Peer Review of a CCW Commissioned report: Beadman, H. (2003) Impacts of Mussel Seabed-Lay bottom cultivation, with special reference to the Menai Strait and Conwy bay candidate special area of conservation.

E.I.S. Rees, P.Dare,P.Dolmer & A.C.Smaal

CCW Contract Science Report No: 657

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PEER REVIEW OF A CCW COMMISSIONED REPORT: BEADMAN, H. (2003) IMPACTS OF MUSSEL SEABED-LAY BOTTOM CULTIVATION, WITH SPECIAL REFERENCE TO THE MENAI STRAIT AND CONWY BAY CANDIDATE SPECIAL AREA OF CONSERVATION. CCW COMMISSIONED REPORT. UNIVERSITY OF WALES, BANGOR.

E.I.S. REES, P. DARE, P. DOLMER & A.C. SMAAL

A report prepared for:

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Contents

1. Background to peer review

In 2003, the Countryside Council for Wales (CCW) commissioned a study to review the environmental impact of mussel cultivation with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation (cSAC). The review, undertaken by the University of Wales, Bangor, considered known and potential impacts of seabed mussel cultivation with particular reference to the protected nature conservation features of the cSAC.

The report "Impacts of mussel seabed-lay bottom cultivation, with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation" was published in June 2003. There then followed a series of meetings between CCW and organisations and individuals with an interest in the Menai Strait mussel fishery, during which it was agreed that a working group should be established to take forward work on the environmental impact of mussel cultivation in the Menai Strait. Although the group's terms of reference and membership have yet to be finalised, there was agreement that the CCW commissioned report should be subject to a peer review. The peer review process is a standard scientific practice, with the aim of providing an independent appraisal of scientific work, thus, in this case, ensuring that the report provides a solid and unbiased base from which to move forward with this important piece of work. Recommendations from the report, peer-review and any further research will feed into a long-term management strategy for the mussel cultivation industry operating in the Menai Strait, to ensure it's compatibility with the marine wildlife and habitats of the area.

2. Aims & objectives of peer review

To provide an independent scientific appraisal of the report "Impacts of mussel cultivation with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation", paying particular attention to three key areas, namely;

(i) Determine whether the known and potential impacts of mussel cultivation have been correctly identified in the report and whether there are any additional impacts (known or potential) that have been omitted.

(ii) Evaluate whether the type of data identified in the report as being necessary to determine the nature and extent of environmental impacts are correct, and whether any additional data should be sought.

(iii) Assess whether the research recommended in the report is appropriate and sufficient in order to determine the nature and extent of the known and potential impacts of the fishery on the marine wildlife features of the Menai Strait and Conwy Bay cSAC. Provide recommendations for any further research required.

3. The Peer Reviews

3.1 The Peer Reviewers

Four experts in the field of shellfish cultivation and it's environmental impact were selected to undertake a full review and evaluation of the CCW commissioned report: Beadman, H. (2003) "Impacts of mussel seabed-lay bottom cultivation, with special reference to the Menai

Strait and Conwy Bay candidate Special Area of Conservation". Representatives from CCW, the mussel industry and other interested parties were involved in the selection of these candidates. The selected four peer reviewers are as follows;

1. Dr A.C. Smaal, Centre for Shellfish Research, Yerseke, The Netherlands
2. Dr Per Dolmer, Danish Institute of Fisheries Research, Charlottenlund, Denmark.
3. Mr Ivor Rees, Menai Bridge, North Wales
4. Dr Peter Dare, Suffolk

The four separate peer reviews now follow.

3.1.1 Peer review by Dr A.C. Smaal

Peer review of: H. Beadman (2003) Impacts of mussel seabed-lay bottom cultivation, with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation, University of Wales, Bangor. CCW contract Science Report no. 580.

Introduction

The report is prepared under contract of the CCW, and gives a description of mussel farming in the Menai strait, including the history, physical conditions, legislation and annual yield. The report's focus is on the role of mussels in the ecosystem and the environmental impact of mussel farming practice, in view of plans to designate Menai Strait and Conwy Bay as an SAC. Recommendations are made to fill knowledge gaps by new research.

The report is well written and gives a comprehensive analysis of the ecological role of mussels and of the impact of the cultivation of mussels on the environment. The analysis is of a qualitative nature as no quantification of the impacts is given. On the basis of literature the potential impacts are presented. Further studies are proposed to address the topics. This approach is in line with the aims of the study as formulated by CCW.

My review will specifically address the following questions:

- Have known and potential impacts of mussel cultivation correctly been identified in the report and are there any impacts that have been omitted?
- Are the type of data identified in the report correct as being necessary to determine the nature and the extent of environmental impacts, or should any additional data be sought?
- Is the research recommended in the report appropriate and sufficient in order to determine the nature and extent of the known and potential impacts of the fishery on the marine wildlife features of Menai strait and Conwy Bay cSAC? Can any further research be recommended?

Impact identification

To identify possible impacts of mussel culture on the environment a description is required of the activities of the fishermen in terms of their influence on the mussel population dynamics.

Mussel culture is essentially extensive aquaculture, i.e. no feed, pharmaceuticals or other substances are added. In general mussel culture means that mussels are re-laid from areas of good spat fall and limited growth to areas with limited spat fall and good growth. After the growth period mussels are being harvested and meanwhile new spat has settled in the mussel seed areas. This can be considered a continuous process resulting in a dynamic equilibrium of the mussel stock composition and distribution, determined by spat fall, seed fishery, growth, predation and harvest.

Analysis of the impact of mussel culture should start by addressing the shift in flow rates and pool size of the mussels of different size classes and the shift in spatial distribution, as a function of the mussel culture activities under consideration. It is therefore a good idea to address the role of natural mussel assemblages in the ecosystem, as is done in par. 3. This paragraph consists of a short qualitative and generic description of processes in which mussels are involved, such as their role as prey for predators, the role in nutrient regeneration, and the capacity to form specific habitats. This is correctly formulated in the report, but lacks focus to be useful as a framework for the identification of shifts in parameter values due to the culture of the naturally occurring mussels. Hence the impact identification results in a series of potential impacts that are formulated in terms of hypotheses. No quantitative impact analysis for the areas under consideration is given.

Evaluation of Section 4 – Impacts of mussel bed cultivation

4.1 Mussel seed collection

The main impact can be expected from possible disturbance of the seabed due to fishery. This is described in the report. No information is given on the amount of seed fishery, and where it is done and what proportion of seed bed area is harvested annually. A straightforward parameter for impact assessment would be the mussel spat fall changes over time in the harvesting areas. If settlement is maintained and no disturbance occurs, seed fishery apparently has no dramatic impact. This is indeed suggested by the report. In the Netherlands, subtidal spat fall is successful very two years on average, while intertidal spat fall was observed every four years as an average of the last 40 years. As stated in the report, seed fishery on intertidal seedbeds is not necessarily harmful as seedbeds have an inherent instability and are vulnerable to waves and storms. Harvesting before winter may even enhance stability, as destabilising mud is removed as well, and non-harvested mussels may remain as mussel bed. In the Netherlands this hypothesis was tested experimentally. Increased stability was not observed, but after winter the reference and fished plots had the same (low) mussel densities. Due to storms the majority of the mussels apparently flushed away during winter.

In conclusion, the report addresses relevant processes that can play a role, but no impacts of seed fishery are described in any detail for the area under consideration.

4.2 Change in benthic communities

The description of changes in benthos concentrates on the role of mussel beds and aggregates for the benthic community, no matter if mussels are natural or cultivated. So it would be more consistent to present large parts of this section under chapter 3 rather than 4. The processes addressed in 4.2 are comprehensive and cover most important aspects. Contradictions in literature about whether mussel beds increase or decrease species richness or abundance are

addressed properly, and they seem to depend on the size of mussel beds and the local environment.

The question is then in how far mussel culture creates mussel beds in new areas, what proportion these are of total natural beds, and in how far these are different from natural beds. The most obvious point is that cultivated beds are removed in a frequency that will be higher than natural beds. The consequences for the benthic community of the shorter residence time of cultivated mussel beds are not addressed, however.

In conclusion, part of the description considers the role of natural beds, and is as such comprehensive. A specific analysis of the impact of mussel culture, and the difference between natural and cultured beds is lacking.

