Theme Session H
Ecological carrying capacity in shellfish culture

ICES CM 2008/H:01

Studying the carrying capacity of Mont Saint Michel Bay (France): respective role of the main filter-feeders communities

Philippe Cugier, Michel Blanchard, Joseph Mazurié, Stéphane Pouvreau, and Frédéric Olivier

The macrobenthic community of Mont Saint Michel Bay (MSMB), located in the Normand-Breton Gulf (English Channel) along the French coast, is mainly dominated by filter-feeders which includes shellfish production (oysters and mussels). Decline in farming production, as well as the significant spread of the invasive slipper limpet *Crepidula fornicata* (150 000 t), have prompted scientists and stakeholders to question the trophic balance between cultivated and wild (native or invasive non-native) filter-feeders. An ecological model of the MSMB was developed, coupling a two-dimensional hydrosedimentary model (SiAM) and biological models for primary production and filter-feeder filtration. The filter-feeder model includes cultivated (mussels *Mytilus edulis* and oysters *Crassostrea gigas* and *Ostrea edulis*), invasive (*Crepidula fornicata*), and wild native species (*Abra alba, Cerastoderma edule, Glycymeris glycymeris, Lanice conchilega, Macoma balthica, Paphia rhomboides, Sabellaria alveolata, Spisula ovalis*). The real distribution for each species is taken into account in the computational grid and individual filtration rates are imposed. For cultivated and invasive species, which represent the highest density levels, biodeposition production is also computed in order to evaluate the role of these biodeposits in re-stimulating the primary production. The pressure of each benthic compartment on primary production is evaluated and mussels and *Crepidula fornicata* appear to be of prime importance in controlling phytoplankton level. From 2008 to 2010, this model will be used by scientists and decision-makers as a tool for exploring several scenarios of farming management and/or environmental factor evolution and their impacts on the ecosystem.

Keywords: carrying capacity, shellfish culture, invasive species, Mont Saint Michel Bay (France).

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ICES CM 2008/H:02

Predicting the carrying capacity of bivalve shellfish culture using a steady, linear foodweb model

Weimin Jiang and Mark T. Gibbs

An investigation into the potential carrying capacity of suspended bivalve culture was undertaken using a linear foodweb model. The investigation involved configuring the model for the present state using all available information, then perturbing the foodweb by introducing the bivalve culture until predetermined carrying capacity limits were achieved. These carrying capacity trigger levels were defined by the production carrying capacity and the ecological carrying capacity. The production carrying capacity represents the theoretical maximum bivalve culture that could be supported in the embayment. This is defined as when the ecosystem collapses down to a nutrient–phytoplankton–culture–detritus dominated system. This level of culture was found to be a yield of bivalve culture of 310 t km^{-2} $year^{-1}$ averaged across the bays in question. By contrast, the ecological carrying capacity was defined as the level of culture that could be introduced without significantly changing the major energy fluxes or structure of the foodweb. This limit was found to correspond to a bivalve culture yield of 65 t km^{-2} $year^{-1}$ averaged across the bays. Introducing large-scale bivalve culture resulted in a decrease in the mean trophic level of the ecosystem, an increase in the total yield, throughput, and efficiency, and the bivalves replaced zooplankton as the major grazers in the modelled system.

Keywords: Tasman and Golden Bays; foodweb model; Bivalve culture; Carrying capacity; Aquaculture sustainability

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ICES CM 2008/H:03

A simple model for estimation of shellfish carrying capacity

Aad C. Smaal and William Silvert

Calculating the carrying capacity of a potential site for shellfish culture is a difficult task involving many different variables. The most important aspect of this calculation is determining the availability of plankton and its reliability as a food supply. Detailed models are available which take into account the physical oceanography and geographical distribution of nutrient sources as well as many other relevant factors, but

these involve long, complicated, and expensive modelling efforts. There is a need for a simplified approach that can be used for preliminary assessment of the viability and potential of prospective sites. This presentation describes a very simplified model formulation. The basis of the model is a calculation of the fate of primary production that is either flushed out of the system or filtered by the bivalves. The results can be expressed as an index of both carrying capacity and stability and only require a very limited set of easily available data for calculation. This should be adequate for identifying potentially viable sites so that further research and detailed modelling programmes can be deployed as efficiently as possible. It also provides a tool for comparison of different sites with regard to their potential carrying capacity.

