

**Midway-report for the MarBioShell-project (2008-2012), approved 4 March 2011 by the Program Committee, Danish Council for Strategic Research**

## **MarBioShell**

The main theme in the reorganized MarBioShell project is research aimed at off-shore production of line-mussels (*Mytilus edulis*) in the Great Belt (Denmark) to compensate for the present decrease in landings from Danish fjords and coastal waters. Methods are being developed to optimize mussel growth, and modelling tools are improved to guide dimensioning of mussel farms. In the laboratory, bioreactor technology is applied to provide controlled mass production of planktonic algae to be subsequently used in controlled growth experiments and bioenergetic and biochemical studies of food intake and assimilation in mussels. In the field, comparative studies of actual growth and production of mussels of different size in selected areas in and outside the Great Belt region are performed with special emphasis on the importance of salinity, current speed, and amount of phytoplankton (chl *a*) in the ambient water. Marked analyses are carried out to estimate whether product differentiation and consumer preferences contribute to the economic sustainability of the suggested new line-mussel production facilities in the Great Belt. Business network and branding, as well as local innovation systems are surveyed and used in future investment decisions. A research- and demonstration line-mussel farm is established in the southern part of Kerteminde Bay, close to the Great Belt. The research- and demonstration facility is a unique opportunity for all work packages within the MarBioShell projekt to work together in solving the main common task, namely to clarify the potential in the broadest sense of cultivating mussels in the Great Belt.

### ***WP0: Management and communication***

Management of the project and organization of the network is ensured by the scientific leader, Hans Ulrik Riisgård, in close co-operation with key participants responsible for the different main fields of the project.

Steering Committee consists of Hans Ulrik Riisgård (chairman, SDU-NAT), Flemming Møhlenberg (DHI), Eva Roth (SDU-SAMF), Niels T. Eriksen (AAU), Jens Honoré Walther (DTU). The steering committee is collectively responsible for: Overall coordination at the network level to ensure progress of the project and budget coherence. Approval of proposals for annual timetables and coordination with other relevant national and international research projects. In coordination with the relevant research schools, ensure research training, PhD-courses and collaboration with national and international companies, research teams and networks. Revise research plans. Observe all commitments to The Danish Council for Strategic Research. Administrate IPR and other legal aspects

Advisory Board will help to ensure the scientific quality and strengthen the international contacts with relevant research for the benefit of the project.

Reporting, seminars etc. (see timetable on last page).

Information Platform: The project has established an information platform in order to disseminate relevant knowledge to potential investors. The target group is businesses and others with an interest in joining a modern and research-based mussel farm business. The information platform will include citizens, tourist and tourism businesses as target groups for

information and communication activities. The role of the platform is to communicate research results in an inspiring and professional way. A working group has been organized with participants from research and business and an activity plan for the platform is in process.

### ***WP1: Production of microalgae***

Responsible PI: Ass. Professor Niels T. Eriksen, Department of Biotechnology, Chemistry and Environmental Engineering, AAU

#### **Aims**

The aim of WP1 is to design and optimize cultures of 'feed-algae' with specific, nutritional compositions, and to develop heterotrophic microalgal cultures of high nutritional value in order to create sufficient productivity for quantitative feeding experiments with mussels at larger scale.

#### Scientific personnel

- Daniel Pleissner (DP) started his 3-year PhD-project on April 1, 2009. Daniel Pleissner is employed at SDU but will conduct approx. 18 months of research on microalgal cultures at AAU.
  - Research assistant Kim Lundgreen (KL), SDU has contributed to the production of phototrophic microalgae for bivalve feeding at Marine Biological Research Centre, Kerteminde since mid 2008.
  - Muge Isleten (MI), exchange PhD student from Ege University, Turkey has completed a 6 month research period working on lipid production in heterotrophic *Cryptochodinium cohnii* from 01.04.09-30.09.09 at AAU.
  - Bjørn Lund Danielsen (BLD), 'diplomingeniørstuderende' at AAU, has completed a 30 ECTS BSc project on starch production in heterotrophic *Galdieria sulphuraria* from 01.03.09-31.10.09.
  - 15 MSc students in biotechnology have at their 5th semester carried out 16 ECST projects on growth, pigment and lipid formation in heterotrophic *Cryptochodinium cohnii*, *Chlorella saccharophila* and *Galdieria sulphuraria* during fall semesters 2008-2010 AAU.
  - Ana García (AG), exchange PhD student from University of Cádiz, Spain has carried out a 3 month project on gas exchange in phototrophic microalgae in photobioreactors, April-June 2010 at AAU
  - Martin Malthe Borch (MMB), guest student from DTU has carried out a 5 ECTS project on controlled CO<sub>2</sub> additions in photobioreactors, Spring 2010 at AAU
  - Döndü Yalçın (DY), MSc exchange student from Ege University, Turkey has carried out a project on isolation of heterotrophic microalgae from Feb-June, 2010 at AAU
  - 15 MSc students in biotechnology have at their 5th semester carried out 16 ECST projects on growth, pigment and lipid formation in heterotrophic *Cryptochodinium cohnii*, *Chlorella saccharophila* and *Galdieria sulphuraria* during fall semesters 2008-2010, AAU.
- Associate Professor Niels T. Eriksen (NTE), AAU is acting as supervisor for the students involved in this project and participates in research activities.

- Professor Hans Ulrik Riisgård (HUR), SDU participates in supervision and research activities.