4.3 Impact of mussel beds on phytoplankton

This paragraph (4.3) also deals predominantly with processes that occur both in natural and cultivated beds. As no specific impact of cultured beds are mentioned, the effect of culture entirely depends on the amount of cultivated beds in relation to wild beds. No data are available about this for the area. The processes that are described in this paragraph are correct and state-of-the-art. However, not all results presented can be considered definitive answers, as part of the work was done in the laboratory, in mesocosms or based on models, and should still be validated for the field situation. I agree that analysis of the carrying capacity is required to evaluate the impact for the areas under consideration. Feedbacks through the filter feeders, resulting in stabilization of the phytoplankton dynamics should than be taken into account as well.

4.4 Effects of faecal and pseudofaecal wastes (biodeposits)

The production of biodeposits is a natural phenomenon for mussel beds, and the various relevant aspects have been treated properly in this paragraph (4.4). The impact of culture largely depends of the type of culture (suspended vs. bottom) and the local environment (sheltered vs. dynamic). As bottom culture tends to occur on sites with relatively high dynamics, in comparison to suspended culture (that obviously needs more shelter), the relative impact shall be limited. This is addressed in the report, but as in the other sections, no estimations are given for the impact of culture in the areas under consideration.

4.5 Effects on nutrient fluxes

This paragraph deals with the role of mussel communities in the uptake and release of inorganic nutrients. This is a general feature of natural and cultured beds. The concept of bivalve filter feeders as nutrient processors is presented correctly. In a table some flux data are presented. The table includes also particulate carbon and phytoplankton uptake rates, which is closely linked to the previous paragraph. In the table only a few of the fluxes are presented from what data are available from literature. A more comprehensive table of both particulate and dissolved fluxes is given in Smaal & Prins, 1993, a reference that is mentioned in the text. Like in previous paragraphs the question remains to what extent the culture will cause shifts in these processes and fluxes.

4.6 Effect of increased food supply for predators

Mussel predators consider on the one hand of a wide range of epibenthos like crabs and starfish, and on the other hand of birds. Extension of mussel bed areas will definitely attract benthic predators, but quantitative relationships are not well known. The report gives some references, and makes distinction of predation on various size classes. An interesting point

might be the role of the predators as prey for other groups in the system, like fish that prey upon crabs or birds that eat starfish, like Eider ducks do. One of the relations, between herring gulls and crabs is mentioned, however. The difference between wild mussel beds and cultivated mussels is not explicitly evaluated. A relevant point might be that cultivated subtidal mussels generally have weaker shells and less fouling of barnacles, hence are more vulnerable to predation.

For the relation with the birds much more studies exist, and for Menai Strait the report refers to an experimental study that showed a positive relation between intertidal mussel beds and wader birds. No further studies such as from Goss-Custard and others are referred to in the report, but that may be part of Caldow's report.

4.7 Impacts of harvesting

The impact of harvesting is treated here in terms of dredging impact. The description has some overlap with par 4.1 on seed fishery. The conclusion is that dredging activities and impact are small relative to natural sediment and suspended matter dynamics. This is comparable with similar practice in the Dutch mussel culture areas Wadden Sea and Oosterschelde estuary. Basically, re-suspension of mud that accumulated on mussel beds can be considered as a process of resetting, as the accumulated mud comes from the system, at least if mussel culture is not a vector in net influx.

Conclusion

This section of the report gives a comprehensive overview of possible impacts of mussel culture on various aspects of the ecosystem structure and functions. Not always a clear distinction is made between effects of wild mussels and of cultured mussels. No quantification is presented of the impacts of mussel culture on the areas under consideration. For the identification of potential impacts the study is effective and well documented.

Data identification

The report identifies a series of processes and variables that describe potential impacts of mussel culture on the ecosystem. Little data have been presented, but extensive references have been made to literature that include quantitative analysis of the role of mussels in the system. For the areas Menai Strait and Conwy Bay, little data are found in the report, and no analysis is given as to what extent these data are available. The main framework for data acquisition and analysis would be a carrying capacity estimation that should include hydrodynamics, geomorphology, ecological data and information on culture activities and plans; this information could be integrated by modelling (see Smaal et al, Aquatic Ecology 31: 423 - 428, 1998).

Conclusion

The report is comprehensive in referring to literature on the role of mussels including data, but no specific attention is given to data available or to be acquired for the areas under consideration.

Research recommendations

The report gives 6 research requirements and some remarks on how the research should be done, focused on phytoplankton depletion monitoring, hydrodynamic modeling, harvest impact, reef condition, food competition and habitat recovery studies. These topics are quite different in type and size of research efforts needed, and seem formulated in a rather unstructured way. At least, no clear relation is found between par 4 and par 7, hence the formulation of possible impacts is not systematically translated into research hypotheses. It seems not consistent that in par 4 carrying capacity studies are recommended, while this is not presented in par. 7. There are close links between different proposed studies such as the monitoring of phytoplankton depletion, and food competition studies that are not explicitly mentioned. Moreover, attention is missing for the collection of basic data on aspects like the size and dynamics of the filter feeder community, the dynamics of the primary production, data on the amount of predators, data on how mussels are cultured and about the dynamics of recruitment that are a prerequisite for a comprehensive impact assessment.

Conclusion
The research recommendations lack structure, and a more systematic analysis of underlying data and processes that are required would be helpful. This also requires a clear formulation of research questions in the framework of policy and management aims for the area. Construction of a conceptual model on the role of wild and cultured mussels in the area would be recommended.

Additional remarks

5 Table 1 has some errors, as the Category B criteria are 6000 faecal coli's rather than 300/100 g flesh
6 Smaal AC in press should be: AC Smaal 2002, Hydrobiologia 484: 89 - 98

Final conclusions

1. The report gives a comprehensive analysis of the ecological role of mussels and of the impact of the cultivation of mussels on the environment. The analysis is of a qualitative nature as no quantification of the impacts is given. On the basis of literature the potential impacts are presented. This results in improved knowledge of the impact of mussel cultivation, hence is an answer to aim 1 of CCW.
2. On the basis of state-of-the-art literature the potential impact of mussel culture is presented in a comprehensive way, hence aim 2 is addressed extensively in par 4.
3. Recommendations for further research are given. The recommendations lack structure and consistency and could be improved by development of a conceptual model. Formulation of testable hypotheses is required. Also the collection of basic data such as stock size of filter feeders should be given attention. Aim 3 and 4 are not fully addressed by the report. To achieve this, detailed management questions would be helpful in order to focus on the most important research questions.

3.1.2 Peer review by Dr P. Dolmer

Peer review of: H. Beadman (2003) Impacts of mussel seabed-lay bottom cultivation, with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation, University of Wales, Bangor. CCW contract Science Report no. 580.

Review objectives

I. Determine whether the known and potential impacts of mussel cultivation have been correctly identified in the report and whether there are any additional impacts (known or potential) that have been omitted.
II. Evaluate whether the type of data identified in the report as being necessary to determine the nature and extent of environmental impact are correct and whether any additional data should be sought.
III. Assess whether the research recommended in the report is appropriate and sufficient in order to determine the nature and extent of the known and potential impacts of the fishery on the marine wildlife features of the Menai Strait and Conwy Bay cSAC. Provide recommendation for any further research required.

The report is reviewed according to the above objectives. In order to structure the review so described impacts from scientific literature can be reflected in local conditions in Menai Strait and Conwy Bay, objective II is reviewed before I and III.

***Ad* II. Evaluate whether the type of data identified in the report as being necessary to determine the nature and extent of environmental impact are correct and whether any additional data should be sought.**

In general, few data is given on the hydrographical/morphological structure of the investigated water body. A map is missing and information on water depths and areas is not given. Furthermore, the biological description of the ecosystem is missing some important data on biomasses of mussels, other dominant filter feeders, food amounts for filter feeders (Chl a), areas of seedbeds. Also the description of shellfish cultivation is superficial, and data on amounts, location and areas of seed collection, amounts, location and areas of culture beds could be informative. The efficiency of the mussel production is not given. In Denmark, investigations of relayed mussels in a non-optimised production indicate that only 50 % of the weight of seed or transplanted larger mussels is harvested. In the German and Dutch part of the Wadden Sea the efficiency is rather confidential but approximately 100 %. If the production in Menai Straits is operating with the same efficiency, then the transplantation of seed move the filtration capacity from seed beds to cultured beds without increasing the filtration capacity significantly. In a well-mixed water body this may not influence availably food for benthic animals on reefs in cSACs. Consequently, due to the scarce data on the ecosystem, including data on the cultivation sector specific conclusions on the impacts in the Menai Strait and Conwy Bay area may be uncertain.

