Quality of Life and Management of Living Resources

Bio-filtration and AQuaculture: an Evaluation of Hard Substrate Deployment Performance within Mariculture Developments

BIOFAQs

5.1.2, 13.1, 13.2 Sustainable Fisheries and Aquaculture

Confidential Progress Report

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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 bio-filter deployments. The objectives relate principally to bio-filter 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:

1) To quantify the validity (effectiveness) of bio-filter 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 bio-filter initiatives within Europe and outside Europe and synthesise this previously disparate research;
   - (iii) examine existing bio-filter 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 bio-filters 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 bio-filters.

2) To optimise bio-filter 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) bio-filter design and performance over a range of temporal scales, a range of environmentally relevant physico-chemial 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 bio-filter fallowing;
   - (iv) the placement parameters of bio-filter deployment in relation to the relative location organic input point source and prevalent hydrological influences.

3) To examine the environmental and regulatory options governing post-bio-filter usage and to provide detailed economic analyses of bio-filter 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 bio-filters 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 bio-filter 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 bio-filter deployment in association with mariculture concerns;
2) guidance on both the physical design of the hard substrate complex intended as the bio-filter 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 bio-filter 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 bio-filter use in association with mariculture within both economic and environmental frameworks on a pan-European scale

Theme B: To optimise bio-filter designs and placement protocols in line with geographical differences and validated model predictions

Theme C: To examine the environmental and regulatory options governing post-bio-filter 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 bio-filtration methodology. From this review will come a synthesis of current bio-filtration 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 bio-filtration deployments by the addition of biogeochemical modules specific to the function of bio-filters 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 bio-filter deployments in association with mariculture development.

WP03. To undertake a programme of mesocosm experiments that will assess bio-filter 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 fallowing dynamics and investigation of bio-filter 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 bio-filter deployments in association with ongoing mariculture concerns. The fieldwork programme will yield data that will be employed to verify the results from the mescosm (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 bio-filters within these regulatory frameworks.

WP06. To prepare pan-European cost/benefit analyses of bio-filter deployment in association with mariculture development with specific reference to environmental value.

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2.2.1 Progress during the first reporting period

In the first reporting period, a literature review report has been completed. This is introduced by a discussion of the environmental impacts of aquaculture, biofiltration processes and techniques, biofiltration characteristics of marine fauna and bio-fouling of marine structures. It is proposed that this review forms the basis of a scientific publication to be submitted to a review journal during 2002. The Milestone (M01) and Workpackage (WP01) are now complete.

Preliminary modelling of the bio-filter location at the UK Dunstaffnage fish farm site in the UK has been undertaken to determine predictions of solids flux at the filter arising from the fish farm (WP02). This required the development of DEPOMOD model code so that a bio-filter domain could be defined. An assessment of the level of exposure of the filter to the fish farm effluent, with particular reference to fine particulate material was also conducted and the bio-filter exposure for different depths was tested. Finally, the relevant data with a view to undertaking similar modelling exercises for all other BIOFAQS fish farm sites has been collated.

It was intended to undertake some modelling predictions of flux to bio-filters for all BIOFAQS partner sites. Although most of the model development in year 1 was undertaken with data from the Dunstaffnage fish farm, it was intended to undertake similar predictions with the developed model for other sites. However, the effort involved by all partners in collating data for the site was reasonably high. This resulted in delays which has prevented modelling of all sites. However, now that most of the data has been collated, this will allow model development undertaken in year 2 of the bio-filter model to be tested with individual site data if required. It may be the case that modelling effort in year 2 is put primarily into biogeochemical bio-filter box model development as field data from each site starts to become available.

The first milestone (M02 A) in this workpackage, development of model modules of bio-filter biogeochemical function: Model V1 is due to be completed in Month 14.

Mesocosm studies (WP03) have been conducted in Crete (*in situ*), Oban (aquarium based) and Piran (*in situ*). Mesocosms have been designed and tested in the different study sites and the initial bio-filter design has been tested. An preliminary assessment of the uptake of fish effluent, particularly suspended particulate material has been conducted and the influence of the bio-filters on the water column in terms of inorganic and organic nutrients, bacteria, cyanobacteria and phytoplankton abundance has been measured either in total or in part in Crete, Oban and Piran. Finally, mesocosm experiments in Crete have monitored the influence of different fish species (sea bream, sea bass) on water quality, in terms of particulate organic carbon (POC) and nitrogen (PON), nutrients, total bacterial counts and urea water at hourly intervals over a 24 hour period.

Preliminary results show that the *net* uptake of suspended particulate material by fouling organisms that colonised the bio-filters in the first 6 months was low and that there was significant release by these organisms of ammonia and phosphate into the water column.

The first milestone (M03 A) in this workpackage, the establishment of mesocosms and the development and testing of initial bio-filter designs is now complete.

Bio-filters and their associated support frames have been designed, constructed and deployed in association with mariculture operations in an experimentally-relevant way and at a field-relevant scale off the west coast of Scotland, in the Black Sea, the Mediterranean and the Gulf of Aquaba (Red Sea) (WP04). The initial proposal to employ biofilters in order to capture fish farm effluents was inspired by the successful deployment of elongated triangular benthic structures adjacent to a commercial fish farm in the Red Sea. In this project (coordinated by partners 2 and 3 of BIOFAQs), the structures became colonized by a rapidly-growing community, consisting of local benthic biota (predominantly suspension feeders). This community clearly removed particles from the water column and showed potential to serve as a means for reducing the broadcast of particles and nutrients to the surrounding marine environment. However, we felt that this prototype biofilter was not the optimal design to fulfill its function and mandate; namely the removal of aquaculture-derived nutrients from the sea.
At the official kick-off meeting held in January 2001 at Oban, Scotland, we proposed to deploy solid substrates for biofiltration purposes in the water column (pelagos) rather than on the seafloor (benthos). Our reasons for re-thinking the placement of the biofiltration structures were as follows:

1. An anecdotal inventory of artificial solid substrates around fish farms (ropes, anchors, sinkers, buoys, net cages, etc.) has shown that the greatest biomasses of attached suspension and filter feeders are situated in the water column and not on the seafloor.
2. Current velocities (hydrodynamics) are generally greater in the water column than near the seafloor and therefore pelagic biofilters are more likely to experience a greater flux of fine particles and nutrients than low-profile benthic biofilters.
3. In addition to trapping of particles and nutrients, one of the objectives of BIOFAQs is removal of this material from the sea, i.e. harvestability. This aspect is logistically, and financially,

much more feasible using units that are suspended in the water column, rather than anchored to the seafloor.

4. Capture of particles by biofilters suspended in the water column is a proven and successful technology, as shown in the case of long-line mussel and bivalve farms operating in eutrophic bays and inlets (e.g. Spain)

5. Nutrient budgets of fish farms indicate that most of the nitrogen and phosphorus released in the effluents occur as dissolved and fine suspended particulate matter. These "light" compounds will not reach the seafloor below the fish cages, but may be carried off to great distances from the farm. The only efficient way to capture this material (and reduce far-field effects) is by placing substrates with large surface area in the water column adjacent to the fish cages.

6. Due to the large flux of nutrients from the fish cages, it is likely (especially in oligotrophic waters) that there is a patch (local bloom) of phytoplankton surrounding the fish cages. These phytoplankton will concentrate mostly in the upper few meters of the water column and will be most efficiently captured and removed by pelagic biofilters.

All the bio-filters are based on the same design and were deployed across Europe over a two week time-span in June 2001. It is envisaged that structural and temporal synchrony will aid comparisons between development rates of bio-fouling communities at the different pan-European study sites. Detailed protocols have also been developed to standardise the approach to field assessments of fish effluent-related impact assessment between the study sites. The protocols cover the measurement of biological, biochemical and hydrological parameters at each site.

Preliminary results, 6 months after deployment show that the bio-filter design and supporting framework have withstood the hydrological conditions at each site and that all the bio-filters have become colonised by fouling organisms. In 2 of the field sites (Oban and Eilat), a greater biomass of organisms has been recorded at the fish farm than at the respective control sites, while the opposite trend has been observed in Piran. In Crete, Piran and Eilat, biofilter surfaces (at both fish farm and control sites) were initially colonized by benthic algae, probably as a result of ample light penetration to 8m depth. In Oban, it is possible that the water was too turbid to accommodate extensive algal growth, though there were observations of red macroalgae at a later stage. The pioneer invertebrate taxon colonizing bio-filters at all sites was the hydroidae, followed by the bryozoa and the polychaetes.

Results of biochemical studies have found that differences in stable isotope fingerprints of particulate organic matter and fouling organisms at reference locations and at fish cages are large enough to be used as a tool for assessment of effectiveness of bio-filters. However, samples of POM and fouling organisms must be repeatedly analysed to enable such assessments.

Difficulties experienced in this WP04, were that despite initial plans to deploy the bio-filters by the end of March 2001, there were delays in transfer of the initial payment to the BIOFAQs partners and thus delays in purchase of the equipment and supplies needed to construct the bio-filters. As a result, bio-filters were deployed only in June 2001.

In addition, the initial sampling protocol involved photographs and video footage of every filter at the two sites. Due to dive restrictions at Oban the dive team were unable to follow the entire protocol as described by E. Spanier and S. Breitstein and a limited photographic documentation protocol was adopted, as described in Annex P1. In June 2001, the manager of the fish farm (study site) informed Oban that the site would be cleared and the entire mooring system replaced by February/ March 2002. This would require removal of the biofilter arrays from the fish farm site by December 2001 and consequently, it was decided that sampling would take place on a monthly basis instead of bi-monthly, as at the other sites. A further difficulty in the sampling, was the removal of the filters from the framework without the loss of biological material. The development of a bio-filter removal device by

T.Katz (CD-Rom P2/3 Bio-filter Removal Device.jpg), solved this problem and together with the use of mesh bags to transport bio-filters to the lab, the loss of material from the filters was minimised. The distribution of certain fouling organisms, particularly hydroids and caprelids was extremely patchy on the bio-filters. Therefore, the entire biofilter was examined (as opposed to sub-sampling the biofilter) for quantification of the fouling communities.

In Eilat, there have been logistical problems related to the operation of the research boat. On occasion this has caused delay in gaining access to the study sites and in carrying out scheduled work. The S4 current meter was non-functional during the first year of this study, however it will be revamped and deployed at the study site during the second year of this project. The major problem that confronts the team in Piran is the ongoing reconstruction of the Marine Biology Station. This has caused delays mainly in processing of samples and in analytical laboratory work. The IMBC team in Crete has experienced some difficulties related to the exposure of the control site. Rough weather conditions imposed a 20 days delay in the second sampling period. During the 2nd and 3rd sampling periods it was impossible to visit the site where the control arrays were deployed.
Progress with the stable isotope analyses in Lubljana was mainly delayed due to the slow rate at which the people at the study sites sent in these samples.

Milestones M05 A (Deployment of bio-filters) and M06 A (Protocol to assess Biofilter Performance) & B (Deployment of bio-filters on a field-relevant scale) have been completed.

A pan-European and global review of legal frameworks related to the use of artificial substrate as a bio-filter for the mitigation of the environmental effects of aquaculture is complete and the identification and collation of appropriate legal materials is almost finished (WP05). An evaluation of the transferability of legal models within the European context is underway and an analytical tool is being developed within the framework of comparative legal analysis based on 'functional' comparative law.

There has been some delay in the completion of work package 5 due to a lack of co-operation on the behalf of certain government agencies in supplying copies or interpretations of national legislation, which given the budgetary cuts made during contract negotiations the project team had limited potential to remedy. Local assistance has, however, been obtained through links established by the partners, such that the effective delay is minimal (3 months). This delay also encapsulates the value added contribution being made through collaboration with a Professor of Law in Slovenia. The work of the other partners and work packages was in no way hindered by the delay in obtaining primary legal documents.

Milestone M07 is to be completed by the end of Year 3.

Table 1: Workpackage and Component Descriptions

WORK PACKAGES		WORK PACKAGE AND COMPONENT DESCRIPTIONS
WP00	0.1	Project co-ordination (*In Progress*)
WP01	1.1	A primary and grey literature review of the current knowledge base relating to mariculture impacts on a pan-European scale (*Completed*)
	1.2	A review of existing bio-filtration methodology (*Completed*)
	1.3	A synthesis of current bio-filtration techniques and how they may be adapted for the European open-system mariculture industries (*Completed*)
WP02	2.1	To add biogeochemical modules to an existing fish farm impact model (DEPOMOD) to predict the performance of bio-filtration deployments (*In Progress*)
	2.2	Field and mesocosm validation of biogeochemical modules (*Not Yet Started*)
	2.3	To develop and validate models that can predict the economic and environmental benefits of bio-filter deployments in association with mariculture development (*Not Yet Started*)
WP03	3.1	Using mesocosm studies, to assess bio-filter design and performance over a range of temporal scales, a range of environmentally relevant physico-chemical parameter variations and under differing loading rates (*In Progress*)
	3.2	To determine energy and nutrient fluxes within WP3.1 in mesocosms with the objective of estimating the conditions under which bio-filters continue to function without the requirement for intervention (removal or cleaning) (*In Progress*)
	3.3	To assess the dynamics of bio-filter fallowing in mesocosms in order to determine recovery rates with or without direct intervention (*Not Yet Started*)
	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 (*Not Yet Started*).
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 (*Completed*).
	4.2	To undertake experimental bio-filter deployments in the field situation within standardised and replicated protocols in order to assess in field performance in detail (*In Progress*).
	4.3	To make field measurements of energy and nutrient fluxes both with and without bio-filter placements in order to quantify changes that may be occurring on deployment of bio-filters (*In Progress*).
	4.4	To undertake detailed pre- and post-deployment hydrographical profiles for model validation purposes (*In Progress*).
	4.5	To record and quantify the rates and biomasses of biological settlement and accumulation on the bio-filters. Special reference will be given to species with known commercial importance (*In Progress*).

	4.6	Where biological communities develop on or around the experimental bio-filter deployments there will be a requirement to quantify bioaccumulation both in terms of potential pollutant uptake and from promoting bio-filters as nutrient sinks. Some work will be carried out in order to identify potential biomarkers of filter quality. Bioaccummulation studies are of primary importance where harvesting of commercially important species is a possibility (see WP4.5). (*In Progress*).
	4.7	An investigation of the fallowing dynamics of the bio-filters will be undertaken once significant bio-filtration in the field has been established. This is of particular importance where pollutant accumulation is a possibility. (*Not Yet Started*).
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 bio-filters within these regulatory frameworks (*In Progress*).
	5.2	To evaluate the transferability of legal models within the European context (*In Progress*).
	5.3	To develop an analytical tool within the framework of comparative legal analysis (*In Progress*).
WP06	6.1	To prepare pan-European cost/benefit analyses of bio-filter deployment in association with mariculture development with specific reference to environmental value (*In Progress*).