#### Past activities (Jan 2008 – Nov 2010)

- A novel 3 L photobioreactor for continuous production of *Rhodomonas* sp. under controlled conditions has been designed, optimised and installed in April 2008 at Marine Biological Research Centre, Kerteminde. Since mid 2008 the photobioreactor has been in use producing algae for mussel feeding experiments. A second reactor is currently used for optimisation of the design and studies of oxygen and carbon dioxide exchange. This reactor will later be used to increase the capacity for production of phototrophic feed algae.
- Heterotrophic *Galdieria sulphuraria* has been produced at Aalborg University and used for mussel feeding experiments at Marine Biological Research Centre, Kerteminde.
- Investigation on growth and lipid content in heterotrophic *Chlorella* spp. has been started.
- Heterotrophic cultures of *Cryptochodinium cohnii* have been studied at Aalborg University, and culture conditions have been optimised with respect to growth, biomass productivity, and the lipid content of the cells.
- Continuous flow cultures of *Cryptochodinium cohnii* subjected to carbon, nitrogen, or phosphorous limitation have been developed and characterised with respect to biochemical composition of the biomass (DP).
- Methods for lipid and fatty acid analysis in *Cryptochodinium cohnii*, based on gas chromatography and staining combined with fluorescence spectroscopy have been developed.
- A novel method for analysis of amino acids in growth media of high salinity has been developed.

#### Future activities (Nov 2010 – Dec 2012)

- Continuous production of phototrophic ‘feed-algae’, *Rhodomonas* sp. in photobioreactors as feed in bioenergetics experiments with blue mussels (see WP2) feeding on phototrophic microalgae (KL, DP)
- Optimisation of photobioreactors presently in use, and novel photobioreactors in collaboration with the new partner, TekFak-SDU-KBM (former Odense Teknikum) (DP, KL, NTE).
- Transfer of heterotrophic cultures from AAU and construction of facilities for heterotrophic algae production at Marine Biological Research Centre, Kerteminde (DP, KL, NTE).
- Continuous production of phototrophic and heterotrophic ‘feed-algae’ as feed in bioenergetics experiments with blue mussels feeding on heterotrophic microalgae (DP, KL).

#### Publications

##### **Scientific articles (peer reviewed)**

Pleissner D, Wimmer R, Eriksen NT (2011) Quantification of amino acids in fermentation media by isocratic HPLC analysis of their  $\alpha$ -hydroxy acid derivatives. *Analyt. Chem.* DOI 10.1021/ac1021908 (in press)

Pleissner D, Eriksen NT (2011) Growth and biochemical composition of *Cryptechodinium cohnii* grown carbon-, nitrogen-, or phosphorous-limited in continuous flow culture. (in prep.)



Figure 1. Left. Photo-bioreactor designed for continuous production of phototrophic feed algae during initial optimisation tests using *Chlorella vulgaris*. Inset indicates scale (3 L). Right. Fluorescence micrograph of *Cryptechodinium cohnii* stained with Nile Red. Yellow fluorescence is from Nile Red dissolved in intracellular lipid droplets. Left inset shows same cells under bright field. Top inset shows cell under dark field.

### Conference contributions

Eriksen NT (2010) Heterotrophic microalgal cultures and the synthesis of pigments of polyunsaturated fatty acids. Workshop on algal biotechnology and cultivation - a Nordic perspective. Gothenburg, Sweden 25/11 2010

Pleissner D, Eriksen NT (2010) Production and control of biochemical composition of the heterotrophic dinoflagellate *Cryptechodinium cohnii* in continuous cultures. Workshop on algal biotechnology and cultivation - a Nordic perspective. Gothenburg, Sweden 25/11 2010

Eriksen NT, Pleissner D, Isleten M (2010) Pigment and lipid synthesis in heterotrophic microalgal cultures (lecture) V<sup>th</sup> International Bioengineering Congress, Izmir, Turkey 16-19/6 2010

Pleissner D, Eriksen NT (2010) Continuous culture of the heterotrophic dinoflagellate *Cryptechodinium cohnii* (poster) 8<sup>th</sup> European Workshop Biotechnology of Microalgae, Potsdam, Germany 7-10/6 2010

## **WP2: Growth and bioenergetics of filter-feeding mussels**

Responsible PI: Professor Hans Ulrik Riisgård, Marine Biological Research Centre, University of Southern Denmark

### **Aims**

The overall aim of WP2 is to provide the necessary growth energetic information that is needed in WP3 for construction of an easy-to-use production model and objectives are to study growth and bioenergetics in mussels living on diets of heterotrophic 'feed-algae' and to establish relationships between feed availability and growth in blue mussels of all sizes in the laboratory and in the field.

### Scientific personnel

- Professor Hans Ulrik Riisgård (HUR) participates in research activities and is acting as supervisor for a number of Ph.D. and master students involved in this project.
- Associate Professor Niels T. Eriksen (NTE), AAU participates in supervision and research activities.
- Daniel Pleissner (DP) started his 3-year PhD-project on April 1, 2009. Daniels Pleissner will conduct approx. 18 months of research on feeding and bioenergetics in blue mussels at Marine Biological Research Centre (SDU), Kerteminde while the remaining time of his PhD project is allocated to WP2.
- Research assistant Kim Lundgreen, SDU works full-time on MarBioShell, carrying out all-round work in lab and field, and he assists the scientific leader Hans Ulrik Riisgård in the administration of MarBioShell.
- Inma Martín Arnan from University of Murcia, Spain has worked for 6 months in 2008-2009 within MarBioShell as a Leonardo da Vinci grant trainee.
- Ana Orts Pérez from University Miguel Hernandez of Elche, Alicante, Spain worked as a Leonardo da Vinci grant trainee for 6 month from August 2009 to January 2010.
- Isabel Barreiro Saavedra from University Alcalá de Henares, Madrid, Spain worked as a Leonardo da Vinci grant trainee from January 2010 to July 2010. She was afterwards employed on the project for 4 month to work as a research assistant from Septmeber 2010 to December 2010.
- Sandrine Serre from National Agronomic Engineering Post Graduate School Toulouse, France worked within the MarBioShell project as a research assistant for 4 month, from September to December 2010.
- Line Bøttiger is a master student studying the effect of salinity on growth of mussels
- Parnuna Egede was master student within MarBioShell studying food uptake and growth of blue mussels; she graduated (M.Sc.) in September 2010.
- Gorm Rønved Larsen, M.Sc. worked 2 months (October and November 2010) as a consultant obtaining and treating environmental monitoring data on phytoplankton biomass in Great Bet and Limfjorden for the last 20 years.