***Ad.* I. Determine whether the known and potential impacts of mussel cultivation have been correctly identified in the report and whether there are any additional impact (known or potential) that have been omitted.**

The literature on shellfish cultivation, the filtration of benthic filter feeders and their impact on the ecosystem, and on the impact of dredging is extensive and the reviews given in this report constitute a balanced extract of studies relevant to seabed-lay bottom cultivation. The report describes the historical background for shellfish farming and introduces local hydrodynamic conditions. Both descriptions is rather superficial and do not bring the reader in a position to evaluate the rest of the review in relation to local conditions. It is commented that *Crassostrea gigas* have been found sporadically. It is outside the scope op this report to evaluate the impact of spreading cultured organisms, but *Crassostrea* has reproduced in the Dutch and German part of the Waddensea, and are forming dense population wiping out mussel beds from certain areas.

Chapter 3 on Environmental and ecological role of mussels state that mussels form a key component of many marine communities". Last in the chapter it is stated "mussels form an integral part of the ecosystem in which they occur". The later statement is too weak: Mussels are key species or entrepreneur-species. They form important substrate for other species, they couple flow of energy and materials between the pelagic and benthic system, changing the structure of the pelagic system and they are an important food-source for a lot of other animals. The importance of bivalves as filter feeders is presented by examples. Examples with mussels should be more useful. Furthermore, data on filter volumes, particle retention sizes should be incorporated in the text.

The review of the Impact of mussel seabed cultivation includes an analysis of seed collection (4.1). The author argues that winter storms may destruct seedbeds if not collected, and in that perspective seed collection explore a resource that otherwise are destructed due to natural processes. In the Kiel Fjord Reusch et al. (1997) demonstrated that mussels are transported to deeper water due to current and wave action, and that the mussels survive dispersal. So, destruction of mussel beds due to storms may disperse the mussels to new areas, and if this also is the case in Menai Strait, the argument that seed collection explores a resource otherwise lost is false. The mussel larvae are dependent on substrate for settlement and repeatedly fishery for seed may deteriorate the substrate if substrate components are removed with seed. Investigations in Denmark has demonstrated that mussel dredging reduce the amount of shells and shell debris, and that a reduced recruitment of mussels can be observed in certain areas due to substrate export from fished areas. The loss of substrate may reduce settlement and a reduced complexity of the seabed increase predation of mussel seed by e.g. shore crabs. Also the density of sessile organisms, dependent on a solid surface for attachment, is reduced as a long-term effect of mussel dredging. The impact on the substrate in seed collecting areas may be a threat to future seed production and to populations of other sessile organisms in Menai Strait and may be evaluated in the report. The chapter ends with the statement that " a certain level of harvesting may even help to stabilise mussel seed beds" without any reference. This statement can be rather controversial in a discussion on impact of mussel/seed dredging and has to be given a more explicit formulation. Are we talking about a more solid inter-attachment of mussels or more stabile species diversity in dredged areas?

Chapter 4.2 Change in Benthic communities, describe the complex structure in a mussel bed and discuss how mussel beds change the benthic fauna by forming mud and by forming habitats for a fauna of organisms associated to mussel beds. The chapter give a very qualified presentation of all relevant subjects.

Chapter 4.3 Impact of mussel beds on phytoplankton. The mussels are very important as eutrofication controllers, and may significantly change the structure of the pelagic system. In

Sweden, it is a political intention to use mussel-farming strategically to remove nutrient from the marine system. In Canada investigations have demonstrated a correlation between cultivated mussel biomass and Chl a in the water (ref.), indicating that mussels and mussel cultivations significantly may reduce food amounts. In order to evaluate the impact of mussel beds on phytoplankton in a local context better information on the local system is needed (see review of Obj. II). An analysis of carrying capacity, and then an evaluation of the impact of food-limitation to mussels and other filter feeders, including filter feeders in cSAC areas, needs some basic data on physical and biological condition and data on culturing activities. An efficient tool to this analysis is an ecosystem model that describes spatial and temporal heterogeneity in the area (see review of Obj. III).

Chapter 4.4 Effects of faecal and pseudofaecal waste. Mussel beds form large amounts of faeces and pseudofaeces, which are accumulated below the mussel bed or are suspended and transported to other areas. The mud is rich in organic material and can results in reduced conditions, anoxia and SH-production. Furthermore, reduced conditions increase denitrification and export of N from the system.

Chapter 4.5 Effects on nutrient fluxes review the important role of mussels in nutrient cycles. Both the mussels and the mussel mud leak ammonium and P, and increase the primary production. The author conclude that " Ammonium release from the mussels themselves is significant higher that the net remineralisation in the sediment". Huge variations exist between locations, and in general is app. 30-60% of the ammonia released from sediment.

Chapter 4.6 Effect of increased food supply for predators. Both mussels that occur naturally and cultivated mussels serve as food source for other invertebrates and shorebird. It is argued that mussel-culturing activities increase mussel biomasses and the food source for predators. This argument rests on the assumption that biomasses in the areas are actually increased and not just transplanted to other areas (se Ad.II). It is pointed out the specific predators has preference for specific size classes of mussels. Cultivation may change the overall size distribution of mussels in the area and then affect the availability of foods for some predators. Cultivation of mussels may ensure a continuous biomass of mussels beneficial to predators.

Chapter 4.7 Impact of harvesting. The use of dredging for mussel harvesting has stimulated a controversy in many areas about the impact on the seabed. Dredging changes the topography and physical structure of the seabed, disturb the fauna, and resuspend sediment including nutrients and oxygen consuming substances. Changes in the benthic fauna following mussel dredging is not only a direct effect of the dredging, but also as an indirect effect of an increased density of scavengers and predators eating harmed animals, or animals excavated from the sediment. A central topic is the recovery time of the habitat. The author reports that the study by Dolmer et al. (2001) measured a recovery time of 40 days. But this study was a short-term study, to short to measure a recovery. The best data on recovery is given by Collie et al. (2000) in a meta analysis of 39 reports on impact of bottom trawls and dredges. As discussed in review of 4.1 a serious problem of mussel dredging is the export of important substrate from the fished areas. A detailed description of the used mussel dredges has to be included here or in chapter 1.

Chapter 4.8 Aesthetic impact. The cultivation of mussels on the seabed does not require any visible structures on the surface. Only the boating activities can have aesthetic impact or is a part of the local character? Today mussel cultures can be hold on submerged long-line systems, where only the navigation marks are visible. But these systems can probably not be

recommended to a high-energy area as Menai Strait, where the mussels have a high production rate on the bottom.

Chapter 5. Focus on Menai Strait and Conwy Bay cSAC is not reviewed due to lack of specific data on local conditions (see II).

***Ad.* III. Assess whether the research recommended in the report is appropriate and sufficient in order to determine the nature and extent of the known and potential impacts of the fishery on the marine wildlife features of the Menai Strait and Conwy Bay cSAC. Provide recommendation for any further research required.**

The review of Research conducted in the UK (6.1) describe six projects that may be relevant to the management and optimising of mussel cultivation in Menai Strait and Conwy Bay area. The projects are not organised in a framework, and common objectives is not given. The projects is rather briefly described but the project 6.1.1 on improving productivity of mussel cultivation (MJ Kaiser) and the project 6.1.4 on near-bed turbulence over mussel beds and coupled effects on mussel growth (MJ Kaiser) may fill some of the scientific knowledge gaps in the areas, whereas project 6.1.2 and 6.1.3 conducted in The Wash is interesting and some of the information may be useful in other areas to. The aim of project 6.1.5 is to solve administration problems of the permissions to collect seed by a better understanding of factors regulating seed distribution and impact of seed collection. This is a rather ambitious project, which could be headline for a whole batch of projects, and has to be put in a larger framework. Project 6.1.6 focus and on turbidity. The project plans to install a turbidity-logging device, and to correlate turbidity to natural and anthropogenic conditions. This is an interesting project but with minor interest for cultivation management.

The review of European research (6.2) is rather superficial and much more information can be given. During the last 10 years several EU-projects have been conducted, and also countries as France have several laboratories, working with topics relevant to this report.
Chapter 7. Research requirements

The analysis of future research requirements describes a number of projects. These projects are not organised in a common framework. That is re commendable. It is not clear, if the scientific community working in the area follow the same strategy, in order to develop strategically knowledge, that can be used in the future management.

Two common frameworks has to be established:

a) Development of an ecosystem model
b) Impact of seed collection and mussel dredging on ecosystem

a) In order to manage the production of cultures mussel following economical end ecological sustainable principles a management tool is needed. This tool could be en ecosystem model that describe hydrographical and physical boundaries in the system, and couple the modelling of distribution and production of microalgae - the distribution and production of mussels (- and other filter feeders), and distributions of birds.