Keywords: aquaculture, shellfish, bivalves, culture, siting, plankton, carrying capacity, model.

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ICES CM 2008/H:04

Modelling nitrogen cycle in a small intertidal estuary: respective influence of environmental factors and cultivated oysters

Karine Grangeré, Aline Gangnery, Cédric Bacher, and Alain Ménesguen

The Baie des Veys, located on the French coast of the English Channel, is an open intertidal estuary (37 km²) with an important oyster farming activity. The main cultivated species is the Pacific oyster (*Crassostrea gigas*) with a standing stock of approximately 10 200 t. This ecosystem is influenced by four rivers which drain an important catchment basin (3500 km²). Previous results showed that phytoplankton production is mainly influenced by terrestrial nitrogen inputs rather than oceanic nitrogen inputs. In this study, nitrogen dynamics were evaluated by developing an ecosystem box model taking into account all major nitrogen sources. This model simulates the Baie des Veys nutrient–phytoplankton–oyster foodweb by coupling a primary production model and an oyster ecophysiological model based on the Dynamic Energy Budget theory. The model is split in two compartments—the water column and the sediment. It was validated using *in situ* measurements of chlorophyll *a*, nutrients, and biometric data on oyster growth. This coupled model allowed us to study the Baie des Veys nitrogen cycle using two different approaches. First, simulations with average environmental conditions were achieved with and without oyster stock in order to highlight the influence of cultivated oysters (filtration, excretion, biodeposition) on nitrogen dynamics. Second, different scenarios with contrasting environmental conditions (fresh-water and nutrient inputs, meteorology) were tested in order to estimate the influence of the environment on the Baie des Veys nitrogen cycle. Finally, the model results were compared with available data from other cultivated ecosystems using relevant indicators.

Keywords: nitrogen cycle, ecosystem model, cultivated oysters, environmental factors.

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ICES CM 2008/H:05

Ecological carrying capacity of mussel culture in fjords

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Coastal Norwegian coastal waters are characterized by fjord systems with surface areas varying from tens to thousands of square kilometres, depths of up to several hundred metres, and exchange exchanges with outside coastal waters regulated by sill depth at the entrance and dominating wind direction at the coast. In summer, the euphotic layer in fjords is stratified primarily as a result of fresh-water run-off and calm wind conditions that restrict vertical mixing of nutrients. Consequently, the euphotic zone is nutrient-limited and the primary production is typically within the interval 1–2 mg C m^{-3} h^{-1}, mainly based on nutrients regenerated in the water column. The annual pimary production rates are 110 to 140 g C m^{-2} $year^{-1}$ and for extended periods after the spring bloom the concentration of chlorophyll *a* is less than 1–2 mg m^{-3}. Fjords and coastal waters in Norway are therefore considered to be low-seston environments with implications for estimates of ecological carrying capacity. Suspended culture of mussels in fjords may change the ecological energy flow in the ecosystem because the dominating littoral is steep and natural stocks of benthic suspension feeders are relatively low. For most of the biodeposits from mussel culture that sink into the deeper basin water, regeneration time has a cycle of many years. Ecological interactions related to bivalve production in low-seston environments, which will be crucial to optimizing the exploitation of carrying capacity in bivalve production and development of management strategies in Norway, are discussed.

Keywords: carrying capacity, fjords, mussels.

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ICES CM 2008/H:06

Impacts of Manila clam cultivation on waders and gulls

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In the Chausey Archipelago (France) the Manila clam (*Ruditapes philippinarum*) cultivation settles on *Lanice conchilega* (Pallas) intertidal beds, which is a high patrimonial value habitat. Sandmason beds are known to be attractive feeding grounds for several bird species. We have previously shown that Manila clam farming negatively impacts populations of *L. conchilega* and the associated benthic macrofaunic assemblages. The present study focuses on the consequences of this activity on secondary consumers, especially waders (Charadrii) and gulls (Laridae). We found that some bird species, which had previously selected the *L. conchilega* beds to feed, leave these feeding grounds after the settlement of new clam concessions. Other bird species seem to adapt and even to benefit from this shellfish farming activity. We discuss the potential consequences of a rapid development of shellfish farming activities along the European coasts on birds, and particularly the impacts related to the massive introduction of bivalve prey on their feeding activity.