### Past activities (Jan 2008 – Nov 2010)

- Investigations of growth and bioenergetics in blue mussels fed phototrophic *Rhodomonas* sp. since mid 2008 at Marine Biological Research Centre, Kerteminde.

- Investigations of growth and bioenergetics in blue mussels fed heterotrophic *Galdieria sulphuraria* during spring 2009 at Marine Biological Research Centre, Kerteminde.
- Design and test of experimental set-up for automatic control of algal concentration and continuous detection of filtering activity and feeding rates in blue mussels, during 2010 at Marine Biological Research Centre, Kerteminde.
- Feeding and growth experiments using phototrophic *Rhodomonas* sp. and heterotrophic *Galdieria sulphuraria* have been carried out at the Marine Biological Research Centre, Kerteminde from mid 2008 to November 2010.
- Two students (Lasse Tellerup Hansen & Michala Karlsen Møller, Tek-Fak-SDU KBM) finished their projects on blue mussels (7. semester afgangprojekt) by the end of 2008.
- Master student Parnuna Egede, SDU, has carried out growth experiments for determination of satiation degree in blue mussels fed different concentrations of phototrophic *Rhodomonas* sp.
- Kim Lundgreen has together with Mads van Deurs, Nordshell company partner within the MarBioShell project, and several students carried out field growth experiments with mussels suspended in net-bags at different locations in the Great Belt and Limfjorden (reference area) during 2008 and 2010.
- A survey of mussel larvae density has been conducted at 4 sites (Svendborg, Musholm, Horsens, Kerteminde) during 2008, and in Kerteminde Bugt during spring and summer of 2009 and 2010.
- Kim Lundgreen and others have together with Bo Hoffmann Jørgensen and Francesca Storti, DTU-Aqua, carried out particle image velocimetry (PIV) measurements for determination of the exhalant jet velocity of mussels to be used in future computational modeling.

#### Future activities (Nov 2010 – Dec 2012)

- Nov 2010 - Dec 2011: Growth and bioenergetics using phototrophic microalgae (see WP1) as feed for blue mussels (KL, DP).
- Nov 2010 - Oct 2011: Growth and bioenergetics using heterotrophic 'feed-algae' of different species and with predetermined biochemical composition (see WP1) as feed for blue mussels of all sizes (DP, KL).
- Nov 2010 - Oct 2011: Characterisation of biochemical and fatty acid composition of blue mussels feeding on phototrophic or heterotrophic microalgae (DP).
- Importance of heterotrophic relative to phototrophic plankton organisms in blue mussel diets in the field will be studied (NTE, DP, HUR).
- May-Dec 2011: Field growth experiments with different size groups of mussels in net-bags at the MarBioShell musselfarm in the Great Belt and possibly other sites in the Great Belt region will be carried out in order to measure the specific growth rate of different size groups of mussels (HUR, KL, NN).
- Due to frequently high current speeds in the Great Belt it is relevant to study the effect of current speed on the shell-opening degree, and thus filtration rate and growth of mussels. This will be studied in controlled flume studies (HUR, KL, NN).
- Due to generally higher salinities in the Great Belt compared to Limfjorden, the effect of salinity on growth will be studied in controlled laboratory feeding experiments (HUR, KL).

•2011-2012: Based on the combined laboratory and field studies on mussels, possible differences in specific growth rates and production potentials of line mussels will be evaluated. In fulfilling this aim, integrated intensive studies with other work-packages during campaign periods, using the research a research- and demonstration farm for cultivation of off-shore line mussels in Kerteminde Bay (Great Belt), are essential.

### Publications

#### **Scientific articles (peer reviewed)**

Riisgård, H.U., Egede, P.P., Saavedra, I.B. (2010). Threshold algal concentrations for pseudofaeces production and incipient saturation reduction of filtration rate of mussels (*Mytilus edulis*). Mar. Biol. (submitted)

Larsen, P.S., Riisgård, H.U. (2010). Validation of the flow-through chamber method (FTC) and steady-state method (SS) to measure clearance rates in mussels. (submitted).

Riisgård, H.U., Lundgreen, K., Saavedra, I.B., Pleissner, D. (2011). Estimated and actual growth of mussels, *Mytilus edulis*, in steady-state feeding experiments. (manuscript)

Riisgård, H.U., Lundgreen, K., Larsen, P.S. (2011). A growth model for relationship between mussel (*Mytilus edulis*) size, specific growth rate, and phytoplankton biomass. (manuscript)

Pleissner, D., Eriksen, N.T., Lundgreen, K., Riisgård, H.U. (2011). Feeding, growth and uptake of fatty acids in blue mussels (*Mytilus edulis*) fed different species of micro-algae (in prep.).

Lundgreen, K., Riisgård, H.U. (2011). Abundance of mussel *Mytilus edulis* larvae in Danish waters (in prep.)

Pleissner, D., Lundgreen, K., Riisgård, H.U. (2011). Online filtration rate measurements of filter feeding mussels at low algal concentrations. (in prep.).

#### **Reports (M.Sc., Engineer, Bachelor)**

Lasse Tellerup Hansen (2008). Blåmuslingers potentiale ved oprensning af havmiljø. Afgangprojekt (dip. ing.) fra Institut for Kemi-, Bio- & Miljøteknologi, Teknisk Fakultet, Syddansk Universitet.

Michala Karlsen Møller (2008). Anvendelse af blåmuslingen, *Mytilus edulis*, i foder. Afgangprojekt (dip. ing.) fra Institut for Kemi-, Bio- & Miljøteknologi, Teknisk Fakultet, Syddansk Universitet.