   The suggested project 7.1 on monitoring of phytoplankton depletion, project 7.2 hydrodynamic modelling, and project 7.5 on competition between filter feeders may

contribute to an ecosystem model. Also data on mussel biomasses, production efficiency, and density of other filter feeders has to be recorded.

b) In order to evaluate the ecological sustainability of the mussel production knowledge on the impact on the benthic fauna, re-suspension and the recovery time may be established. The impact of seed collection on substrate and benthos is not described. Also project 7.3 on impact of harvest and mussel-mud break up may contribute to the framework as also project 7.6 on recovery.

Project 7.4 on health of reefs in the Menai Strait is a monitoring program. The ecosystem model may be used to explain observations.

3.1.3 Peer review by Mr I. Rees

Peer review of: H. Beadman (2003) Impacts of mussel seabed-lay bottom cultivation, with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation, University of Wales, Bangor. CCW contract Science Report no. 580.

DECLARATIONS OF INTEREST

I was an appointed Member of North Western and North Wales Sea Fisheries Committee during most of the time the mussel cultivation industry in the Menai Strait was growing. I therefore have a non-pecuniary interest through shared responsibility for the regulatory regime under which this mussel fishery takes place.

As a former member of the academic staff of the School of Ocean Sciences, which was contracted to do the report, it could be deemed that I am not a totally disinterested party, though I had no direct involvement in supervision or support of the studies

General comments and background

1. The report attributed to H.A. Beadman appears to be based largely on her PhD thesis (supervisor Dr M. Kaiser). The thesis was mainly concerned with a rather narrower topic than a general study of the impacts of the mussel cultivation industry in the Menai Strait. The major part of the work for her thesis was on changes to invertebrate assemblages associated with the areas where the mussels were being re-layed, cultivated and harvested (Beadman 2003 & Beadman et al, submitted (now in press in J. Appl. Ecol.). For the purposes of the CCW Report the review part of the thesis was, I am told, supplemented by other people associated with Centre for Applied Marine Sciences in Menai Bridge. Although these others wrote small parts of the document their names are not included in the attribution.

2. In addition to the main report under Helen Beadman's name there is a Summary, which was prepared separately by CCW staff. The Summary goes somewhat beyond the main report and in places puts different emphases on potential effects than the basic Contractor's Report. Thus the present spiral bound CCW Contract Science Report No. 580 actually contains two not entirely coincident reports. One is based on a student thesis and the other strays into being nearer to a policy preparation document. A revision should be considered in which these

discrepancies could be sorted out and a clearer separation made between policy development and the science supporting such policy. A revised report would best serve information needs if it became a multi-author document with a stronger input from fisheries managers

3. To someone seeing just the title of the report in a reference list the title could be misleading. Clearly the document does not fully cover, nor should it be expected to cover all aspects of the potential impacts and interactions with all the myriad of other uses of the Menai Strait. It would be preferable for such a CCW science report to consider just the potential and perceived ecological effects of mussel cultivation on marine wildlife, particularly in respect of this cSAC for which CCW has the prime statutory responsibilities.

4. By starting the title with *Impacts of mussel cultivation*.... It might be taken as a review of impacts of all methods of mussel cultivation (rafts, bouchot etc.). In practice just one method of cultivation is used in the Menai Strait, this being a derivative of the Dutch flatbed method. An alternative title for a revised report might perhaps be *Ecological consequences of flatbed mussel cultivation in the Menai Strait*. The fact that need for such a review of mussel cultivation arose in part out of the designation of the Strait as a cSAC, could be left for fuller explanations in the Summary and the Introduction sections of such a revised report. The report could not be expected to fully cover the impacts of sourcing seed mussels on other areas, whether or not some of these may also be cSACs and whether this may or may not have significant impacts on areas for which CCW has no responsibility.

4. When reviewing the present document I concentrated attention on 5 main aspects:-

A. How adequate is the information given on the mussel cultivation industry in the local area, particularly the history of the development and growth of mussel cultivation. Bearing in mind the proximity of the areas used for mussel cultivation to a major centre of marine biological expertise, were there were previous local concerns about ecosystem effects prior to SAC designation?
B. The extent to which perceived and potential ecological effects were adequately assessed, having regard to inevitable uncertainties and whether predictions could be assigned any degree of confidence by reference to scientific literature.
C. Whether the report gives an adequate background to a reader not versed in the complexities of statutory conservation measures and the history of such matters in the Menai Strait, including maps of the distribution of biotopes and where the real "jewels" of particular conservation concern lie within the wider cSAC . The spatial relationship of these "jewels" to the mussel lays is seen as particularly important.
D. The extent to which the report explains the hydrographic and ecological peculiarities of the Menai Strait, particularly as they relate to the success of mussel cultivation and any consequential effects of this industry on the general ecology of the Strait.
E. Adequacy of supporting information on mussels, mussel bed biotopes and the relative size of natural mussel communities in the Menai Strait without the effective extension to them through the flat-bed cultivation method.

5. Of the above aspects, those under (**A**) dealing with explanations of the history of the development are deficient in several respects. The phase of the development in the 1960s by the late R.H. (Dick) Baird are overlooked. My understanding is that it was external financial and marketing matters, caused when parent companies changed hands, which were the cause

of more difficulties than actual problems with developing cultivation techniques. There ought to be data in MAFF, White Fish Authority and Sea Fisheries Committee archives on this early phase of the operation. There were photographs and reports in the fishing press of the mussel cultivation operations in the Baird era (World Fishing did an article). It would also have been possible to interview Gwyion Davies, a retired member of the MAFF Conwy laboratory staff living in N Wales, who made assessments of stocks and growth rates when Dick Baird was pioneering the mussel cultivation. Of particular relevance now is the extent of the "natural" mussel beds in the Bangor area before flatbed mussel cultivation began. The reports makes no mention of the hand-gathering fishery and the numbers of men previously involved in it. At the time when the Several Order came in this hand-gathering was regulated by permits issued by the SFC, so good data exists on this fishery in the early days. Hand gathering has now declined in the Ballast Bank area to a very low level for socio-economic reasons and the relatively poor quality of the mussels high on the shore. It is also relevant that several studies were being made in the Menai Strait at that time which do not appear in the reference list. This includes work by Buchan, Floodgate & Crisp on suspended loads in the Menai Strait. The first two authors, both retired staff from the Menai Bridge laboratory still live locally. As part of this work Crisp had made initial calculations of the extent to which the mussel beds were removing particles from the water column of the Strait at various seasons. Also overlooked is the fact that in the 1960's Professor Crisp had several research students studying mussel filtration and pumping rates in relation to particle concentrations, temperature and salinity. Other relevant work from that era was by Kenchington who studied zooplankton in the Strait. This had, by implication, relevance to the origins of the water mass moving through the Strait as the proportions of the indicator Chaetognaths *Sagitta setosa* and *S. elegans* change from time to time,. Kenchington also wrote a paper on the detrital particles turning up in the zooplankton samples. Another area of relevant study somewhat overlooked is the series of studies on phytoplankton and chemistry, for example there is a paper from 1970 by Ewins & Spencer on the annual cycle of nutrients in the Menai Strait. As there is a database on such chemical and phytoplankton data from the Strait, put together by CAMS, I would have expected this to have been given more emphasis.

6. When considering the wider influence of mussels in the Strait, the report seems to imply that nearly all the beds arise from cultivation activities. This is clearly wrong even in respect of both the Menai Strait East and the West Several Order areas. As noted above, Ballast Bank off Port Penrhyn had a long-standing hand worked fishery. In the West area, the quite large mussel bed at Brynsiencyn / Tal y Foel, is a natural one. Indeed parts of it were authorised to be cleared away to assist Oyster cultivation. There was a history of the Brynsiencyn bed being hand worked by Conwy fishermen at times when the resource in their own estuary was low. In the recent past there have also been significant natural beds in the NE Menai Strait at Lleniog and near the old Beaumaris baths. It would therefore be of some relevance to have calculated estimates of the extent and biomass of the natural beds versus the present cultivated lays.

7. There is a general lack of information in the report on the mechanics of the cultivation operations. The copy I have lacks any maps or other illustrations, though two figures are mentioned in the text. It would be useful to include photographs of the operations. I would also have liked to see more information on the quantities of seed being brought in from the various seed sources and the sizes of mussels involved, as well as a much longer run of statistics on the output from the fishery. The situation may be complicated as there are believed to have been some exports of mussels still small enough to be regarded as seed for re-laying elsewhere. As some of the effects come from dredging operations to move mussels

within the Several Order from high to low level areas it would have been valuable to have an insight into the numbers of dredging operations beyond those needed to harvest the mussels for sale.