Keywords: shellfish farming, shorebirds, Manilla clam, Lanice conchilega.

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ICES CM 2008/H:07

Working towards consensus: application of shellfish carrying capacity in management of Rhode Island aquaculture

Carrie Byron, David Alves, David Bengtson, Robert Rheault, and Barry Costa-Pierce

Oyster farming is growing rapidly in Rhode Island, expanding in a five-year period (2001–2006) from a $300 000 industry on 18 farms to a $1.3 million industry on 28 farms. This expansion has wild clam harvesters concerned about the loss of fishing grounds. In response to this resource use conflict, the RI Marine Fisheries Council, which comments to the state aquaculture permitting authority on aquaculture lease applications (Costal Resource Management Council (CRMC)), announced that they would refuse to consider any new aquaculture leases until a long-term aquaculture plan for RI was in place. The fundamental question is what, if any, limits should be placed on shellfish aquaculture production in RI. The CRMC revitalized its Working Group on Aquaculture Regulations (WGAR) consisting of representatives from aquaculture, wild harvest, environmental management, and academicians who identified issues necessary to understand before proceeding: water quality, disease, aquatic nuisance species, physical impacts of aquaculture gear, essential fish habitat, carrying capacity, and an ecosystem approach to aquaculture. Of these issues, the one that drew unanimous interest was carrying capacity: what is the production and ecological carrying capacity for oyster aquaculture in Narragansett Bay and RI's coastal ponds? We present a framework of monitoring and modelling to guide management of shellfish aquaculture. Given that the problem facing RI also faces or will face many other states, we regard this as an excellent opportunity to advance the process of modelling ecological carrying capacity with the involvement and assistance of stakeholders.

Keywords: carrying capacity, shellfish,.

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ICES CM 2008/H:08

Ecosystem interactions with mussel culture in Newfoundland coastal waters

M. R. Anderson, R. B. Rivkin, D. Deibel, R. J. Thompson, T. J. Edwards, J. Stacey, and J. Ryan

The environmental impacts of bivalve aquaculture and the requirements for sustainable bivalve production are closely linked. Shellfish aquaculture depends entirely upon the local and regional environment to supply food and remove the degradation and waste products. Although there is no net addition of nutrients, there is the potential for alteration of nutrient cycles, planktonic prey, and benthic habitats. Cultured bivalves consume plankton produced over a much wider area than the physical footprint of the farm, resulting in localized, high rates of organic matter deposition and remineralization in both water column and sediments. There is thus the potential for strong feedback from the waste products of animal metabolism to the production of autotrophic and heterotrophic bivalve prey. We examined the impact of high-density shellfish culture on pelagic and benthic ecosystem processes in a two-year field study of mussel farms and nearby reference sites on the northeast coast of the Island of Newfoundland, Canada. The farms were located in sheltered bays and differed in sustainable stocking density and time to market. The biomass of microplankton, but not mesozooplankton, differed significantly between farm and reference sites, with in-farm microplankton being up to twofold greater than in other Newfoundland coastal waters. Although sediment organic matter, redox, and sulfide levels did not differ between farms and reference sites, there were differences in benthic infauna, and higher rates of sediment-to-water fluxes of NH_4^+ and PO_4^+. Our results

indicate the potential for significant feedback from mussels to *in situ* planktonic processes which in turn influence mussel production. Site-specific responses indicate, however, that bathymetry and stratification play a key role in determining the magnitude of the feedback and hence system productivity.

Keywords: bivalve aquaculture, environmental response, nutrient regeneration, productive capacity.