Annette Høyvald (2009). Fedtsyrer i muslinger. Afgangprojekt (dip. ing.) fra Institut for Kemi-, Bio- & Miljøteknologi, Teknisk Fakultet, Syddansk Universitet.

Daniel Pleissner (2009). Chemostat-aquarium-system (CAS) for long term investigation of mussel filtration and growth. (Individual Ph.D. study activity report, August 2009). Biological Institute, University of Southern Denmark.

Lærke Arentoft Johansen (2010). "Faglig formidling i praksis – Formidling af MarBioShell-projektet til tre målgrupper." (Bachelorprojekt afsluttet september 2010). Biologisk Institut, Syddansk Universitet.

Sabrina Maria Nothlev Sørensen (2010). "Faglig formidling i praksis – Formidling af MarBioShell-projektet til tre målgrupper." (Bachelorprojekt afsluttet september 2010). Biologisk Institut, Syddansk Universitet.

Parnuma P. Egede (2010). Food uptake and growth of blue mussels (*Mytilus edulis*) - a combined laboratory and field study. (M.Sc. thesis; 15 September 2010). University of Southern Denmark.

Line Bøttiger (2011). Growth of blue mussels, *Mytilus edulis*, and effects of salinity. (M.Sc. thesis, in prep.). Biological Institute, University of Southern Denmark.

### ***WP3: Mussel farm models***

Responsible PIs: Head of Innovation Flemming Møhlenberg, DHI & Associate Professor Jens Honoré Walther, DTU

#### **Aims**

The overall aim of the research in WP3 is to develop easy-to-use tools that can aid planning and design of offshore mussel farms. The objectives and activities to achieve this are as follows:

- Develop concepts, methods and ultra-fine scale models for description of the flow around individual mussels and smaller clumps of mussels
- Develop methods and fine scale models for description of the flow around mussel growth lines and nets established in a farm under varying current and wave conditions
- Upscale ultra- and fine-scale models by parameterization of horizontal dispersion and mixing and implement refined mussel growth formulations (from WP2) in meso-scale models to be integrated seamless with coupled larger-scale hydrodynamic-ecological models
- Calibrate and verify mussel farm models using dedicated lab and field campaigns

#### *Scientific personnel*

Head of Innovation Flemming Møhlenberg, DHI

Head of Innovation Erik Damgaard Christensen, DHI

Lars Yde, DHI

Ciaran Murrey, DHI

Johannes Tophøj Rasmussen, DTU

Francesca Storti, DTU (PhD-student: Sept 2009 - April 2010)

Bo Hoffmann Jørgensen, DTU (Post Doc)

Past activities (Jan 2008 – Nov 2010)

- Meso-scale 2-dimensional models ( $1000 \times 500$  m) have been established to model current speed and transports of algae into a section of a mussel farm. Mussel growth lines ('droppers') are implemented as "piers" where the diameter and flow resistance can be varied by the user. Spatial resolution (grid cell sizes) has been varied between 1 m and 0.25 m. Mussel growth is implemented using a "simple" saturation-function between algal carbon concentration and net growth rate that further are scaled to shell length using an allometric function. Grazing loss of phytoplankton is implemented by multiplying growth rate by 3-4 assuming gross growth efficiency between 20 and 33%. The range in resistance and dispersion has been set using a rather comprehensive Norwegian data set (Strohmeier et al. 2005; raw data submitted), but neither current speed ( $< 5$  cm/s) nor Chl-a ( $1-3 \mu\text{g/l}$ ) are representative for the Great Belt.
- Through an external grant (€ 34.000) from the European Fisheries Fund) the current model set-up has been used in 2008 to predict the potential for mussel production near to three Danish fish farms. Although the model still needs to be improved (see above) we believe that even in its current state this tool is superior to most other tools in use.
- During winter and spring 2009 the 2-D model has been transferred to 3-D models allowing for modeling of mussel farms in stratified waters, characterized by 2-way flows, and depth gradients in flow speed and phytoplankton. Models have tested thoroughly for mass conservation and numerical stability, and at present the model tool appears robust.
- An external FTP project "Multiscale Simulations Using Particle Vortex Methods with Application to Bluff Body Flow" (FTP grant 274-08-0258) has allowed us to develop a large scale three-dimensional detailed model of the flow in complex geometries, including flows in biological systems. The goal of the FTP project is to study the aerodynamic stability of long suspension bridges, but we have used this opportunity to perform validation of the software on biological relevant flows - here the flow through a mussel (Fig 2).
- We have performed detailed measurements of the flow rate and the exhalant jet from mussels (Fig. 3). The measurements were conducted at the Marine Biological Research Center (SDU) in Kerteminde. The flow measurements have been used to provide boundary conditions for ultra-fine scale models. Preliminary simulations have been conducted and compare with the measurements, and the work has been submitted to Marine Ecology Progress Series.

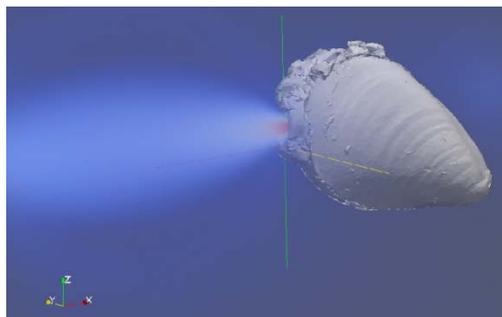


Figure 2. Numerical simulation of the exhalant flow from a mussel. The simulations were performed using an in-house 3D vortex method code. The picture shows the flow speed. The simulations were

made by Florian Willerval and Charles Thouny from Ecole d'Ingenieurs en Genie des Systemes Industrial, La Rochelle, France during their visit to DTU MEK.