Table 2: Workpackage List

WP no.	WP Title	Responsible participants[1]	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
		TOTAL	358.5			

[1] Workpackage leader listed first

Table 3: List of Milestones

MILESTONE NUMBER	TITLE AND DESCRIPTION	DELIVERY DATE[1]	PARTICIPANTS	WP NO.
M01	FULL LITERATURE REVIEW Publication of a full literature review identifying the practical, technological and legalistic possibilities for bio-filtration 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 bio-filter 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 bio-filter designs B. Full assessment of bio-filter performance trials in mesocosm experiments C. Deliverance of mesocosm-tested design criteria to initiate or improve field deployments of bio-filters	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 bio-filters 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	BIO-FILTER DEPLOYMENT A. Deployment of bio-filters 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	BIO-FILTER PERFORMANCE DATASET Deliverance of complete datasets relating to the biological, biogeochemical and hydrological performance of the field deployments. A. A set of field measurement protocols designed to standardise the approach to field assessment of nutrient-related impact assessment B. Deployment of initial bio-filter designs on a field-relevant scale C. Delivery of intermediate assessment of field performance D. Delivery of final assessment of field performance	 9 9 20 36	1, 2, 3, 4, 5, 7, 8	WP04.3 WP04.6 WP04.4 WP04.7 WP04.5 WP02.2
M07	SOCIO-ECONOMIC COST/BENEFIT ANALYSIS Empirical estimates of the economic costs/benefits associated with bio-filter 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.	 36	1, 2, 3, 4, 6	WP06.1

1 Milestone Completed ( )

Table 4: List of Deliverables

DELIVERABLE NO	DELIVERABLE TITLE	WP	DELIVERY DATE (MONTH)	PARTNERS	NATURE	DISSEMINATION LEVEL	DISSEMINATION TARGET
D01	Field deployment of some bio-filters in association with mariculture concerns (*Completed*)	04	9	1, 2, 3, 4, 5, 7, 8	O	RE*	PR, PM
D02	Report summarizing the findings of the review (*Completed*)	01	12	1, 2, 3, 4, 5, 7	pR	PU	AC, PR, PM
D03	Bibliographic database resulting from the review (*In Progress*)	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 (*In Progress*)	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 (*In Progress*)	05	12	1, 3, 4, 5, 6	O	RE*	AC, PR, PM
D06	Legal compendium and management guidance for bio-filter deployment (*In Progress*)	05	12	1, 3, 4, 5, 6	pR/O	PU	AC, PC, PM
D07	Mesocosm-derived design criteria for bio-filter modeling and field deployment/revision A. Mesocosms and initial bio-filter design criteria and standardised experimental protocols (*Completed*) B. Report on all bio-filter performance trials in mesocosm experiments in a format that will influence or modify field trials (*In Progress*)	03	 10 20	1, 2, 3, 5	O	RE*	AC, PR
D08	Collation of field data required for environmental model validation (*In Progress*)	04	24	1, 2, 3, 4, 5, 7, 8	O	RE*	AC, PR
D09	Mesocosm-derived determinations of sustainable bio-filter loading rate estimates A. Energy and nutrient flux assessment of design and performance (*In Progress*) B. Loading rate against performance data for accepted bio-filter designs (*Not Yet Started*)	03	 18 30	1, 2, 3, 5	O	RE*	AC, PR

D010	A. Biogeochemical bio-filter model V1 (*In Progress*) B. Biogeochemical bio-filter model V2 (*Not Yet Started*) C. Biogeochemical Bio-filter model V3 (*Not Yet Started*)	02	14 24 36	1, 2, 7	O	RE*	AC, PR, PM
D011	A collated detailed assessment of the field performance of bio-filters A. Established measurement criteria that will be used in the field (*Completed*) B. Field deployment of experimental bio-filters (*Completed*) C. Pre-deployment site assessments (*Completed*) D. Intermediate assessment of field performance (*Not Yet Started*) E. Post-deployment site assessment for feedback into deliverable D010C (*Not Yet Started*) F. Final assessment of field performance (*Not Yet Started*)	04	 9 9 9 20 30 36	1, 2, 3, 4, 5, 7, 8	pR/O	PU	AC, PR, PM
D012	An assessment of fallowing dynamics of bio-filters A. Mesocosm derived fallowing dynamics data (*Not Yet Started*) B. Field derived fallowing dynamics data (*Not Yet Started*)	03, 04	 30 36	1, 2, 3, 4, 5, 7, 8	pR/O	PU	AC, PR, PM
D013	Summary of cost/benefit analyses of bio-filter deployments (*Not Yet Started*)	06	36	1, 2, 3, 4, 6	pR	PU	AC, PR, PM
D014A	Final programme reports (*Not Yet Started*)	00	36	all	fR	PU	EC, AC, PR, PM
D014B	Annual Report 1 (*Completed*)	00	12	all	pR	RE	EC
D014C	Annual Report 2 (*Not Yet Started*)	00	24	all	pR	RE	EC
DO14D	Annual Report 3 (*Not Yet Started*)	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)

2.2.1.1 Discussion-Conclusion

In the first reporting period, a comprehensive literature review has been compiled that is the first to directly address the issue of mitigation by biofiltration for marine sites on a European scale. The review contains a synthesis of current bio-filtration techniques and will be of considerable benefit to the fish farming and scientific community.

The preliminary results from the fieldwork studies suggest that the design of filter deployed at the pan-European study sites is both robust and able to support a fouling community. It is still too early, however, to draw any conclusions from either the modelling, fieldwork or mesocosm studies.

The legal analysis is still in progress and the results from this workpackage will be discussed in the next Annual Report.

2.2.1.2 Future Action

The next project co-ordination meeting is planned to coincide with Ocean Sciences 2002, Hawaii (11 – 15 February) and the following meeting will either be hosted by IOLR (Eilat) or a central European city (TBA) in the summer.

D. Angel is organising a 10 day workshop in Eilat for BIOFAQs partners in 2002. MERAMED and MEDVEG partners have also been invited to attend. Funding is being sought through the EU Accompanying Measures scheme.

All partners will continue to work towards the completion of the workpackages outlined in the Technical Annex.

2.2.1.3 *Action Requested from the Commission*

None

2.3 DESCRIPTION OF WORK PACKAGES

Work package number:	WP00.1
Start date or starting event:	1
Completion date:	36
Current status:	**In Progress**
Partners responsible:	**1**, 2
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (project co-ordinator)	14.0 (5.0)
• Partner 2 (scientific co-ordinator)	6.0 (4.0)
• TOTAL	20.0 (**9.0**)

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 it's 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

Progress during the first reporting period

The project has hosted two co-ordination meeting in the first reporting period. The first PCMs was hosted by SAMS in Oban, Scotland on 12-14 January 2001 and the second was hosted by the IMBC in Crete on 26-29 June 2001. MERAMED partners attended both of these meetings. In addition, progress has been monitored throughout the year with monthly progress reports co-ordinated by SAMS and produced by E. Cook. The next PCM meeting will be held at the Ocean Sciences Conference in Hawaii (11 – 15 February 2002). A number of project partners are presenting papers at a special 'Aquaculture' session organized by Dror Angel (Partner 2).

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

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
Current Status:	**Completed**
Partners responsible:	**1**, 2, 4, 5
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (co-ordinator)	1.5 (1.5)
• Partner 2	2.0 (2.0)
• Partner 4	1.0 (1.0)
• Partner 5	2.0 (2.0)
• TOTAL	6.5 (**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

Progress during the first reporting period

A literature review and overview have been completed relating to the relevant pelagic impacts of marine cage aquaculture. The review includes; a detailed synthesis of literature relating to the enrichment of the natural environment, the impact of this enrichment in different environments and methods of minimizing this impact (Annex WP01). It is proposed that this review forms the basis of a scientific publication to be submitted to a review journal during 2002.

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 bio-filtration may be used to ameliorate.

Work package number:	WP01.2
Start date or starting event:	1
Completion date:	8
Current Status:	**Completed**
Partners responsible:	**1**, 2, 7
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (co-ordinator)	0.5 (0.5)
• Partner 2	2.0 (2.0)
• Partner 7	0.25 (0.25)
• TOTAL	2.75 (**2.75**)

Objectives
- To review existing bio-filtration methodologies.
- To evaluate the transferability of bio-filtration techniques to open-system mariculture.

Description of work
This work package will initially involve a desk-based review of the existing methodologies employed for bio-filtration (in closed, semi-close, or open systems), past works that have attempted bio-filtration 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.

Progress during the first reporting period

A literature review has been completed relating to bio-filtration processes used in waste management. This discusses the use of biological sewage treatment, wetlands, recirculating aquaculture systems, integrated land-base mariculture systems and integrated finfish aquaculture systems at sea (Annex WP01). A review of the legal/ regulatory status of substrate deployments throughout Europe will be completed by February (See Annex P6).

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 bio-filtration use in association with mariculture.

Work package number:	WP01.3
Start date or starting event:	1
Completion date:	8
Current Status:	**Completed**
Partners responsible:	**1**, 2, 3, 7
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (co-ordinator)	1.0 (1.0)
• Partner 2	2.0 (1.5)
• Partner 3	3.0 (3.0)
• Partner 7	0.25 (0.25)
• TOTAL	6.25 (**5.75**)

Objectives

- To provide a synthesis of the current bio-filtration 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.

Progress during the first reporting period

A synthesis of current bio-filtration techniques and how they may be adapted for the European open-system mariculture industries (Annex WP01).

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 bio-filtration 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
Current Status:	**In Progress**
Partners responsible:	**1**, 2, 7
Person months per partner (months already devoted are shown in brackets*):	
• Partner 1 (co-ordinator)	6.0 (1.5)
• Partner 2	2.0 (0.5)
• Partner 7	0.5 (0)
• TOTAL	8.5 (**2.0**)

* The time already devoted above is for the model development described in the following section. The following partners have committed some resources to collating information from farmers for modelling purposes: SAMS(1), IOLR (2), NIB (4), IMBC (5).

Objectives

To model bio-filter function at the biogeochemical process level.

Description of work

Using an existing impact model (DEPOMOD, see Annex WP02 for details) 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 bio-filter 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.

To undertake development of code of the existing model DEPOMOD, the following objectives were set for year 1.

1. To undertake some preliminary modelling of the bio-filter location at the UK Dunstaffnage fish farm site in the UK to determine predictions of solids flux at the filter arising from the fish farm. This requires development of DEPOMOD model code so that a bio-filter domain can be defined.

2. With particular reference to fine particulate material, assess the level of exposure of the filter to the fish farm effluent and test the bio-filter exposure for different depths.

3. To collate relevant data with a view to undertaking similar modelling exercises for all other BIOFAQS fish farm sites.

The DEPOMOD model is a fish farm model used in the UK industry and regulatory bodies for predicting dispersion of particulate matter (Cromey et al., 2000). The model, developed at Dunstaffnage Marine Laboratory and validated at numerous UK salmonid fish farm sites, is currently being developed and validated for the Mediterranean situation in the MERMED project. The model was designed to require input data readily available from the fish farmers so that the model could be widely used and tested without requiring extensive additional collection of data.

The use of DEPOMOD in this exercise was to assist in the assessment of the level of exposure of the bio-filter to particulate material arising from the farm. As the current model is designed to predict the amount of solids flux at the sea bed (g m^{-2} yr^{-1}), some modification of the code was required to enable inclusion of a bio-filter domain in the model grid. By including a bio-filter domain of specified position in the grid and dimensions, it was possible to predict the mass of particles which intersected the bio-filter for different scenarios. Calculations could then be made to determine the percentage of the total mass discharged from the farm intersecting the filter and the corresponding flux value (g m^{-2} filter h^{-1}). Given the variation in hydrodynamic conditions expected at the site, the predictions of bio-filter exposure will vary significantly on short time scales. Different scenarios can be used in the model to test optimum siting of the bio-filter in relation to its depth, size and efficiency in intersecting particular size particles. Additional information and principal equations for the DEPOMOD model are given in the annex. The development of the model to take a bio-filter domain and model set up for the DML BIOFAQS site is described.

Grid generation

The data in Table 1 (Annex WP02) were used in the DEPOMOD grid generation module for Dunstaffnage fish farm. The data source for each variable is also given. A grid was generated using DEPOMOD containing bathymetry data and cage positions. Figure 1 (Annex WP02) shows the grid generated for Dunstaffnage site orientated in a north–south direction. Cell resolution was kept sufficiently fine to retain detail close to the cages. Bathymetry data were Lowest Astronomical Tide (LAT) referenced and these were corrected with a mean tidal height to give mean depth. There is no capability to model changes in sea level elevation in DEPOMOD. Sensitivity analyses with DEPOMOD have shown that varying the tidal height with time has little effect on the predictions compared with when a mean tidal height is used in the model grid. The bio-filter was positioned in the model grid 10 metres from the edge of the cage group at the NE end of the group, similar to field deployment position (F in Fig. 1, Annex WP02).

Particle tracking

For modelling purposes, hydrodynamic data from current meter measurements were taken to represent the whole of the model grid area horizontally. In reality, current speed and direction is likely to vary in different areas around the farm. However, as a small deposition footprint is anticipated and the bio-filter is in close proximity to the farm, the measured current data are assumed to be typical for the area surrounding the cages. Few researchers have successfully modelled the effect of cages on flow regime, so this cannot be taken into account. The current meters were deployed at a distance of less than 100 m from the cages, in accordance with UK regulatory guidelines. Hourly averages were used in the model, calculated from the raw 10 minute data (Table 2; Annex WP02). The model was run for 27 days releasing particles every hour according to the amounts of waste discharged from the cages.

Faecal particles were assigned a settling velocity from a normal distribution with a mean of 3.2 cm s^{-1} and standard deviation of 1.1 cm s^{-1} (n = 43 particles). These measurements were made in the DEPOMOD project and agree with other researcher's data. This variable was further tested for fine particulate material. Waste food particles were assigned a settling velocity of 10.8 cm s^{-1} which is the mean of a data set collected in the DEPOMOD project. This data set consisted of sixteen data sets (range 6 – 17 cm s^{-1}) measured by numerous researchers post 1998, therefore giving measurement of settling velocity of feed regularly used in the last two years. Both food and faecal attributes are for salmonids and slower settling velocities are expected for smaller species at other BIOFAQS partner sites.

A total of $3.8*10^5$ particles were assigned in the particle tracking model and increasing this number any further did not change the flux predictions and only resulted in increased computational time. The particle tracking model assumes a continuous release of food and faecal material over a 24 hour period and particles start in a random position in the fish cage. The path of each particle is evaluated every 6 seconds in the model which is an optimum value for modelling of the bio-filter.

The random walk model (Allen, 1982) simulates horizontal and vertical dispersion of solids in addition to the advective transport by currents. The model moves each particle in a random direction with a step length determined from horizontal and vertical dispersion coefficients and the time the particle is in the turbulent field (see annex for details). Data on dispersion coefficients are generally lacking in UK coastal areas around fish farms, with the exception of surveys undertaken by DML with DGPS drifting buoys. As data is absent for the Dunstaffnage site, the data used in the model are general figures, commonly used in modelling studies of UK coastal areas and sea lochs. These values are also used by UK regulatory bodies in fish farm management models. A DGPS drifter survey at the Dunstaffnage site is planned for year 2 of the BIOFAQS project.

The bio-filter array was modelled as a single volume rather than specifying individual volumes taken up by each individual filter. Given that a pair of arrays has a length of 9 m, two pairs with a gap of 2 metres between each pair gives a total length of 20 m. The height and width of the array in the model is 1 metre. Representing the bio-filter to more accurate dimensions was considered unnecessary for the purposes of this study. A schematic diagram of how the bio-filter was represented is shown in Figure 2 (Annex WP02). Given that an area of 20 m^2 (20 m length * 1 m height) was perpendicular to the main axis of flow, this area was used in the model. Over the modelled period, as a particle intersected the filter its mass was stored in memory and then tagged so that its mass could not be counted again. Calculations of flux were then calculated assuming a surface area of 20 m^2 perpendicular to the flow.