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ICES CM 2008/H:09

Operational models of carrying capacity applied to a Norwegian fjord

Jon Grant, Ramón Filgueira, Cedric Bacher, and Øivind Strand

Estimation of production carrying capacity for shellfish culture has become a major focus in research, with operational models applied at culture sites worldwide. Fundamental to these efforts are an understanding of the relationship between nutrients, primary production, and shellfish bioenergetics. The potential for manipulation of nutrients via artificial upwelling has been undertaken in a Norwegian fjord in the CANO Project. Research in this area includes several types of models of varying spatial scales. One of the more useful configurations has been a box model allowing variation in the location of the upweller as well as the sites of mussel culture. Using optimization routines we maximize mussel production in the upper fjord based on projected nutrient/phytoplankton enhancement by the upweller. The limitations of this type of model are discussed in comparison with a fully spatial model where the results can be mapped in detail.

Keywords: carrying capacity, models, mussel culture, fjords.

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ICES CM 2008/H:10

Modelling interactions between mussel farm biodeposition, sediment biogeochemistry and nitrogen recycling in the northern Adriatic Sea (Italy)

D. Brigolin, R. Pastres, S. Covelli, S. Predonzani, and M. Giani

The present work, developed in the framework of the ECASA EU project, aims at studying the local impact of mussel biodeposition on sediment biogeochemistry by means of an integrated mathematical model. The model was obtained by coupling two models: (i) MERAMOD, which is widely used as a tool for assessing deposition from fish cages, and was adapted to the simulation of mussel farm biodeposition; (ii) an early diagenesis model, which was developed within this work, and is capable of predicting vertical profiles of organic carbon, dissolved oxygen, NH_4^+, NO_3^-, SO_4^{2-}, dissolved inorganic P, Mn^{2+}, and Fe^{2+} as well as the nutrient and dissolved oxygen fluxes at the water–sediment interface. The integrated model was first calibrated on a purposely designed set of field data collected at a longline mussel farm located offshore near Venice, in the northwestern Adriatic Sea. A set of simulations was carried out, in order to study the potential impact of mussel farming, associated with the different scenarios of mussel density, bathymetry, and hydrodynamic regimes. Simulation results indicate that the impact of a mussel farm per unit area is sensitively lower than the one induced by finfish cage farming. However, the overall impact on N and P cycles is significant, given the extension of the licensed areas. Furthermore, model results indicate that the entity of the impact can vary dramatically in response to the scenario considered, suggesting the potential use of this type of model as a tool for the optimization of site selection and farm dimensioning.

Keywords: mussel farming, aquaculture impact model, environmental carrying capacity.

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ICES CM 2008 H:11

A box model of carrying capacity for mussel aquaculture in a Norwegian fjord

Ramón Filgueira and Jon Grant

Shellfish carrying capacity is determined by the interaction between cultured species and the ecosystem, principally constrained by environmental characteristics and particularly food availability. A recent experiment carried out in Lysefjord (southwest Norway) has shown that artificial upwelling of nutrient-rich deeper water stimulates phytoplankton growth, potentially increasing the carrying capacity for mussel cultivation. With the aim of evaluating aquaculture effects and assisting in the development of sustainable mussel culture in Lysefjord, an object-oriented model of environmental–mussel aquaculture interactions and mussel carrying capacity was constructed. A multiple box ecosystem model was developed with highly

configurable GUI-based software (Simile) that allows explicit coupling between boxes, which represent regions of the fjord. Once the box model was developed and calibrated, subsequent application of PEST (Parameter ESTimation) allowed optimization of different variables of the model in order to manage mussel production according to carrying capacity criteria. The Simile model and the simultaneous application of PEST allowed several scenarios, taking into account different stocking densities and the creation of new cultivation areas. In a second talk on this topic (session H), we compare the results of this model to those of a fully spatial model of Lysefjord constructed on a finite element grid.

Keywords: carrying capacity, models, mussel culture, fjords.

