

*Quality of Life and Management of Living Resources*

**BIOFiltration and AQUaculture:  
an Evaluation of Hard Substrate Deployment Performance  
within Mariculture Developments**

**BIOFAQs**

5.1.2, 13.1, 13.2 Sustainable Fisheries and Aquaculture

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	PARTNER 3: <i>Centre for Maritime Studies, Haifa University,</i> <i>Israel</i> .. .. .	33
	PARTNER 4: <i>Marine Biological Station, National Institute of</i> <i>Biology, Piran, Slovenia</i> .. .. .	34
	PARTNER 5: <i>Institute of Marine Biology Crete, Greece</i> .. .. .	35
	PARTNER 6: <i>Centre for the Economics and Management of</i> <i>Aquatic Resources, University of Portsmouth, UK</i> .. .. .	35
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## 1. OBJECTIVES AND EXPECTED ACHIEVEMENTS

This research project will demonstrate the effectiveness of reducing the environmental impacts of organic inputs from intensive mariculture by using biofilter deployments. The objectives relate principally to biofilter use over a pan-European scale that includes the inshore coastal waters of all the project partner states (*ie* will include fieldwork and experimental conditions relative to the Mediterranean and Red Sea interests of Israel). The project has three inter-related principal objectives:

To quantify the validity (effectiveness) of biofilter use in association with mariculture within both economic and environmental frameworks on a pan-European scale. As components of this the project aims to:

- (i) review the current knowledge base relating to mariculture impacts on a pan-European scale;
  - (ii) appraise current and past biofilter initiatives within Europe and outside Europe and synthesise this previously disparate research;
  - (iii) examine existing biofilter designs to determine design principals that could be transferred from aquarium recirculation systems to open water deployments;
  - (iv) develop and/or advance quantitative impact assessment models and methodologies;
  - (v) undertake test field deployments of biofilters in association with existing mariculture concerns over a range of mariculture types and impact levels;
  - (vi) examine the potential for combining additive mariculture concerns with the physical structure of the biofilters.
- 1) To optimise biofilter designs and placement protocols in line with geographical differences and validated model predictions. This objective will be assessed principally through mesocosm experimentation and will examine:
- (i) biofilter design and performance over a range of temporal scales, a range of environmentally relevant physico-chemical parameter variations and under differing organic loading rates;
  - (ii) energy and nutrient fluxes in order to estimate levels at which intervention (removal or cleaning) will be required;
  - (iii) the dynamics and/or requirements for biofilter fallowing;
  - (iv) the placement parameters of biofilter deployment in relation to the relative location organic input point source and prevalent hydrological influences.
- 2) To examine the environmental and regulatory options governing post-biofilter usage and to provide detailed economic analyses of biofilter use compared with existing practices. Within this objective, the project aims to:
- (i) review the current regulatory status of mariculture impacts and hard substrate deployments in European waters and to ascertain the likely acceptance of biofilters within these regulatory frameworks;
  - (ii) evaluate the transferability of legal models within the European context;
  - (iii) develop an analytical tool within the framework of comparative legal analysis;
  - (iv) prepare pan-European cost/benefit analyses of biofilter deployment in association with mariculture development with specific reference to environmental value.

Through the achievement of these specific objectives, the project will deliver:

- 1) a comprehensive trans-European assessment of the environmental benefits of biofilter deployment in association with mariculture concerns;
- 2) guidance on both the physical design of the hard substrate complex intended as the biofilter as well as the size and location of the deployments in relation to estimated organic load profiles and the prevailing hydrological dynamics of the deployment site;

- 3) a socio-economic cost/benefit analysis of biofilter employment compared with non-deployment;
- 4) guidelines on the regulatory framework required for such deployments;
- 5) targets for future research priorities after the termination of the initial project within a determined framework of standardised research protocols;
- 6) a network of researchers and practitioners in the field through the mutual publishing of findings and the formal and informal exchange of data and results integral to the project via joint fieldwork programmes and the annual workshops. The network will be widened outwith the project partners through a close association with the MERAMED programme and through selective invitations from representatives of the mariculture industry and statutory regulatory bodies to attend the final workshop;
- 7) dissemination of the findings of the project both within Europe and beyond, including academics, practitioners and policy makers through
  - (i) the publication of academic papers, trade press articles, notes and project reports;
  - (ii) the posting of project summaries on a project-specific internet site;
  - (iii) presentations at conferences, workshops and industry meetings.

## 2. PROJECT WORKPLAN

### 2.1 INTRODUCTION

The project is comprised of six work packages:

- WP 01: Review of current knowledge base
- WP 02: Mariculture impact modelling
- WP 03: Mesocosm studies
- WP 04: Field studies
- WP 05: Legal analysis and regulations
- WP 06: Cost/benefit economics

In addition to the work packages outlined above, a co-ordination activity (WP 00) will also be undertaken by the co-ordinator. This is an administrative rather than research activity.

The research objectives of the project are presented as six work packages. However, within this structure there are cross cutting themes that may be addressed by one or more of the work packages. The themes adopt the following disciplinary split:

- Theme A: To quantify the validity (effectiveness) of biofilter use in association with mariculture within both economic and environmental frameworks on a pan-European scale
- Theme B: To optimise biofilter designs and placement protocols in line with geographical differences and validated model predictions
- Theme C: To examine the environmental and regulatory options governing post-biofilter usage

WP01. To provide a primary and grey literature review of the current knowledge base relating to mariculture impacts on a pan-European scale; to include a review of existing biofiltration methodology. From this review will come a synthesis of current biofiltration techniques and how they may be adapted for European open-system mariculture industries.

WP02. To advance existing fish farm impact/dispersal models to predict the performance of biofiltration deployments by the addition of biogeochemical modules specific to the function of biofilters and their potential ability to increase remineralisation rate through increased

substrate area. Field validation of predictive environmental impact models will be employed to further develop and validate models that can predict the economic and environmental benefits of biofilter deployments in association with mariculture development.

- WP03. To undertake a programme of mesocosm experiments that will assess biofilter design and performance over a range of temporal scales, a range of environmentally relevant physico-chemical parameter variations and under differing loading rates. The full assessment of performance will incorporate determinations of energy and nutrient fluxes, examination of following dynamics and investigation of biofilter design (location criteria and physical characteristics within a geographical variant context) with specific reference to determining surface area availability requirements.
- WP04. An extensive fieldwork programme will be undertaken using, where practicable, test biofilter deployments in association with ongoing mariculture concerns. The fieldwork programme will yield data that will be employed to verify the results from the mesocosm (WP03) and modelling (WP02) work packages.
- WP05. To review the current regulatory status of mariculture impacts and hard substrate deployments in European waters and to ascertain the likely acceptance of biofilters within these regulatory frameworks.
- WP06. To prepare pan-European cost/benefit analyses of biofilter deployment in association with mariculture development with specific reference to environmental value.

## 2.2 PROJECT STRUCTURE, PLANNING AND TIMETABLE

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Table 1: Workpackage and Component Descriptions

WORK PACKAGES		WORK PACKAGE AND COMPONENT DESCRIPTIONS
WP00	0.1	Project co-ordination
WP01	1.1	A primary and grey literature review of the current knowledge base relating to mariculture impacts on a pan-European scale.
	1.2	A review of existing biofiltration methodology
	1.3	A synthesis of current biofiltration techniques and how they may be adapted for the European open-system mariculture industries
WP02	2.1	To add biogeochemical modules to an existing fish farm impact model (DEPOMOD) to predict the performance of biofiltration deployments
	2.2	Field and mesocosm validation of biogeochemical modules
	2.3	To develop and validate models that can predict the economic and environmental benefits of biofilter deployments in association with mariculture development.
WP03	3.1	Using mesocosm studies, to assess biofilter design and performance over a range of temporal scales, a range of environmentally relevant physico-chemical parameter variations and under differing loading rates.
	3.2	To determine energy and nutrient fluxes within WP3.1 in mesocosms with the objective of estimating the conditions under which biofilters continue to function without the requirement for intervention (removal or cleaning).
	3.3	To assess the dynamics of biofilter fallowing in mesocosms in order to determine recovery rates with or without direct intervention
	3.4	To investigate reef design (location criteria and physical characteristics within a geographical variant context) in mesocosms with specific reference to determining surface area availability requirements.
WP04	4.1	To establish and verify field measurement criteria that will input into the required model verifications (WP2.2) with the objective of developing normalised, pan-European protocols applicable to the impact models.
	4.2	To undertake experimental biofilter deployments in the field situation within standardised and replicated protocols in order to assess in field performance in detail.
	4.3	To make field measurements of energy and nutrient fluxes both with and without biofilter placements in order to quantify changes that may be occurring on deployment of biofilters.
	4.4	To undertake detailed pre- and post-deployment hydrographical profiles for model validation purposes.
	4.5	To record and quantify the rates and biomasses of biological settlement and accumulation on the biofilters. Special reference will be given to species with known commercial importance.