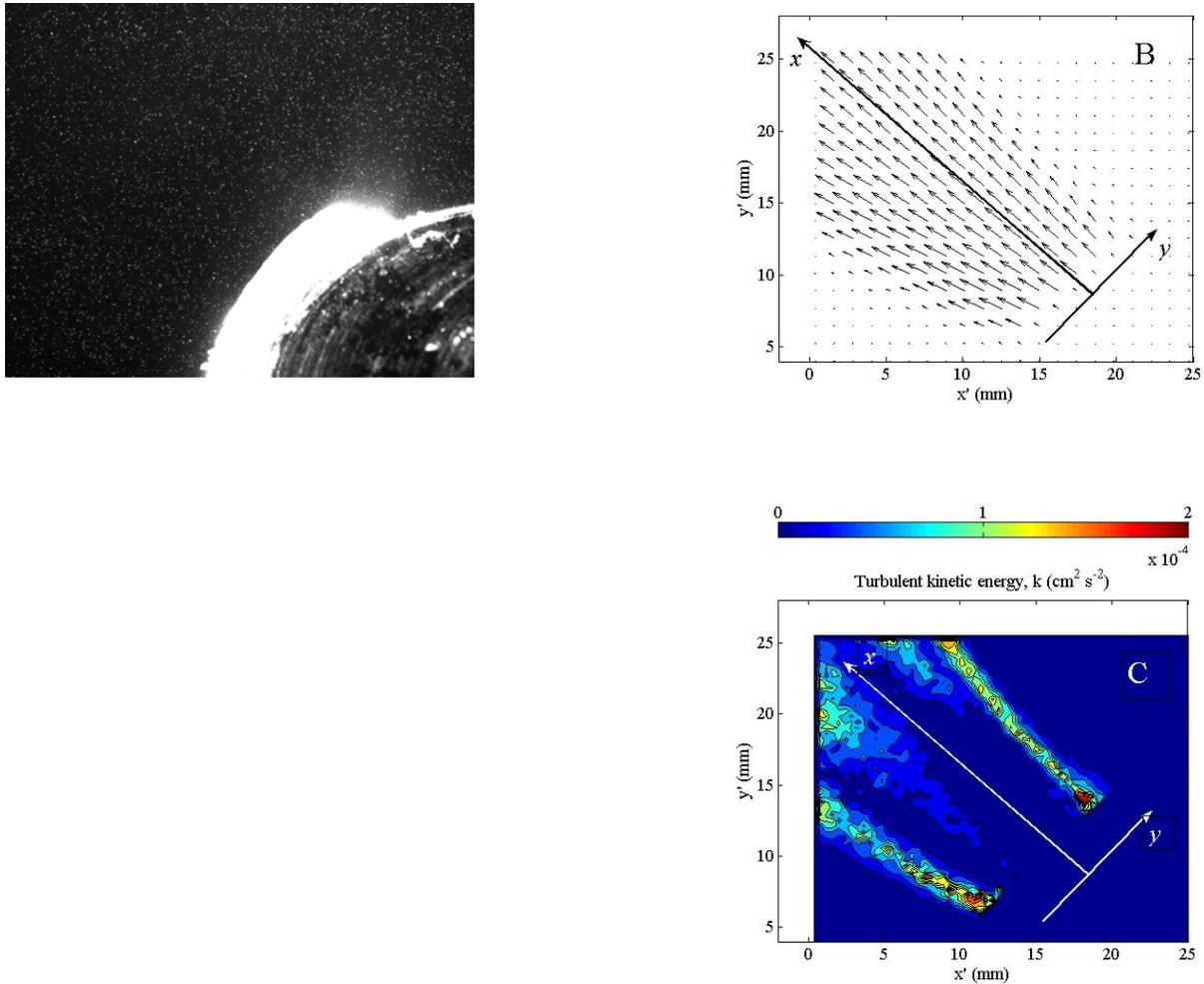


Figure 3. *Mytilus edulis*. (A) PIV image of captured field showing seeding particles in the jet flow, the exhalant siphon and part of the shell to the lower right. (B) Averaged vector field of the exhalant jet. (C) Contour plot of turbulent kinetic energy showing jet spreading by shear layers.

Future activities (Nov 2010 – Dec 2012)

- Critical functions and elements in the meso-scale model are the magnitude of resistance of mussel ‘droppers’ (i.e. represented by ‘piers’ in the model), the associated dispersion (i.e. transport of algae from main stem flow to the pier grid cells) and the mussel growth function, especially 1) the minimum concentration that allows positive growth across different sized mussels, 2) contribution from non-algal particles such as proto- and mesozooplankton. The future activities will address these critical functions:

- Develop, test and apply a Lagrangian, Navier-Stokes equation solver based on the three-dimensional particle vortex method to describe the complex flow around individual mussels and around groups of mussels sitting on a growth rope.
  - Upscale ultra-fine scale models to ‘fine scale’ models for description of the flow around mussel growth lines and nets by modeling the resistance from the mussels and lines as a moving porous medium (CFD).
  - Incorporate process descriptions of flows from ultra-fine and fine scale models into farm-scale models by parameterizing dispersion and mixing functions.
- Incorporate refined mussel growth functions, quality and availability of food (studied and quantified in WP2) in the farm model
- Thorough test of mussel farm model during 2 dedicated 2-week field campaigns at the research- and demonstration mussel farm in the Great Belt (see below)
  - Using bottom deployed ADCPs for quantifying depth gradients of flows inside and outside of mussel farm
  - Sampling mussels along mussel farm and quantifying ingestion rate of algal pigments using the ‘defaecation method’ and using in situ fluorometers for upstream algal concentration
  - Test and validate the mussel farm model based on long-term monitoring of abundance, biomass and growth rates of mussels at 8-10 fixed positions in the research- and demonstration mussel farm in the Great Belt (WP7).