8. When considering the dispersal of mussel mud disturbed during dredging there seems to have been no consideration of the probable bias to particular stages of the tide for dredging to take place. Because Port Penrhyn is tidal the vessels will usually go out as soon as there is sufficient water on a flood tide and then return after high water. Bearing in mind there is a null point in Bangor Pool between the water flooding from the two ends of the Strait and that this moves, this is a complex but important issue. It will have a bearing on where disturbed mussel mud may move and where it may re-deposit. Re-suspension patterns from dredging for harvest could be different from dredging to re-locate part grown mussels both seasonally and in the duration of dredging relative to times of high water on springs and neaps.

9. To some extent the special features of the Strait as an area for growing mussels are inadequately dealt with. Fundamentally, it is the regular renewal of the water over the beds due to the tidally driven residual flow through the Strait that is probably the key. For an area sheltered from severe wave action and to have such flow characteristics must be very rare, if not unique. This has several important consequences. First is the quality and phytoplankton status of the incoming water. Most of this comes from a slightly eutrophic neritic sea area (Greater Liverpool Bay). I would have expected to see mention of the status of this water and including information on the composition of the phytoplankton community at various seasons, not just on fluorimeter readings. There is relevant scientific literature on this and on the way mussel gills handle particles of various types and sizes at various concentrations, which should have been considered. Two phytoplankton species seem of immediate relevance here. *Phaeocystis pouchetii* blooms frequently in the spring. It produces detrimental conditions for many other marine organisms so one would expect to have seen mention of the bloom effects on the condition of the mussels. The other is *Coscinodiscus wailseii*, a non-native centric diatom of unusually large size which has come to dominate the plankton in Red Wharf Bay / Conwy Bay in the autumn – winter period.

10. Another set of features relevant to mussel filtration effects locally is that unlike many places where "shadow" effects have been noted on cockle beds which occur on flats with mussel beds seaward of them, here the reverse is the case. At least some of the water flowing over the Bangor mussel lays will have previously flowed on and off the extensive Traeth Lafan tidal flats where there are at times a large populations of cockles. Overall depletion of phytoplankton in the Strait needs to take account of these cockle beds as well as many other filter feeders if the whole is to be put into context.

11. While there is discussion of re-mineralisation of nutrients by the mussels and from mussel mud, it seems to be overlooked that owing to the rate of the residual flow and lags in rates of utilisation the effect if any will be felt mainly when the Strait water mixes into much larger volumes of sea water in Caernarfon Bay.

12. A significant deficiency in the report is that there is no mention of the well-known propensity for shellfish re-laying operations to act as significant vectors for the introduction of non-native species to new areas. Of several potential invasive species that might cause ecological changes in the Menai Strait, the slipper limpet *Crepidula fornicata* is an obvious example. This species is likely to cause undesirable effects both to the conservation interest and to the shellfish cultivation industry when it spreads to this area. This is a filter feeding

species capable of completely carpeting the seabed. In the 1980's the UK had a statutory system to reduce the risks of the spread of such species to new areas (Molluscan Shellfish (Control of Deposit) Order). This statutory arrangement was solely to protect the industry, not for nature conservation reasons. It was later rescinded and such controls now seem only to apply to organisms brought in from outside the EU. To protect the conservation interest of localities such as the Menai Strait where shellfish cultivation coexists with or adjoins areas of high conservation value this situation needs to be reviewed as a matter of urgency. In the short term a voluntary agreement might be enough but a statutory arrangement might be ultimately be required. It could be similar to that which governs movements of non-native fresh water fish within Britain. I am not aware of the present point that *Crepidula* has reached, though it is thought to have been found in Milford Haven, near Tenby and in Swansea Bay. Other non-natives that come to mind are Jap Weed *Sargassum muticum*, which has already made the jump from the south coast of England to reach the western Menai Strait. It was first found in 2001. It had previously also made the jump to Strangford Lough. It is first thought to have reached Europe with cultivated oysters. It may be relevant that both in Strangford and in the Menai Strait the first finds were made close to oyster cultivation sites. Yet another non-native that could have an influence here is another American bivalve species *Ensis directus*. This razorfish seems to occupy a niche not used by European species of the genus. It reached abundances in Holland and the Wash where it supported new fisheries using dredges. There may be habitats in the Strait that would suit it. There are recent reports of paired valves of *Ensis americanus (=directus)* being found by conchologists at two sites near the mouth of Milford Haven.

Specific notes, comments and corrections

A. Beadman contract report

Section 1. General Background – needs to start with some mention of why the review was undertaken.

Section 1,1. The information about oyster fisheries in the distant past is of little relevance while the historical background to the present Several Orders is inadequate. Appendix 1 is inadequate. There are no maps.

Section 1.2. Badly needs maps and more information on tides. It would have been easy to get tidal ranges for Penmon, Beaumaris, Menai Bridge and other points in the SW part of the Strait at Mean Springs and Neaps by referring to conversion tables in the annual Admiralty Tide Tables. I am not sure what relevance the maximum velocity at Belan is, whereas, more information on the cycles of velocities in the Bangor area would be. The units are surely wrong. Velocities are metres per second not cubic metres per second. Discussion of whether tides are stronger in the narrows at Belan or the Swellies is irrelevant. The states of tide when Rymell released floats at Bangor Pier needs to be stated. At the end of this section there is confusion of compass directions. North-west should read north-east and south-east should read south-west.

Section 2. The rights associated with Several Orders and the setting up of them might usefully have been amplified. The distinction with Regulating Orders is not clearly made. Fishery byelaws relating to the relaxation of size limits, permits for dredging seed and

associated matters are of rather more relevance to ecological impacts than shellfish hygiene regulations and public health classification categories.

Section 3. As some mussel beds are considered to be biogenic reefs under the Habitats Directive it would have been useful to refer to the UK Marine SACs project volume on Biogenic Reefs (Holt et al 1998). This contains discussions of the way *Mytilus edulis* has a particularly wide ecological niche and forms beds of different types in a variety of different circumstances. The long-term stability of beds and recruitment to them is also dealt with. The reference list in Holt et al (1998) includes some relevant ones missed from Beadman's review.

Section 4.1 The statement that there is "no legislative support" for removing seed mussels is somewhat misleading. The arrangements for issuing permits may not be ideal but a regulatory framework does exist.. There needs to be mention here of the differing types of mussel bed and the patterns of recruitment to them (see Holt et al 1998). Last line 1st pg of 4.1 statement about spatial scale of seed removal has nothing to back it up.

Section 4.2 Last para is "interstitial" meant here as there is no previous mention of Meiofauna.

Section 4.3 Could be more specific about volumes of water filtered by mussels. There is a large literature on this including work done at Menai Bridge. This is highly relevant to any modelling of the clearance of water by mussels. Last but one paragraph (pg 11). It is wrong that mussel cultivation occurs at both ends of the Strait. Mussel beds do but not fully re-layed and cultivated ones.

Section 4.4 pg 12 2nd para more consideration is needed of the statement from Stuart et al (1982) that faecal material is more easily re-suspended. The whole question of the incorporation of faecal pellets into the sediment so that it becomes part of the cohesive underlying sediment is much more complicated than this. More consideration is needed bearing in mind the differences between rates of settlement, which can be higher for faecal pellets than more dispersed particles, and re-suspension of particles that have already settled. At the end of this paragraph there is mention of the suggestions that turbidity in the Strait may have increased. There have been several analyses of the available data as well as that by Birkett & Maggs. For example Chris Lumb looked at the Secchi Disk data. In earlier times before mussel cultivation became important there was evidence of greater turbidity. There was also evidence from the distribution of algae on the Telephone Cable transect first established by Knight-Jones. A closer look at the data shows that the duration of periods with turbid water changed rather than the absolute levels of the suspended particles. In the reference list the Birkett & Maggs paper is listed as "microalgae" when it concerned "macroalgae". The last para on pg 12 mentions the build up of mussel deposits increasing exposure times. This may be relevant in areas with small tide ranges, it is less important where the tide range is as large as in the northern end of the Menai Strait.

Section 4.8 on aesthetic effects is not really relevant to the cSAC and as it does not fully cover this issue it would be best if left out.

Section 5. Table 1 lacks any explanation of what the letters in the table mean. On page 20 a Fig 2 is mentioned but not included in the report.

Section 8 References. Pg 28 The last two references on this page shown as "submitted" are just one which is in press in J.Appl.Ecol.
Birkett & Maggs 2001 Macroalgal?
Dare 1976 More details needed. Paper is in Fish Invest Ser II No 28.