	4.6	Where biological communities develop on or around the experimental biofilter deployments there will be a requirement to quantify bioaccumulation both in terms of potential pollutant uptake and from promoting biofilters as nutrient sinks. Some work will be carried out in order to identify potential biomarkers of filter quality. Bioaccumulation studies are of primary importance where harvesting of commercially important species is a possibility (see WP4.5).
	4.7	An investigation of the following dynamics of the biofilters will be undertaken once significant biofiltration in the field has been established. This is of particular importance where pollutant accumulation is a possibility.
WP05	5.1	To review the current regulatory status of mariculture impacts and hard substrate deployments in European waters and to ascertain the likely acceptance of biofilters within these regulatory frameworks.
	5.2	To evaluate the transferability of legal models within the European context.
	5.3	To develop an analytical tool within the framework of comparative legal analysis.
WP06	6.1	To prepare pan-European cost/benefit analyses of biofilter deployment in association with mariculture development with specific reference to environmental value.

Table 2: Workpackage List

WP no.	WP Title	Responsible participants <sup>1</sup>	Person-months	Start month	End month	Deliverable no.
WP00	Project Co-ordination	1, 2	20.0	1	36	D014
WP01	Literature review	1, 2, 3, 4, 5, 7	14.5	1	8	D02, D03
WP02	Predictive model development and validation	1, 2, 7	25.0	9	36	D010
WP03	Mesocosm studies	5, 1, 2, 3	77.0	4	30	D07, D09, D012
WP04	Field based investigations	2, 1, 3, 4, 5, 7, 8	184.0	3	36	D01, D08, D011, D012
WP05	Evaluation of associated legal issues	6, 1, 3, 4, 5	22.0	1	12	D04, D05, D06
WP06	Economic cost/benefits analyses	6, 1, 2, 3, 4	16.0	25	36	D013
<b>TOTAL</b>			<b>358.5</b>			

<sup>1</sup> Workpackage leader listed first

Table 3: List of Milestones

MILESTONE NUMBER	TITLE AND DESCRIPTION	DELIVERY DATE	PARTICIPANTS	WP No.
M01	FULL LITERATURE REVIEW Publication of a full literature review identifying the practical, technological and legalistic possibilities for biofiltration use in association with mariculture, to include provision of executive summaries, a summary report, academic papers and a bibliographic database.	12	1, 2, 3, 4, 5, 6, 7	WP01.1 WP05.1 WP01.2 WP01.3
M02	MODEL DEVELOPMENT AND EVALUATION A. Development of model modules of biofilter biogeochemical function: Model V1. B. Calibration and refinement of modules using mesocosm and field data: Model V2 C. Validation and refinement of modules with field data. Packaging of the model (V3) and supporting publications (academic papers and technical reports).	14 24 36	1, 2, 7	WP02.1 WP03 WP02.2 WP04 WP02.3
M03	MESOCOSM-TESTED DESIGN CRITERIA A. The establishment of mesocosms and the development and testing of initial biofilter designs B. Full assessment of biofilter performance trials in mesocosm experiments C. Deliverance of mesocosm-tested design criteria to initiate or improve field deployments of biofilters	10 20 30	1, 2, 3, 5	WP03.1 WP03.4 WP03.2 WP03.3
M04	DATASET OF ORGANIC LOADING REGIME CRITERIA Prediction of a matrix of organic loading regimes within which the performance of the biofilters is not impaired, to include the collation of a dataset of organic loading regime criteria. To be based on mesocosm experiments.	30	1, 2, 3, 5	WP03.1 WP03.2 WP03.4
M05	BIOFILTER DEPLOYMENT A. Deployment of biofilters in association with mariculture operations in an experimentally-relevant way to represent a geographical spread that is relevant to the pan-European aims of the programme. B. Legalistic overview of deployment regulation	9 12	1, 2, 3, 4, 5, 6, 7, 8	WP04.1 WP05.2 WP04.2 WP05.1

M06	<p><b>BIOFILTER PERFORMANCE DATASET</b>  Deliverance of complete datasets relating to the biological, biogeochemical and hydrological performance of the field deployments.</p> <p>A. A set of field measurement protocols designed to standardise the approach to field assessment of nutrient-related impact assessment</p> <p>B. Deployment of initial biofilter designs on a field-relevant scale</p> <p>C. Delivery of intermediate assessment of field performance</p> <p>D. Delivery of final assessment of field performance</p>	<p>9</p> <p>9</p> <p>20</p> <p>36</p>	<p>1, 2, 3, 4, 5, 7, 8</p>	<p>WP04.3    WP04.6</p> <p>WP04.4    WP04.7</p> <p>WP04.5    WP02.2</p>
M07	<p><b>SOCIO-ECONOMIC COST/BENEFIT ANALYSIS</b>  Empirical estimates of the economic costs/benefits associated with biofilter deployment to produce an analytical framework for measuring the external costs and economic impacts of intensive mariculture, and a comparison between damage costs and prevention costs of mariculture pollution.</p>	<p>36</p>	<p>1, 2, 3, 4, 6</p>	<p>WP06.1</p>

Table 4: List of Deliverables

DELIVERABLE NO	DELIVERABLE TITLE	WP	DELIVERY DATE (MONTH)	PARTNERS	NATURE	DISSEMINATION LEVEL	DISSEMINATION TARGET
D01	Field deployment of some biofilters in association with mariculture concerns	04	9	1, 2, 3, 4, 5, 7, 8	O	RE*	PR, PM
D02	Report summarizing the findings of the review	01	12	1, 2, 3, 4, 5, 7	pR	PU	AC, PR, PM
D03	Bibliographic database resulting from the review	01	12	1, 2, 3, 4, 5, 7	O	RE*	AC, PR, PM
D04	Synthesis of existing legal regimes and revisions desirable by case study and pan-European	05	12	1, 3, 4, 5, 6	pR	PU	AC, PR, PM
D05	Bibliographic database of relevant legal and regulatory literature relating to marine hard substrate deployments	05	12	1, 3, 4, 5, 6	O	RE*	AC, PR, PM
D06	Legal compendium and management guidance for biofilter deployment	05	12	1, 3, 4, 5, 6	pR/O	PU	AC, PC, PM
D07	Mesocosm-derived design criteria for biofilter modeling and field deployment/revision A. Mesocosms and initial biofilter design criteria and standardised experimental protocols B. Report on all biofilter performance trials in mesocosm experiments in a format that will influence or modify field trials	03	10 20	1, 2, 3, 5	O	RE*	AC, PR
D08	Collation of field data required for environmental model validation	04	24	1, 2, 3, 4, 5, 7, 8	O	RE*	AC, PR
D09	Mesocosm-derived determinations of sustainable biofilter loading rate estimates A. Energy and nutrient flux assessment of design and performance B. Loading rate against performance data for accepted biofilter designs.	03	18 30	1, 2, 3, 5	O	RE*	AC, PR
D010	A. Biogeochemical biofilter model V1 B. Biogeochemical biofilter model V2 C. Biogeochemical Biofilter model V3	02	14 24 36	1, 2, 7	O	RE*	AC, PR, PM

D011	A collated detailed assessment of the field performance of biofilters E. Established measurement criteria that will be used in the field F. Field deployment of experimental biofilters G. Pre-deployment site assessments H. Intermediate assessment of field performance I. Post-deployment site assessment for feedback into deliverable D010C J. Final assessment of field performance	04		1, 2, 3, 4, 5, 7, 8	pR/O	PU	AC, PR, PM
			9				
			9				
			9				
			20				
			30				
			36				
D012	An assessment of fallowing dynamics of biofilters A. Mesocosm derived fallowing dynamics data B. Field derived fallowing dynamics data	03, 04		1, 2, 3, 4, 5, 7, 8	pR/O	PU	AC, PR, PM
			30				
			36				
D013	Summary of cost/benefit analyses of biofilter deployments	06	36	1, 2, 3, 4, 6	pR	PU	AC, PR, PM
D014A	Final programme reports	00	36	all	fR	PU	EC, AC, PR, PM
D014B	Annual Report 1	00	12	all	pR	RE	EC
D014C	Annual Report 2	00	24	all	pR	RE	EC
DO14D	Annual Report 3	00	36	all	pR	RE	EC

Delivery date is the month number from the start of the programme

Nature of the deliverable is: pR (periodic report); fR (final report); O (other)

Dissemination level is: PU (public); RE\* (restricted circulation in the short-term – will be made publicly available towards the end of the programme).

Dissemination targets are: AC (academic community), PR (practitioners), PM (policy makers), EC (European commission)

These deliverables will be supplemented by the production of academic papers for publication in the international peer-reviewed literature and conference papers for presentation at international conferences throughout the project.

