles HERVE, Ika MEIDY, Evelyne GOUBERT
with the help of Oyster farmers and representatives

PLAN of presentation

I- Introduction (5 diaps)
Oyster culture in France / Bay of Quiberon
The problem of mortalities
=> the researches developed

II- Factors of mortality
- How to study them ? => specific protocol
- Main results identifiying one cause for young oysters and another cause for adult oysters

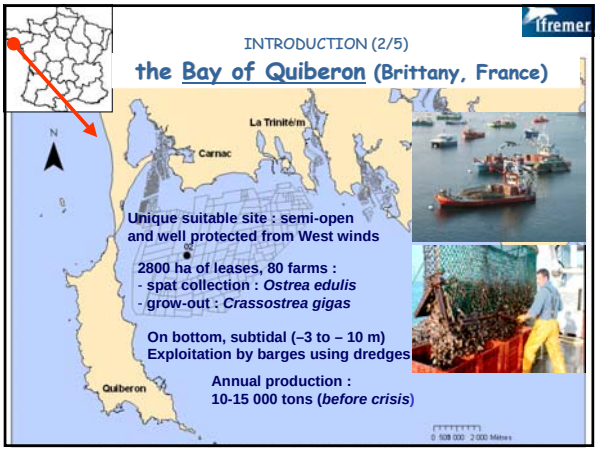
III- Conclusion & Perspectives
- Solutions for restoring production capacities ?

INTRODUCTION (1/5) : Oyster culture in France / Quiberon Bay

France	Quiberon Bay
➢ *C.gigas* 120 000 tons/year (whole weight), before crisis	➢ *C.gigas* 15 000 tons/yr (before crisis): grow-out only
➢ *O.edulis* 2000 tons / year	➢ *O.edulis* (spat collection)
➢ **Entreprises:** 3000	➢ **Entreprises:** 80 (larger)
➢ **Diverse sites and techniques** ▪ mainly intertidal ▪ bags = preserved from predators	➢ **A specific site and technique** ▪ subtidal ▪ (bottom culture = exposed to predators)
➢ **The present crisis** ▪ Since 2008 ▪ Virus disease on spat (until one year of age)	➢ **Present crisis** ▪ Since 2006 ▪ Mortalities on spat + adult oysters

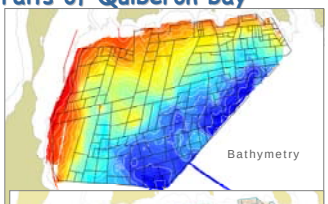
=> Oyster culture rather than wild stocks has to be restored

INTRODUCTION (2/5)
the Bay of Quiberon (Brittany, France)



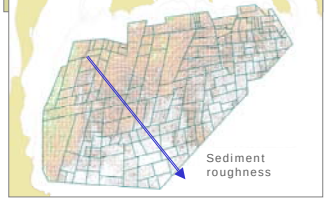
INTRODUCTION (3/5)
Benthic traits of Quiberon bay

Water depth
(from 3 m to 10 m)
Plus 5 m of tidal amplitude

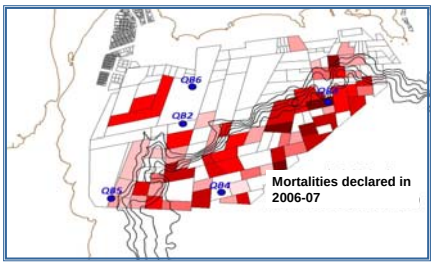


Sediment roughness*
(from sandy to muddy southward)

*(120 KHz Sonar & RoxAnn)



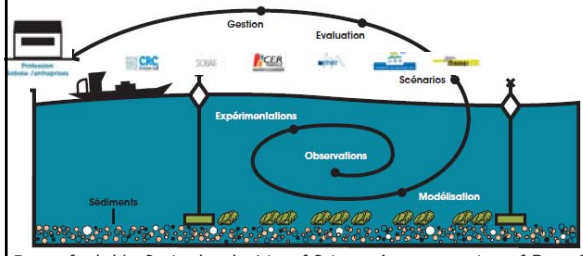
INTRODUCTION (4/5) : the problem
= increasing mortalities of *C.gigas*
(notably since 2006)



- ***All year classes* affected (different from national spat mortalities)**
- ***Spatially delimited* mortalities : higher in the deeper south area**
- ***Severe economic / social consequences* : un-profitability, disengagement from leases, workers dismissals…**

INTRODUCTION (5/5) : the research program "Risco" (2010-2012)

A research program, devoted to DIAGNOSTIC AND RESTORATION of oyster culture in the bay of Quiberon was undertaken, after 5 years of abnormal mortalities. This study implicates both industry, socio-economic experts and biologists, with an interdisciplinarity approach: it aims at applied results, through risk analysis and management.