B. Summary (prepared by CCW)

Para 1. Statement that mussel farming first successfully commenced in the 1980s is not strictly correct.

Conclusions and main recommendations

1. The initial concept of having a report, or reports, prepared on aspects of the potential for mussel cultivation to impact on the nature conservation interests of the Menai Strait was worthwhile. The two set of interests co-exist and are likely to continue to do so. No evidence was presented of significant concerns prior to the Strait being designated a cSAC or for this having an influence on the quality of the features for which the designation was made.
2. The direct effects of cultivation activity on the benthic biotopes in the muddy sand areas over which the mussel lays have extended mussel biotopes were shown to be well enough understood as a result of Helen Beadman's PhD research. This also applies, from parallel studies by CEH to the extent to which wading birds are benefiting from the extra availability of mussels of preferred sizes and higher food content as well as organisms preying on the mussels such as shore crabs. As the fringe of the Traeth Lafan Local Nature Reserve, designated primarily for birds, overlaps with the mussel lays the lays are shown to be beneficial to birds within the NE Menai Strait area.
3. The sections of the report background dealing with the history of mussel cultivation in the Strait need quite a lot of revision to include more data. To understand the effects, more data is needed on the cultivation operations. These could usefully be backed up with photographs and diagrams. The Appendix on landings statistics is inadequate and needs to include statistics on seed dredging.
4. The hydrography and water column ecology sections need revision to put the data more into the local context and to bring in data that is available for the local but not used.
5. Maps need to be included showing the lays, the general morphology of the Strait, local tide patterns and the distributions of biotopes including natural mussel beds.
6. A particular omission was lack of consideration of the possibility of the arrival of non-native marine species being brought to the Strait through longer distance transport of seed mussels for which the new generation of larger mussel dredgers are specifically designed.
7. The report would benefit from being revised in several significant ways. I would have preference for a multi-author document with more input from the fisheries managers that all significant players could have "ownership" of. Alternatively I would expect a more policy orientated document to be produced by the joint working group.

3.1.4 Peer review by Dr P. Dare

Peer review of: H. Beadman (2003) Impacts of mussel seabed-lay bottom cultivation, with special reference to the Menai Strait and Conwy Bay candidate Special Area of Conservation, University of Wales, Bangor. CCW contract Science Report no. 580.

There are four parts to my response : (A) General comments; (B) Individual sections comments; (C) Supplementary historical information additions; (D) Whether the report meets CCW objectives.

A. General Comments

The format and content of the report both require further work to bring the report to an acceptable standard either, as a scientific assessment or as a working document that could be used by CCW for site management purposes. I would suggest that considerable restructuring and some additional information is required. The basic literature review, which is sound enough (if heavy going in places), seems to have been extracted from a thesis and used without adequate cross reference to the local conservation and mussel industry contexts. In particular, the report (as submitted to CCW) lacks an introduction, site maps, adequate faunal and mussel industry information, and a final conclusions section as well as an executive summary (the last having had to be prepared by CCW).

Before addressing (at D) CCW's specific aims for this peer review, I shall comment on many individual points in the text (often by using a telegraph style for brevity).

B. Specific Comments on Sections

Title: This should be amended to 'Potential effects of mussel cultivation .....' 'Impact' is defined (OED) as a collision or profound effect; but is now an over-worked eco-jargon term that often is incorrectly applied to over-stress the importance of something (as here) that has not been demonstrated. 'Potential effects' or perhaps 'Potential adverse effects' is preferable!

Introduction: There is none! A succinct account is needed of the background to the CCW concerns that have led to the commissioning of this report (ref. sections 1.2-1.3 in the CCW peer reviewers' guide lines doc.).

Section 1 General background

1.1 Historical background of shellfish farming in the Menai Strait

This account is inadequate, with little hard information on the industry, and it lacks maps of either (i) the cSAC showing sensitive sites and wild mussel beds, (ii) mussel cultivation areas. It needs a starting paragraph along the lines of section 1.2 in the CCW guidance doc. for peer reviewers.

This should start with a description (with maps) of the relevant parts of the cSAC, followed by a good account of the mussel industry's history and current operations (including site maps). The existence of long-standing natural mussel beds, of substantial biomass, should be acknowledged (see later). An alternative scheme would be to have separate detailed sections

for the cSAC and mussel industry accounts. These would form a clearer context for the assessment.

1.1, para 2 – Inadequate history of mussel operations and associated MAFF Conwy research ; see information I have prepared (at C).

1.1, para 4 – I am noting later (at C) some earlier landings data; substantial tonnages were produced, intermittently, long before present firms appeared on the scene. (Note: recent very high tonnages, as quoted in CCW docs, need careful checking to ensure that they all refer to landings from the local lays, and do not include marketable mussels shipped in from elsewhere - for depuration and sale), or merely in transit to other processors.

1.2 Hydrodynamics of the Menai Strait
1.2 , p.4, para 1 – should velocities be in m/sec and not cubic metres/sec?
Figure 1 is missing from my copy
7 knots - value should be in m/sec (as above)

1.2, p.4, para 2 – 'north-westerly' should read 'north-easterly'?
Excursion data suggest a rapid dispersal of mud plumes.

1.2, p.4, para 2 'NW' should read 'NE', and 'SE' should be 'SW'?
Throughout report there seems to be confusion about the alignment of the strait.

2. Legislation
The statutory orders sites should be shown on a map.

3. Environmental and ecological role of mussels
I think that there is a more detailed account in EN's recent Biogenic Reefs literature review and management report, published ca. 2000 (I do not have access to a copy at present).

p.6, para 2 - there are no walrus or turtles in N. Europe!
" - last sentence unclear – plain English, please!

p.6, para 3 – ' output faeces' = 'release faeces' (output is avoidable jargon)
(Note: large beds, being efficient biological filters, also remove faecal pathogens from polluted discharges into estuarine waters, including the Menai Strait).

4. Impacts of mussel seabed cultivation
Note: Cultivated plots of mussels at Bangor cannot be treated in isolation; there is a substantial and perennial biomass of wild mussel beds adjacent at Bangor and Beaumaris (see my notes at C).

4.1 Mussel seed collection
Start with para 3 (p.8), then give relevant details of commercial *modus operandi* , including seed collection season, relaying biomass densities, tidal levels/sites etc.

p.7, para 1 & 2 - note principal commercial settlement sites are on hard stable substrates with niches, such as the gravel/stony grounds at Caernarfon Bar and Morecambe Bay. These substrates are not damaged by dredges because seed harvests can only occur when deep biodeposits have accumulated. Such grounds are resettled by mussel spat in most years.

p.7, para 2, last 2 sentences - unclear; 'o of m' = many times smaller ; give some figure examples (hectares). Exploratory dredging may be offshore where no requirements for skippers to report activities.

p.8, para 3 - move to start section (as noted above).

p.8, para 4 – seed biomass and annual variability were studied at Morecambe Bay (Dare 1976, in section 8) and since then by sea fishery committee surveys (in reports).

What is meant by harvesting level?

4.2 Change in benthic communities

p.8, para 1 - Relaying: need more detailed info on – biomass densities, approx shell sizes, season of relaying, tidal levels etc.

p.9, para 4 – densities; any published values to compare with Bangor beds?

p.10, para 2 - where is the 'eastern' MS? = north-eastern? = Bangor? This sentence could be improved.

4.3 Impacts of mussel beds on phytoplankton

This section seems to be too hypothetical/speculative and full of imponderables to throw much light on the specific Bangor issue. No mention of the possible effects of nearby wild mussel stocks, or indeed of other large bivalve populations on nearby Traeth Lafan or further south in the Strait.

p.10, para 1 - spelling error – should be Oosterschelde.

Phytoplankton depletion arguments are speculative, and seem rather contradictory/ confused/ confusing. If mussels are non-selective feeders, how do they have selective effects on phyto-compositions – have pseudofaeces something to do with it? (Need to distinguish between filtration and ingestion). Mussels are thought to have lowered eutrophication in Dutch Waddensea (high turbidity and strong currents locally), so why not in Menai Strait?

Mussels feed virtually at the boundary layer. If the water column is stratified (in summer), will this reduce or enhance any potential for mussels to influence phytoplankton community structure?

p.11, para 3, first sentence – too positive, i.e. is the effect likely to be detectable? ; and separable from effects of wild mussel biomass and other bivalves?

p.11, para 3 - There is no significant cultivation in the southern part of the Strait – just 1-2 hand-worked plots (mainly oysters) near a small wild mussel bed at Tal-y-Foel.

