

ECASA Study Site Report

Cephalonia

Greece

ECASA partners: UoC, UGOT

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Non Technical Summary A 1-page summary in layman's language.

1. Cephalonia Fishfarms S.A produces sea bass and sea bream since 1982. The site that was selected for ECASA sampling (Kokkinos Vrakhos) has been active since 1984. Recently, the farm has started producing organic products as well.
2. The Gulf of Cephalonia is a closed bay protected by all winds except from those coming from the south. Maximum depth near the mouth of the bay is 50m.
3. The cages are located in depths ranging from 18 to 25 m.
4. The site has been surveyed by IMBC in 1995 (two times), 1996 (three times), 1997 (three times), 2001 (once), and in 2006 by UoC (ECASA survey).
5. One benthic and one water column transect were sampled during ECASA survey. Both transects were established towards the direction of the main current and they shared four stations in common, 0, 25, 50 m from the edge of the cages, plus the control station, ca 1 km upstream. In addition, the benthic transect included two stations at a distance of 5 and 10 m from the cages while the water column transect included two more stations at a distance of 100 and 200 m from the cages.
6. Sediment samples were collected using plexiglas corers of internal diameter 9.4 cm for macrobenthos use and 4.4 for the rest of the analyses (LOI, CHN, Chla, PSA, TOP, meiofauna). Water column samples were collected using Niskin bottles. Phytoplankton bioassay experiments were set up for five days at selected stations of the water column transect.
7. Water column nutrients, POC and PON concentrations measurement was not an efficient method in tracing nutrient loading due to fish farming. On the contrary, the phytoplankton bioassay experiment was very successful in detecting environmental effects on water column.
8. Organic carbon, organic nitrogen and chla *a* levels in the muddy sediments of the area were very low and decreased with increasing distance from the cages.

9. No gradient of redox potential or organic matter determined by LOI was detected along the sediment transect.
10. The univariate indices calculated for macrobenthic community could show differences between the impacted station under the cages and reference conditions but could not detect and demonstrate very clearly a gradient of impact.
11. Likewise, all meiofaunal variables did differentiate impacted from reference conditions.
12. Using AMBI index, a gradient of macrobenthic community structure was detected. A heavily disturbed community occurred at the station under the cages, which was moderately disturbed further away and up to a distance of 10 m, after which slightly disturbed conditions were defined.
13. MOM model was used for estimating the environmental effect of the fish farm on Zone A. The model indicated that the selected layout of the cages does not allow optimum performance of the farm. However, the site is suited for fish farming due to the rather high current speed which allows an overall good water and sediment quality.
14. The holding capacity of the farm is estimated to be about 900 tonnes/year. The estimated total holding capacity of the farm is thus below the present production of the site with a maximum biomass of 2000 tonnes. The limiting criteria at this site is the water quality in the cages, as in periods of low current speed oxygen levels are quite low as well. However, the holding capacity may increase by either changing the configuration of the farm or by decreasing FCR_{real} .
15. Among the various indicators tested in this site primary production changes as determined by setting up bioassay experiments, CHN analysis of organic carbon and nitrogen in surficial sediments, chl *a* concentrations in sediment and AMBI index are pointed out as the best indicators for monitoring environmental effects of fish farming in such an environment as the studied one.

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1 Introduction to the aquaculture operation

1.1 Introductory background statement

The Company

Cephalonia Fishfarms S.A has been established since 1982 and since then it produces mainly sea bass and sea bream. The company employs 65 people, all of them native. It has 2 marine sites and 1 hatchery with an average output for the period 2003-2005 of approximately 1.000 tonnes. Kokkinos Vrakhos (Red Rock), the site which was selected for ECASA sampling, has been active since 1984. Recently, the farm has started producing organic products as well.

Field campaign

In July 2006 a field survey was carried out at Cephalonia Fishfarms S.A. The participants were from ECASA partner no 7 (Haifa University, WP5 leader) and ECASA partner no 8 (University of Crete, WP3 leader). The site was visited for a week, for the period 3-8/7/2006, during which the field workplan that was established for the greek sites has been followed. In particular, the following activities have been carried out:

- Sediment sample collection (scuba-diving)
- Water column sample collection
- Secchi depth measurement
- CTD deployment
- Bioassay experiment deployment

Prior to this visit as well as during the field campaign, UoC has been in contact with the manager of the fishfarm, Dimitris Troyanos. The major difficulty encountered during fieldwork in Cephalonia was the high turbidity of the water, which was the reason for the delay of sediment sampling.