Figure 1: Management Structure

		MONTH																																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
WP0	0.1	P1, P2																																			
WP1	1.1	P1, P2, P4, P5																																			
	1.2	P1, P2, P7																																			
	1.3	P1, P2, P3, P7																																			
WP2	2.1	P1, P2, P7																																			
	2.2	P1, P2, P7																																			
	2.3																									P1											
WP3	3.1	P1, P2, P3, P5																																			
	3.2	P1, P2, P3, P5																																			
	3.3	P1, P5																																			
	3.4	P1, P2, P3, P5																																			
WP4	4.1	P1, P2, P3, P4, P5, P7, P8																																			
	4.2	P1, P2, P3, P4, P5																																			
	4.3	P2, P3, P4, P5, P7, P8																																			
	4.4	P1, P2, P3, P4, P5												P1, P2, P3, P4, P5												P1, P2, P3, P4, P5											
	4.5	P1, P2, P3, P4, P5, P7, P8																																			
	4.6	P1, P2, P3, P4, P8																																			
	4.7																									P1, P4											
WP5	5.1	P1, P3, P4, P5, P6																																			
	5.2	P5, P6																																			
	5.3	P6																																			
WP6	6.1	P1, P2, P3, P4, P6																																			

**Key:** Month: month from start of project; WP: work package; Pn: project partner n (1-8)

## 2.3 DESCRIPTION OF WORK PACKAGES

Work package number:	WP00.1
Start date or starting event:	1
Completion date:	36
Partners responsible:	1, 2
Person months per partner:	
• Partner 1 (project co-ordinator)	14.0
• Partner 2 (scientific co-ordinator)	6.0
• TOTAL	20.0

### Objectives

- To co-ordinate each component of the project and each partner's contribution;
- To arrange project workshops and co-ordination meetings;
- To ensure the project is running to schedule;
- To identify and rectify any problems that may arise during the course of the project;
- To co-ordinate and complete the administrative requirements of the project (e.g. cost statements, interim reports etc.);
- To co-ordinate and complete all project deliverables.

### Description of work

The project will have three workshops during its duration where technical aspects of the work will be presented, discussed and revised where necessary. In addition, project co-ordination meetings (PCMs), comprising just the principal investigators, are to be held at approximately 5-6 month intervals, timed to ensure the satisfactory completion of the work packages: either in terms of planning, monitoring or reviewing the work undertaken within each work package. Any potential problems will be identified at the meetings, and a means of overcoming the problem devised by the project team. Three of these PCMs will be held during the workshops. The other three will occur in a 5-6 month period after each workshop. In addition to co-ordination meetings, remote communications (e-mail, bulletin boards and video conferencing) will also be used to ensure satisfactory progress on the project. Where possible, workshops and PCMs will occur with, or back-to-back with those of the MERAMED programme

### Deliverables

The only formal output from the co-ordination component of the project will be the interim and final progress reports and associated cost statements. Where appropriate, the proceedings of the workshops will be collated for dissemination purposes.

### Milestones and expected results

The milestones will be the submission of the interim progress reports. The expected results are that the project is running smoothly and to schedule.

Work package number:	WP01.1
Start date or starting event:	1
Completion date:	8
Partners responsible:	1, 2, 4, 5
Person months per partner:	
• Partner 1 (co-ordinator)	1.5
• Partner 2	2.0
• Partner 4	1.0
• Partner 5	2.0
• TOTAL	6.5

### Objectives

- To provide a synthesis of the existing primary and grey literature relating to the current knowledge base of mariculture impacts on a pan-European scale.

### Description of work

This work package will involve a desk-based review of the primary and grey literature and the outputs of past and current research of relevance to the project with specific attention paid to existing literature and research on the impacts of mariculture within Europe

### Deliverables

- Targeted summaries of the findings of the work package
- A report summarising the findings

### Milestones and expected results

The review will contribute to the publication of a full review (milestone 1). The expected results will be an executive summary, a summary report, and a contribution towards academic papers and a bibliographic database. This review information will identify the mariculture impacts that biofiltration may be used to ameliorate.

Work package number:	WP01.2
Start date or starting event:	1
Completion date:	8
Partners responsible:	1, 2, 7
Person months per partner:	
• Partner 1 (co-ordinator)	0.5
• Partner 2	2.0
• Partner 7	0.25
• TOTAL	2.75

### Objectives

- To review existing biofiltration methodologies.
- To evaluate the transferability of biofiltration techniques to open-system mariculture.

### Description of work

This work package will initially involve a desk-based review of the existing methodologies employed for biofiltration (in closed, semi-close, or open systems), past works that have attempted biofiltration within a mariculture context and the legal/regulatory status of hard substrate deployments throughout Europe. Some of this literature and research has been previously identified in the context of other



projects. However, this information will be up-dated and supplemented through searches on bibliographic databases and the internet.

The existing base of contacts with individuals and groups who are currently or have previously been involved in relevant research will be built on and invitations to attend the planned workshops will be made where appropriate to elicit the current state of knowledge and to obtain key information.

On the basis of the review, reports will be produced, detailing the transferability and applicability of the findings of the research and methodologies used to the European context.

### Deliverables

- Targeted summaries of the findings of the work package
- A report summarising the findings

### Milestones and expected results

A contribution towards the publication of the full review (milestone 1). The expected results within this milestone will be executive summaries, a summary report, and contributions towards academic papers and a bibliographic database. The bibliographic database will be published on a dedicated BIOFAQs website, divided into subject areas and cross referenced. The website will have open access, and the database will be in a downloadable format suitable for searching. This review information will identify the practical, technological and legalistic possibilities for biofiltration use in association with mariculture.

Work package number:	WP01.3
Start date or starting event:	1
Completion date:	8
Partners responsible:	1, 2, 3, 7
Person months per partner:	
• Partner 1 (co-ordinator)	1.0
• Partner 2	2.0
• Partner 3	3.0
• Partner 7	0.25
• TOTAL	6.25

### Objectives

- To provide a synthesis of the current biofiltration techniques and how they may be adapted for the European open-system mariculture industries.

### Description of work

This work package will integrate the information yielded from WP01.1 and WP01.2. On the basis of the review, reports will be produced, detailing the transferability and applicability of the findings of the research and methodologies used to the European context.

### Deliverables

- Targeted summaries of the findings of the work package
- A report summarising the findings
- Academic papers for publication in refereed journals
- Bibliographic database of relevant literature and research in Europe and globally

### Milestones and expected results

The publication of the full review will be milestone 1. The expected results within this milestone will be executive summaries, a summary report, academic papers and a bibliographic database. This review information will identify the practical, technological and legalistic possibilities for biofiltration use in association with mariculture, and will be used to focus and modify the research directions of the overall project.

Work package number:	WP02.1
Start date or starting event:	9
Completion date:	24
Partners responsible:	1, 2, 7
Person months per partner:	
• Partner 1 (co-ordinator)	6.0
• Partner 2	2.0
• Partner 7	0.5
• TOTAL	8.5

### Objectives

- To model biofilter function at the biogeochemical process level

### Description of work

Using an existing impact model (DEPOMOD) and also using developments of this model made within the MERAMED programme, this work package will produce a predictive model that will estimate the potential change in impact associated with biofilter deployment. This WP will complement work done in MERAMED but there will be no duplication. Moreover, the BIOFAQs model would be much less transferable to warm and/or microtidal environments without the expected progress in developing DEPOMOD for such environments in MERAMED. For micro-tidal environments, longer term measurements of current speed obtained through MERAMED (and existing data) will be used to drive the physical aspects of the model, thus BIOFAQs has some dependence on both the field and modelling components of MERAMED. The modelling work proposed in MERAMED can be seen as a linear development of DEPOMOD into a new environment whereas the modelling proposed here uses DEPOMOD and its successor as input but is essentially a biogeochemical box model rather than a Lagrangian system and is therefore tangential to DEPOMOD development.

### Deliverables

The model will be delivered to the partners in 3 phases approximating to Version 1: an uncalibrated process module for DEPOMOD; Version 2: a further developed module calibrated with initial mesocosm and field results and Version 3: a further developed model with parameter validation from field experiments. DEPOMOD is already a highly user-friendly windows-driven model and all module versions will be in the same usable format and with appropriate documentation.

### Milestones and expected results

This work package will contribute to the delivery of Milestone 2A, 2B and 2C of the project. It is expected that the model versions will be utilized by the partners as each of the versions becomes available and that a positive feedback between end-user and modelers will result in a well tested final version which will encapsulate process understanding gained through the project. The expected result is that the model will enable prediction of the potential beneficial environmental effects of biofilter deployment for a given environment.