Progress during the first reporting period

Progress in the first reporting year has been primarily taken up with modification of existing code as detailed in the Methodology section, setting up/testing of the model for the UK Dunstaffnage site and collation of data for other BIOFAQS partner fish farms.

Bio-filter domain verification - To test for the intersection of particles on the filter volume, the bio-filter was increased to the size of the whole grid to check that 100% of the released particles intersected this domain. As this was the case, the filter was placed in the model domain to its correct size (20m*1m*1m).

Figure 3 (Annex WP02) shows the distribution of particles intersecting the bio-filter at the Dunstaffnage site. The corresponding flux of particles using the data described and for different filter depths is shown in Figure 4 (Annex WP02).

Table 3 (Annex WP02) gives results on the percentage of solids released from the farm intersecting the filter at different depths. These results are based on settling velocities measured from salmonids which are generally quite fast. As expected, the exposure of the bio-filter increases with depth as particles being released from inside the cages quickly pass out of the surface waters. In addition to these model runs, finer particles with slower settling velocities were used in the model without any uneaten waste feed particles. Settling velocities were set to 1.5 cm/s for faecal material and the model run. This quantifies the percentage of fine waste particle released from the farm intersecting the bio-filter.

The modelling indicates the level of exposure of the bio-filter to particulate material arising from the farm. In the scenarios where a normal settling velocity distribution was used and uneaten feed modelled, the level of exposure was less than 0.2% of the total mass wasted from the farm. Testing the effect of using fine particulate material in the model only, did not significantly increase the level of exposure. Even when the filter was moved to different depths of the water column, exposure was less than 1% of total solids released. Where the actual depth of the filter was used in the model, less than 0.2% of solids released intersected the filter.

The modelling study implies that the exposure of the current size bio-filter to the particulate material being released from the Dunstaffnage farm is very small. Varying the depth of the bio-filter did not significantly improve exposure. These results indicate that exposure of the bio-filter and its function in removing wastes is likely to be far higher for dissolved than particulate wastes. The release position of waste particles from within the cage volume and subsequent exit position from the cages has not been verified by any researchers and this is continually debated. Qualitative evidence suggests that uneaten fish feed may roll down the cage sides and exit at the cone at the bottom of the net. Faecal material however, is thought to start in the cages at the surface where fish have defecated after eating. This material then exits the sides of the cages at a much shallower depth, thereby being discharged from near the surface. The model is sensitive to particle starting position and the is default setting is a random distribution within the cage. To test the effect on particle starting position on bio-filter exposure, particles were assigned a random starting position in the top 5 m of the cages. This does result in slightly higher exposure of the filter to fine particulate material as expected. However, these levels are still less than 1% of the total of fine material discharged.

The collation of data for other BIOFAQS partner fish farms has proved to take a reasonable amount of effort, due to the difficulty in obtaining such information from farmers and the sensitive nature of the data. Table 4 (Annex WP02) shows the progress to date for each site. Collation of bathymetry and

cage layouts, which is the most labour intensive task in model data preparation, has been completed for all sites. In year 2, it will be discussed with BIOFAQS partners whether similar predictions of bio-filter exposure would be useful for each site. It may be the case that effort in year 2 is put primarily into biogeochemical bio-filter box model development as data from each site starts to become available.

Preparation of model data for the Sitia site (IMBC) has been complementary to the modelling work undertaken for this site in the MERAMED project. As well as collation of general information for the site, hydrographic data and bathymetry data collected for this site has benefited the modelling work packages in both projects.

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.

D010:

D. Biogeochemical bio-filter model V1 - month 14
E. Biogeochemical bio-filter model V2 – month 24
F. Biogeochemical Bio-filter model V3 – month 36

None of these deliverables are to be met in this reporting period. It is expected that a box model will be developed in year 2, thus achieving Deliverables D010 A and B.

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 bio-filter deployment for a given environment.

M02:

A. Development of model modules of bio-filter 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).

These milestones have the same time scales as the deliverables i.e. in the second reporting year. Development of the existing model to achieve milestone have been described. In particular, a component of this milestone has required collation of data from other BIOFAQS partner sites for setting up of models. A substantial amount of data has been collated to date.

Work package number:	WP02.2
Start date or starting event:	13
Completion date:	36

Current Status:	**Not Yet Started**
Partners responsible:	**1**, 2, 7
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (co-ordinator)	4.0 (0)
• Partner 2	4.0 (0)
• Partner 7	1.0 (0)
• TOTAL	9.0 (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 bio-filter 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
Current Status:	**Not Yet Started**
Partners responsible:	**1**, 2, 7
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (co-ordinator)	4.0 (0)
• Partner 2	3.0 (0)
• Partner 7	0.5 (0)
• TOTAL	7.5 (0)

Objectives
- To deliver fully validated models that can predict the economic and environmental benefits of bio-filter 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 bio-filter 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 bio-filter 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
Current Status:	**In Progress**
Partners responsible:	**5**, 1, 2, 3
Person months per partner (months already devoted are shown in brackets):	
• Partner 5 (co-ordinator)	16.0 (10.0)
• Partner 1	7.0 (5.0)
• Partner 2	8.0 (0.5)
• Partner 3	5.0 (0)
• Partner 4 (unplanned)	0.0 (1.0*)
• TOTAL	36.0 (**15.5**)

*Not included in total as work was additional to original plan

Objectives

- Using mesocosm facilities, the workpackage will assess bio-filter 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 bio-filter 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 seabed 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 bio-filter 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.

During the meetings in Oban (January 2001) and Crete (June 2001) there was a change in emphasis on the use of bio-filters from benthic to pelagic. This was based on arguments related to the biology of the fouling organisms that are expected to colonise bio-filters as well as on practical issues related to the time needed for the expression of natural processes affected by bio-filtration. Consequently, there was a change in the design of the mesocosm studies in order to address properly the general issues described in WP03, i.e. to assess the performance of bio-filters as a means of improving environmental conditions around cage farms.

To this end it was agreed to use mesocosms:

(a) *in situ* mesocosms for the study of the changes in water quality induced by the fouling communities growing on bio-filters (Partner 5 & 4);

(b) land-based mesocosms to quantify the effects of the bio-filters on suspended particulate material and dissolved inorganic nutrients (Partner 1); and

(c) land-based mesocosm-tanks to quantify the effects of the fish feeding process on biological and chemical variables of the seawater (Partner 5).

By combining the information of the above points (a), (b) and (c), it is possible to estimate the number of bio-filters needed in order to obtain a pre-defined level of improvement of water quality conditions.

In Crete (Partner 5), it was decided to use *in situ* mesocosms, i.e. transparent, plastic bags that are big enough to contain one filter (a cylinder of 0.7 m height and 0.5m diameter) to ensure as realistic as possible estimates. A diver has put them in the water in such a way as to include one fouled bio-filter during a particular time of a day. A control bag (containing a clean, i.e. not-fouled filter) was placed in the water containing also the same type of water and in identical ambient conditions. Water samples were taken from each bag at regular time intervals. After that the bags and the filters were removed and processed in the same way as all other filters collected for BIOFAQs WP4.

This experimental design presents the following advantages:

(a) bio-filter performance is assessed *in situ*, i.e. under the natural conditions prevailing in the water column around a fish farm without any change in temperature, radiation, nutrients etc,

(b) the "natural plankton communities" are the very ones encountered in the vicinity of the farm and their interplay with the water column variables is included in the experimental design. The "standard plankton variables" such as Chla, bacteria and plankton cells are also monitored during the *in situ* experiments; plankton is likely to be consumed by suspension- or filter- feeders growing on the bio-filters,

(c) they allow avoiding the stress on the bio-filter community due to changes in ambient conditions during the transportation of the bio-filter from the deployment site to the tank.

The disadvantages are the standard disadvantages and problems of the fieldwork (weather conditions, power supply, divers, storage limitations etc) and the problem of access to the cages during the dark hours of the day. A last potential problem is that of oxygen in the bags, which we anticipate will not be significant for short time scales (24-48h) but it will certainly not allow using this method for a very long time.

In Slovenia, *in situ* mesocosm experiments were carried out in the Bay of Piran (CD-Rom P4, Map of Study Site.jpg). Each selected bio-filter was enclosed within a clear acrylic plastic (Perspex) octagonal box with a volume of about 110 litres (CD-Rom P4, Mesocosm Design.jpg). The same filters at the site close to the fish farm (SL) and at the control site (CL) were enclosed during subsequent field experiments to assess the oxygen demand of the fouling community over time (at different intervals from bio-filter immersion). A fine-scale profiler (University of Western Australia) was connected to the Perspex chamber with short inox connectors. The upper and lower parts of the Perspex chamber were sealed with polyethylene bags that served as a volume compensating bags since samples for nutrients and phytoplankton biomass were also taken during the 24 hours.
For dissolved oxygen measurements we left the profiler's pump to operate for 5 min before measurements were done, followed by a 20 second measurement period in which we got about 1000 data which were averaged. The procedure was repeated every hour during the 24 hours.
As a measure of changes in water quality we followed fluctuations of inorganic nutrients (nitrate, nitrite, phosphate, silicate), total nitrogen and phosphorus, particulate organic carbon and particulate nitrogen, phytoplankton abundance and HPLC pigments, bacterial and cyanobacterial biomass.

Samples were collected 5 times over 24 hours in September and at the start and end of the experiment in July, August and November.

In Scotland (Partner 1), it was decided to undertake the mesocosm studies in tank-based facilities at Dunstaffnage Marine Laboratory (CD-Rom P1, Mesocosm Trials.jpg). This decision was made due to the severe weather conditions that can be experienced on the west coast of Scotland in late Autumn and early Winter. Bio-filters from the fish farm (56°27.090N; 05°27.733W) and control sites (56°27.058 N; 05°27.344 W) were collected and held in 2 m diameter, circular tanks (1900 l) for 24 hours to allow for acclimatisation. Three filters from each site were then randomly selected from the holding tank and placed in 1 m diameter circular tanks that contained 140 l mesocosm bags (Diameter 55cm; Height 60 cm) (CD-Rom P4, Mesobag & Filter.jpg). The mesocosm bags containing the filters removed from the fish farm site were filled with seawater from 2 m diameter tanks containing Atlantic Cod (*Gadus morhua*) at a stocking density of 10.5 kg/ m^3. This stocking density was lower than the density used at the fish farm (approx. 25 kg/ m^3) due to the reduced volume of water in the tanks compared to open cage mariculture. The three mesocosm bags containing the filters removed from the control site were filled with sand-filtered seawater. For a control, three 'clean' bio-filters were placed in mesocosm bags containing seawater from the Atlantic Cod tanks and three 'clean' filters were placed in mesocosm bags containing sand-filtered seawater. Water samples were collected for Suspended Particulate Material (SPM) and dissolved inorganic nutrients (ammonia, phosphates, nitrates and nitrites) over a 48 hr period. See Annex P1 for detailed methodology.

In addition, land-based mesocosm-tanks of 8.5m^3 were used regularly in Crete to perform 24h experiments for different species (sea bream, sea bass), ages and seasons. The water input and the discharge is sampled at hourly intervals and the water samples are analysed for particulate organic carbon (POC) and nitrogen (PON), nutrients, total bacterial counts and urea. Temperature and O_2 concentrations were monitored during the entire sampling period.

By means of these experiments, we will be able to:

(a) determine the diel variability in N+P discharge which is very variable in cage farming, as was recently shown by Karakassis et al. (2000) (Partner 5);

(b) determine the N+P discharge from the bio-filters over a 48 hour period (Partner 1);

(c) make sure that the differences in concentrations are high enough to be measured by our methods (Partner 5 & 1);

(d) identify which variables are the most appropriate to be included in our sampling programme (Partner 5 & 1);

(e) determine the net uptake of suspended particulate material by the bio-filters (Partner 1); and

(f) obtain estimates for a (tentative) mass balance for N and P which will allow the optimisation of the use of bio-filters at the commercial scale (Partner 5).

Progress during the first reporting period

During the first year of the project *in situ* mesocosms were designed in Crete and Scotland and working protocols for the mesocosm experiments were agreed. Mesocosm experiments were carried out in Crete and Scotland between June and November 2001. The bio-filter performance, therefore, was assessed both over a range of temporal scales, fouling biomass and diversity.

- **Partner 5: Experiments in Crete**

(a) *in situ* mesocosms

Experiments were carried out in July and November 2001. During the first experiment (July) we faced several sampling problems. For that reason the results obtained were only indicative and are not presented here. A period of readjustment and improvement of the design of the sampling apparatus followed and the second experiment of November (the one of October was not performed due to inadequate sea conditions) took place successfully. The existing (biological) data are presented in Fig. 1 (Annex P5). A bio-filter close to the fish farm was enclosed in a mesocosm-bag and samples were taken at 13:00, 14:20, 15:15, 16:10 and 16:45 h.
A clear decline with time can be observed for picoplankton: heterotrophic bacteria and cyanobacteria *Synechococcus* whereas the signal was not obvious for particulate organic carbon (POC) and nitrogen (PON). On the other hand, nanoplankton and microphytoplankton presented a less explicit pattern: diatoms (DIAT), photosynthetic (PN) and heterotrophic (HN) nanoflagellates, they all showed an increase until 15:15 and then declined.
The consumption rate of plankton prey and particulate organic matter by the fouling organisms was calculated: for the cyanobacteria *Synechococcus* it was 270 ìg C/g dry weight of fouling organisms/h at the beginning of the process and it declines afterwards: 80, 60 and 70 ìg C/g dry weight of fouling organisms/h during the following hours. The decline was less abrupt for bacteria: 2.15 mg C/g dry weight of fouling organisms/h at the beginning and then 1.73, 1.24 and 1.32 mg C/g dry weight of fouling organisms/h.

(b) land-based mesocosms-tanks
Experiments were carried out in April, September and November 2001 in mesocosms-tanks of 8.5m^3 containing sea bass of 1, 31 and 53 g respectively. Samples were taken at the input and the discharge of the tank at hourly intervals over 24h and were later analysed for nutrient concentration as well as particulate organic carbon and nitrogen, Chla and total bacterial counts. Some analyses are already completed while others are in progress. From the existing data (Fig. 2, 3 and 4, Annex P5) it can be seen that despite the high water supply (exchange rate: 50%/h) NH4 concentration was significantly higher in the discharge water than in the input water in all three experiments, i.e. independent of season or fish size. The same was found to hold true for PO_4 for part of the day (April, November) or for the entire day (September). NO_3 and SiO_2 ions did not show any differences during April. Particulate organic carbon (POC) and nitrogen (PON) were higher in the discharge water in all seasons. Chla concentration was higher in the discharge water during the entire day in September and bacteria presented higher counts in the output water only during a part of the day in April.

- **Partner 1: Experiments in Scotland**

Mesocosm experiments were performed on a monthly basis from July to October 2001. Poor weather conditions prevented the retrieval of bio-filters from the field site in November 2001. The experiments were designed to measure suspended particulate material uptake and the release of dissolved inorganic nutrients by the bio-filters.

Suspended Particulate Material (SPM): Water samples were collected at 0 Hr and 48 Hrs from the mesocosms. A small net uptake of SPM was measured for the bio-filters collected from the fish farm from August to October and from the control sites in August and October. There was a net release of SPM from the control site filters during the experiment in September. The net uptake of SPM for filters obtained from both sites decreased between August and September which corresponds with a significant increase in the biomass of the fouling organisms (Table1, Annex P1).