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ICES CM 2008/H:12

Phytoplankton depletion by mussel aquaculture: high-resolution mapping, ecosystem modelling, and potential indicators of ecological carrying capacity

Peter J. Cranford, Øivind Strand, Tore Stroheimer, Michael Dowd, William Li, and Jon Grant

Mussels held in suspended culture have an exceptional capacity to filter the water column and reduce suspended particle concentrations. However, seston depletion is only of concern if phytoplankton are cleared faster than they can be replaced by tidal exchange and primary production. The occurrence of significant phytoplankton depletions over extended periods and relatively large scales is directly linked to the concepts of production and ecological carrying capacity owing to food limitation and alterations in ecosystem structure, material fluxes and pathways, and nutrient cycling. Knowledge of ecosystem interactions with shellfish aquaculture supports the growth of a sustainable industry and the development of an ecosystem-based management approach. Phytoplankton depletion was documented at mussel aquaculture farms in Canada and Norway using a computer-controlled, towed undulating vehicle (BIO-Acrobat) that collects geo-referenced CTD and chlorophyll *a* data. Rapid synoptic surveys with intensive horizontal and vertical sampling permitted high-resolution three-dimensional mapping of phytoplankton variations over farm to coastal ecosystem scales. Several particle-depletion indicators of relevance to defining site production and ecological carrying capacity were investigated based on geospatial analysis of these data. The number of fundamental ecosystem processes influenced as a result of phytoplankton depletion and utilization by mussels, and the complexity of their interactions makes it difficult to predict the effects of the culture on many ecosystem properties without also resorting to a model. Applications of a nitrogen budget and ecosystem box model were investigated to aid in defining indicators that summarize ecosystem properties and help to define the ecosystem carrying capacity.

Keywords: mussel culture, phytoplankton depletion, ecological carrying capacity, production carrying capacity, ecosystem models, indicators.

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ICES CM 2008/H:13

Towards determination of the carrying capacity of Scottish sea lochs for shellfish aquaculture

M. J. Gubbins, C. Greathead, T. Amundrud, P. Gillibrand, P. Tett, M. Inall, A. Hawkins, J. S., **[?Q1]** and I. M. Davies

Currently Fisheries Research Services operates a simple ranking system to estimate the relative risk of cultured shellfish exhausting the available food supply in Scottish sealochs. This is based on a precautionary comparison of potential filtration rates to loch flushing rates and the results are used to provide advice for the determination of seabed lease and planning applications for new and expanding shellfish farms. The basis of this ranking is described alongside details of work underway to develop a more sophisticated modelling approach to predict shellfish carrying capacity. This work aims to couple the established ShellSIM shellfish model to physical (ACExR) and biological (LESV) models recently developed to predict assimilative capacity for finfish farming in sealochs during a study funded by the Scottish Aquaculture Research Forum (SARF). The ACExR physical model simulates the seasonal cycle of physical conditions within a sealoch, treating the loch as a three-layer system. A coupled Loch Ecosystem State Vector (LESV) model predicts seasonal variations in chlorophyll and oxygen accounting for a wide range of factors including: nutrients (including inputs from fish farms), bio-optics, phytoplankton (two types), and zooplankton grazing. Inclusion of the ShellSIM model to predict shellfish responses to changing environmental variables will allow studies of the synergies between finfish and shellfish farming and allow capacity estimates to be set. A two-year SARF project aims to further develop and test the existing models, collate physical, chemical and biological boundary condition data, and test the model against measurements of shellfish growth.

Keywords: sealoch, mussel farming, shellfish culture, carrying capacity, modelling.

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ICES CM 2008/H:14

Predictive ecological modelling for suspended shellfish aquaculture systems: assessing biodeposition and benthic effects with Shellfish-DEPOMOD

A. M. Weise, C. J. Cromey, M. D. Callier, P. Archambault, J. Chamberlain, and C. W. McKindsey

Numerical modelling provides an effective means to evaluate the interactions between aquaculture activities and the ecosystem. To date, modelling effort with regard to shellfish cultivation has focused primarily on predicting bivalve growth and production carrying capacity rather than environmental interactions. Modelling the nearfield effects of shellfish aquaculture through biodeposition has received little attention, and consequently there is a need for effective models to predict the organic flux from culture sites to the bottom. Here, we present the application of a particle waste dispersal model to predict the nearfield effects of biodeposition from suspended shellfish culture. Results will be presented on the development and application of Shellfish-DEPOMOD. The model was tested at three coastal mussel *Mytilus edulis* farms with differing hydrodynamic regimes in Quebec, Canada. For each site, the model results were validated by comparing predictions with observed deposition measured *in situ* with sediment traps. The relationship between long-term biodeposition and benthic descriptors was assessed. Overall, the model predictions compared favourably with observed sedimentation rates both in terms of flux and extent of dispersion. Alterations to the benthic community were observed at high deposition rates. Model parameter uncertainties and limitations will be discussed in the context of ecosystem-based management of marine areas.