Work package number:	WP02.2
Start date or starting event:	13
Completion date:	36
Partners responsible:	1, 2, 7
Person months per partner:	
• Partner 1 (co-ordinator)	4.0
• Partner 2	4.0
• Partner 7	1.0
• TOTAL	9.0

### Objectives

- To perform field validations of the predictive environmental impact models.

### Description of work

This workpackage will investigate the predicted environmental parameter changes estimated from the Model versions 1 and 2. This will be used to quantify the validity of the model. Field and mesocosm measurements will be fed back into later generation models that will be further validated.

### Deliverables

- A field/mesocosm-validated predictive model for determining the benefits of biofilter deployment on a farm by farm basis.

### Milestones and expected results

This work package will contribute to the delivery of Milestones 2B and 2C of the project. The field/mesocosm-validation will be essential in quantifying the robustness of the model predictions. The expected results will be the basic validated model engine as well as a detailed database of environmental parameter measurements.

Work package number:	WP02.3
Start date or starting event:	25
Completion date:	36
Partners responsible:	1, 2, 7
Person months per partner:	
• Partner 1 (co-ordinator)	4.0
• Partner 2	3.0
• Partner 7	0.5
• TOTAL	7.5

### Objectives

- To deliver fully validated models that can predict the economic and environmental benefits of biofilter deployments in association with mariculture development.

### Description of work

The results from the feedback field and mesocosm validations will be incorporated into Model V2 to produce the final model V3 with full supporting literature.

### Deliverables

- A field validated, predictive model for determining the benefits of biofilter deployment on a farm by farm basis.

### Milestones and expected results

This work package will complete delivery of Milestone 2C of the project. This will be the development of a model that can predict changes in environmental impact caused by biofilter introduction. The milestone will be completed by the finalised version of the model being packaged to enable third party usage.

The expected results are the satisfactory attainment of the work package milestones, the predictive model, a user-friendly software package for the model and supporting publications (academic papers and technical reports).

Work package number:	WP03.1
Start date or starting event:	4
Completion date:	30
Partners responsible:	5, 1, 2, 3
Person months per partner:	
• Partner 5 (co-ordinator)	16.0
• Partner 1	7.0
• Partner 2	8.0
• Partner 3	5.0
• TOTAL	36.0

### Objectives

- Using mesocosm facilities, the workpackage will assess biofilter design and performance over a range of temporal scales, a range of environmentally relevant physico-chemical parameter variations and under differing loading rates.

### Description of work

Mesocosm studies will be employed in order to test many of the theoretical assumptions relating to biofilter deployment. The use of mesocosms in the context of environmental impact assessment is an established methodology. The mesocosms will be established in tank-based facilities and will be representative of the sea bed types. Organic enrichment can be simulated using partially decomposed feed stuffs and/or by containment of fish species maintained user-relevant conditions. A range of biofilter models (to represent differing designs and surface areas) will be introduced to the mesocosms and the performance will be assessed primarily through water column sampling and analysis of nitrate and ammonia levels, and the relative levels of aerobic degradation in the organic matter.

### Deliverables

- Experimental data on design and performance that can be utilized in the modelling (WP02) and the field deployment (WP04) components of the project.
- Estimates of acceptable loading rates for each design will be obtained that will have direct relevance to farm husbandry practices.

### Milestones and expected results

This work package will contribute to the delivery of Milestone 3. This is to deliver fully-tested biofilter design criteria to work package 4 (WP04). These criteria will either drive proposed biofilter deployments or assist to alter existing deployments. The expected results are the satisfactory attainment of the work package milestones, the necessary data on which to base proposed biofilter field deployments or modify existing deployments (either in design or placement location), and supporting publications (academic papers and technical reports).

Work package number:	WP03.2
Start date or starting event:	4
Completion date:	30
Partners responsible:	5, 1, 2, 3
Person months per partner:	
• Partner 5 (co-ordinator)	8.0
• Partner 1	2.0
• Partner 2	5.0
• Partner 3	5.0
• TOTAL	20.0

### Objectives

- To determine energy and nutrient fluxes in mesocosm studies with the objective of estimating the conditions under which biofilters continue to function without the requirement for intervention (removal or cleaning)

### Description of work

A range of biofilter models (to represent differing designs and surface areas) will be introduced to the mesocosms and the performance will be assessed primarily through water column sampling and analysis of nitrate and ammonia levels, and the relative levels of aerobic degradation in the organic matter. Using these methods of assessment, an experimental matrix will be performed testing variables of organic loading, biofilter design and physico-chemical fluctuation (temperature and salinity changes) on biofilter performance.

### Deliverables

- Experimental data on design and performance that can be utilized in the modelling (WP02) and the field deployment (WP04) components of the project.
- Estimates of acceptable loading rates for each design will be obtained that will have direct relevance to farm husbandry practices.

### Milestones and expected results

This work package will contribute to the delivery of Milestone 3. This is to deliver fully-tested biofilter design criteria to work package 4 (WP04). These criteria will either drive proposed biofilter deployments or assist to alter existing deployments. The expected results are the satisfactory attainment of the work package milestones, the necessary data on which to base proposed biofilter field deployments or modify existing deployments (either in design or placement location), and supporting publications (academic papers and technical reports).

Work package number:	WP03.3
Start date or starting event:	8
Completion date:	30
Partners responsible:	5, 1
Person months per partner:	
• Partner 5 (co-ordinator)	6.0
• Partner 1	2.0
• TOTAL	8.0

### Objectives

- To assess employing mesocosms the dynamics of biofilter following in order to determine recovery rates with or without direct intervention.

**Description of work**

Mesocosm experiments will be used to assess or estimate the rates of recovery (where applicable). Even if a biofilter receives too much organic material to function effectively, the rate of recovery for the same area of seabed may be accelerated in the presence of biofilters. Biofilters that have been fouled in previous mesocosm experiments will be left to assess the dynamics of recovery. Mesocosms fouled in the absence of biofilters will be allowed to recover with the addition of clean biofilter deployment. As part of the recovery assessment, the degree of stability of the accumulated matter on the biofilters will be measured in order to estimate levels of resuspension caused by intervention or removal.

**Deliverables**

- Experimental data on design and performance that can be utilized in the modelling (WP02) and the field deployment (WP04) components of the project.
- Estimates of acceptable loading rates for each design will be obtained that will have direct relevance to farm husbandry practices.

**Milestones and expected results**

This work package contributes to Milestone 4 and will identify rates of recovery of both the biofilters and the impacted sediments both with and without intervention. This is of importance in quantifying the level of contribution that biofilters may play in aiding the potential acceleration of post-impact recovery. The expected results are data relating to recovery dynamics and supporting publications (academic papers and technical reports)

Work package number:	WP03.4
Start date or starting event:	8
Completion date:	30
Partners responsible:	5, 1, 2, 3
Person months per partner:	
• Partner 5 (co-ordinator)	2.0
• Partner 1	4.0
• Partner 2	5.0
• Partner 3	2.0
• TOTAL	13.0

**Objectives**

- To investigate reef design (location criteria and physical characteristics within a geographical variant context) with specific reference to determining surface area availability requirements.

**Description of work**

In addition to the physical design of the biofilters, it is possible that the location, number of biofilters and the directional presentation criteria will influence performance. In mesocosms, the performance effects driven by the orientation of placement with respect to the prevalent current direction will be measured. In addition, the effects of the proximity of location to the point source will also be assessed.

**Deliverables**

- Experimental data on design and performance that can be utilized in the modelling (WP02) and the field deployment (WP04) components of the project.

**Milestones and expected results**

This work package will contribute to the objectives of Milestone 3. These criteria will either drive proposed biofilter deployments or assist to alter existing deployments. The expected results are the satisfactory attainment of the work package milestones, the necessary data on which to base proposed biofilter field deployments or modify existing deployments (either in design or placement location), and supporting publications (academic papers and technical reports)

Work package number:	WP04.1
Start date or starting event:	2
Completion date:	12
Partners responsible:	2, 1, 3, 4, 5, 7, 8
Person months per partner:	
• Partner 2 (co-ordinator)	4.0
• Partner 1	2.0
• Partner 3	3.0
• Partner 4	1.0
• Partner 5	2.0
• Partner 7	0.5
• Partner 8	1.0
• TOTAL	13.5

### Objectives

- To establish and verify field measurement criteria that will input into the required model verifications

### Description of work

The fieldwork component of the programme will include the field deployment of biofilters in association with existing mariculture concerns. Some partners have already undertaken test deployments in preliminary studies. Deployments will be either under sea cages and/or placed in close proximity. All deployments will be replicated at least. The efficiency of the biofilters as a means of retaining particulate and soluble wastes will be determined through the analysis of fixed carbon, nitrogen and phosphorous on the filters, carried out over a range of temporal scales to infer performance. An additional indicator of performance will be the rate and turnover of fouling biomass accumulation. This will be measured through simple biomass change per unit area per unit time estimates and through established underwater respirometry techniques. Although the basic methodologies are accepted and are attainable there will be a requirement to establish and verify field measurement criteria that will input into the required model verifications. This will be carried out before the deployments begin in order to standardize the approach to deployment

### Deliverables

- The establishment of the measurement criteria that will be employed in the field

### Milestones and expected results

This workpackage will contribute data that will aid the delivery of milestones 2 and 5. This work package will influence the deployment criteria of biofilters in the field and will contribute to the quality of a field-validated revision of existing environmental impact models. Results will also be measurable through the publication of related information (academic papers and technical reports).