Nutrient Analysis: The results from the nutrient analysis showed a significant increase in ammonia and phosphate concentrations in the mesocosms containing the bio-filters collected from the fish farm and control sites during the 48 hour mesocosm trials from July to October 2001 (Tables 2 & 3 respectively, Annex P1). There were no significant increases in the nitrate and nitrite concentrations

in the mesocosms trials in any of the treatments. In addition, a significant increase in the release of ammonia and phosphate from the fish farm and control bio-filters was observed between August and September 2001. High concentrations of ammonia and phosphate were also found in July 2001 in mesocosms containing bio-filters collected from the fish farm. The results are slightly higher in the mesocosm trials conducted in Oban compared to those in Slovenia during September 2001. An increase in ammonia and phosphate concentrations of 17.90 µM and 1.25 µM for the control site bio-filter and 26.16 µM and 2.25 µM for the fish farm bio-filter respectively over the first 24 hours of the mesocosm trial (See Annex P4: Results).

Temperature and Oxygen: The temperature in the mesocosms ranged from 14.5 ^{o}C (± 0.43) in August 2001 to 13.49 ^{o}C (± 0.25) in October 2001. The oxygen (%) remained relatively constant throughout the mesocosm experiments at 86.6 % (± 6.5).

- **Partner 4: Experiments in Slovenia**

Field measurements were collected in September and November at both locations and in July and August only at fish farm site. Only analyses for oxygen consumption, nutrients and chlorophyll are already completed while others are in progress. Higher respiration rates were recorded during both experiments at control location (CL) than at location close to fish cages (SL) (Fig. 2 – September experiment, Annex P4). A clear decline with time was also observed for chlorophyll biomass. The results from the nutrient analysis showed a significant increase in the ammonium concentration during 24 hours incubation: 10.65 and 13.25 µM at control site and 5.76 and 17.21 µM at fish cage site in September and November, respectively. An increase was also observed for phosphate concentrations: 0.08 and 0.15 µM at control site and 0.12 and 0.10 µM at fish cage site in September and November as well as total phosphorus and total nitrogen.

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.

Preliminary results are already obtained whereas some of the analyses are in progress. Data has been produced on particulate uptake and release that can be utilized in the modeling component of the project. The experiments will be repeated during the second year of the project as foreseen in the technical annex of the project.

The mesocosm experiments at the sites selected by Partners 2 and 3 will be carried out during the second year of the project with the involvement of scientists from the other participating labs. Experiments to meet the second deliverable on loading rates will be started in Year 2.

Milestones and expected results

This work package will contribute to the delivery of Milestone 3. This is to deliver fully-tested bio-filter design criteria to work package 4 (WP04). These criteria will either drive proposed bio-filter 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 bio-filter field deployments or modify existing deployments (either in design or placement location), and supporting publications (academic papers and technical reports).

MO3:

A. The establishment of mesocosms and the development and testing of initial bio-filter designs. Completed.
B. Full assessment of bio-filter performance trials in mesocosm experiments – This assessment is in progress and a substantial amount of data has been collected to date.
C. Deliverance of mesocosm-tested design criteria to initiate or improve field deployments of bio-filters – Bio-filter design has been modified for the Year 2 field trials in Oban on the basis of the results obtained in the mesocosm trials at SAMS (Partner 1) during Year 1.

Work package number:	WP03.2
Start date or starting event:	4
Completion date:	30
Current Status:	**Not Yet Started**
Partners responsible:	**5**, 1, 2, 3
Person months per partner (months already devoted are shown in brackets):	
• Partner 5 (co-ordinator)	8.0 (0)
• Partner 1	2.0 (0)
• Partner 2	5.0 (0)
• Partner 3	5.0 (0)
• TOTAL	20.0 (0)

Objectives

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

Description of work

A range of bio-filter 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, bio-filter design and physico-chemical fluctuation (temperature and salinity changes) on bio-filter 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 bio-filter design criteria to work package 4 (WP04). These criteria will either drive proposed bio-filter 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 bio-filter 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
Current Status:	**Not Yet Started**
Partners responsible:	**5**, 1
Person months per partner (months already devoted are shown in brackets):	
• Partner 5 (co-ordinator)	6.0 (0)
• Partner 1	2.0 (0)
• TOTAL	8.0 (0)

Objectives

- To assess employing mesocosms the dynamics of bio-filter fallowing 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 bio-filter 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 bio-filters. Bio-filters that have been fouled in previous mesocosm experiments will be left to assess the dynamics of recovery. Mesocosms fouled in the absence of bio-filters will be allowed to recover with the addition of clean bio-filter deployment. As part of the recovery assessment, the degree of stability of the accumulated matter on the bio-filters 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 bio-filters and the impacted sediments both with and without intervention. This is of importance in quantifying the level of contribution that bio-filters 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
Current Status:	**Not Yet Started**
Partners responsible:	**5**, 1, 2, 3
Person months per partner (months already devoted are shown in brackets):	
• Partner 5 (co-ordinator)	2.0 (0)
• Partner 1	4.0 (0)
• Partner 2	5.0 (0)
• Partner 3	2.0 (0)
• TOTAL	13.0 (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 bio-filters, it is possible that the location, number of bio-filters 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 bio-filter 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 bio-filter 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
Current Status:	**Completed**
Partners responsible:	**2**, 1, 3, 4, 5, 7, 8
Person months per partner (months already devoted are shown in brackets):	
• Partner 2 (co-ordinator)	4.0 (4.0)
• Partner 1	2.0 (2.0)
• Partner 3	3.0 (3.0)
• Partner 4	1.0 (1.0)
• Partner 5	2.0 (2.0)
• Partner 7	0.5 (0.5)
• Partner 8	1.0 (1.0)
• TOTAL	13.5 (**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 bio-filters 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 bio-filters 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

Progress during the first reporting period

The design of the experimental bio-filters was addressed at the kickoff meeting held in Oban immediately after the official starting date of the project. Although the BIOFAQs project was inspired by benthic bio-filters deployed on the seafloor near a fish farm in Eilat, Israel (CD-Rom P2/3, Benthic biofilter.jpg), we decided to focus initially on the use of bio-filters suspended in the water column around the fish cages as these will: a) have greater access to the dissolved and suspended particulate matter released from the fish farm and b) be easier to remove from the sea for in situ respirometry measurements, biomass determinations and mesocosm experiments. Despite the numerous differences in local hydrodynamics, weather conditions, water quality, etc. at the 4 field sites, we decided to employ a **common bio-filter design** (Fig.2, Annex WP04) that would enable subsequent inter-comparisons of bio-filter performance across the pan-European scale included in this project.
Methodologies employed in this workpackage included: construction and deployment/mooring of the bio-filter arrays, bio-filter photography (both underwater and in the lab), bio-filter removal (sampling) and replacement, processing and analysis of the bio-filters and bio-filter-associated organisms in the laboratory, sediment trap deployment and sample analysis, collection of sediment from the seafloor, collection and initial processing of samples for subsequent stable isotope analysis (See WP04 for detailed methodologies).

Deliverables

- The establishment of the measurement criteria that will be employed in the field (Annex WP04)

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 bio-filters 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
Current Status:	**In Progress**
Partners responsible:	**2**, 1, 3, 4, 5
Person months per partner (months already devoted are shown in brackets):	
• Partner 2 (co-ordinator)	4.0 (2.0)
• Partner 1	2.0 (1.5)
• Partner 3	5.0 (2.0)
• Partner 4	2.0 (2.0)
• Partner 5	10.0 (3.0)
• TOTAL	23.0 (**10.5**)

Objectives

- To undertake experimental bio-filter deployments in the field situation.

Description of work

Bio-filters will be constructed and deployed based on information gained from pilot study deployments and mesocosm experiments. The design and construction of bio-filters will be undertaken with emphasis on low cost of materials/construction/deployment, and on removeability of the structures to enable fallowing of the site, as necessary. Each programme partner who will be deploying bio-filters 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.

Progress during the first reporting period

Bio-filter design, construction and deployment.

At all of the study sites, the basic bio-filter units were identical in **material** (black NETLON Str7011, 25 mm square mesh), **shape** (cylinder) and **dimensions** (500mm height; 250mm diameter) (Figs 1 & 2, Annex WP04). Although it would have been possible to locally purchase similar mesh material in each of the partner countries, we preferred to postpone the deployments of the bio-filters at sea by a few months in order to ensure that the basic bio-filter units would not be simply similar, but rather **identical** at all of the study sites. The bio-filters were supported on sturdy plastic frames (arrays), which were designed to remain at a constant depth (CD-Rom P2/3, Complete Array.jpg and Array Post-Deploy.jpg) by means of anchor moorings and sets of buoys to facilitate removal and replacement of bio-filter units. Due to particular constraints at each of the sites (e.g. bottom depth, current velocities, local navigation requirements, etc.), the design of the bio-filter arrays, the moorings and the buoys at the 4 sites was very similar, but not uniform, yet this was not expected to influence performance of the individual bio-filter units. The sets of 4 bio-filter arrays (4 next to the fish cages and 4 at the control site) were oriented perpendicular to the predominant current direction in order to maximize contact with the bio-filter surfaces and bio-filtration activity. In addition to structural uniformity of the bio-filters, we also succeeded in deploying the bio-filter systems at sea during the same 2 weeks between the middle and end of June 2001. The temporal synchrony is helpful for comparison of the development rates of bio-fouling communities at the individual sites.

Preliminary Results

Biofilter Design

Overall, it appears that the experimental bio-filter and array design was successful for the variety of environments that it was deployed in. The bio-filter arrays have been in the sea for more than 6 months so far and there have been no reports of bio-filter failure or collapse.

Difficulties experienced

Despite initial plans to deploy the bio-filters by the end of March 2001, there were delays in transfer of the initial payment to the BIOFAQs partners and thus delays in purchase of the equipment and supplies needed to construct the bio-filters. As a result, bio-filters were deployed only in June 2001.

Deliverables

- The field deployment of bio-filters in association with mariculture concerns

Milestones and expected results

The successful deployment of bio-filters in association with mariculture on which to base the field deployment research will satisfy the requiments of Milestone 5.

Work package number:	WP04.3
Start date or starting event:	6
Completion date:	36
Current Status:	**In Progress**
Partners responsible:	**2**, 3, 4, 5, 7, 8
Person months per partner (months already devoted are shown in brackets):	
• Partner 2 (co-ordinator)	8.0 (1.0)
• Partner 3	5.0 (1.0)
• Partner 4	20.0 (12.1)
• Partner 5	12.0 (4.0)
• Partner 7	4.0 (1.5)
• Partner 8	13.0 (2.5)
• TOTAL	62.0 (**22.1**)

Objectives

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

Description of work

The efficiency of the bio-filters 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 bio-filter efficiency will be the measurement of temporal change in the benthic communities, in and around the

bio-filter 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.

Progress during the first reporting period

Bio-filter photography and sampling of bio-filters

One of the objectives in this workpackage was the detailed description of the temporal dynamics of the biota associated with the bio-filters. Whereas most of the organisms associated with the bio-filters were attached (benthic), there were also loosely-attached and free-swimming fish and invertebrates in this community. The only way in which we could document the more elusive organisms was by careful underwater photography. A detailed photography protocol was compiled by Steve Breitstein and Ehud Spanier (Annex WP04). This protocol is suitable for sites with good underwater visibility, such as Crete and Eilat, but is less suitable for use in Oban and Piran where visibility is generally poor. Where necessary, the underwater photography protocol was revised to match local conditions and logistical considerations (see Annex P1). In order to minimize conflicts and interference between the underwater photographers and the bio-filter samplers, photography was completed prior to bio-filter sampling, where possible.

Bio-filters were sampled either once a month (Oban) or every other month (Crete, Piran, Eilat) and sampling was generally carried out over several days. During the sampling week one randomly pre-selected bio-filter unit was removed from each of the 8 bio-filter arrays. In order to minimize mechanical disruption of the bio-filters during the removal process (and loss of attached organisms) a special **Bio-filter Removing Tool** (CD-Rom P2/3, Bio-filter Removing Tool.jpg; for further details, see Annex P2/3) was designed and constructed by T. Katz (Eilat). Following its detachment, each bio-filter was carefully enclosed in a "transport device" (CD-Rom P2/3, Bio-filter Transport Device.jpg) to minimize mechanical disruption and loss of attached particles during transport of the bio-filter units to the lab. In Piran and Eilat, a special barrel that also protected the bio-filter against mechanical disrution was employed, while in Oban and Crete, a fine-mesh net or plastic bag was used. New bio-filters were then secured in the spaces left by the removed ones such that the general hydrodynamic environment within the bio-filter arrays would be unaltered (CD-Rom P2/3, Removal & Replacement). The sampled bio-filters were transfered to the boat and thereafter transported to the laboratory as rapidly as possible for processing. In the event that mesocosm work was planned prior to bio-filter processing at the laboratory, this was carried out, either at sea or in mesocosm tanks/aquaria.

Bio-filter processing

Freshly-retrieved bio-filters were carefully removed from the transport device, bio-filter units were untied and the mesh spread out. Ten randomly pre-selected subsamples (5x5 squares) were cut from the net and all subsamples were photographed on both sides after being labelled, using a digital camera (see, for example, CD-Rom P2/3, Net subsample.jpg). Six of the subsamples were used for taxon-specific analysis of the attached community (dry biomass and organic matter determined for each group) and the remaining 4 subsamples were used to assess total dry weight, biomass accumulation and organic composition (proximate analysis). From the parts of the net remaining after removal of the 10 sub-samples we collected the most abundant attached macro-invertebrates, such as solitary tunicates and sea-anemones, for taxonomic identification and for stable isotope analysis (see below). In Oban, the entire bio-filter was examined for taxonomic identification and community analysis, due to extremely patchy distribution of the attached organisms.

Nutrient uptake by bio-filters, as assessed by stable isotope analysis

Stable carbon and nitrogen isotopic composition may be used: (1) to trace the dispersal of organic matter around fish farms, and (2) to assess the effectiveness of the experimental bio-filters in trapping fish farm effluents and nutrients. By comparing $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios in organisms to the ratios in fish feed, we expect to be able to quantitatively assess the bio-filters' utilization and removal of fish farm effluents from the system.

Prior to bio-filter deployment, samples of surface sediment and suspended organic matter were taken in the close vicinity of the fish cages, where we anticipate to find the highest levels of organic matter originating from the fish farm. Similar samples were taken at nearby reference locations with comparable hydrographical and geochemical characteristics, that are not influenced by the farms. Samples of fish food used in the farms were also analysed. Fish from the cages and wild fish of same or similar species (e.g. spariids around the Eilat and Crete farms) will be captured outside the cages for isotope analysis. Following bio-filter deployments, animal and plant samples will be removed from the bio-filters, as described above; dried and taken for stable isotope analysis. Collection of these samples is planned on a seasonal basis.