Keywords: modelling, aquaculture impacts, mussel farms, biodeposits, benthic impacts.

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ICES CM 2008/H:15

Secondary productivity of fish and macroinvertebrates in mussel aquaculture sites

Philippe Archambault, Brianna G. Clynick, and Christopher W. McKindsey

Artificial reefs provide shelter for many species and aquaculture structures may function in a similar way in that they provide a complex three-dimensional habitat for marine organisms and/or modify the surrounding environment. Furthermore, aquaculture structures may increase the productivity of mobile species similarly to natural complex habitats, such as seagrass beds. This project tested the general hypothesis that suspended bivalve culture increases the abundance and productivity of fish and macroinvertebrates. Fish and macroinvertebrates were sampled in different areas within farms sites and in adjacent natural vegetated and unvegetated habitats in the Magdalen Islands, eastern Canada. The instantaneous growth rate of winter flounder (*Pseudopleuronectes americanus*), sand shrimp (*Crangon septemspinosa*), and the rock crab (*Cancer irroratus*) were estimated using physiological indicators (RNA/DNA ratios). The results demonstrated that fish and macroinvertebrate assemblages are not similar between mussel sites and natural structurally complex seagrass beds. Winter flounder and rock crab were abundant in mussel farms. This study suggests that there was a comparable secondary productivity of these mobile species within mussel farms sites and in adjacent natural vegetated and unvegetated habitats. As future development of mussel aquaculture increases in many regions around the world, the methods presented here will provide baseline information on the abundance and secondary productivity of fish and macroinvertebrates associated with aquaculture sites.

Keywords: mussel aquaculture, secondary productivity; environmental impact; benthic macroinvertebrates and fish.

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ICES CM 2008/H:16

Farmed mussel biodeposit production and dose-dependent influence on benthic communities

Christopher W. McKindsey, Myriam D. Callier, Philippe Archambault, and Andrea M. Weise

Much work has examined the influence of benthic loading from suspended bivalve culture on benthic infaunal communities. However, little effort has been directed at determining the production of biodeposits

and dose-dependent effects of biodeposition on such communities. A study was done to determine the mussel size-dependent production of biodeposits *in situ* and characterize biodeposit sedimentation dynamics. Based on the results of this study, an *in situ* manipulative experiment was done to evaluate the dose-dependent response of biodeposition on sandy benthic infaunal community structure. Benthic communities sampled with sediment cores were used to create mesocosms which were exposed over 50 days to seven different levels of mussel biodeposition by varying the densities of mussels (0, 1, 2, 3, 4, 5, 6 mussels, equivalent to 0, 127, 255, 382, 510, 637, and 764 mussels m^{-2}). Benthic communities responded as would be predicted from the Pearson and Rosenberg (1978) model of organic enrichment. The abundance and biomass of opportunistic species (*Capitella* sp.) were observed to increase in the mesocosms exposed to the highest mussel density. Sensitive species such as *Tellina agilis* and *Pherusa plumosa* tended to decrease in abundance and biomass with increasing mussel density. These results are discussed with respect to their importance to predictive ecological modelling for bivalve aquaculture.

Keywords: mussel aquaculture, biodeposit production, organic enrichment, benthic effects, mesocosm, AMBI.

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ICES CM 2008 /H:17 Poster

Modelling the influence of the environment on the interannual variability in biological performances of the Pacific oyster (*Crassostrea gigas*) cultivated in the Baie des Veys estuary (France)