Work package number:	WP04.2
Start date or starting event:	6
Completion date:	36
Partners responsible:	2, 1, 3, 4, 5
Person months per partner:	
• Partner 2 (co-ordinator)	4.0
• Partner 1	2.0
• Partner 3	5.0
• Partner 4	2.0
• Partner 5	10.0
• TOTAL	23.0

### Objectives

- To undertake experimental biofilter deployments in the field situation.

### Description of work

Biofilters will be constructed and deployed based on information gained from pilot study deployments and mesocosm experiments. The design and construction of biofilters will be undertaken with emphasis on low cost of materials/construction/deployment, and on removeability of the structures to enable following of the site, as necessary. Each programme partner who will be deploying biofilters has sites available to them to undertake the deployment. The size, design and orientation of the initial placements will be defined from initial programme meetings. This may be revised as the mesocosm studies progress.

### Deliverables

- The field deployment of biofilters in association with mariculture concerns

### Milestones and expected results

The successful deployment of biofilters in association with mariculture on which to base the field deployment research will satisfy the requirements of Milestone 5.

Work package number:	WP04.3
Start date or starting event:	6
Completion date:	36
Partners responsible:	2, 3, 4, 5, 7, 8
Person months per partner:	
• Partner 2 (co-ordinator)	8.0
• Partner 3	5.0
• Partner 4	20.0
• Partner 5	12.0
• Partner 7	4.0
• Partner 8	13.0
• TOTAL	62.0

### Objectives

- To quantify the effects of biofilter deployment through field measurements of energy and nutrient fluxes

### Description of work



The efficiency of the biofilters as a means of retaining and/or filtering particulate and soluble wastes will be determined through the analysis of carbon, TSS, ammonia, nitrite, nitrate, phosphates and dissolved oxygen on or in the filters, carried out over a range of temporal scales to infer performance. An additional indicator of performance will be the rate and turnover of fouling biomass accumulation. This will be measured through simple biomass change per unit area per unit time estimates and through established underwater respirometry techniques.

Sediment geochemistry and the structure of benthic communities provide a valuable means for quantifying the degree of organic enrichment. Therefore an additional method of assessing biofilter efficiency will be the measurement of temporal change in the benthic communities, in and around the biofilter deployments. Sediment profiling will be used to detect community response to benthic enrichment and the anticipated recovery period through the identification of changes in geochemical variables and the univariate and multivariate analyses of the macro- and meio-fauna.

### Deliverables

- A detailed assessment of field performance measured through energy/nutrient fluxes, hydrographical profiling, biological settlement and bioaccumulation

### Milestones and expected results

This workpackage will deliver complete datasets relating to the biological, biogeochemical and hydrological performance of the field deployments. The successful delivery of these datasets will result in the achievement of Milestone 6. The expected results will be based on the satisfactory attainment of the work package milestone. This work package will result in the attainment of datasets relating to the performance of biofilters in a field situation. Results will also be measurable through the publication of related information (academic papers and technical reports).

Work package number:	WP04.4
Start date or starting event:	6
Completion date:	34
Partners responsible:	2, 1, 3, 4, 5
Person months per partner:	
• Partner 2 (co-ordinator)	3.0
• Partner 1	2.0
• Partner 3	3.0
• Partner 4	19.0
• Partner 5	4.0
• TOTAL	31.0

### Objectives

- To undertake detailed pre- and post-deployment hydrographical profiles for model validation purpose.

### Description of work

Changes in hydrography, affected by the physical introduction of additional man-made structures may be causative of detectable changes. Hydrographical surveys will therefore be an essential component of this work package. It is envisaged that where deployments are to be undertaken that hydrological surveys are conducted before and after deployment

### Deliverables

- A detailed assessment of the hydrographical profiles of the deployment areas before and after the biofilter deployments.

- Collation of data for model validation

### Milestones and expected results

The results from this workpackage contribute to the delivery of complete data sets relating to the biological, biogeochemical and hydrological performance of the field deployments (Milestone 6). The results also feed back into the revision of the environmental impact model in accordance with continued validation using the field performance data (Milestone 2). The expected results are the satisfactory attainment of the work package milestones. This work package will assimilate information relating to the performance of biofilters in a field situation and will contribute to a field-validated revision of existing environmental impact models. Results will also be measurable through the publication of related information (academic papers and technical reports).

Work package number:	WP04.5
Start date or starting event:	11
Completion date:	36
Partners responsible:	2, 1, 3, 4, 5, 7, 8
Person months per partner:	
• Partner 2 (co-ordinator)	8.0
• Partner 1	2.0
• Partner 3	12.0
• Partner 4	6.0
• Partner 5	2.0
• Partner 7	1.0
• Partner 8	6.0
• TOTAL	37.0

### Objectives

- To record and quantify the rates and masses of biological settlement/accumulation on the biofilters.

### Description of work

An indicator of biofilter performance will be the rate and turnover of fouling biomass accumulation. This will be measured through simple biomass change per unit area per unit time estimates and through established underwater respirometry techniques.

### Deliverables

- A detailed assessment of the field performance of biofilters measured through energy/nutrient fluxes and bioaccumulation

### Milestones and expected results

The data attained from this workpackage will contribute to the delivery of complete data sets relating to the biological, biogeochemical and hydrological performance of the field deployments (Milestone 6). The expected results will be contribute datasets relating to the performance of biofilters in a field situation. Results will also be measurable through the publication of related information (academic papers and technical reports).

Work package number:	WP04.6
Start date or starting event:	13
Completion date:	36
Partners responsible:	2, 1, 3, 4, 8
Person months per partner:	
• Partner 2 (co-ordinator)	5.0
• Partner 1	2.0
• Partner 3	5.0
• Partner 4	1.0
• Partner 8	2.0
• TOTAL	15.0

### Objectives

- To quantify bioaccumulation within developing biological communities in terms both of pollutant uptake and nutrient accumulation..

### Description of work

Where biological communities develop on or around the experimental biofilter deployments there will be a requirement to quantify bioaccumulation both in terms of potential pollutant uptake and from promoting biofilters as nutrient sinks. Some work will be carried out in order to identify potential biomarkers of filter quality. Bioaccumulation studies are of primary importance where harvesting of commercially important species is a possibility (see WP4.5).

### Deliverables

- A detailed assessment of field performance measured through biological settlement and bioaccumulation

### Milestones and expected results

The data attained from this workpackage will contribute to the delivery of complete data sets relating to the biological performance of the field deployments (Milestone 6). In areas where the possibility of harvesting from the biofilters exists, a quantitative and qualitative assessment of this potential will be undertaken. Results will also be measurable through the publication of related information (academic papers and technical reports).

Work package number:	WP04.7
Start date or starting event:	25
Completion date:	36
Partners responsible:	1, 4
Person months per partner:	
• Partner 1 (co-ordinator)	2.0
• Partner 4	1.0
• TOTAL	3.0

### Objectives

- To investigate the following dynamics of field-deployed biofilters.

### Description of work

The fouling and bioaccumulation actions of the deployed biofilters may produce significant reservoirs of biological fouling, nutrient accumulation and pollutant concentration. When the filters are

colonized to a level that no longer supports biofiltration at an optimal level, or if the farming activity ceases, there will be periods of fallowing for the biofilter units. These studies will examine:

- [a] the potential for resuspension if the biofilters are removed;
- [b] the potential for recovery if the biofilters are left *in situ*;
- [c] the dynamics of pollutant accumulation (*ie* do the biofilters retain pollutants at a much higher level than would be found if allowed to dilute without intervention?)

### Deliverables

- An assessment of fallowing dynamics

### Milestones and expected results

The data attained from this workpackage will contribute to the delivery of complete data sets relating to the biological performance of the field deployments (Milestone 6). It is expected that removal will produce resuspension but the rates cannot be quantified at present. Leaving the biofilters *in situ* may be the desirable option but the structures will probably not recover this way. The costs/benefits of removal and/or recovery will be examined in WP06. Results will be measurable through the publication of related information (academic papers and technical reports).