Preliminary Data

Biofilter Biomass Dynamics

In Oban, the total biomass of fouling organisms on the bio-filters increased significantly at both the fish farm and control sites over the first four months of the experimental period, reaching 357 (+/- 22) g m^{-2} and 248 (+/- 66) g m^{-2}, respectively. In comparison to the control site, there was significantly greater biomass at the fish farm site within 3 months of immersion. In Eilat, there was a significant increase in bio-filter biomass between the first and second sampling dates and significantly greater biomass, after 4 months immersion at the fish farm (154 +/- 31 g m^{-2}) than at the control site (51 +/- 13 g m^{-2}). In Piran, the total biomass on the bio-filters at both fish farm and control sites increased significantly during the 5 months following bio-filter deployment. Unlike the situation in Eilat and Oban, the biomass of fouling organisms in Piran was consistently higher at the control site (495 g m^{-2} after 5 months) than next to the fish farm (190 g m^{-2} after 5 months). In Crete, there was evidence of an increase in bio-filter biomass at the sheltered fish farm site (262 +/- 106 g m^{-2} after 5 months), but due to rough seas it was not possible to sample bio-filters at the control site. The reader is referred to the individual reports in Annexes P1 - 5 for further details regarding biomass accumulation.

In all of the deployments, there was an accumulation of biomass on the bio-filters as the structures have become colonized by benthic organisms and in most cases, this increase in biomass has been consistent and positively correlated with time. In 2 of the field sites (Oban and Eilat), we found greater biomass at the fish farm than at the respective control sites, while the opposite trend was observed in Piran. It is not clear why we find this conflict in biomass accumulation, but it may be related to grazing of the bio-filter communities. It is therefore very likely that the biomass accumulation that we have measured once per month or once every other month is really an underestimation of the true biomass, since we have not considered those community members that grew yet were grazed and removed from the bio-filters. Whereas we do not have any quantitative evidence of grazing, we do have some anecdotal observations: starfish (feed on bivalves) were found on bio-filters in Oban (CD-Rom P1, Juvenille *Asterias*.jpg), sea urchins (graze attached algae) were found on bio-filters in Eilat, fish (feed on bivalves and other invertebrates) were associated with bio-filters in Eilat (CD-Rom P2/3, Wild Fish.jpg) and Oban (CD-Rom P1, Lumpsucker.jpg), etc. If the grazing activity is very intense and unequal at different sites (e.g. different intensities of grazing at the control vs the fish cages), it may lead to very different conclusions regarding the function of the bio-filters at different sites.

Conclusion: It is necessary to consider various approaches to observe grazing and to quantify loss of biomass (attached organisms) due to grazers. Whereas it is difficult to quantify grazing in the field, it may be possible to develop a better understanding regarding the growth dynamics of the biofilter community by increasing the frequency of biofilter observations and sampling.

Taxonomic Composition of the Biofilter Communities

In Oban, a total of 36 species in 9 different phyla were identified on the bio-filters over the first 4 months of immersion. The main taxa recorded on the bio-filters included; the hydroid *Obelia longissima*, the tunicate *Ascidiella sp*., the crustacean, *Caprella linearis* and the bivalve, *Aequipecten opercularis*. There was no significant difference in the biomass or abundance of taxa on the bio-filters between the fish farm and the control sites, with the exception of the bivalves, *A. opercularis* and *Mytilus edulis* at the end of four months. These bivalves exhibited a higher abundance at the fish farm site compared to the control.

The initial coloniser of the bio-filters at both sites was the hydroid *O. longissima*. A large number of nudibranchs *Eubranchus farrani* was observed on the bio-filters at the fish farm site in the first month. After two months of immersion, the diversity of taxa on the bio-filters increased and included hydroids and tunicates at both sites. Juvenile bivalves, *M. edulis* and *A. opercularis* and the crustacean *Aora gracilis* were particularly abundant at the fish farm site. The tube-dwelling polychaetes (Terebellidae) and the errant polychaetes (Nereidae) were significantly more abundant at the control site compared to the fish farm site. After three months of immersion, a dramatic increase in the abundance of tunicates (*Ascidiella sp*.), bivalves (*A. opercularis* and *M. edulis*), crustaceans (amphipods and *C. linearis*) and a colonial bryozoan (*Membranipora membranacea*) was observed on the bio-filters at both experimental sites. Shoals of juvenile herring, *Clupea harengus* were observed within 2 – 5 m of the bio-filters at the fish farm site and juvenile lumpsuckers, *Cyclopterus lumpus* (CD-Rom P1, Lumpsucker.jpg) were attached to bio-filters at both sites. At the last sampling, four months after immersion, the abundance of tunicates *Ascidiella sp*. and bivalves *M. edulis* and *A. opercularis* had increased significantly, whereas the biomass of the hydroids, *O. longissima* and caprelids, *C. linearis* decreased slightly compared to the previous month. A high proportion of the bivalves (>75 %) were found to be dead on two bio-filters sampled from the fish farm site. This was attributed to the presence of 2 –3 seastars *Asterias rubens* on these filters (CD-Rom P1, Asterias.jpg). In addition, small specimens of an unidentified red alga were found on the bio-filters at each site.

In Eilat, the bio-filters became covered with unidentified filamentous, mucous-secreting macroalgae within the first month following immersion. In general, the same taxonomic groups occurred at both the farm and the control sites, but in different proportions. In addition to the filamentous macroalgae, bryozoans (*Bugula sp*. and others) and hydroids (*Thyroscopus fruticosus* and *Serfularidae sp*.), as well as flat, white colonial tunicates (*Didemnum candidum*). The other groups had little biomass: sea anemones, solitary red tunicate [*Styela truncata* (Ritter)], worms, decapods, small gastropods, bivalves, purple bryozoa, serpulids, brittle stars and red shrimp. Some of the organisms are still in a process of identification. Fish (mainly rabbit fish *Siganus sp* and cardinal fish *Apogon spp*) were observed around and in the bio-filters at both sites (CD-Rom P2/3, Fish Shoal.jpg).

Four months after immersion, visual observations of the bio-filters suggested that there higher abundances of fouling organisms on the bio-filters around the fish cages. At the farm site the major groups were solitary tunicates, sea anemones- mostly *Rhodactis rhodostoma* and the alga *Jania sp*., while at the control site, the community was dominated by hydroids- mostly *T. fruticosus* and solitary tunicates. Taxa that were common at both sites included: white colonial tunicates- *D. candidum*, red bryozoa and orange sponges. The other taxa present in low abundances included: worms, decapods, gastropods, bivalves, serpulids, sea urchins, brittle stars and red shrimps. In addition, small stony coral colonies were identified on bio-filters at both sites. Identification and calculation of species specific biomass is in progress. Many more fish (in comparison to the August sampling); mainly *Siganus sp.* and *Apogon sp*. were recorded in and around the bio-filters at both sites.

There was concern that subsampling of the bio-filters might yield "noisy" data (i.e. high variance due to patchy distribution), however the results were analyzed and indicated that the subsamples provide good representation of the biofilter community.

In Piran the initial colonisation (after about one month immersion) of bio-filters was dominated by autotrophs at both sites; the main taxa recorded were: *Ceramium sp*., *Antithamnium sp.*, *Polysiphonia sp.*, *Champsia sp.*, *Enteromorpha sp.*, *Cladophora sp*.) and numerous diatoms embedded in mucilage. At both sites, only a few invertebrates were observed; among these the bryozoan, *Schizobranchiella sanguinea* and hydroid, *Obelia sp*. were most abundant. Vagile fauna associated with bio-filters included amphipoda, decapoda and opistobranch molluscs. During subsequent surveys we observed that algal fouling was reduced. At the last sampling, about 5 months after immersion, the dominant fouling organism was the bryozoan, *S. sanguinea* followed by the ascidian, *Microcosmos sp*., serpulid polychaetes, the molluscs, *Mytilus galloprovincialis* and *Ostrea sp.* and hydroids.

In Crete the macroscopic community community associated with bio-filters adjacent to the fish farm (4 months after deployment) included (in descending order of abundance): serpulid polychaetes, chlorophyta, hydroids, Sabellidae, amphipoda, sponges, *Bothryllus sp*., rhodophyta, bivalves, gastropods, and nereid polychaetes. The rough seas precluded comparison among the bio-filters taken from the fish farm site and the control site.

In Crete, Piran and Eilat, biofilter surfaces (at both fish farm and control sites) were initially colonized by benthic algae, probably as a result of ample light penetration to 8m depth. In Oban, it is possible that the water was too turbid to accommodate extensive algal growth, though there were observations of red macroalgae at a later stage. The pioneer invertebrate taxon colonizing bio-filters at all sites was the hydroidae, followed by the bryozoa and the polychaetes. There was a temporal increase in diversity at all of the sites, yet one of the drawbacks of infrequent sampling (every other month) is that small-scale temporal dynamics in community composition may be overlooked or altogether missed, and as discussed above, the effect of grazing on the biofilter communities is unknown. The biofilter communities will be monitored during the second year of the project and we will compare between the taxonomic data at the 4 study sites and within each study site (fish cages vs control site).
Additional information regarding the taxonomic composition of the biotic communities associated with the bio-filters may be found in the individual reports found in Annexes P1 - 5.

Stable Isotope Data
Sediment samples from Oban showed a significant difference in $\delta^{13}C$ value between the impacted area under the cage (mean = –22.1‰) and the reference site (mean = -21.6‰), indicating that the organic carbon at the 2 sites had different origins. On the other side, the difference in $\delta^{15}N$ was almost insignificant (+6.9‰ under the cage vs +6.6‰ at the reference site, standard deviation = $\pm$0.2‰). In comparison, sediment samples from Crete showed much bigger differences ($\delta^{13}C$= -18.8, $\delta^{15}N$ = +5.4‰ under cage vs -20.4 ‰ and +2.4% at reference site), suggesting a large impact of the particulate organic matter falling from the cages. The sediment samples from Eilat exhibited similar differences as Crete. Sediment samples were not taken in Piran.

Particulate organic matter (POM) collected by sediment traps from under fish cages (at all of the sites) was generally enriched in ^{15}N and ^{13}C as compared to POM from the reference sites. The exception to this pattern was observed in the POM samples collected in Oban; corresponding to the results of $\delta^{15}N$ of the enriched sediments. It is possible that this difference is related somehow to the fact that the Scottish farm is the only site out of the 4 in this study that rears salmon. ^{15}N enriched N under the fish cages is attributed to the source of POM, i.e. detrital material deriving from such sources as decomposing fish food and faecal pellets. Because the differences were not always significant and the patterns were not always consistent, there is a need to obtain more samples in order to establish a clearer trend in these data.

Isotopic analysis of fish liver samples taken from caged fish in Piran showed a significant difference among individuals; 4 individuals were analysed, with $\delta^{13}C$ values ranging from −24.4 to −21.6‰ (analysed in 3 replicates) and $\delta^{15}N$ from +10.5 to 11.1‰. Isotopic analysis of fouling organisms from Eilat revealed small, but systematic differences among biota under cages versus reference locations. In all cases, although relatively large differences among individuals were observed, organisms on substrates under cages were enriched in ^{15}N compared to the organisms from the reference site by approx. 0.3‰.

From the first year of observation, we conclude that differences in stable isotope fingerprints of particulate organic matter and fouling organisms at reference locations and at fish cages are large enough to be used as a tool for assessment of effectiveness of bio-filters. However, samples of POM and fouling organisms must be repeatedly analysed to enable such assessments. The reader is referred to the full report of partner 8 (Annexes WP04 & P8) for further details regarding stable isotope analyses of the samples taken thus far in this study.

Difficulties Experienced

The initial protocol involved photographs and video footage of every filter at the two sites. Due to dive restrictions at Oban the dive team were unable to follow the entire protocol as described by E. Spanier and S. Breitstein and a limited photographic documentation protocol was adopted, as described in Annex P1. In June 2001, the manager of the fish farm (study site) informed Oban that the site would be cleared and the entire mooring system replaced by February/ March 2002. This would require removal of the biofilter arrays from the fish farm site by December 2001 and consequently, it was decided that sampling would take place on a monthly basis instead of bi-monthly, as at the other sites.
A further difficulty in the sampling, was the removal of the filters from the framework without the loss of biological material. The development of a bio-filter removal device by T.Katz (CD-Rom P2/3 Bio-filter Removal Device.jpg), solved this problem and together with the use of mesh bags to transport bio-filters to the lab, the loss of material from the filters was minimised. The distribution of certain fouling organisms, particularly hydroids and caprelids was extremely patchy on the bio-filters. Therefore, the entire biofilter was examined (as opposed to sub-sampling the biofilter) for quantification of the fouling communities.
In Eilat, there have been logistical problems related to the operation of the research boat. On occasion this has caused delay in gaining access to the study sites and in carrying out scheduled work. The S4 current meter was non-functional during the first year of this study, however it will be revamped and deployed at the study site during the second year of this project.
The major problem that confronts the team in Piran is the ongoing reconstruction of the Marine Biology Station. This has caused delays mainly in processing of samples and in analytical laboratory work.
The IMBC team in Crete has experienced some difficulties related to the exposure of the control site. Rough weather conditions imposed a 20 days delay in the second sampling period. During the 2nd and 3rd sampling periods it was impossible to visit the site where the control arrays were deployed.
Progress with the stable isotope analyses in Lubljana was mainly delayed due to the slow rate at which the people at the study sites sent in these samples.

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 bio-filters 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
Current Status:	**In Progress**
Partners responsible:	**2**, 1, 3, 4, 5
Person months per partner (months already devoted are shown in brackets):	
• Partner 2 (co-ordinator)	3.0 (0)
• Partner 1	2.0 (0)
• Partner 3	3.0 (0)
• Partner 4	19.0 (3.0)
• Partner 5	4.0 (0.5)
• TOTAL	31.0 (**3.5**)

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

Progress during the first reporting period

Work has been started in Year 1 to address the issue of how the bio-filters will influence the hydrography around the field sites. Measurements of current speed and direction have been made by Partners 4 & 5 (see Annexes P4 & 5 respectively) and the results have been sent to Partner 1 for inclusion in the modeling component of the project. The majority of work for this workpackage is planned for Year 2.

Deliverables

- A detailed assessment of the hydrographical profiles of the deployment areas before and after the bio-filter 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 bio-filters 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
Current Status:	**In Progress**
Partners responsible:	**2**, 1, 3, 4, 5, 7, 8
Person months per partner (months already devoted are shown in brackets):	
• Partner 2 (co-ordinator)	8.0 (4.0)
• Partner 1	2.0 (0.5)
• Partner 3	12.0 (4.0)
• Partner 4	6.0 (1.8)
• Partner 5	2.0 (0.5)
• Partner 7	1.0 (0)
• Partner 8	6.0 (0)
• TOTAL	37.0 (**10.8**)

Objectives

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

Description of work

An indicator of bio-filter 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.

Progress during the first reporting period

See workpackage WP04.3 above.

Deliverables

- A detailed assessment of the field performance of bio-filters 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 bio-filters 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
Current Status:	**In Progress**
Partners responsible:	**2**, 1, 3, 4, 8
Person months per partner (months already devoted are shown in brackets):	
• Partner 2 (co-ordinator)	5.0 (1.0)
• Partner 1	2.0 (0)
• Partner 3	5.0 (0)
• Partner 4	1.0 (0)
• Partner 8	2.0 (0)
• TOTAL	15.0 (**1.0**)

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 bio-filter deployments there will be a requirement to quantify bioaccumulation both in terms of potential pollutant uptake and from promoting bio-filters as nutrient sinks. Some work will be carried out in order to identify potential biomarkers of filter quality. Bioaccummulation studies are of primary importance where harvesting of commercially important species is a possibility (see WP4.5).