Karine Grangeré, Alain Ménesguen, Sébastien Lefebvre, and Cédric Bacher

The Baie des Veys, located on the French coast of the English Channel, is an open estuary and intertidal ecosystem (37 km^2) which is influenced by four rivers and sustains an important oyster farming activity (10 200 t). Some year-to-year differences in the phytoplankton dynamics and in the biological performances of cultivated oysters were observed. In order to assess whether environmental variability may significantly affect ecosystem dynamics, a box model was developed. This model simulates the Baie des Veys nutrient–phytoplankton–oyster foodweb by coupling a primary production model that simulates trophic resources and an oyster ecophysiological model. It was validated using *in situ* measurements of chlorophyll *a*, nutrients, and biometric data on oyster growth. This model allows us to assess the influence of some factors such as trophic interactions, watershed supplies (fresh water, nutrients, suspended particulate matter), or meteorological variations, on the seasonal and interannual variability of oyster physiological state (growth and reproduction). Several years with contrasting environmental and meteorological conditions were simulated. Results showed an influence of nutrients and suspended particulate matter inputs from rivers on the initiation and the magnitude of the phytoplanktonic bloom. At the same time, an interannual variability was also observed in oyster growth and reproduction. A significant effect of temperature on the period of spawning was highlighted. The next step will consist of the integration of this coupled model in a hydrodynamic model in order to better understand the observed spatial differences in oyster biological performances in relation to the effect of water circulation on food production and availability for filter-feeders.

Keywords: ecosystem model, environment, oyster ecophysiology

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ICES CM 2008 /H:18 Poster

Comparison of residence time, phytoplankton turnover, and oyster filtration time in an estuarine bay (Baie des Veys, France) to assess interactions between cultivated oysters and ecosystem

Karine Grangeré, Cédric Bacher, and Sébastien Lefebvre

The carrying capacity of an ecosystem is defined as the maximum biological production for aquaculture. Growth and mortality of cultivated shellfish depend on environmental characteristics such as temperature, food concentration, and suspended particulate matter. Shellfish production therefore depends on key factors: food availability (primary production), renewal of seawater (residence time), and food utilization (ecophysiology). The combination of these factors allows us to assess and compare the carrying capacity of several ecosystems using mathematical models in order to define relevant indicators of aquaculture impact and potentiality. The study site is an estuarine bay called Baie des Veys, located in Normandy (France). This intertidal ecosystem (37 km^2) is influenced by four rivers, and characterized by an important oyster farming activity (10 200 t). To define indicators, a three-dimensional hydrodynamic model was coupled to a transport model and an equation for oyster filtration. Interactions between the oysters and the ecosystem were assessed by simulating the transport of a tracer with or without oysters for several cases of forcing functions (e.g. tide level, river flows, wind forces, and direction). The residence time was also estimated and compared to oyster filtration time and measured phytoplankton turnover time. Comparison with similar characteristics in other

systems will allow us to assess whether interactions between oysters and the Baie des Veys ecosystem play a key role in ecosystem functioning. The next step will consist of linking a biological submodel to the existing hydrodynamic model with the general aim of predicting oyster growth as a function of environmental conditions.

Keywords: residence time, phytoplankton turnover, oyster filtration, aquaculture.

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ICES CM 2008/H:20 Poster

Recruitment and production of the blue mussel on navigation buoys in the St Lawrence system (estuary and gulf)

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Monitoring blue mussel recruitment is necessary to enhance the aquaculture of this species. Navigation buoys are collected and cleaned yearly by Coast Guard Canada and thus act as standard recruitment surfaces for benthic species. The blue mussel is the most abundance species observed on buoys. The use of navigation buoys as collectors in a monitoring programme is of great advantage because of the large spatial coverage and the low sampling costs. Quantitative samples of blue mussel abundance, biomass, and size were obtained in 2005 and 2007, on more than 150 navigation buoys moored from May through November from different areas of the Estuary and Gulf of St Lawrence (EGSL), Canada. The objective is to determine the relationships between recruitment parameters (abundance, biomass, and size) and some environmental factors such as temperature, salinity, chlorophyll *a*, and current velocity over a large spatial scale. Furthermore, data collected between 1980 and 1985 on the same navigation buoys are used to analyse the interannual variability and identify areas of persistent high recruitment and secondary production through time. These results are particularly relevant to the aquaculture industry.

Keywords: aquaculture, recruitment, production, blue mussel, buoys.