Work package number:	WP05.1
Start date or starting event:	1
Completion date:	12
Partners responsible:	6, 1, 3, 4, 5
Person months per partner:	
Partner 6 (co-ordinator)	5.0
• Partner 1	1.0
• Partner 3	2.0
• Partner 4	4.0
• Partner 5	2.0
• TOTAL	14.0

### Objectives

- To produce legal and management guidance for regulatory bodies within the partner countries in relation to the use of hard artificial substrate as a biofilter for the mitigation of the environmental effects of aquaculture.
- To undertake a pan-European and global review of legal frameworks.

### Description of work

This work package will involve a desk-based review of the literature and the identification and collation of appropriate legal materials. This will include pertinent materials within the fields of law governing, *inter alia*, marine aquaculture, marine environmental management, coastal planning and management, property and use rights, fisheries management and artificial reef deployment. A range of sources will be used, e.g. Eurolaw, European References, FAOLex, Lexis, national online and hard copy sources, original documents and secondary sources (including journals), as appropriate. The partners will be instrumental in the translation of materials for use in the analytical process. The initial focus will be on the case study countries and the deployment of experimental units.

The sourcing and preliminary review of secondary sources and primary legal documents in the case study countries will be followed by contacts with government agencies responsible for the regulation of the industry to establish the mode of implementation and the administrative procedures undertaken within the regulatory process. This will be used to elaborate on and identify the regulatory regime in practice and to provide guidance for the application for the permits and authorisations required for the deployment of the experimental units. Once guidance has been issued in respect of the deployment of

the experimental units, the geographical coverage of this work package will be broadened to the pan-European and global levels.

### Deliverables

- A report summarising the findings of the work package
- Academic papers for publication in refereed journals
- This sub-work package will also contribute to :
  - Bibliographic database of relevant literature and research in Europe and globally
  - A compendium of legislation, manner of implementation for the context in question, institutional frameworks by country, and legal sources.

### Milestones and expected results

In combination with the provision of scientific evidence needed, the results from this workpackage will produce guidance on the permits and authorisations required for full-scale deployments of the biofiltration units in the case study countries (Milestone 5).

Work package number:	WP05.2
Start date or starting event:	1
Completion date:	12
Partners responsible:	6, 5
Person months per partner:	
• Partner 6 (co-ordinator)	5.0
• Partner 5	1.0
• TOTAL	6.0

### Objectives

- To evaluate the transferability of legal models within the European context

### Description of work

The various legal/regulatory and institutional models for the provision and governance of biofilters under current legal regimes within the partner countries and pan-European will be produced on the basis of the material collated in WP05.1, using comparative legal analysis developed in WP05.3 as the methodological framework. Recommendations for country and context specific modifications to the existing regimes to provide for their provision and governance will subsequently be made. The transferability and applicability of the findings of the research and methodologies used will be assessed and the various deliverables produced.

### Deliverables

- A report summarising the findings
- Academic papers for publication in refereed journals
- This sub-work package will also contribute to :
  - Bibliographic database of relevant literature and research in Europe and globally
  - A compendium of legislation, manner of implementation for the context in question, institutional frameworks by country, and legal sources.

### Milestones and expected results

The completion of the legal review, the identification of a typological classification of legal models and the isolation of modifications necessary and feasible within the constraints of existing legal regimes and political agendas, for the deployment of biofilters in both the case study/partner countries and elsewhere in Europe (Milestone 1).

Work package number:	WP05.3
Start date or starting event:	1
Completion date:	6
Partners responsible:	<b>6</b>
Person months per partner:	
• Partner 6 (co-ordinator)	2.0
• TOTAL	2.0

## Objectives

- To develop an analytical tool within the framework of comparative legal analysis

## Description of work

In order to evaluate the transferability of legal models within the European context, the legal and regulatory frameworks within different countries and regions will require comparative analysis. Analytical tools that can compare legal models between countries are necessary in order to assess acceptability and cost/benefit parameters. This workpackage will involve a desk-based review of the literature, targeting the elicitation of appropriate frameworks of analysis, notably comparative legal analysis. The review, in combination with the clarification of the functions to be addressed by regulatory frameworks, will be utilised in the development of an appropriate comparative analytical methodology for the use in this project and similar applications.

## Deliverables

- A review of the methodological framework and its applicability to the context in question
- Academic papers for publication in refereed academic journals

## Milestones and expected results

This sub-work package is instrumental in: the satisfactory completion and rigour of the legal review; the identification of a typological classification of legal models; and the isolation of modifications necessary and feasible within the constraints of existing legal regimes and political agendas, for the deployment of biofilters in both the case study/partner countries and elsewhere in Europe (Milestone 1).

Work package number:	WP06.1
Start date or starting event:	25
Completion date:	36
Partners responsible:	6, 1, 2, 3, 4
Person months per partner:	
• Partner 6 (co-ordinator)	12.0
• Partner 1	1.0
• Partner 2	1.0
• Partner 3	1.0
• Partner 4	1.0
• TOTAL	16.0

## Objectives

- (i) to review the external economic costs caused by the environmental impact of aquaculture, and to survey the measures available for internalising these costs.
- (ii) to explore the economic and financial implications of mitigating the environmental damage from cage aquaculture using hard substrate deployment

## Description of work

The work package is in two parts. Firstly, it will involve a desk-based review of the literature on the environmental impact of aquaculture and the economic externalities which these engender. This review will aim to identify the range of environmental impacts, their attribution to intensive versus extensive production systems and the nature of the economic damage caused. This will be followed by a survey of the control measures which are currently and potentially available for the internalisation of these externalities, including governmental regulations (e.g. zoning, discharge limits related to water quality, stocking density limits, etc.) and market-based instruments (e.g. tariffs on production, tradeable permits, etc.)

The second part of the work package will involve an economic appraisal of the effects of hard substrate deployment in mariculture. A capital budgeting model will be developed in order to assess the costs of installing a specified biofilter unit adjacent to a commercial fish farm in order to meet a legally-imposed environmental target. (Defined in terms of an appropriate biological or physical performance indicator, such as a given percentage reduction in BOD). Data will be derived (a) from the results of the other work packages (e.g. in terms of a knowledge of the relationship between water quality and production) and (b) economic data derived from published sources and supplemented by appropriate fieldwork. A crucial aim of the capital budgeting exercise will be not simply to derive the investment costs of hard substrate deployment but to see how far any of the economic benefits could be appropriated by the fish farm undertaking the investment (e.g. in terms of increased permitted stocking density or production).

## Deliverables

- A workshop report containing (i) a literature review (ii) summarising the methodology and results of the investigation
- Academic papers for publication in refereed journals
- Paper for presentation at the Annual Conference of the European Association of Fisheries Economists

## Milestones and expected results

The principal milestone will be estimates of the costs associated with the deployment of hard substrates adjacent to intensive mariculture systems.

The results of the work will (I) provide an analytical framework for measuring the economic damage associated with environmental impacts of aquaculture (ii) demonstrate how the financial and competitive position of commercial fish farms, facing the increasing demands of meeting higher environmental standards, will be affected by the installation of biofilters.



### 3. ROLE OF PARTICIPANTS

<i>Participant number:</i>	01
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*Name and address of participating organisation:*

Centre for Coastal and Marine Sciences  
 Dunstaffnage Marine Laboratory  
 PO Box 3  
 Oban  
 Argyll PA34 4AD  
 United Kingdom

*Scientific Team:*

Dr Kenny Black – team leader, chemist  
 Dr Martin Sayer – deputy team leader, hard substrate research, marine biology, diver  
 Dr Chris Cromey - modeller  
 Dr Paul Provost – remote sensing, hydrographer, diver  
 One Post Doctoral Research Assistant (to be appointed)  
 One Project Manager (to be appointed)

*Objectives:*

To optimise artificial hard substrates design and placement protocols by review of existing literature, modelling, mesocosm experimentation and field deployment monitoring and measurement in order to minimise the environmental impact of waste from fish farms.

*Workplan:*

To contribute to the following workpages (person-months in parentheses):

WP00.1(14.0)  
 WP01.1(1.5), WP01.2(0.5), WP01.3(1.0)  
 WP02.1(6.0), WP02.2(4.0), WP02.3(4.0)  
 WP03.1(7.0), WP03.2(2.0), WP03.3(2.0), WP03.4(4.0)  
 WP04.1(2.0), WP04.2(2.0), WP04.4(2.0), WP04.5(2.0), WP04.6(2.0), WP04.7(2.0)  
 WP05.1(1.0)  
 WP06.1(1.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):

D01(9), D02(12), D03(12), D04(12), D05(12), D06(12), D07(20), D08(24), D09(30), D010(36),  
 D011(36), D012(36), D013(36), D014(36).