Progress during the first reporting period

Partner 2 has begun proximate analysis of material collected from the bio-filters from the fish farm and control sites (Table 2, Annex P2/3). Preliminary results suggest that the chemical composition of material on the bio-filters was very similar at the 2 sites, with the exception of phosphorus which was significantly higher at the fish farm, suggesting the bio-filters may serve as a means to trap phosphorus released from the fish cages. It is not yet clear whether the differences in accumulated phosphorus are due to differences in the composition of communities at the 2 sites or to enhanced phosphorus retention in similar organisms near the farm. The high ash content in the bio-filter biomass is due to a high proportion of organisms with calcium-carbonate skeletons. The material was not analysed for the accumulation of pollutants, particularly chemotherapeutants, since treatment against sealice etc. is not used in Eilat.

It is planned that Partners 1,3,4,8 will start this Workpackage in Year 2.

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 bio-filters 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
Current Status:	**Not Yet Started**
Partners responsible:	**1**, 4
Person months per partner (months already devoted are shown in brackets):	
• Partner 1 (co-ordinator)	2.0 (0)
• Partner 4	1.0 (0)
• TOTAL	3.0

Objectives

- To investigate the fallowing dynamics of field-deployed bio-filters.

Description of work

The fouling and bioaccumulation actions of the deployed bio-filters may produce significant reservoirs of biological fouling, nutrient accumulation and pollutant concentration. When the filters are colonized to a level that no longer supports bio-filtration at an optimal level, or if the farming activity ceases, there will be periods of fallowing for the bio-filter units. These studies will examine:

[a] the potential for resuspension if the bio-filters are removed;

[b] the potential for recovery if the bio-filters are left *in situ*;

[c] the dynamics of pollutant accumulation (*ie* do the bio-filters 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 bio-filters *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
Current Status:	**80% Complete**
Partners responsible:	**6**, 1, 3, 4, 5
Person months per partner (months already devoted are shown in brackets):	
• Partner 6 (co-ordinator)	5.0 (5.0)
• Partner 1	1.0 (1.0)
• Partner 3	2.0 (2.0)
• Partner 4	4.0 (4.0)
• Partner 5	2.0 (0.2)
• TOTAL	14.0 (**10.2**)

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 bio-filter 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.

Progress during the first reporting period

The desk-based review of the literature is complete, with the identification and collation of appropriate legal materials almost there. There is still material to come in from Slovenia, Greece and Israel, but it is scheduled to permit a delivery date for this work package and the deliverables of month 15. A range of sources and areas of law have been addressed, with the review focusing in on that pertinent to the questions being raised. The partners have been instrumental in the translation of materials for use in the analytical process, although this process is still ongoing. The services of a multi-lingual lawyer have also been selectively used in Israel. The initial focus of the work package was on the case study countries and the deployment of experimental units, but with the co-operation of national agencies outside the case study countries has developed (as intended) on a pan-European basis.

Contact has been made 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. However, co-operation has been limited, and largely focused on the authorization of the experimental units. Cooperation on non-experimental aspects of the legal regime in Greece, Israel and Slovenia has necessitated the use of local intermediaries (through the partners) to secure material. Collaboration with a previous EU funded concerted action on the regulatory aspects of aquaculture and other groups with specialisms in the field have also been undertaken and proven useful.

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.

Most of these deliverables will be ready for month 15 of the project (to incorporate the final material in-coming and the contribution of a Slovenian legal collaborator, due in February or March) with the academic papers following a month thereafter.

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 bio-filtration units in the case study countries (Milestone 5).

Progress on this milestone is well underway, with an expected delivery date of month 15.

Work package number:	WP05.2
Start date or starting event:	1
Completion date:	12
Current Status:	**80% Complete**
Partners responsible:	**6**, 5
Person months per partner (months already devoted are shown in brackets):	
• Partner 6 (co-ordinator)	5.0 (5.0)
• Partner 5	1.0 (1.0)
• TOTAL	6.0 (**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 bio-filters 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.

Progress during the first reporting period
The material collected during this workpackage and the previous one have been compiled electronically in accordance with a analytical framework founded in comparative law, such to provide the basis for these recommendations. This work is well underway, but will ultimately be completed once all pertinent information has been obtained and analysed in conjunction with the previous work package. This work package will be completed by month 15.

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.

Most of these deliverables will be ready for month 15 of the project (to incorporate the final material in-coming and the contribution of a Slovenian legal collaborator, due in February or March) with academic papers following a month thereafter.

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 bio-filters in both the case study/partner countries and elsewhere in Europe (Milestone 1).

Progress on this milestone is well underway, with an expected delivery date of month 15.

Work package number:	WP05.3
Start date or starting event:	1
Completion date:	6
Current Status:	**80% Complete**
Partners responsible:	**6**
Person months per partner (months already devoted are shown in brackets):	
• Partner 6 (co-ordinator)	2.0 (2.0)
• TOTAL	2.0 (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.

Progress during the first reporting period
This workpackage involved a desk-based review of the literature, targeting the elicitation of appropriate frameworks of analysis, notably comparative legal analysis, which has greatest applicability in terms of the objectives of this project. This review has been compiled into a draft paper outlining the framework of analysis ultimately adopted and its theoretical foundations: 'functional' comparative law. The review is awaiting the finalisation of the previous two sub-work packages to establish whether refinements to the review are required on the basis of practical implementation (a dimension rarely taken into consideration within the literature on this subject). The review has formed the basis of a framework of analysis for the documentation, interpretation and comparison of the

material incoming through the activities of the previous two work packages. This work package and the review will be completed, along with the other legal work packages, in month 15.

Deliverables

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

Completion of the review is anticipated for month 15, with the academic papers following within a month thereafter.

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 bio-filters in both the case study/partner countries and elsewhere in Europe (Milestone 1).

The research component of this milestone has been completed, subject only to refinement upon the completion of the milestones of the previous two work packages.

Work package number:	WP06.1
Start date or starting event:	25
Completion date:	36
Current Status:	**Due to start in Year 3 (although literature review underway)**
Partners responsible:	**6**, 1, 2, 3, 4
Person months per partner (months already devoted are shown in brackets):	
• Partner 6 (co-ordinator) (0 charged for)	12.0 (1.0)
• Partner 1	1.0 (0)
• Partner 2	1.0 (0.5)
• Partner 3	1.0 (0)
• Partner 4	1.0 (0)
• TOTAL	16.0 (**1.5**)

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 bio-filter 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).

Progress during the first reporting period

Due to the timetable for this work package being focused on year three of the project, only a literature review has been undertaken so far. This review has targeted the need to ensure that the scientific component of the project will satisfy the data requirements of the subsequent economic analysis and to familiarise the economists on the team with the scientific and operational aspects of the bio-filters.

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

Due in year 3 of the project.

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 bio-filters.

Not expected until the end of year 3.

3. ROLE OF PARTICIPANTS (CHANGES UNDERLINED)

Participant number:	01

Name and address of participating organisation:
Scottish Association for Marine Science
Dunstaffnage Marine Laboratory
Dunbeg
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
Dr Elizabeth Cook - Post Doctoral Research Assistant. Marine biology, diver
Mrs Allison Black - Project Manager

Contractual Links to other Participants:
None

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 (indicates those already delivered):
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).

Research activities during the first reporting period:

WP01: Literature Review. A review of bio-filtration was conducted by Partner 1 and review material was collated from all the Partners involved in this workpackage. Consequently, a synthesis has been produced of all the existing primary and grey literature relating to the current knowledge base of mariculture impacts on a pan-European scale. In addition, a review of existing bio-filtration methodologies and techniques has been produced and this has discussed how these methods and techniques may be adapted for European open-system mariculture industries (Annex WP01).

WP02 : Modelling. The main objectives of the research undertaken in the first reporting period were to: modify existing model code so that predictions could be made of the exposure of the bio-filter to discharged particulate effluents from the farm; vary the depth of the filter and settling velocity of discharged solids to assess exposure; collate information on all other BIOFAQS partner sites.

The DEPOMOD model which is used for prediction of dispersion of particulate wastes from fish farms, was modified so that a bio-filter domain could be defined in the model grid. Code development and modelling scenarios were undertaken for the UK partner fish farm, Dunstaffnage. The bio-filter dimensions and depth below the surface were specified and the model was run for a period of 27 days using 3 current meter records to describe hydrodynamic flows around the farm. As particles intersected the bio-filter over the modelling period, the mass of each particle was stored in memory so that daily and average flux calculations (g solids m^{-2} filter h^{-1}) could be undertaken. In addition, the exposure of the bio-filter to wasted solids was expressed as a percentage of the total of solids released from the farm during the modelling period. The functionality of the bio-filter domain in the model grid was verified by setting the bio-filter volume to be equal to the whole model grid. In this test, 100% of all solids released from the farm were found to intersect the bio-filter, as expected. Scenarios using different settling velocity data spectra, bio-filter depth and particle cage starting positions were modelled.

The level of exposure of bio-filter to wasted solids in all scenarios was less than 1% of the total of solids discharged from the farm. Due to the characteristics of coarse particles with fast settling velocities being released from the farm, exposure of the bio-filter increased with depth. Using slower settling velocities for finer particles resulted in some increase in exposure, but was still less than 1% of total solids discharged. Semi-quantitative evidence exists for faecal material being discharged at the surface as fish defecate after eating, so a scenario was undertaken to test exposure when particles are released randomly from the cages in the top 5 m. This effectively doubled the exposure of wasted solids to the bio-filter, but was less than 0.5%. This modelling study implies that a very much larger bio-filter would be required to result in significant exposure to particulate material released from the farm. This evidence also implies that as exposure of the bio-filter to particulate material is so small, the function of the bio-filter may well be primarily aimed at removing dissolved contaminants. The vertic al dispersion of dissolved contaminants in the plume will be much lower than particulate contaminants, due to the particulates having negative buoyancy. Higher concentrations and therefore a higher percentage of released dissolved contaminants are likely to reach the bio-filter.

Much progress was made with collating information from each partner. The information listed in Table 4 (Annex WP02) may be used in either similar simulations as described above or in running the box model to be developed in year 2. However, accurate feed input information is required for this to be undertaken and further information will be requested for each site.

WP03: Mesocosm Studies

a) The experimental design for the mesocosm experiments was discussed during the first project workshop in Oban and finalized during the second meeting in Crete.

b) The mesocosm experiment was designed and the apparatus was constructed to suit the aquarium-based experimental design in Scotland.

c) The aquarium-based mesocosm experiments were conducted each month from July to October, no experiments could take place in November 2001 due to poor weather preventing the collection of bio-filters.

d) The mesocosm experiments included:

- The measurement of suspended particulate material (SPM) at 0 Hr and 48 Hrs.
- The measurement of dissolved inorganic nutrients (ammonia, phosphate, nitrate and nitrite) at 0, 6, 12, 24 and 48 hrs.

e) Analysis of the water samples was undertaken using a Lachat instruments autoanalyser.

WP04: Field Studies. The study area in located in the nearshore coastal waters (less than 1.5 km from shore) on the west coast of Scotland (CD-Rom P1, Study Site.jpg). There is one fish farm in this area owned by Hydro Seafoods GSP.

a) The design of the bio-filters was led by Paul Provost (Partner 1) and the final design was the result of several meetings and e-mail discussions among Paul Provost, Timor Katz, Steve Breitstein and Janez Forte. A trial array and prototype filter was constructed at SAMS and digital photographs of these structures was circulated to the relevant partners. In addition, P. Provost organized and organized the shipment of the bio-filter mesh which was produced by NETLON in the U.K to the Partners.

a) 8 arrays of 11 bio-filters each were constructed at SAMS, according to the design produced by P. Provost (Annex WP04).

b) The bio-filter arrays were deployed on the 18 June 2001 according to the common schedule adopted within the project.

c) The bio-filters were sampled monthly from July to October 2001. No sampling occurred in November 2001 due to poor weather condition. The sampling involved:

b) Underwater Video Census and Photography: This was conducted as stated in the Protocol devised by Partner 3 (Annex WP04). Slight modification were made to this protocol however due to constraints imposed by budget and dive time.

c) Bio-filter Removal & Replacement: This procedure was completed each month according to the protocol provided by Partner 2 (Annex WP04)

d) The bio-filters were sampled according to the protocol described by Partner 2 (Annex WP04).

e) Samples of biological material were collected, freeze dried and sent to Partner 8 for stable isotope analysis.

f) Particulate matter from the control and fish farm site was sampled using a sediment trap in June and November 2001. The material was processed according to the protocol provided by Partner 8 (Annex WP04) and the samples were sent to Partner 8.

g) Water temperature was monitored every 5 minutes from 18 June onwards using temperature loggers attached to the arrays. Data loggers were collected and downloaded every two months.

h) Water samples were collected using 1 litre NiO bottles from the fish farm and control site on the 30 August and 25 October 2001.

WP05: Legal Analysis

- Copies of permits/ official documents from the Scottish Executive, the Crown Estate and the Scottish Environment Protection Agency (SEPA) that a fish farmer has to obtain concerning the layour, design, size, discharges etc. of the study site were sent to Partner 7. In addition, plans and maps of the study site were sent to Partner 7.

Significant difficulties or delays experienced during the first reporting period:

WP02: It was intended to undertake some modelling predictions of flux to bio-filters for all BIOFAQS partner sites. Although most of the model development in year 1 was undertaken with data from the Dunstaffnage fish farm, it was intended to undertake similar predictions with the developed model for other sites. However, the effort involved by all partners in collating data for the site was reasonably high. This resulted in delays which has prevented modelling of all sites. However, now that most of the data has been collated, this will allow model development undertaken in year 2 of the bio-filter model to be tested with individual site data if required. It may be the case that modelling effort in year 2 is put primarily into biogeochemical bio-filter box model development as field data from each site starts to become available.

Sub-contracted work during the first reporting period:

No work was sub-contracted during the first reporting period.

Participant number:	02

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:
Dror Angel - Team Leader
Timor Katz – Technician *(a new position resulting from this award)*
Noa Eden - Technician
Ingrid Lupatsch*
Elena Raskin*
Sergei Turshin*

* minor involvement

Contractual Links to other Participants:
None

Objectives:
To optimise bio-filter designs and placement protocols in order to achieve maximal bio-filtration efficiency, by a combination of mesocosm experimentation and field deployment of bio-filters

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).

Research activities during the first reporting period:

WP01 - The primary and grey literature on the impacts of mariculture on the Gulf of Aqaba and on the eastern Mediterranean Sea has been reviewed and summarized (Annex P2) and this has been sent to partner 1. Commercial net cage mariculture is practically non-existent in the mostly unprotected waters of the eastern Mediterranean, off the shores of Israel and is currently limited to 2 fish farms in the northern tip of the Gulf of Aqaba. The Gulf of Aqaba farms, which are the subject of a large, ongoing debate regarding their environmental impact on the Gulf, serve as the focus of our research in this project. In addition to the summary of local fish farm impacts, we have compiled a review of existing bio-filtration methodology as it is employed in a wide variety of applications (Annex P2). On the basis of the literature review we are in the process of formulating a synthesis of current bio-filtration techniques and how they may be adapted to open-system mariculture practices.

WP02 - The data required for the modelling component: sketch of farm layout including cage numbers, dimensions, spacing between cages, bathymetry of the fish farm area in the northern part of the Gulf of Aqaba (the "North Beach"), position of the bio-filter arrays, hydrodynamic data (current velocity and direction), wind speed and direction, feed composition, feeding rates and frequencies, feed conversion ratio, farm biomass and species reared, have been collected, organized and sent to partner 1.