Fieldwork, *in situ* sample processing and further laboratory analysis were carried out according to the appropriate methodologies described in the Book of Protocols.

1.2 Summary statement of key site specific environmental issues

The Gulf of Cephalonia is a closed bay protected by all winds except from those coming from the south. Maximum depth near the opening of the bay is down to 50m and the sea bottom is characterized by muddy sediments. Current direction is 160° NW-SE. During winter, water column is homogenized with lowest temperature 13° C and relatively low surface salinity. In summer, a thermocline with a temperature difference of 8-10 degrees is observed. The site is characterized by high dispersion and high water renewal. The land area of the site is rural, however, two major towns are located on the branches of the bay, Argostoli and Lixouri. Records exist on the appearance in the bay of an endangered species of loggerhead, while in a coastal area adjacent to the bay there are marine caves where the critically endangered species of Mediterranean monk seal nests.

1.3 Information of farmer's environmental strategy:

Cephalonia Fishfarms has a ten years lease contract with the Hellenic State for using the sea floor at Kokkinos Vrakhos. The different types of licenses that Cephalonia Fishfarms has been granted and the authorities which are responsible for providing those licenses are presented in Table 1.1.

The monitoring system of the farm involves the measurement of 6 physicochemical parameters at each site of the company, plus one at a control site. The environmental policy of the company complies with ISO14000 standards in order to enable maximum production and minimum environmental effects. Selected as well as organic culture fishmeals are used for feeding through an automated computer system. A daily inspection of the cage nets by professional divers enables the control of escapees which is kept to zero.

1.4 Overview of Regulatory controls, consents and monitoring requirements

Licensing requirements for aquaculture farms in Greece addresses various issues such as, environment, public health, fisheries, archaeological sites and tourist activities protection, as well as secure navigation, shipping rules, avoidance of public peace and scenic views disturbance (Papoutsoglou 2000). Thus, licensing of greek fish farms is

quite complicated, involving a high number of administrative bodies: Prefecture branch of Ministry of Rural Development and Food – Department of Fisheries & Aquaculture, Ministry of Mercantile Marine, Ministry of Defence (Hellenic Navy), Ministry for the Environment, Physical Planning and Public Works, Hellenic Tourism Organization (underwater antiquities), Archeological service, Local Authorized Service. At the moment, there is not a general monitoring scheme that should be applied at all farming sites; it rather depends on local authorities requirements. However, an effort is currently being made for establishing minimum requirements for a general monitoring system applicable at all fish farm sites.

Table 1.1. Licensing of Cephalonia Fishfarms

	License	Administrative body
Sea cages	authorisation decision of environmental standards	Ministry of Rural Development and Food Ministry for the Environment, Physical Planning and Public Works
	company formation & operation license lease	Ionian region, Directorate of Rural development Hellenic State
Hatchery	authorisation decision of environmental standards	Ionian region, Directorate of Rural development
	formation & operation license	Ionian region, Directorate of Rural development
	discharge consent	Prefectural administration of Cephalonia - Ithaca, Directorate of Public Health
Packing plant	license for operation	Prefectural administration of Cephalonia - Ithaca, Veterinary Directorate

2 Site specific regulatory and management background

2.1 The regulatory status of proposed location with respect to fish farming developments.

Currently, there is no management plan for the area. According to the European Network Natura 2000, a coastal area located southern from the fish farm sites (Argostoli – Vlahata) is considered as a Site of Community Importance (SCI)

2.2 Site description

Unfortunately, no data are available for Zones B and C of the site.

2.3 Detailed description of the farm

The fish farm is using alternate site locations for the production of sea bream and sea bass. Currently, it consists of 34*50m, 35*60m and 8*40m circular cages, 32 rectangular cages 7*15, 15 quadrangle metal cages 15*15 (depth of the cages 7-10 m), 1 AKVA feeding system, 2 barges with feeding cannons, feeders with a timer set at 7*15. The cages have been made in Livadia by TEAP while feed suppliers are several (Kego, Feedus, Aller aqua, Astrea). The company owns 4 boats, 1 metal working boat for carrying feed to the cages and 3 boats for the transport of employees. At the barge a chemical WC is available for the staff, while at the hatchery staff facilities include two toilets, a shower and a coffee room. The company employs in total 65 people.