<i>Participant number:</i>	02
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*Name and address of participating organisation:*

National Center for Mariculture, Israel Oceanographic & Limnological Research Ltd (IOLR)  
 Environment Research Group  
 National Center for Mariculture  
 Israel Oceanographic & Limnological Research  
 PO Box 1212  
 North Beach  
 Eilat 88112, Israel

*Scientific Team:*

Team Leader: Dror Angel

Technician: Timor Katz\*

Technician: Noa Eden

(\* a new position resulting from this award)

*Objectives:*

To optimise biofilter designs and placement protocols in order to achieve maximal biofiltration efficiency, by a combination of mesocosm experimentation and field deployment of biofilters

*Workplan:*

To contribute to the following workpages (person-months in parentheses):

WP00.1(6.0)

WP01.1(2.0), WP01.2(2.0), WP01.3(2.0)

WP02.1(2.0), WP02.2(4.0), WP02.3(3.0)

WP03.1(8.0), WP03.2(5.0), WP03.4(5.0)

WP04.1(4.0), WP04.2(4.0), WP04.3(8.0), WP04.4(3.0), WP04.5(8.0), WP04.6(5.0)

WP06.1(1.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):

D01(9), D02(12), D03(12), D07(20), D08(24), D09(30), D010(36), D011(36), D012(36), D013(36), D014(36).

<i>Participant number:</i>	03
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*Name and address of participating organisation:*

Marine biology and marine resources

The Leon Recanati Institute for Maritime Studies

University of Haifa

Mount Carmel

Aba Hushi St.

Haifa 31905

Israel

*Scientific Team:*

Prof. Ehud Spanier - team leader

Stephen Breitstein - senior diving officer

Amir Yurman - diving officer

Yossi Zilbiger – research assistant (a new position resulting from this award)

*Objectives:*

To optimise artificial hard substrates design and placement protocols by field deployment, monitoring and experimentation in order to minimise the environmental impact of waste from fish farms.

*Workplan:*

To contribute to the following workpages (person-months in parentheses):

WP01.3(2.0)

WP03.1(5.0), WP03.2(5.0), WP03.4(2.0)

WP04.1(3.0), WP04.2(5.0), WP04.3(5.0), WP04.4(3.0), WP04.5(12.0), WP04.6(5.0)

WP05.1(2.0)

WP06.1(1.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):

D01(9), D02(12), D03(12), D07(20), D08(24), D09(30), D011(36), D012(36), D013(36),  
D014(36).

<i>Participant number:</i>	04
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*Name and address of participating organisation:*

National Institute of Biology  
Marine Biological Station Piran  
Fornače 41  
6330 Piran  
Slovenia

*Scientific Team:*

Alenka Malej, team leader  
Branko Čermelj, Ph.D., geochemistry\*  
Vlado Malačič, Ph.D., physical oceanography  
Nives Kovač, Ph.D., biogeochemistry  
Patricija Mozetič, Ph.D. plankton ecology\*  
Boris Petelin, M.Sc., data base & elaboration  
Valentina Turk, Ph.D., microbial ecology\*  
Borut Vrišer, Ph.D., benthic ecology  
Aleksander Vukovič, Ph.D. algology\*  
\* - minor involvement

*Objectives:*

To undertake field deployments of biofilters in association with an existing mariculture site in Slovenian coastal waters, carry out field measurements of nutrient fluxes and hydrographic conditions, and quantify biological settlement. In addition the partner will contribute to the review of current knowledge on regulatory status of mariculture impacts and hard substrate deployments.

*Workplan:*

To contribute to the following workpages (person-months in parentheses):

WP01.1(1.0)

WP04.1(1.0), WP04.2(2.0), WP04.3(20.0), WP04.4(19.0), WP04.5(6.0), WP04.6(1.0), WP07 (1.0)

WP05.1(2.0)

WP06.1(1.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):

D01(9), D02(12), D03(12), D04(12), D05(12), D06(12), D07(20), D011(36), D012(36), D013(36),

D014(36).

<i>Participant number:</i>	05
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*Name and address of participating organisation:*

Institute of Marine Biology of Crete (IMBC)  
 Department of Marine Ecology and Biodiversity  
 PO Box 2214  
 71003 Heraklion  
 Crete  
 Greece

*Scientific Team:*

*Dr Ioannis Karakassis*  
 Dr Paraskevi Pitta  
 Dr Panos Drakopoulos  
 Dr Mihalis Paspatis  
 Dr Chris Smith  
 Ms Ioanna Akoumianaki  
 Ms Konstantia Papadopoulou  
 2 Research Technicians

*Objectives:*

To conduct mesocosm experiments to determine energy and nutrient fluxes and to assess biofilter design, performance and dynamics. To undertake measurements relating to the performance of field deployments of biofilters in association with existing mariculture sites. To contribute to the literature and legal reviews.

*Workplan:*

To contribute to the following workpages (person-months in parentheses):

WP01.1(2.0)  
 WP03.1(16.0), WP03.2(8.0), WP03.3(6.0), WP03.4(2.0)  
 WP04.1(2.0), WP04.2(10.0), WP04.3(12.0), WP04.4(4.0), WP04.5(2.0)  
 WP05.1(2.0), WP05.2(1.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):  
 D01(9), D02(12), D03(12), D04(12), D05(12), D06(12), D07(20), D08(24), D09(30), D011(36),  
 D012(36), D014(36).

<i>Participant number:</i>	06
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*Name and address of participating organisation:*

Centre for the Economics and Management of Aquatic Resources  
 University of Portsmouth  
 Locksway Road  
 Southsea  
 PO4 8JF  
 United Kingdom

*Scientific Team:*

Helen Pickering

David Whitmarsh  
 Lorna Cromar  
 Carl James  
 (Legal Researcher to be appointed)

*Objectives:*

To undertake a pan-European and global review of legal frameworks aimed at extrapolating guidance in relation to the use of hard artificial substrate as a biofilter for the mitigation of the environmental effects of aquaculture for partner countries and other countries within Europe. To review and explore the economic and financial implications of mitigating the environmental damage from cage aquaculture using hard substrate deployment.

*Workplan:*

To contribute to the following workpages (person-months in parentheses):  
 WP05.1(5.0), WPO5.2(5.0), WP05.3(2.0)  
 WP06.1(12.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):  
 D04(12), D05(12), D06(12), D013(36), D014(36).

<i>Participant number:</i>	07
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*Name and address of participating organisation:*

School of Ocean and Earth Science  
 University of Southampton  
 Southampton Oceanography Centre  
 Southampton SO14 3ZH  
 UK

*Scientific Team:*

Dr Ken Collins (team leader, funded 6months)  
 Dr Phillip Smith (funded 3 months)  
 Dr Antony Jensen (not funded by this programme)

*Objectives:*

To contribute expertise and experience of studying artificial hard substrate biological communities.  
 To apply above study techniques to assessment of biofilter performance

*Workplan:*

To contribute to the following workpages (person-months in parentheses):  
 WP01.2(0.25), WP01.3(0.25)  
 WP02.1(0.5), WP02.2(1.0), WP02.3(0.5)  
 WP04.1(0.5), WP04.3(4.0), WP04.5(1.0)

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):  
 D01(9), D02(12), D03(12), D08(24), D010(36), D011(36), D012(36), D014(36).

<i>Participant number:</i>	8
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*Name and address of participating organisation:*

Department of Environmental Sciences  
Jožef Stefan Institute  
Jamova 39  
1000 Ljubljana  
Slovenia

*Scientific Team:*

Dr. Sonja Lojen, team leader  
Dr. Nives Ogrinc  
Dr. Jože Kotnik  
Stojan Žigon, technician

*Objectives:*

To contribute analytical support in terms of C and N stable isotopic analyses used for screening of the environmental conditions and food-web structure in the aquatic ecosystems affected by intensive mariculture (a) before the deployment of biofilters, and (b) assessment of the effectiveness of biofilter use in association with mariculture by monitoring changes in isotopic fingerprints of selected indicators.

*Workplan:*

To contribute to the following workpages (person-months in parentheses):

WP04.1(1.0), WP04.3(13.0), WP04.5(6.0), WP04.6(2.0)

In practice, the contribution of P8 will be the employment of isotopic methods in assessment of biodiversity in affected marine environments by measurements of  $^{13}\text{C}/^{12}\text{C}$  and  $^{15}\text{N}/^{14}\text{N}$  ratios in representative samples of fish food, particulate organic matter, dispersed material collected in traps, sediment, and fish tissues (muscle, bone, stomach content). Measurements will be performed on seasonal basis. Validated and optimised analytical methods will be used and regular participation in the state of the art interlaboratory comparisons will be assured.

*Deliverables:*

To contribute to the following deliverables (see Table 3; delivery date in parentheses):  
D01(9), D08(24), D011(36), D012(36), D014(36).