### Publications

#### **Scientific articles (peer reviewed)**

Riisgård, H.U., Jørgensen, B.H., Lundgreen, K., Storti, F., Walther, J.H., Meyer, K.E., Larsen, P.S. (2010). The exhalant jet of mussels (*Mytilus edulis*). Mar. Ecol. Prog. Ser. (submitted)

#### **Reports**

Charles Thouny, Florian Willerval (2010). Numerical simulation of the exhalent jet flow from the blue mussel *Mytilus edulis*. (student report 12/17/2010). Danish Technical University

### ***WP4: Mussel farm design and harvest***

Responsible PI: Head of Innovation Flemming Møhlenberg, DHI Water-Environment-Health, Hørsholm

#### **Aims**

The overall aim is to develop settling lines and production ropes that prevent crowding of mussels and reduce loss of production. A related aim is to test various methods in accordance with the selected designs.

#### Scientific personnel

Flemming Møhlenberg, DHI

NN, DHI

Past activities (Jan 2008 – Nov 2010)

Non- activities start spring 2010

Future activities (Nov 2010 – Dec 2012)

Excessive crowding, low individual growth and mussel loss by sloughing off of the growth lines are characteristic features of mussel farms with low workers attendance, while frequent inspection, seed harvest and ‘re-socking’ can improve farm productivity markedly, but at high operational costs.

Alternatively, growth systems that either automatically carries out ‘self-thinning’ when mussels are growing or restricts settling to limited areas of growth lines will constitute near-optimal growth systems that can be implemented at industrial scale. The activities will test 2-3 hypothesis and systems:

- Settling- and growth lines that expands in length during 2-4 months after settling

Abundance and growth of mussels settling on “Swedish” bands deployed folded using wire straps until 2-4 months after settling and unfolded bands.

- If above successful develop in cooperation with associated company settling- and production bands that elongates ‘automatically’ by e.g. rotting strands

- Pre-treated settling- and growth lines that prevent settling from certain areas, e.g. after treatment with readily degradable biocide that after 2-4 month allows the growing mussels to inhabit the former treated areas.

- Settling- and growth lines that structurally include woven material that are avoided by mussel larvae and subsequently degrade allowing growing juveniles to expand to these areas

Patent application, if any test is successful.

**WP5: Market analysis**

Responsible PI: Eva Roth, Associate Professor, Department of Environmental and Business Economics, SDU, Esbjerg

**Aims**

The group is responsible for carrying out part of the socio-economic research of the project. The aim falls within 3 integrated studies:

1) Market analyses, what are the market structure, consumer preference and demand in the EU for blue mussel?

2) Ascertain mussel farmer’s risk perception and risk management strategies.

3) Model the real economic risk of HAPs, E-coli and oxygen depletion incidents for mussel aquaculture (in cooperation with the SPICOSA project).

Scientific personnel

Associate Professor Eva Roth.

Professor Hans Stubbe Solgaard

PhD student Dewan Ali Ahsan

PhD student Thong Tien Nguyen

Post.Doc, PhD Lars Ravn Jonsen

Past activities (Jan 2008 – Nov 2010)

**Progress in risk research.** A questionnaire survey has been conducted (Dewan Ahsan, Eva Roth) to analyze the risk perception and the risk management strategies of the farmer. The survey was carried out in October-November period, 2008. In the questionnaire we included 24 risk sources of mussel farming and 24 different types of management strategies which can reduce the risk in mussel farming. The response rate is high as we covered 72% of sample (13 out of 18) though the number sample is small. The results are presently being analyzed and an article has been submitted to a peer reviewed journal, and another paper has been accepted and presented at a conference in Sao Paulo, Brazil. The results have been published late 2010:

Ahsan, Dewan; Roth, Eva. Farmers' risk perception and risk management strategies in an emerging mussel aquaculture industry in Denmark. / I : Marine Resource Economics . 2010 ; Vol. 25, Nr. 3, 01.01.2010

**Progress in bio-economic production modeling.** We have formulated the mathematical model and establishing the data input for the production model (which will also provide the scientific risk in the industry) but has found it more laborious than expected. The conceptual model has been formulated in collaboration with SPICOSA (Science and Policy Integration for Coastal system Assessment) project and the model is still in developing stage, although we succeeded in getting the model to run, validated through hind casting and actually get very interesting results from the different scenarios introduced in the model. By this model, we are trying to explain the real risk of *E. coli*, HABs and oxygen depletion events in the mussel industry. In future, the model will also incorporate the marketing risk analysis part as well. (Karen Timmermann and Stiig Markager, DMU and Grete Dinesen, DTU-Aqua in cooperation with Eva Roth, Lars Ravn Jonsen and Dewan Ahsan, IME, SDU). The basic model is still being worked on. The empirical data have been introduced, and as SPICOSA is almost a finished project the input from the MarBioShell has been utilized in the following publications and posters:

### Publications

#### **Peer reviewed**

Dinesen GE, Timmermann K, Roth E, Markager S, Ravn-Jonsen L, Hjorth M, Holmer M, Støttrup JG. Mussel production and WFD targets in the Limfjord, Denmark: an integrated assessment for use in system-based management. [Submitted to 'Ecology & Society']

#### **Non-peer reviewed**

Støttrup JG, Dinesen GE, Timmermann K, Markager S, Roth E, Ravn-Jonsen L. 2010. Integrated assessment for use in system based management: WFD nutrient targets and mussel production in the Limfjord, Denmark. ICES CM2010/B:09: 1-14. [Printed online September 2010]

#### **Posters**

Dinesen GE, Ahsan D, Dolmer P, Holmer, Hjort M, Jarlbæk H, Hoffman E, Markager S, Roth E, Sverdrup-Jensen S, Petersen JK, Timmermann K, Støttrup JG. 2010. The Limfjord, Denmark. SPICOSA study site 5. [Presented at the SPICOSA SAF meeting, Istanbul 2010]