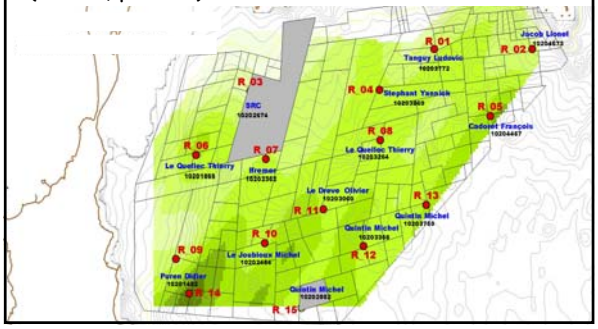


It was funded by Regional authorities of Brittany (western province of France)

II-Factors of mortality : 3 main hypothesis among others

Specific protocol (2010): « cages » in 15 stations

So as to be able to quantify phenomenons and isolate factors (sediment, predators) : better than direct estimations on the bottom



Cages design

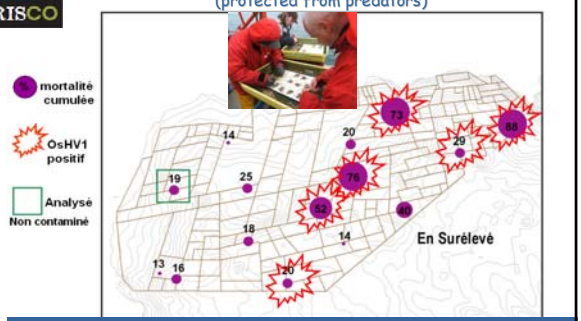
- 3 factors tested:
  - sediment (on bottom/surelevated)
  - predators (with/without protection)
  - + Age classes (1/2 yrs old)
- 1 month interval monitoring (during 1 year)

=> Growth, mortality, predation, pathology,

Additionnal studies on sedimentology, water quality, ecophysiology…

Results (1)

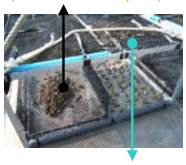
Mortalities of 1-year old oysters (protected from predators)



For 1 year-old oysters, abnormal mortalities are limited to the East Zone *(why?)* & linked to Herpes-Virus OsHV1

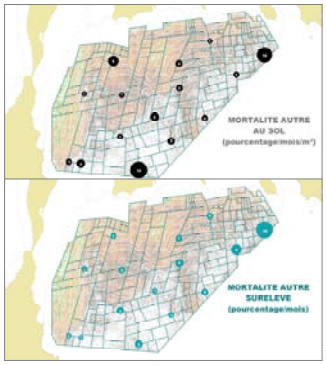
(2) Mortalities of 2-year oysters, protected from predators : bottom effect ?

ON BOTTOM :
1-4 %/month
(3 stations excepted)

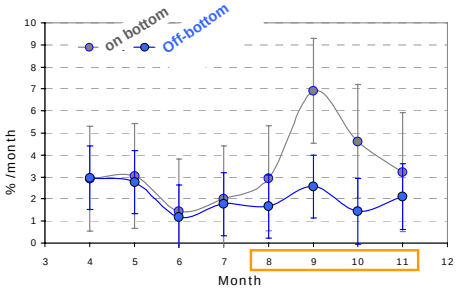


OFF BOTTOM
1-4 %/month
(1 station excepted)

=> *limited* «bottom effect»



When this « bottom effect » ?
(2-year oysters protected from predators)



=> « Bottom effect » between august and november, in these few stations *(organic decay ?)*

Results (3) : unprotected oysters spatial distribution of predators

Oyster drills

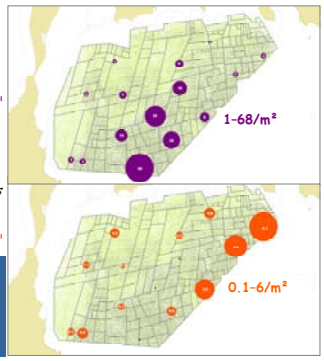
Ocenebra erinacea

Pteropurpura (Ocinebrellus) inornata

Starfish

Asterias rubens

Marthasterias glacialis

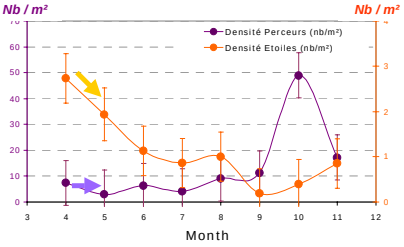


=> Localized (*why ?*) and exclusive distribution areas for oyster drills and starfish