4.4 Effects of faecal and pseudofaecal waste

p.12, para 3 - mussel mud dispersal – need to know when operators harvest crops – and especially when they actively disperse the bio-mud deposits – season, tidal state and water depth, frequency of operations. Are sensitive taxa active (susceptible) at those times?

4.5 Effect on nutrient fluxes

No comments.

4.6 Impacts of increased food supply for predators

p.15, para 1 - update reference Davies (1966) with following more detailed work (also MAFF): Dare, P.J., Davies, G. & Edwards, D.B.E. (1983). Predation on juvenile Pacific oysters (*Crassostrea gigas* Thunberg) and mussels (*Mytilus edulis* L.) by shore crabs (*Carcinus maenas* (L.)). Fisheries Research Technical Report, MAFF Directorate of Fisheries Research, Lowestoft, (73), 15pp.

p.15, para 2 – para not specific to Bangor whereas the following MAFF (unpublished) info is. (a) starfish: destroyed early attempts at sublittoral culture in early 1960s, obliging company to concentrate on intertidal (slower growth) zone ; (b) shore crabs: destroyed 1-2 tonne experimental plots at Tal-y-Foel within 1 month of relaying in summer (see also above reference) ; oystercatchers: during 1968/69 winter a flock of 280-715 (average 485) birds consumed an estimated 85t of the 900t of small mussels re-laid on a 12 acre (5ha) lay at Siliwen shore in summer 1968 (Dare & Potts, internal report).

p.16, para 1 – see last comment; the numbers of oystercatchers (plus turnstones) on the Siliwen lay were far greater than would have been expected from a similar area of mud.

4.7 Impacts of harvesting

Need some account first of the *modus operandi* at Bangor, e.g. harvest season, frequency (daily/weekly), any tidal constraints, rotation of crops on lays.

p.16, para 1 - need to make clearer distinction between the observations from offshore and intertidal studies.

p.17, para 2 – sensitive species: what/where are they?

p.17, para 3 – hand-worked small lays: personal experience at this site found negligible effects on sediment integrity or on birds - limited number of days worked and only by day, alternative feeding areas on nearby natural mussel bed or mud flats both day and night).

4.8 Aesthetic impacts

Any changes to shore elevation (~ 0.5-1m) will be undetectable from shore (~ 0.5km away). Dredging frequency – any info on how many days per week the dredgers are operating, and how many vessels at one tide? (Note – many people like to see fishing boats working!).

5. Focus on Menai Strait and Conwy Bay cSAC

This entire section should head the report, setting the context for the assessment.

5.1.1 Reefs

Where are the 'surrounding reefs' ; how far from the mussel lays?

5.1.2 Mud/sand flats
This is a re-iteration of 4.2; no risk assessment.

Figure 2 – is missing.

5.2 Impacts of various mussel cultivation scenarios on the cSAC

5.2.1 Present levels
p.20, para 1 – 'Swellies' – water will not all have already passed over cultivated mussel beds alone, but also over wild mussel beds and other bivalve populations. Too much speculation ensues ref phytoplankton.

p.20, para 2 - repetition from earlier sections.

5.2.2 Industry expansion
Again rather speculative/hypothetical.

p.21, para 1 - need to define 'mussel cover. If refers to increase in the % of a given lay area covered by mussels, i.e. a biomass density increase, then bird numbers/density might not rise proportionally - due to intra-specific spacing (aggressive) behaviour. If, however, total area of cultivation increases (more and/or bigger lays) then an increase in total bird numbers should be expected.

p.21, para 2 – water flow directions – there is no SE or NW!; where would 'expansion' take place? Para speculative and probably better deleted.

5.2.2 Cessation – no comment, other than that infauna would be expected to revert to near pre-1960 situation ; species are known rapid re-colonisers.

Report needs to have a CONCLUSIONS & RECOMMENDATIONS section here. This should *inter alia* : (a) identify the sensitive cSAC components of main concern to CCW; (b) attempt to rank the relative risks to these taxa from each potential effect of local cultivation ; (c) note current related research areas ; (d) identify priority research fields (to be detailed in appendices, see below).

6. Current & Future Work

6.1 Research conducted in the UK
Projects in progress (6.1.2 to 6.1.4) should go into an Appendix 1, together with the European research titles in progress. The other two (proposed) projects should join those of Section 7 to form a different appendix (Appendix 2).

Comments on proposed 6.1 projects:

6.1.5 Mussel seed resources – fisheries and environmental issues
Seems (as presented here) to be an over-ambitious, poorly defined and very costly exercise on the scale proposed, particularly regarding ephemeral offshore beds. How would one measure 'impact' and on what ? – for example in Morecambe Bay, unless there are very

sensitive sites very nearby. Problem should be manageable pragmatically using existing collective experience from previous long-term studies (Morecambe Bay) and seed management measures already applied at Morecambe Bay and Wash. Project should focus on the Menai Strait seed resource (Caernarfon Bar) and the S. Wales site (Whiteford Burrows) used by Bangor growers. Form a working group to produce a provisional management strategy and agree an achievable project of greater direct relevance to the Menai Strait. Priority rating = medium.

6.1.6 Menai Strait turbidity and other covariate surveillance
A sound and practical proposal.

7. Research requirements
All to form Appendix 2. Should be referred to in Conclusions & Recommendations section. My initial comments on specific proposals in this section are given below. The CCW request to evaluate future research needs will be further addressed later (at D).

7.1 Monitoring and assessment of phytoplankton depletion
How would one determine 'impact' on other taxa (i.e. those of special conservation concern) without detailed information on their diets? (but see 7.5). How would allowance be made for effects of adjacent wild mussel stocks at Bangor? Unnecessary (and overly expensive) to monitor the entire strait ; there are no large cultivated mussel lays in southern end. Better to concentrate study within an area (say) 2 miles either side of Bangor cultivations ; which would include most sensitive taxa/sites?

Note : fluorimeters provide an index only of total chlorophyll, and do not give quantitative data on plankton structure (that is a much bigger 'ball game').

Note: use of caged mussels – OK, if of homogeneous origin (from same age-class, shore level, size) and set out at identical biomass density, shore level/s and time. Need to measure environmental data, especially tidal flow rates through cages, at each site.

7.2 Hydrodynamics modelling on the Menai Strait
Should be a priority project. How much data are already available from earlier work at Menai Bridge marine laboratory?

7.3 Impact of harvest and mussel mud break up
OK – should be a short study, integrated with 7.2 (above).

7.4 Health of reefs in the Menai Strait
Work for CCW to undertake, presumably, but is there not already good information on these reef communities?

7.5 Competition between filter-feeders
Good fundamental biological study with applied aspects. Links in with 7.1 (above). Presumably test species will be the 'sensitive' taxa and mussels. Cockles should also be compared since they constitute a large biomass within the cSAC.

7.6 Recovery studies of underlying marine habitats and associated communities

Not worth doing; effects already known/predictable from other similar studies ; species involved are common in-fauna capable of rapidly re-colonising mud flats.

C. Supplementary Historical Information (from MAFF Conwy files)

The following notes provide a brief account of the first 20 years or so (1958 – 1980) of mussel cultivation in the Menai Strait, and some of the associated research – by the MAFF Conwy shellfish laboratory - into mussel stocks, cultivation and ecology in the strait. This background information can be inserted into Section 1.1.

Mussel cultivation

Started around 1958, when Severnside Oyster Co. began relaying and depuration at Siliwen. By early 1960s, operations extended to Bangor Flats and to channel bottom between Bangor flats and Beaumaris-Gallows Point. Sublittoral cultivation attempts in the latter area were abandoned because of heavy starfish predation. From 1963 to 1972, annual production from intertidal lays averaged ~700 tons (MAFF statistics), using seed taken from Caernarfon Bar (sublittoral, e.g. 4,900t during 1968-70) and Morecambe Bay (intertidal), and larger mussels from various sources beyond the Menai Strait. Seed supply was intermittent and unpredictable, and annual production very variable.

From about 1971, Welsh Seafood's Ltd took over operations and built a processing plant near Caernarfon, and installed modern Dutch machinery for making up-market mussel products. A large suction dredger collected and transported small seed mussels from Morecambe Bay and Caernarfon Bar to lays on Bangor Flats. In 1974, some 2,000t were re-laid from the latter source; unfortunately, this lay was washed away in January 1975 by an unusual combination of a severe NE gale during spring tides. The company never recovered, and had ceased operations by about1976.

There was then a hiatus until Myti Mussels Ltd took over and succeeded where the pioneers had failed. MAFF landings data for Bangor cultivators (ostensibly all from local lays) since 1993 are listed below; it is uncertain whether these are all complete (treat as confidential):
1993 (294t) ; 1994 (no data) ; 1995 (1,009t) ; 1996 (5,825t) ; 1997 (5,360t) ;
1998 (6,080t) ; 1999 (217t) ; 2000 (2,170t) ; 2001 (6,699t) ; 2002 (5,119t).