WP04: Field Studies - Our study area is situated in the nearshore coastal waters (less than 1 km from shore) at the northern end of the Gulf of Aqaba, Red Sea (Fig. 2, Annex P2/3). There are two fish farms in this area: Ardag and Dagsuf (alias Suf Fish) and we are currently focusing our study on the Ardag farm site (A) (see Fig 3, Annex P2/3). See Annex P2/3 for detailed methodology for this work package. It is important to state here that the entire process of designing, constructing and deploying the bio-filters and the supporting arrays at the study site in Eilat was undertaken as a collaborative project between partners 2 and 3.

a) Bio-filter Design: The detailed design of the bio-filters, the bio-filter arrays, lashings, flotation and mooring were the product of several meetings and e-mail discussions among Paul Provost, Timor Katz, Steve Breitstein and Janez Forte.

b) Construction: 88 bio-filters employed in the eight arrays used in Israel were built jointly at the RIMS Maritime Workshop by members of the IOLR staff (Timor and Noa), the RIMS staff (Steve and Amir) and several graduate students from the University of Haifa.

c) The bio-filter arrays were deployed in June 2001 according to the common schedule adopted within the project.

d) Bio-filter Monitoring: Timor Katz and Noa Eden carried out weekly dives at the bio-filter sites to assure that these systems were intact and secure.

e) The bio-filters were sampled in August and October 2001. The sampling involved:

- Underwater Video Census and Photography : This was conducted as stated in the Protocol devised by Partner 3 (Annex WP04).
- Bio-filter Removal & Replacement: This procedure was completed each month according to the protocol provided by Partner 2 (Annex WP04)

i) The bio-filters were sampled according to the protocol described by Partner 2 (Annex WP04).

j) Samples of biological material were collected, dried and sent to Partner 8 for stable isotope analysis.

k) Current speed and direction and water temperature was measured on each sampling dive.

l) Preliminary water samples were collected on the 18 October by Timor Katz and Anat Tsemel.

WP06 - An analysis of the economic advantage of bio-filter deployment in conjunction with the Eilat fish farms has been initiated. The first step in this process is compilation of all available data regarding the cost to the farms in actions related to the public perception of the fish farms as having negative impacts on the marine environment in general and on the natural treasures of the Gulf of Aqaba (e.g. coral reefs) in particular. The second step (not yet begun) is to assess the financial benefit associated with bio-filter deployments.

Significant difficulties or delays experienced during the first reporting period:
Despite initial plans to deploy the bio-filters by the end of March 2001, there were delays in transfer of the initial payment to the BIOFAQs partners and thus delays in purchase of the equipment and supplies needed to construct the bio-filters. As a result, bio-filters were deployed only in June 2001. (This delay has had ramifications in terms of the field-sampling program of all groups except ours, due to adverse weather and sea-conditions at all but the Eilat site). We have experienced logistical problems related to the operation of our research boat and on occasion this has caused some delay in gaining access to our study sites and in carrying out our scheduled work. There were initially some difficulties (mainly communication problems) related to coordination of the design of the bio-filters among the partners, but these were eventually sorted out and Liz Cook has established a frequently updated contact list to ensure efficient communication among all of the BIOFAQs participants. Suspended solids sampling for stable isotope analyses at the control site, using sediment traps, has been arduous, mainly due to the fact that the suspended solids levels are naturally low in the Gulf of Aqaba. Several 48 h deployments were required to obtain the minimal amount of material required for this work. The initial protocols established for sampling bio-filters, transporting to the lab and processing these for biomass and taxonomic analyses proved to be inappropriate. As a result, the data gathered during the first sampling was not very informative. After some brainstorming, the protocols were revised and these were employed during the second and third samplings which were much more successful.

Sub-contracted work during the first reporting period:
None

Participant number:	03

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
Anat Tsemel– graduate research assistant

Contractual Links to other Participants:
None

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).

Research activities during the first reporting period:

WP01: Literature Survey. Ehud Spanier and Anat Glazer made a renew literature survey on biofouling and filtering organisms (Annex P3).

WP04: Field Studies (Detailed methodologies are shown in Annex P2/3)

a) Bio-filter design: Steve Breitstein was among others including Paul Provost, Janez Forte and Timor Katz who produced the detailed design of the bio-filters, the bio-filter arrays, lashings, flotation and moorings after several meetings and e-mail discussions.

b) Construction: Steve Breitstein, Amir Yurman and several graduate students from the University of Haifa were involved in constructing 88 bio-filters employed in the eight arrays used in Israel jointly with member of the IOLR staff (Timor Katz and Noa Eden) at the RIMS Maritime Workshop.

c) The bio-filter arrays were deployed in June 2001 according to the common schedule adopted within the project.

d) The bio-filters were sampled in August and October 2001. The sampling involved:
   - Underwater Video Census and Photography : This was carried out by Steve Breitstein and Amir Yurman as stated in the Protocol devised by Ehud Spanier and Steve Breitstein (Annex WP04). The underwater videotaping/still photography protocol was prepared before first sampling and was revised in September based on the experience of the first bio-filter sampling (beginning of August 2001).
   - Bio-filter Removal & Replacement: This procedure was undertaken by Noa Eden, Timor Katz and Anat Tsemel and was completed each month according to the protocol provided by Partner 2 (Annex WP04)

e) The bio-filters were sampled according to the protocol described by Partner 2 by N. Eden, T. Katz and A. Tsemel (Annex WP04).

f) Samples of biological material were collected, dried and sent to Partner 8 for stable isotope analysis.

g) Current speed and direction and water temperature was measured on each sampling dive.

h) Timor Katz and Anat Tsemel carried out preliminary water sampling on the 18 October. (With some difficulties with a defect 2.5 litre Go-Flo sampling bottle). NO_2 was below the detection limit (0.1 ìM) for the method used and Ammonia was low at both sites: 0.408 ìM in the control site and 0.43 ìM near the bio-filters in the vicinity of the fish cages.

WP05: Legal issues

Ehud located up-to-date ENGLISH versions of legal provisions governing Israel:
1.Israel Planning and Building Law, 1965.
2. Israel Licensing of Business Law, 1968.
3. All Israel Lands Laws.

Ehud arranged a professional legal translation and helped in translating the requirements of the Israel Ministry of Environmental Quality regarding fish cage Mariculture (+ annexure).

Significant difficulties or delays experienced during the first reporting period:

Bio-filters sampling: On the first sampling, 6th to 9th of August, some of the biota was falling off the bio-filter mostly into the protecting bags, (Annex P2/3) although the divers were very careful. However the diver removing the tie-wraps had to stand on the lower bar and pull up on the upper bar to release the vertical post. This causes a shaking to the bio-filter that shakes off some material from the bio-filter. In order to solve this problem Timor developed a tool, which uses some sort of

cam or leverage device to remove the vertical post from the T joint without needing to stand on the bar and pull, may solve this problem.
Also regarding the analysis of the biota of the sampled bio-filters we tried to improve the quantification and identification methods with sampling. In the October sampling we separated the underwater video and photographic operation from sampling and the visual recording preceded the bio-filter sampling in a few days. Also in the October sampling we sample only 2 bio-filters per day (instead of four units), which leave more time for identification and quantification of the biota.

Water sampling: On the preliminary water sampling Timor and Anat were having difficulties working with defect 2.5 Go-Flo sampling bottles, which ended up in insufficient replicates and probably polluted samples, therefore, the results shown are not quite credible.

Sub-contracted work during the first reporting period:
None

Participant number:	04

Name and address of participating organisation:
National Institute of Biology
Marine Biological Station Piran
Fornaèe 41
6330 Piran
Slovenia

Scientific Team:
Scientific team
Alenka Malej, team leader
Branko Èermelj, geochemistry*
Vlado Malaèiè, physical oceanography
Nives Kovaè, biogeochemistry
Patricija Mozetiè, plankton ecology*
Valentina Turk, microbial ecology*
Borut Vrišer, zoology
Aleksander Vukoviè, algology
Technical staff
Janez Forte, fieldwork leader
Tihomir Makovec
Mira Avèin
Silva Maslo*
* minor involvement

Contractual Links to other Participants:
None

Objectives:
To undertake field deployments of bio-filters in association with an existing mariculture site in Slovenian coastal waters, carry out field mesurements 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).

Research activities during the first reporting period:

WP01: Literature Review. The relevant primary and grey literature on the impacts of mariculture on environment in the Adriatic has been gathered (Annex 1), reviewed and sent to partner 1.

WP02: Modelling. The data required for the modelling component (farm layout sketch including cage numbers, dimensions, shapes and spacing between cages, bathymetry of the fish farm area and Bay of Piran, bio-filter position, hydrodynamic data including current and wind speed and direction, feed characteristics and feed input, farm biomass and species reared, FRC) have been collected and submitted to partner 1.

WP03: Mesocosm Studies. An experiment was conducted to assess the enrichment (eutrophication) potential of water collected within the fish cage by carrying out an enclosure experiment from 30 July to 3 August 2001. Analysed parameters included: inorganic nutrients (nitrate, nitrite, phosphate, silicate), total nitrogen and phosphorus, particulate organic carbon and particulate nitrogen, primary production, phytoplankton abundance and HPLC pigments, bacterial abundance, bacterial and cyanobacterial biomass. Laboratory analyses are in progress.

WP04: Fieldwork. ***Study area and mariculture site***. Our study was conducted in the Gulf of Trieste (Bay of Piran) in the northern Adriatic Sea, which is shown in Fig. 1 (CD-Rom P4, Map of Study Site.jpg). There are two fish farms in the Bay of Piran: our study was done at farm Lera d.o.o. Detailed methodologies and results can be found in Annex P4.

a) Bio-filter design: In the Piran laboratory the design of bio-filter arrays and the plan of moorings was discussed and prepared in February/March by J. Forte and T. Makovec following conclusions reached during the meeting in Oban in January. The system was also discussed with S. Breitstein, T. Kimor, P. Provost, to whom a sketch of the proposed design was sent by e-mail.

b) Construction: The system of bio-filters, supporting frames and moorings were constructed in May/June 2001.

c) Pre-deployment surveys included analysis of water column characteristics (Table 1; Annex P4) and measurements and evaluation of currents in the area of the fish farm.

d) Deployment: The bio-filter arrays were deployed from the MBS research boat Sagita from 22 to 27 June.

e) Field surveys after bio-filter deployment were carried out 3 times: on July 30 – August 3; September 26-28; and November 20-22, 2001. A list of parameters and number of samples collected in the water column and sediment trap is presented in Table 1 (Annex P4). In addition, during all three post-deployment field surveys we carried out the following activities:

- under-water video census and photography of bio-filters,
- 24-hour respiration and water quality measurements of selected (enclosed) bio-filters at both sites: fish cage (SL) and control site (CL),
- 24-hour measurements of currents,
- bio-filter removal and replacement.

f) Sample Processing: Sampled bio-filters were further processed in the laboratory using methodology described in Annex P4.

Significant difficulties or delays experienced during the first reporting period:
Major reconstruction of the MBS building started in January 2001and construction work at times seriously hindered our work, especially our abilities to complete laboratory analyses. It is expected that the end of 2002 will complete the construction of new laboratories.

Sub-contracted work during the first reporting period:
None

Participant number:	05

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

Mr Manolis Tsapakis

Dr Paraskevi Pitta

Dr Panos Drakopoulos

Ms Ioanna Akoumianaki

Ms Maria Naletaki

Mr Santi Diliberto

Contractual Links to other Participants:
None

Objectives:
To conduct mesocosm experiments to determine energy and nutrient fluxes and to assess bio-filter design, performance and dynamics. To undertake measurements relating to the performance of field deployments of bio-filters 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).

Research activities during the first reporting period:
WP01.1: The IMBC team provided a review paper summarizing the existing knowledge on the

environmental impacts of aquaculture in the Mediterranean in respect of water column and the seabed (Annex P5). A file containing recent bibliographic references on this subject from different parts of the world was compiled at 6 months from the beginning of the project and sent to Partner 1.

WP03: In the framework of this workpackage, the IMBC team

a) provided the experimental design for the mesocosm experiments, discussed during the first project workshop in Oban and finalized during the second meeting in Crete,

b) designed and constructed the apparatus for the *in situ* mesocosm experiments in Crete,

c) carried out *in situ* mesocosm experiments during July and November 2001,

d) carried out diel high frequency sampling experiments on fluxes of nutrients, particulate organic carbon (POC) and nitrogen (PON) and bacteria using land-based mesocosms containing sea bass of different sizes and during different seasons (April, September and November 2001),

e) carried out biological and chemicalanalyses of the samples collected.

WP04: In the framework of this workpackage, the IMBC team

d) constructed 8 arrays of 11 bio-filters each, according to the instructions of the WP coordinator using standard material with small modifications to ensure better performance in the extreme hydrodynamic conditions of the selected site in Crete,

e) deployed the bio-filter arrays in the end of June according to the common schedule adopted within the project,

f) sampled the bio-filters during July, October and November 2001, and processed the samples according to the guidelines provided by the colleagues responsible for the respective tasks

g) Four of the ten pieces (5 x 5 squares each) were processed according to the protocol produced by Partner 2 (Annex WP04) and samples for chemical and isotope analysis were collected. Particulate matter from the control and fish farm site was sampled using the filtration method every time when the bio-filters recovered. All the samples collected were sent to the task responsible.

h) Data were collected for farm production as well as for water and wind currents from the selected site. The meteorological parameters (mean and gust wind speed and direction) were recorded every 10 minutes from 2nd of July 2001 until now. The water current and direction were recorded at two depths (5m under the surface of the sea and 5m above the bottom) from 2nd of July to 4th of August and from 24th of November until now). The time interval between the measurements was 10 min. The data were sent to the task responsible.

WP05: In the framework of this workpackage, the IMBC team

a) provided information on legal aspects of aquaculture based on existing bibliographic sources,

b) assisted the workpackage co-ordinator in obtaining Greek legal documents, providing also translated material where needed.

Significant difficulties or delays experienced during the first reporting period:
The IMBC team has experienced some difficulties all related to the exposure of the selected site. Rough weather conditions imposed a ca 20 days delay in the second sampling period. During the 2nd

and 3rd sampling period it was impossible to visit the site where the control arrays were deployed.

Sub-contracted work during the first reporting period:
No sub-contracted work with the exception of professional divers used during the last field expedition.

Participant number:	06

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
Hannah White (Legal Researcher)

Contractual Links to other Participants:
None

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 bio-filter 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).
Note that the first three of these deliverables will now be delivered in month 15, reflecting the value added contribution of a local post-graduate researcher and Professor of Law in Slovenia under the auspices of a Slovenian government award. The majority of the content of these deliverables is ready, awaiting the finalisation of the Slovenian component and the subsequent comparison of the material retrieved from Slovenia with the other geographical foci of the study.

Research activities during the first reporting period:
WP5.1: The literature review has been completed, along with primary legal materials and sources

identified. Much of the pan-European material has been obtained, although certain primary legal material is still to come in from Slovenia, Greece and Israel (albeit scheduled). The partners have assisted in translation and continue to do so, with additional legal translation undertaken in Israel. Translation software was also purchased and used in-house to facilitate the identification of material requiring additional translation. Although contact has been made with government agencies, co-operation has been limited and largely focused on the experimental units. Local intermediaries have been used to attempt to encourage co-operation. This is proving more successful. Collaboration with groups with specialisms in the field has been undertaken.

WP5.2: Electronic compilation has been undertaken of material collated in accordance with the analytical framework by this work package and the previous. The comparative and evaluative process is underway, albeit delayed by the delay in some primary material coming in for the case study countries. The pan-European component is well underway.