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Assessing trophic carrying capacity of the Baie des Veys (Normandy, France) with a biological model

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The Baie des Veys is an important site of shellfish culture in Normandy. The Pacific oyster (*Crassostrea gigas*) is the main species in culture with a standing stock of about 10 200 t, but the oyster culture industry has recently faced several mortality crises and oystermen want to optimize activity in the bay. The aim is to optimize rearing densities as a function of ecosystem capacity but also to protect the bay from an ecological point of view. In this context, a first step was to develop a biological deterministic model to assess the trophic carrying capacity. The model takes into account nutrients, phytoplankton, and oyster compartments as well as inputs from the watershed which are known to have a major influence on this ecosystem. This model was coupled with an ecophysiological model simulating oyster growth and based on the dynamic energy budget theory. A first set of scenarios was undertaken with different values of standing stock in order to test the effect of density on oyster growth and to assess the trophic capacity of the bay. A growth indicator was then developed in which growth is given as a function of the oyster number. Oyster growth also varies according to environmental conditions. A second set of scenarios was then undertaken in order to examine the effect of environmental variability (e.g. water temperature, residence time, watershed inputs) on oyster growth. A second step was to use the model to study the ecological carrying capacity of the bay. This topic was addressed in another communication.

Keywords: carrying capacity, *Crassostrea gigas*, modelling

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Influences of salinity shock on antennal gland cells and moulting rate of narrow-clawed crayfish (*Astacus leptodactylus*)

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In this investigation the effects of salinity shock on variations of green gland cells and moulting of narrow-clawed crayfish (*Astacus leptodactylus*) was studied. Five groups at salinities of 4, 6, 8, 10, and 12 g L^{-1} with three repeats were prepared along with a control group. The samples were gradually transferred from fresh

water to salt water. After 72 hours all the samples were transferred from saltwater to fresh water in order to subject them to salinity shock. Then numbers and times of moulting were noted. The most moulting was observed in 10 (66.7%), 12 (54.17%), and 8 g L^{-1} (41.7%) respectively at the first two weeks. Results of statistical analysis showed significant relationship between salinity shock and numbers and the time of moulting (p<0.05). Antennal gland samples were taken from the crayfish before and after salinity shock and immediately fixed in Bouin solution. To study the samples, 5-µm sections were made and stained with H&E. In a histological study of the antennal glands, tissue hyperplasia was clearly observed in treated specimens. In a histological study of antennal glands with increased salinity, decrease in antennal gland cells size was observed. In contrast, after salinity shock, the size of the antennal gland cells increased to 12, 10.5, and 10 µm in 10, 12, and 8 ppt respectively. These changes indicated increasing water uptake and consequent increase in antennal gland cell size in each treatment. According to these results, salinity shock causes increase of body osmolarity, water reabsorption in antennal glands, and consequently increase of body size. It thus plays an important role in moulting and growth of crustaceans.

Keywords: *Astacus leptodactylus*, moulting, salinity, antennal gland, crayfish.

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Does intertidal mussel aquaculture in highly dynamic systems enhance biodiversity?

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The concept of ecological carrying capacity is often driven by a negative public perception of aquaculture. In contrast to finfish culture, shellfish farming does not require the addition of food for the animals being cultured to grow. To date, research on the environmental effects of mussel culture has mainly focused on benthic processes linked to expected increases in organic matter deposition. However, these studies differ greatly in their findings, in part because they have been done in contrasting hydrosedimentary environments, although few have considered the extreme end of this spectrum. The present study was done in the intertidal zone of the Chausey Archipelago (France), a highly dynamic system (tidal amplitude ~14 m) where mussel aquaculture installations (bouchots) are subjected to strong currents favouring the dispersion of biodeposits. The main objective of this study is to determine the small-scale influence of bouchot mussel aquaculture on the surrounding benthic infaunal community (i.e. abundance, diversity, assemblage structure). The general hypothesis is that bouchot mussel aquaculture increases the abundance and diversity of benthic infauna. In summer 2007, sampling was done at six sites, including reference sites, to determine the spatial variability of benthic infaunal communities. Analyses done to date show that total abundance was greatest close to bouchots. This suggests a positive influence of these installations on benthic communities in this highly dynamic system. Further results will be presented and discussed.

Keywords: benthic infauna, biodiversity, mussel aquaculture.

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