## 4. PROJECT MANAGEMENT AND COORDINATION

### 4.1 ADMINISTRATIVE AND SCIENTIFIC COORDINATION

Dr Kenneth Black will be the administrative co-ordinator of the project. Dr Black has previously co-ordinated 2 successful EU FAR/AIR projects and is responsible for the management of several major research projects relating to the environmental impacts of mariculture. As administrative co-ordinator he will be responsible for progress control, reporting and quality assurance. He will be supported in this role by Dr Dror Angel (partner 2) and Dr Martin Sayer (partner 1). This Administrative Group will have monthly meetings by conference phone or video conference to monitor the timely delivery of Work Package outputs.

The scientific aspects of the project will be managed by a steering group (SG) which includes the principle investigators from each of the Principal Contractors and the leaders of each of the Work Packages. Explicitly this group will include:

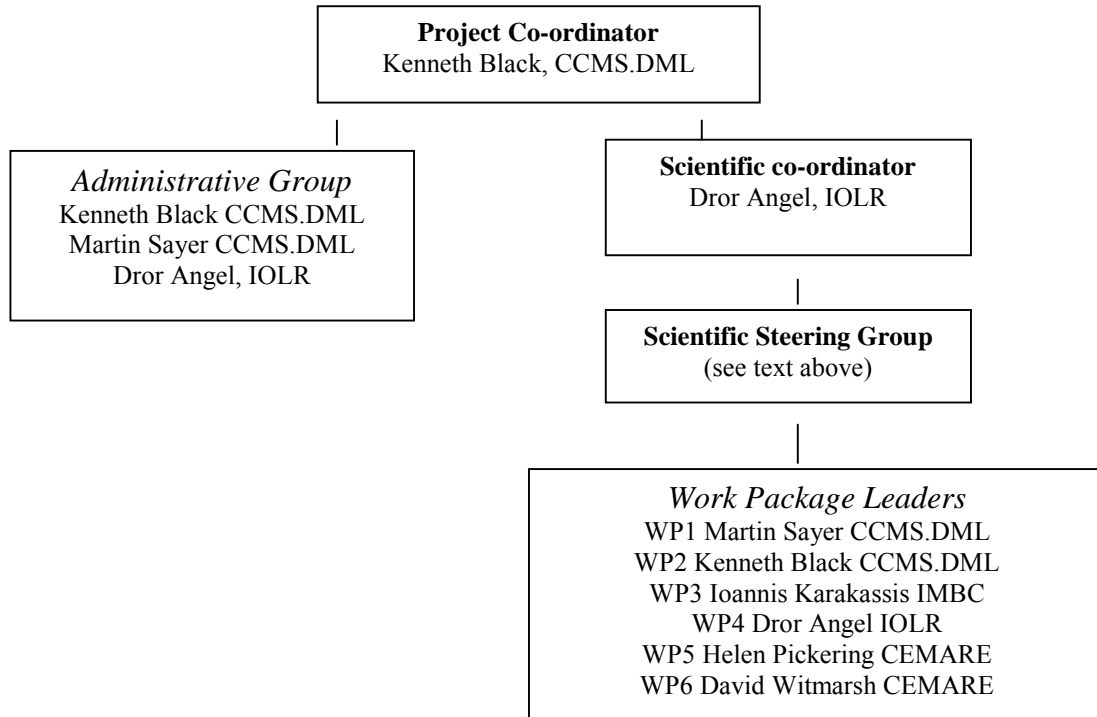
- 1 Dr Martin Sayer, CCMS.DML, UK
- 2 Dr Dror Angel, IOLR, Israel
- 3 Prof Ehud Spanier, Haifa Univ., Israel
- 4 Prof Alenka Malej, MBS.NIB, Slovenia
- 5 Dr. Ioannis Karakassis, IMBC, Greece
- 6 Dr. Helen Pickering, CEMARE, UK
- 7 Dr Ken Collins, Southampton University, UK

The project steering group will be chaired by the Scientific co-ordinator Dr Dror Angel from partner 2. The SG as a whole will be responsible for co-ordination of all field and laboratory science and provide a formal interface between Work Package leaders. The SG will formally meet 6 times during the project, together with other key project members, depending on the phase of the project. Of these 6 meetings three have already been provisionally arranged:

- 1 Technical workshop - beginning of year 1 to standardise research techniques and protocols across the programme, in Dunstaffnage, Oban Scotland (1-3 days)
- 2 Progress meeting - early/mid year 2, ILOR, Eilat, Israel (2-4 days)
- 3 Conference focused on the presentation of research outputs to a large international audience of scientists, end-users, and policy makers - end of year 3, IMBC, Crete (2-4 days).

In addition to these face-to-face meetings, full use will be made of the video conference facilities of the partner institutions. The most important method of communication will, however, be emails. In addition to normal organisational intercourse, each partner will prepare a short description of progress and activities to be sent to the co-ordinator on a monthly basis. The co-ordinator will edit these together to provide a regular project newsletter not only for the information of the partners but also for use in publicising the project.

In accordance with the requirements of the Consortium agreement that will be produced for the project, a co-ordination committee (CC) will be set up. This will consist of a sub-set of the members of the SG such that all partners are represented and will meet at the same time as the project meetings. The CC will specifically deal with issues that relate to the progress, performance and allocation of responsibilities of each of the consortium partners.



Quality assurance aspects relate to methodology and research outputs. The initial project meeting will focus on establishing protocols for those methods that will be common to several sites. For example, where hard substrates are established in association with mariculture, local partners will be highly involved in maintaining basic environmental records and it vital that these are comparable between sites. For functions which are specific to one partner but will be applied across all sites, it is vital that each of the partners can trust data gathered by such specialists. It is, therefore, appropriate that each of the laboratories operate to the principles of good laboratory practice such that all data generated can be trusted as having originated from assured sources.

4.2 LINKS AND COORDINATION WITH MERAMED

The aims and objectives of the BIOFAQs programme have close links (as well as two common partners – p1 and p5 in BIOFAQs) to those of the MERAMED programme, also funded in this round. It is intended to conduct all co-ordination meetings at joint locations with planned periods of overlap where information exchange can occur between the two programmes. Structuring the programme meetings in this way will also reduce some of the travel costs. Where possible, fieldwork output will be optimised by combining periods of fieldwork by the two common partners. The final programme conference will be common to both programmes to facilitate total information exchange and again reduce travel and administrative costs.

This degree of integration has already been established through an initial joint liaison meeting between members of both programmes at Amsterdam (04-07 May 2000), immediately prior to the submission of this annex.



## 5. EXPLOITATION AND DISSEMINATION ACTIVITIES

The key scientific outputs from the project will be peer reviewed and, therefore, have in-built quality screening. It is important that plans to produce papers for high quality international peer reviewed journals are prepared early in the project and that appropriate measures are taken to ensure that experimental design is statistically rigorous. It is recognised that it is of crucial importance that research be turned into high quality outputs. The management of this process will be a key function of the Administrative Group.

In addition to paper outputs, partners will be encouraged to present their work at important international meetings. Computer models produced or developed during the project will be made available to bona fide research users. An end-of-Programme conference will be called at the conclusion of the programme in association with MERAMED (see above). In addition to inviting scientists from related disciplines, efforts will be made to attract practitioners from the European mariculture industry as well as legislators associated with impact regulation. Details of the BIOFAQs programme will be available on the world-wide-web for unrestricted information dissemination.

Intellectual Property Rights will be shared amongst the partners according to Box 8 of Part 1 of the Guide for Proposers. In addition, IPR issues will be fully discussed at the first project meeting and a formal IPR agreement signed between partners.

## 6. ETHICAL ASPECTS AND SAFETY PROVISIONS

Regarding legal aspects; a key aspect of this project is an assessment of the legal and regulatory issues surrounding the use of hard substrates as bio-filters around fish farms. As far as is presently understood small-scale experimental use of such structures should present no significant problem for the project but the consortium is well aware of the potential legal and regulatory difficulties that might face commercial users, which will differ between countries. These will be fully explored within the project and in terms of the quality of the outputs, peer reviewed by academic, practitioner and governmental legal experts for each legal regime addressed. In all cases where field deployments of biofilters are undertaken, they will be removed at the end of the experimental period.

The research work will include office-based work, fieldwork (including use of small boats and diving), laboratory experimentation and sample analyses. All aspects of these work categories carry health and safety implications for personnel at each of the partner institutions. The lead partner will develop before the start of the programme a *pro forma* for each partner to complete. This will identify health and safety considerations to be taken into account by each partner. All personnel will be aware of the relevant EU health and safety directives for each part of the intended work programme.

Partner 1 houses the UK Centre for Scientific Diving, and there is a high knowledge base within that Centre relating to the use of diving and small boats in association with science. This knowledge base will be called on by BIOFAQs to advise on experimental design and application. Where practical, the new European standards for Scientific Diving will be implemented by this programme.