WP5.3: The literature review has been undertaken, and the appropriate framework of analysis identified and developed for the application in hand – based on 'functional' comparative law. A draft paper and electronic database have been written and used in the identification and processing of the material pertinent to the other two work packages.

Significant difficulties or delays experienced during the first reporting period:
There has been some delay in the completion of work package 5 due to a lack of cooperation on the behalf of certain government agencies in supplying copies or interpretations of national legislation, which given the budgetary cuts made during contract negotiations the project team had limited potential to remedy. Local assistance has, however, been obtained through links established by the partners, such that the effective delay is minimal (3 months). This delay also encapsulates the value added contribution being made through collaboration with a Professor of Law in Slovenia. The work of the other partners and work packages was in no way hindered by the delay in obtaining primary legal documents.

Sub-contracted work during the first reporting period:
None

Participant number:	07

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 bio-filter 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).

Research activities during the first reporting period:
WP01: Contributed to literature review (WP 01)

WP04: Deployed bio-filter cylinders in Southampton dock to provide test material for incubation techniques.

Developing and constructing portable oxygen incubation apparatus for bio-filter cylinders to be used at partner sites comprising:

- Collapsible incubation chamber (with mixing and sampling pumps)
- Pulsed oxygen probe
- Winkler titration apparatus, automated amperometric endpoint detection
- PAR light and temperature sensors

Advised Dror Angel, Israel (Partner 2) on Winkler titration apparatus.

Significant difficulties or delays experienced during the first reporting period:
None

Sub-contracted work during the first reporting period:
None

Participant number:	*8*

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 (not employed on BIOFAQs due to post-doc commitments)
Dr. Jože Kotnik (not employed on BIOFAQs project for 6 months)
Stojan Žigon, technician
Dr. Polona Vreèa (Replacement for Dr Ogrinc & Dr Kotnik)
Dr. Barbara Vokal (Replacement for Dr Ogrinc & Dr Kotnik)

Contractual Links to other Participants:
Associated to partner No.4 – Marine Biological Station, National Institute of Biology, Piran, Slovenia

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 bio-filters, and (b) assessment of the effectiveness of bio-filter 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 $^{13}C/^{12}C$ and $^{15}N/^{14}N$ 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).

Research activities during the first reporting period:
WP01: Literature survey
WP04: Field Studies:

- Preparation of sampling strategy for stable isotope analyses
- $^{15}N/^{14}N$ and $^{13}C/^{12}C$ analyses of obtained samples. Results of C and N stable isotope analyses are collated in Tables II-IV (Annex WP04; Partner 8).

(See Annex WP04 for methodology and technical protocols).

Significant difficulties or delays experienced during the first reporting period:
The stable isotope analyses are in significant delay compared to the planned schedule since samples from fish farms were not sent regularly. Attached is the table of missing and not yet analysed samples according to the sampling strategy set in March 2001. If the samples were collected we will analyse them as soon as they arrive. If not, the strategy of isotopic analyses and expected outcome must be reconsidered in agreement with all partners.

Sub-contracted work during the first reporting period:
None

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:

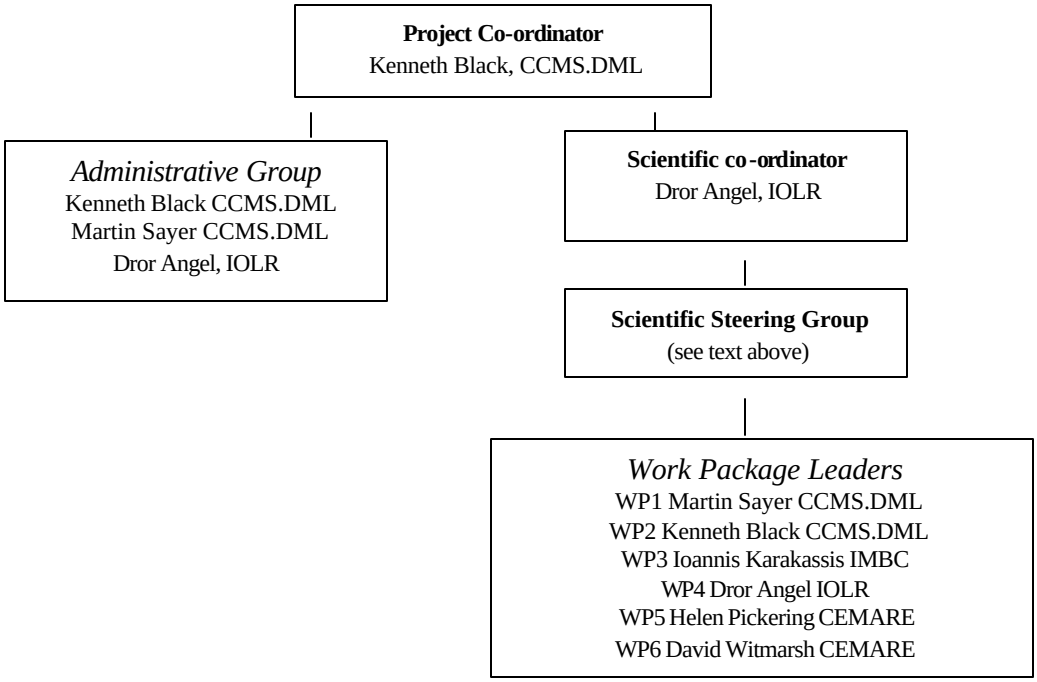
1 Dr Martin Sayer, CCMS.DML, UK
2 Dr Dror Angel, IOLR, Israel
3 Prof Ehud Spanier, Haifa Univ., Israel
4 Prof Alenka Malej, MBS.NIB, Slovenia
5 Dr. Ioannis Karakassis, IMBC, Greece
6 Dr. Helen Pickering, CEMARE, UK
7 Dr Ken Collins, Southampton University, UK

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 progammes 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 bone 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.

- *Communication of Project Results:*

Partner 1: Kenny Black has presented a poster (Annex P1) produced by Elizabeth Cook at a conference entitled 'AQUACULTURE AND ITS ROLE IN INTEGRATED COASTAL ZONE MANAGEMENT' Oostende, Belgium, April 19-21, 2001 and an abstract submission was also accepted for the proceedings of the TECAM Seminar on Environmental Impact Assessment of Mediterranean Aquaculture Farms (September 2001). Elizabeth Cook has given a presentation on BIOFAQs to the Association of Scottish Shellfish Growers (11 October 2001). Elizabeth Cook has produced a technical leaflet (TL2001-013) for 'Aquaflow' the European network for the dissemination of aquaculture RTD information. The leaflet can be found at www.aquaflow.org. Elizabeth Cook has also designed and maintained the BIOFAQs website in Year 1. This website can be found at www.sams.ac.uk/biofaqs and it contains general information about the project, contact names and addresses, details of the progress meetings, links to other relevant websites, a table of deadlines to show the projects progress and a password protected 'Partners Only' page which displays the monthly progress reports and any other information relevant to the project partners. The number of visitors to the website has been monitored from the 15 August 2001 and the counter has recorded 366 people visitors to the site between 15 August and the 31 November 2001.

Partner 2: Dror Angel co-chaired (with Marina Cabrini) a session on "Links between aquaculture and environment" at the Winter Meeting of the American Society of Limnology and Oceanography in Albuquerque, New Mexico (February 12-16, 2001). He presented a paper at this session entitled: Using bio-filters to reduce effluent dispersal from marine net-pen fish farms co-authored by Angel, Spanier, Eden & Katz and briefly described the objectives of the BIOFAQs project.
Dror Angel presented a paper at the Open Ocean Aquaculture IV meeting in St Andrews, Canada in June, 2001 entitled: A new approach to sustainable mariculture: stimulating natural bio-filters to capture fish farm wastes, coauthored by Eden, Katz, Breitstein, Yurman and Spanier. Existing data from the joint artificial reefs project in Eilat were presented and the BIOFAQs project was mentioned in the context of conclusions and future work. Dror will co-chair (with Marianne Holmer) a special

session on "Mariculture and Its Impacts on the Marine Environment: ***what we know and what we don't"*** at the 2002 Ocean Sciences meeting in Honolulu, Hawaii (February 11-15, 2002). Such a session will provide an opportunity for aquaculture researchers to meet a large number of marine and aquatic scientists from a broad range of backgrounds in order to establish links and potential collaborations with them.

Partner 3: Ehud Spanier presented a paper entitled: "Dynamics of fish communities in the vicinity of caged fish aquaculture farms in the Northern Gulf of Eilat (Aqaba)", co-authored by Eden, Angel, Katz, Breitstein and Yurman at the annual conference of the Zoological Society of Israel, held the Ben-Gurion University, Beer-Sheva on December 24, 2000. Ehud presented a paper entitled "The potential use of artificial reefs and bio-filters to reduce the environmental impacts of fish farms in the Northern Gulf of Eilat" on the "Ecology and quality of the Marine Environment" session of the 31st annual meeting of the Israel Society for Ecology and Environmental Quality Sciences, held in Tel - Aviv on May 1st, 2001. The paper was co-authored by Dror Angel, Noa Eden, Timor Katz, Steve Breitstein, Amir Yurman and Yossi Zilbiger. On May 28, Ehud Spanier presented a lecture at the Department of Environmental Sciences, Institut J. Stefan, Ljubljana entitled: Artificial reefs in the Mediterranean coast of Israel and the potential use of artificial reefs and bio-filters to reduce the marine environmental impact of fish net cage farms in the northern Gulf of Eilat (Aqaba), Red Sea, Israel".

Partner 4: BIOFAQs poster was displayed during workshop »Releasing development potentials at the eastern Adriatic coast in the areas of aquaculture, fisheries and tourism« (3 – 7 October 2001, Dubrovnik, Croatia) that was attended by about 60 experts from academic and research institutions, aquaculture, fishery and tourist companies, governmental representatives from Albania, Bosnia and Herzegovina, France, Greece, Croatia, Italy, Norway, Slovenia, United States, Yugoslavia) and from international organisations (FAO, UNEP/PAP/RAC). A talk entitled »Coastal aquaculture development as a part of integrated coastal zone management in Slovenia« was also presented. BIOFAQs objectives and expected achievements were also presented to participants (about 40) of NATO Advanced Research Workshop »An evaluation of progress in coastal policies at the national level: A transatlantic and Euro-Mediterranean perspective, held in Ljubljana, Slovenia July 4-6, 2001.

Partner 5: The IMBC team has taken the opportunity of presentations and/or invited lectures to national and international conferences and workshops to inform scientists, aquaculture producers and regulators, providing a short description of the aims of BIOFAQs and by distributing the web-site address of the project (Figure 1). These meetings were:

1. IOC – "Benthic indicators group" 2nd workshop (Charleston, USA, 27/2-2/3/2001)
2. ESF- Euroconference on Marine Biodiversity (Corinth, Greece, 5-10 May 2001)
3. First Mediterranean Meeting of the BIOMARE project (Corinth, Greece, 10-12 May 2001)
4. Workshop of the MERAMED project (Heraklion, Greece, 28-29/6/01)
5. Workshop of the AQCESS project (Aberdeen, UK 5-7/10/01)
6. 10th Hellenic Congress of Ichthyologists (Chania, Greece, 18-10 October 2001)
7. 8th International Exhibition of Fisheries, Aquaculture and Relevant Equipment "Aliia 2001", Hellenic Organization of International Trade Fairs (Athens, Greece, 1-4 November 2001)

A brief description of the project and the web site address have also been sent to a large number of scientists interested in environmental impacts of aquaculture asking for IMBC reprints on this issue.

Information for the public: Information on BIOFAQs (with particular reference to the name of the project and the EU) was disseminated to local TV and radio stations. A press release covering BIOFAQS as well as MERAMED and AQCESS projects was sent out (and published in most cases)

to Greek and Crete newspapers (Figure 1, Annex P5), radio and TV stations, some of which asked for live interviews on this issue (2 local TV stations, 4 national radio stations).
Education: the methodology and the preliminary results and the project were used in University lectures at the Biology Dept, University of Crete (Heraklion) and the Dept of Environmental Engineering, Technical University of Crete (Chania) as an example of a multidisciplinary approach to problem solving and environmental impact assessments.
Other end users: Information on the project has been communicated via letters, fax or phone calls to the Ministry of Agriculture (the Director of the section in charge of aquaculture), local authorities (port authorities, fisheries inspectors), producers' associations (Greek Federation for Mariculture; Union of Fish farmers of the North Aegean Sea) and to fish farmers who kindly provided access to their facilities.

The IMBC team is planning to circulate/send out a leaflet with brief summary of the project, short description of the aims of BIOFAQs and the web-site address in the following meetings and end-users/policy makers:

- Benthic dynamics: In-situ surveillance of the sediment-water interface, Univ. Aberdeen & SAMS, Aberdeen, 25-29 March 2002
- Second International Conference on the Oceanography of the Eastern Mediterranean and Black Sea: Similarities and Differences of Two Interconnected Basins, Middle East Technical University (METU), Ankara, Turkey, 14-18 October, 2002
- European Federation of Marine Science and Technology Societies 1st International Conference (with theme sessions on Biodiversity, Fisheries & Aquaculture, Sustainability and Pollution), Athens, 27-29 September 2002
- Hellenic Ichthyologists Symposium, Greece, end 2002 (times & place tba)
- Hellenic Symposium on Oceanography and Fisheries, Greece, early 2003 (times & place tba)
- Greek Ministry of Agriculture and Fisheries, Aquaculture Directorate, Fisheries & Inland waters Directorate
- EU official/administrator and liaison to the Greek Operational Programme for Fisheries
- Fisheries inspectorates in Chania, Heraklion, Agios Nikolaos and Rethymnon
- Greek Federation for Mariculture
- The North Aegean Fishfarmers Association
- Private Consultant Firms (APC Ltd, NAYS, Marfish)

Information on the project (scope, aims, objectives, web page address) will also be published in the following greek trade magazines:

- Fishing News (trade magazine related to the fisheries-aquaculture sector)
- Fishfarming (trade magazine related to the aquaculture sector)
- Thalassografes (magazine of the Greek Federation of Mariculture)

The IMBC team has also compiled a comprehensive list of recipients for the BIOFAQs newsletter including greek producers & associations, national authorities, consultants, educational and research bodies.

Partner 6: No such activities were undertaken in Year 1 of the project.

Partner 7: Visited Dr Altan Lok, Ege University, Izmir, Turkey in June 2001 who has interests in aquaculture and artificial reefs. As a result of this visit he has implemented the BIOFAQs module

deployment (and sampling) protocol at a fish farm site near Izmir. Three sampling events have been made to date describing biomass and species composition. Dr Sonja Lojen, Slovenia (Partner 8) has agreed to receive samples for Turkey for stable isotope analysis.

Partner 8: No such activities in the first reporting period were taken. A poster presenting preliminary results of isotope research was presented at the 2nd European Meeting on Environmental Chemistry in Dijon, France, December 12th-15th (Annex P8).

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 bio-filters 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: SAMS 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.
Partner 2: None
Partner 3: A collection permit to sample marine organisms from the bio-filters in Eilat was given to our group by the Israeli Nature Reserves authority.
Partner 4: None
Partner 5: None
Partner 6: There have been no ethical or safety issues arising during year 1 of the project.
Partner 7: None
Partner 8: No special concerns regarding ethical aspects.