Dinesen GE, Timmermann K, Markager S, Roth E, Ravn-Jonsen L, Hjort M, Petersen JK, Holmer, M, Støttrup JG. 2010. The Limfjord, Denmark. SPICOSA study site 5. [Presented at the Littoral Conference, London 2010]

Dinesen GE, Timmermann K, Markager S, Roth E, Ravn-Jonsen L, Hjort M, Holmer M, Støttrup JG. 2010. The Limfjord, Denmark. SPICOSA study site 5. [Presented at the SPICOSA SAF meeting, Malta 2010]

**Progress in the marketing study.** The marketing study is included in a much larger PhD-plan investigating consumer preferences and demand for Blue Mussels in European markets. The plan is accepted by the PhD-board and includes a demand analysis and consumer preference (PhD student named Thong Tien Nguyen has been employed in February, 2009 and is responsible for the market study. Prof. Hans Stubbe Solgaard is PhD-supervisor). Consumer preference and demand for blue mussel is investigated at two levels that are at the market level and individual consumer level.

#### Past activities (Jan 2008 - Nov 2010)

The marketing research has in reality been done although not yet published. The project has investigated demand for mussel at market level by using secondary data. The work has been finished. The aims of this part is to understand what factors influence the mussel price and how consumer evaluate the mussel characteristics at the market level. Two papers of this issue have been finished:

- Hedonic price for mussels in auction market: Using secondary data from auction market in Yerseke, the Netherland, the study estimate hedonic price model for mussels at the wholesale market. The results show that biological characteristics of mussels such as meat content and size are most important factors determining mussel price in the wholesale market. The mussel having meat content above 40% and the size less than 50 pieces per kg would get it highest implicit price. The other factors are also important determinants of the price are “impurity” of mussel lots, heterogeneity of size, and time and place of harvest.

- Inverse demand system for mussels in the EU: The aim of study is to investigate the relationship between quantity consumed and price of the mussels from major producers in the EU. Farmed mussels from France, Spain, Italy, and the Netherland are price inflexible, which means price elastic, while wild catch mussel from Denmark are almost unit price flexible, which means unit price elastic. The study also shows that if the scale of consumption increases by 1%, i.e. all quantities consumed increase by 1%, the ex-vessel price of mussels declines by 0.983% for Danish, 1.065% for Italian, 1.102% for Spanish, 1.067 for French, and only 0.493% for Holland mussels. In addition, cross-price flexibilities between mussels are small and many are closed to zero. This suggests that the mussel products from different countries are less quantity-substituted or quantity-complemented each others.

#### Future activities (Nov 2010 - Dec 2012)

The PhD-project of Thong Tien Nguyen is planned finished early 2012 and the final results will be available from the dissertation. A Danish language dissemination of results is planned.

**Risk perception and risk management.** The results are planned disseminated further through a Danish article.

**Bio-economic model (in collaboration with SPICOSA).** The work is still in progress and one article is presently in preparation within the broader team of collaboration.

### ***WP6: Networks, branding and regional development***

Responsible PI: Professor Flemming Just, Professor, Head of Department, Department of Environmental and Business Economics, Southern Denmark University.

#### **Aims**

To contribute to the development of organization, brands and innovation system for multifunctional off shore mussel production in Denmark. WP6 will in cooperation with business partners and research (MarBioShell WPs) use the suggested research- and demonstration mussel farm at Kerteminde to investigate and organize a multifunctional mussel production that is indented to be integrated with tourism and experience-economy in the area (tours, gastronomy, etc.). There is a need for organizing cooperation with the municipality, authorities, business partners and researchers, organization of a local company (cooperative or similar), development of business plans, cooperation with retail and consumers, and the tourism industry etc. The specific project enables the development of models for establishment of multifunctional off-shore mussel production on a national scale by collection of experiences from line-mussel production in Limfjorden, Denmark and development strategies to be applied specifically in the Watten Sea, Denmark.

Research questions: How to create an economically sustainable off-shore mussel production? How to create demand for mussels and associated experience economy? How to organize businesses along the value chain and across sectors?

#### ***Scientific personnel***

Flemming Just, Professor, IME, Southern Denmark University. WP responsible and engaged in network and innovation studies and regional policy.

Bodil Stilling Blichfeldt, Associate Professor, TIC, Southern Denmark University. Engaged in branding analysis and marketing strategy. Bodil Stilling Blichfeldt is taking up a new position 1. February, 2011 and has finished her part of the project.

Klaus Lindegaard, Associate Professor, IFUL, Southern Denmark University. Engaged in organisation and innovation analysis and regional policy. Klaus Lindegaard is starting in a new position on 1. February, 2011 and therefore leaves the project.

The team from WP 5 will continue the work on WP6 in consistency with the merger between their departments which commenced 1. January 2010.

#### ***Past activities (Jan 2008 – Nov 2010)***

WP 7c on innovation, learning, networking and regional development has been active in organizing project cooperation between business partners and researchers by conducting a series

of meetings between the business partners and the researchers of the WP's, which has been organized in a biology group, a technology group and a economy group across research institutes and universities. Focus has been on dialogue around experiences, problems and needs of the business partners. As the reconstruction of the project has changes the focus on the integration directly between multiple business partners and resulted in a more targeted establishment of a research plant, the work has changes accordingly. The business opportunities and the consumer preferences guiding the development of future product assortments have been initiated and will guide the future work on WP7b+WP7c. WP7b on branding has in accordance with project plans been active with the study of existent and possible marketing strategies related to place branding.

### Publications

#### **Non-peer reviewed**

Stilling-Blichfeldt, Bodil. "Town of Mussels". A Danish case study on place branding, food festivals and community identity. CLF Working Paper No. 08/2010.

### Future activities (Nov 2010 – Dec 2012)

- WP6 works with 3 overlapping and partly mutual supplementary investigations. First (1) the WP will be active in organizing the research- and demonstration mussel farm at Kerteminde as an independent multifunctional business, based on mussel production together with tourism and experience economy. Second the WP will develop models and recommendations on establishment and operation of mussel farms nationally, and the regional and innovation policy perspectives involved.