2.4 Proposed management strategy

The production cycle of the farm is 3 years and the highest biomass is 2.000 tonnes for which 3.500 tonnes of feed are used. Antibiotics (mainly TRIBRISSEN) are rarely used only during hatching. The fish are both photo-manipulated and normal. The expected FCR is estimated between 1.7 and 2.4. The stocking density range is 10-12 kg m⁻³.

2.5 Physical farm logistics, including type of gear used

Five types of cages of different shape and dimensions are used (circular, rectangular, quadratic), with a net depth that ranges between 7-10 m from the surface. Submersible frame is used for mooring. The 4 boats of the company are used for accessing the cages from 3 different areas, namely Argostoli, Lixouri and a very small natural marina, Agios Konstantinos. No lightning is used below or above the water. The company does not apply any kind of measure to prevent predators approaching the cages.

2.6 Production and Processing

Fish are transferred for slaughtering to the packing plant in tanks with water and ice. It is claimed that no wastes are produced from slaughtering.

3 Description of the site and quantification of effects on the environment – existing information only, not collected by ECASA.

3.1 Land use, landscape and visual quality

The farm has been in Kokkinos Vrakhos since 1984 and appears to have a stabilized production of sea bream and sea bass. There is no other farm within the bay; however, another fish farm exists on the northeast coast of the island, opposite to Ithaca, 20 km of land away from Kokkinos Vrakhos. In the broader area, which is characterized as rural, fisheries, tourism and agriculture are quite developed, though not in the immediate vicinity of Kokkinos Vrakhos. Therefore, it appears to be no conflict among the farm and the rest of the major anthropogenic activities. The low number of new technology cages which are deployed by the farm at the specific location minimize the visual intrusiveness of the site. The most visible element is the old metallic rectangular cages which are about to be removed from the site.

The nearest to the farm settlement is Farsa which is located approximately 2 km northwest from the farm. The permanent population of this village is approximately 500. Argostoli, the capital of the island, is located 4 km southward. It is the biggest town in the island, with a population of 10.000 people that is increasing during summer. Lixouri, with a population size of 4.000 people is found on the opposite site of the bay, westwards, at a distance of 2 nm from the farm.

3.2 Hydrography and water quality

As most parts of the coastal area of Greece, the Gulf of Cephalonia has not been studied in terms of hydrography and topography and therefore, important information such as residence time of water, flushing rates as well as hydrographic models are lacking. However, within the framework of national (OPRT) and European research projects (MERAMED) it was possible to study the area in the very near vicinity of the farm and gather some information on the hydrography of the area. The information that is presented in this section is extracted from reports that have been written within the framework of the above mentioned projects.