MAFF Research in Menai Strait

(a) Surveys of potential cultivation areas

Work during 1959-60 identified 4 sites (2 intertidal, 2 sublittoral) as being probably productive mussel grounds, with a total area of ~ 250 acres (100ha) :

Bangor flats – low shore between dock and Afon Ogwen = ~ 140 acres (55ha);
Siliwen – low shore = ~ 15 acres (6ha);
Channel bottom, Bangor flats to Garth/Gallows Point = ~ 75 acres (30ha);
Channel bottom, Siliwen = ~ 20 acres (8ha)

The potential annual productivity of these 4 grounds was estimated at ~ 6,250t, but that would require a similar input of seed mussels. During 1963-72 average annual production (700t) was only 11% of potential due largely to shortage of accessible seed resources and sometimes high mortality on lays (handling and predation).

(b) Surveys of wild mussel beds
Natural resources were assessed as potential relaying stocks but found often to be unsuitable. A very large high-level mussel bed has occurred on the Ballast Bank off Bangor for at least 100 years. In 1959, this bed covered 114 acres (45ha), entirely above low water mark of neap tides, and contained some 8,000t of old low quality mussels of no use for relaying; but the faunal community was an important food resource for many shore birds (1970s personal observations for BTO). This bed still exists.

Similarly long-standing intertidal beds occur also either side of Beaumaris, and were hand-harvested by Conwy men and others from time to time in the 1950-70s. No surveys were made of these stocks, but total biomass may exceed 500t.

In the southern strait, a small high shore bed is located at Tal-y-Foel, but in the narrows off Belan Point (Caernarfon Bar) there is a unique sublittoral gravel/stone ground where large but ephemeral seed resources occur frequently. This site has been the prime seed resource for the Bangor cultivators since the 1960s. In summer 1971, a diving survey (by MAFF, industry and Menai Bridge laboratory) gave a biomass estimate of 4,500-6,100t of small mussels on a 46 acre (18ha) ground. In summer1974, 2,000t of seed were harvested from here and re-laid on Bangor Flats (see above).

(Note: Cockle stocks on Traeth Lafan have been surveyed by NWNWSFC on several occasions in recent years, and biomass estimates probably given in their reports).

(c) Other research
From 1960-80, mussel biology was studied, and cultivation trials made, at Bangor and the MAFF shellfish culture experimental site at Tal-y-Foel. The extensive programme covered such aspects as : spat settlement, growth, survival, predators, biodeposition, and methods of improving yields from lays etc. Applied work involved *ad hoc* assessments for the cultivators on dredging and handling problems; some of the related publications are listed in the report section 8.

D. Does the Report meet CCW Project Objectives ?

1. Determine known and potential impacts of mussel cultivation in Menai Strait

The following 8 fields of potential interactions with cSAC and other interests were identified from literature and their known or possible biological effects were reviewed:

- Seed collection – changes associated invertebrate communities, and reduces food for dependent (predator) faunas;
- Benthic communities – structural changes to in-fauna under re-laid mussel lays;
- Phytoplankton depletion – reduction in biomass, and species composition changes, in food available to other competing filter-feeding taxa;
- Mussel waste products (biodeposition) – smothering of grounds *in situ* (mussel mud), re-suspension and fall-out elsewhere of particulate material, and provision of new high energy resource for decomposers;
- Nutrient fluxes – enhanced re-cycling from biodeposits on mussel lays affects primary production;
- Predators – re-laid mussels increase food supplies for (at least) starfish, crabs and birds;
- Aesthetics – fishing vessels v. visual perceptions of scenic value;

- Harvesting – re-suspension of particulates and release of nutrients from mussel lay biodeposits.

The literature review is rather brief but quite adequate for present purposes in high-lighting the principal processes that could be operating in and around the mussel culture sites in the strait. Although such a review could be more comprehensive (there is an enormous literature on mussel ecology and cultivation), given time, the present reporter should have consulted the extensive information collated in the EN Biogenic Reefs management manual.

I would like to see an attempt made to rank the 8 'impacts' in approximate order of likely importance; so that priority research areas can more easily be identified, presumably with particular respect to those sensitive taxa/sites of major conservation concern.

The report treats mussel cultivation at Bangor in isolation and does not place it in its full local faunal context. Its premise is that only cultivated mussels could affect cSAC interests, and does not consider the existence of large biomasses of wild mussels on beds adjoining the cultivations, nor those of cockles and other bivalves on nearby Traeth Lafan. Somehow, the relative effects of wild mussels (at least) on primary production, phytoplankton depletion and nutrient fluxes should be considered.

2. Data requirements

The report does not specify, in terms of specific parameters, the precise types of biological and environmental data that will be required to demonstrate impacts. A few units are mentioned here and there in the text.

3. Research recommended

The proposals in the report relate to some of the 8 fields listed above (at D1); see also my previous comments on them in sections 6 and 7. Figures in parentheses are the report sub-sections. In general, this is a good package of proposals though some will need to be thought through or focused more rigorously. Proposals that merit consideration for early starts are those hydrographic and plankton projects relating to measuring events in the water column. These will provide hard information using standard data collection and analytical procedures. The other proposals need refining.

Seed collection (6.1.5)

There is clearly a need for some work, given the levels of concern expressed by CCW, EN, NWNWSFC and SWSFC over Bangor industry annual requests to exploit both regular and ephemeral known resources to an ever increasing extent. A balanced management policy therefore needs to be developed. My view on the research proposal (and see earlier) is that field work should focus on the two Welsh sites of greatest interest to growers and conservationists – the sublittoral site within the cSAC at Menai Strait, and the intertidal site at Whiteford Burrows (Glams.). Hard-focused studies at these sites could be productive. A collation of known biological and fisheries information (CEFAS, SFCs) from other currently exploited and proposed sites around the English coast should be undertaken in parallel.

Phytoplankton depletion (7.1)

Some comments have already been given earlier. This proposal would address a fundamental feature of mussel bed dynamics and it should form the basis of work at Bangor, in

conjunction with the hydrodynamics study of water flowing over and around the cultivations (7.2). My concern (again) is that studies should concentrate on a defined section of the strait – around the Bangor lays – so that effort is not dissipated along the entire strait. The work will need to distinguish between the effects from cultivated and wild mussel stocks. Phytoplankton species compositions will need to be evaluated; fluorimetry measures only total chlorophyll.

Hydrodynamics (7.2)
This is a priority; it will underpin most of the other research. In particular, one needs to predict flow directions and times between the mussel lays and sensitive sites at different tidal states.

Turbidity surveillance (6.1.6)
This links in well with proposals 7.1, 7.2 and 7.3, and will provide (economically) hard data on historical as well as on-going variability water conditions around the mussel beds.
Mussel waste products (7.3)
The proposed study of sediment plumes dispersal is worth doing, as a concise topic in conjunction with the hydrodynamics project.

Health of reefs (7.4)
A management task for the CCW survey diving team, I would suppose.

Competition between filter-feeders (7.5)
Another good basic biological study, but could be held back (perhaps) pending results from the reef surveys (7.5) and from the first year or so of the phytoplankton study. There is probably an extensive literature to be reviewed first.

Benthos recovery studies (7.6)
I would give this proposal low priority (see earlier comments). Is there not adequate information from studies elsewhere (Netherlands and Bangor)? The pattern of mussel lays and biomass is likely to be too variable in space and time for long-term recovery study at particular locations. Possibly, a simple monitoring of in-fauna at fixed stations could be undertaken (by MSc or third year students).

This reviewer's additional research suggestions are given below:

Wild mussel stocks
There is a need to assess the present biomass status of the mussel stock on the ballast bank off Port Penrhyn, for (a) comparison with that on mussel lays and (b) use in other projects, e.g. phytoplankton depletion and suspended particulate matter. This would involve mapping mussel distributions and tidal level contours, plus sampling surveys to measure total biomass, size and age structure, biodeposits, and possibly also the associated faunal community. (Some of the general features may be listed already in the cSAC files).

Mussel industry description
Though not strictly a research topic, a good account of the history, annual productivity and present operational practises of the growers is needed to: (a) set the mussel cultivation fully in the context of the cSAC , (b) help interpret results from scientific field studies, and (c) suggest ways in which the industry could adjust to specific environmental concerns arising

from the research work. Information and data sources: MAFF/CEFAS, NWNWSFC, industry.