- Business case: Establishment of mussel farm, activities, equipment, economy, employees, plans, innovation activities, networks.

- Innovation cases: MarBioShell-projects, research-business cooperation on practical use of research on biological and technological aspects of off-shore mussel farming, especially optimizing the revenue on different growth conditions, technological solutions and market conditions for sales of final produce.

Thong Tien Nguyen's PhD project is continuing by investigating the preference and demand for mussel at individual consumer level. By using choice experiment method, the future study will estimate the elasticity of demand for mussel at the individual consumer level, and the cross-elasticity of mussels with other seafood products. The studies will also answer questions what are determinants of mussel preference and choice, this characteristics are not considered in market level studies by using consumer survey and method of structural equation model. This choice experiment will contribute to the overall analysis of both the business case and the innovation case as consumer behavior and consumer preferences determine the product produced.

WP6 is engaged in networking and organize focus groups with relevant actors for the multifunctional research- and demonstration mussel farm and promote interaction and exchange between business partners and researchers along the project period in order to produce biological, technological and economical viable and environmentally sustainable

business plans and models for establishment of off shore mussel production. The WP6 will conduct research seminar in 2011 and conference in 2012 between WP on market analysis and WP component on branding in order to develop marketing strategies for place based branding of mussel products and experience economy. WP6 is engaged in the information platform activities of MarBioShell 2010-2012.

### ***WP7: Cross-cutting issue: Research- and demonstration mussel farm***

Responsible PI: Professor Hans Ulrik Riisgård, Marine Biological Research Centre, University of Southern Denmark

#### **Aims**

In 2010 the MarBioShell-project established a research- and demonstration farm for cultivation of off-shore line mussels in Kerteminde Bay (Great Belt) in collaboration with a current partner, the commercial mussel company Nordshell. The plan is to construct and operate a 25% full-scale experimental mussel farm during the years 2010-2011 (cost around 200,000 DKR per year minus anticipated income from the sale of mussels together with tourism activities and eventually sale of the plant when the project period is terminated). The research- and demonstration farm is a unique opportunity for all work packages within MarBioShell to work together in solving an important common task, namely to throw light on the potential, in the broadest sense, to cultivate off-shore line mussels in a rational manner in the Great Belt, thus opening the way for a new trade and employment in this region.

#### *Activities (Nov 2009 - Dec 2012)*

- Mussel larvae settling and mussel growth
- In situ measurements of current flow, chl-a, grazing impact of mussels
- Calibration of mussel-farm models
- Test of harvest methods
- Test of thinning out on growth and grazing impact
- Optimizing of mussel-farm design
- Importance of heterotrophic relative to phototrophic plankton organisms in blue mussel diets in the field
- Organization, innovation, branding and regional development

#### *Scientific leaders and participating WP's*

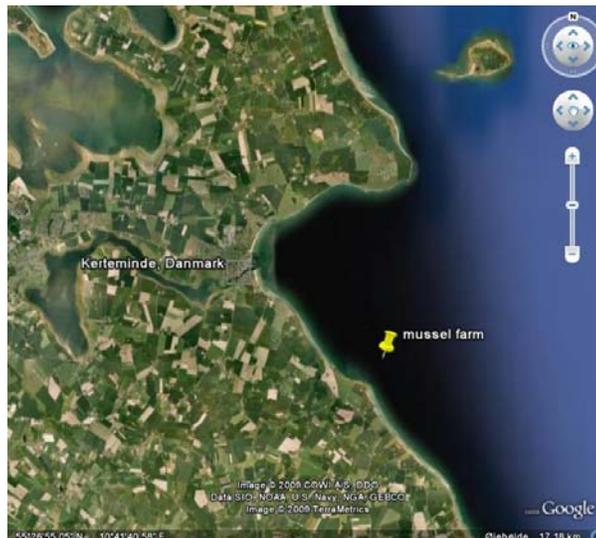
- Hans Ulrik Riisgård (WP2)
- Flemming Møhlenberg (WP3 & WP4)
- Jens Honoré Walther (WP3)
- Eva Roth (WP6)
- Niels T. Eriksen (WP1)

#### **Supplementary comments**

The research- and demonstration mussel farm was established in 2010 in the southern part of Kerteminde Bay, close to the Great Belt and near Risinge Hoved, with a distance of two

nautical miles from the Marine Biological Research Centre (SDU) at the harbour of Kerteminde which is also the port from where the mussel farm is being operated. The mussel farm covers an area of  $175 \times 250$  metres. It consists of 15 long-lines with 1.000 metres of on-growing rope on each long line. The output is estimated to be approximately 4 kg mussel per metre about 1 to 1.5 years after the first settling of mussel larvae. The mussel culture has been established in close cooperation with the present MarBioShell-partner, Nordshell which has the necessary experience and the equipment needed. The same partner also do service and running operations, and is responsible for the harvest of mussels. The partner has, due to many years in the business well-established contacts to other mussel farmers (domestic and overseas), the mussel industry and equipment suppliers.

In connection to the rope culture and the closely associated research activities it may also be possible develop a range of other related activities to be examined in more details by WP6. This could be tours for tourists in cooperation with the nearby Fjord & Belt Centre (Kerteminde) which is a self-governing marine research and experience centre with some 60.000 visitors every year. Other possibilities are events with local restaurants and the local fishery, and Kerteminde is well-known for its long tradition for fisheries and seafood industry.



*The research- and demonstration farm for line-mussels was established in 2010 in Kerteminde Bay (Great Belt).*

MarBioShell timetable of reconstructed project 2009-2012. Time course for start and end of the different research activities and their interconnectivity are shown in the diagram below. Also planned meetings of Steering Group, Advisory Board, Research Seminars and Conference are shown in addition to time for reporting.