Abundance of predators
=> monthly evolution

Oyster drills **stable** *(reproduction period excepted)*

Starfish **seasonal** *(migrations)*



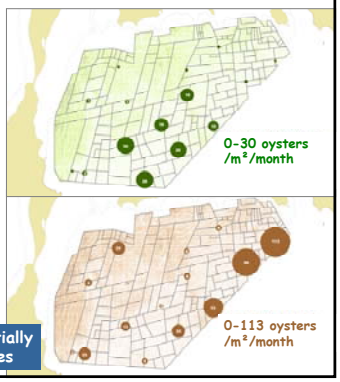
Starfish : max in spring then decrease

Oyster drills : stable *(artifact in october)*

Mortalities of 2 year-oysters induced by predators

Oyster drills

Starfish

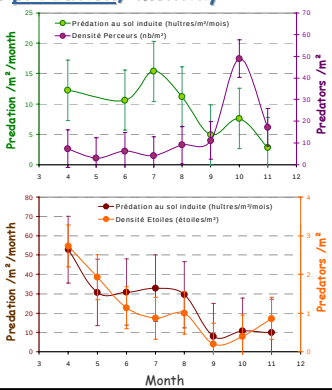


⇒ High oyster mortalities spatially related to Predators densities

Predators density vs Oysters mortality from predation, monthly

Oyster drills
=> approximate fit

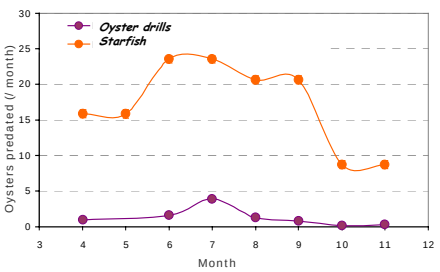
Starfish
=> Very good fit



Efficiency of predation

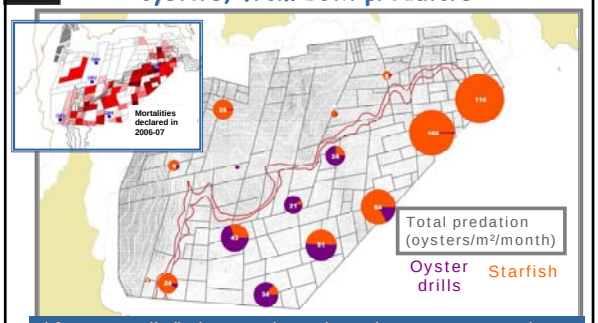
Oyster drills

Starfish



=> Both species exhibit a seasonal predatory activity, with a peak in summer

Cumulated mortalities of unprotected oysters, from both predators



(if not controlled) these predators have the capacity to eradicate the oyster seedings, in the deeper part of the bay. Note that this distribution (2010) fits to previously (2006) declared mortalities.

One additional predator : the sea bream *Sparus aurata*

Sparus aurata

➢ Not observed in our experiment, but « problematic » in the western part of the bay (oyster farmers complain)

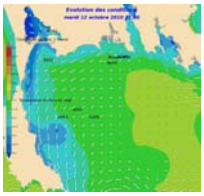
III- CONCLUSION & PERSPECTIVES for 1 year-old oysters

(1/3)

➢ The 1 year-oysters cultivated in this bay may be protected from predators by using *bottom cage culture* for instance

➢ But they are also affected by Herpes-virus OsHV-1 :

- *hydrodynamic models* and dispersion simulations since virus sources may help understand the spatialization of these mortalities
- but *solutions are more national than local (genetic selection…)*



http://quib.previcot.com/data/zones/ 2010-10-12_00 (source : Actimar)

CONCLUSION for 2-year-old oysters

(2/3)

➢ The high mortalities on 2-year oysters, in the south-western part of the bay are mainly due to predation by seastars + oyster drills (and only locally to the proximity with sediment)

➢ Additionnal investigations remain to be completed : ecotoxicology, predators cycles, modelling… etc

➢ but preventive and curative actions against predators may already be evaluated, tested, undertaken…

http://quib.previcot.com/data/zones/ 2010-10-12_00 (source : Actimar)

PERSPECTIVES / SOLUTIONS for 2 year-old oysters

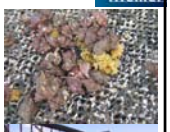
(3/3)

Oyster drills :

1- initially not to introduce them (with oyster seeds)

2- at spawning period (spring, autumn): deploy surelevated supports so as to collect breeders and egg capsules

3- at harvest : lift dredges smoothly and finally dredge with a small mesh



« fauberts »

Starfish :

Harvest them (fauberts…)

Fish :

Capture them (nets…)
Repulse them ?

For all :

Cultivate oysters in mesh bags (costly in this site !)

=> to be tested since 2012, with implication of socio-economic experts and farmers

Acknowledgments

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Labelled by « Pôle Mer de compétitivité Bretagne-PACA »

with a partnership between industry and science : (Ifremer and Universities of Vannes and Nantes)

=> Let they be thanked


Thanks for your attention