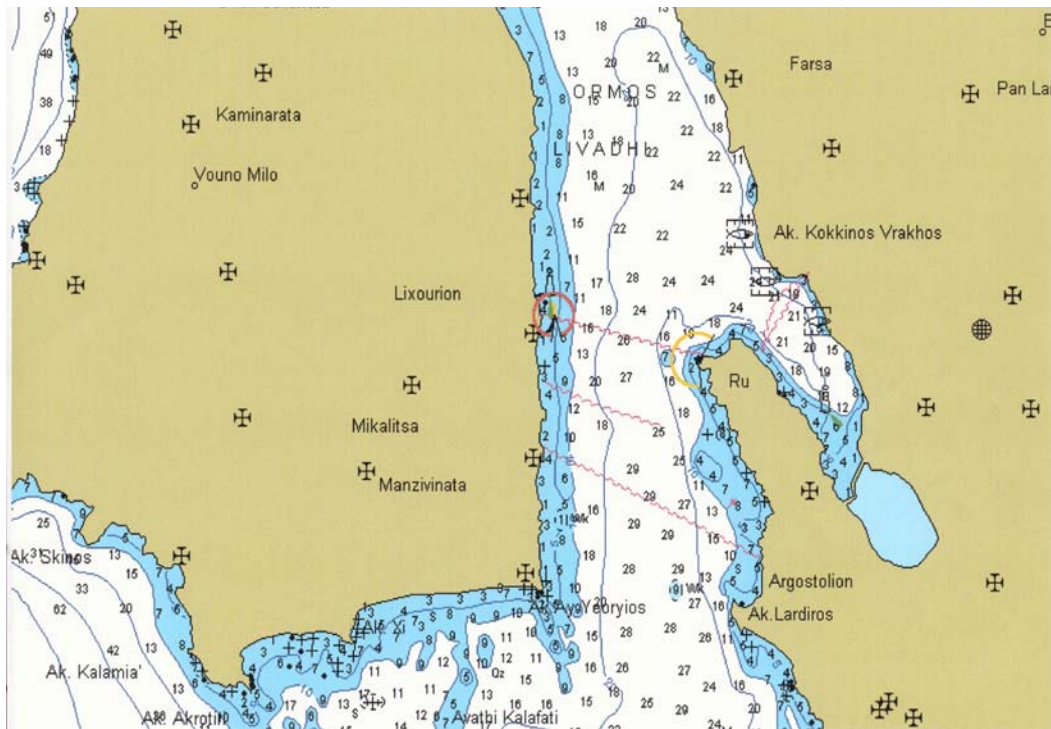


Figure 3.1. Map of Cephalonia bay



Figure 3.2. Kokkinos Vrakhos



Figure 3.3. Part of the fishfarm layout at Kokkinos Vrakhos

The Gulf of Cephalonia is a closed bay protected by all winds except from those coming from the south. During winter, water column is homogenized with lowest temperature reaching 13° C and relatively low surface salinity. In summer, a thermocline with a temperature difference of 8-10 degrees is observed. Current measurements were made at the site by IMBC during the period July 1995 – January 1997 using Aandera current meters of RCM-7 type. Current direction was 160° NW-SE with an average speed 2.4 cm/s. Maximum speed was recorded at 17.1 cm/s.

Drogue surveys were undertaken by SAMS in July 2001 to assess the amount of dispersion in the area around the fish farm. A very large area was surveyed including five rows of cages, most of which were situated in areas with a depth between 20 and 25 m. Although light winds were measured during the drifter survey dispersion was quite high. The drifters were advected in a SE direction and there appeared to be some tidal activity in this area not linked with the winds measured at the site. After a period of time, the drifters reversed in direction and were advected in a NW direction, followed by another shorter period in which they were advected in a southerly direction. Averaged drifter speeds were up to 7 cm/s. Potential for dispersion is also quite high as there is a reasonable fetch for winds from the NW.

The study of the nutrient concentrations at the site (Pitta et al. 1999) indicated that although, the farm is located in a very enclosed bay, it is subjected to adequate water renewal imposing continuous dilution of the effluents and preventing the formation of relatively stagnant water even within the cages. Therefore, it appears that there is no risk of eutrophication resulting from fish farm activities.

Background information with regard to the phytoplankton of the area can be found in the study by Pitta et al. 1999 (Appendix 2).

3.3 Bathymetry, geology and habitats.

Maximum depth near the opening of the bay is down to 50m (**Figure 3.4**) and the sea bottom is characterized by muddy sediments. There is no substrate map available at the moment.

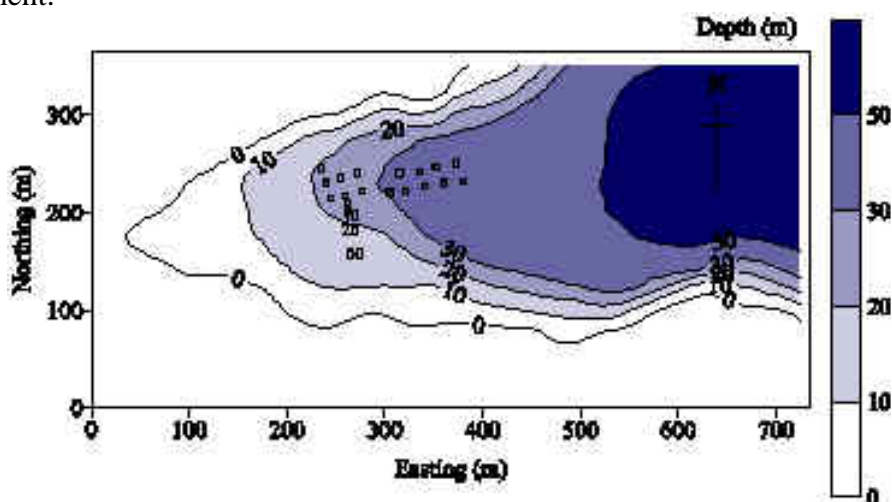


Figure 3.4. Bathymetry of the Gulf of Cephalonia (from MERAMED).

3.4 Benthos and sediments

IMBC (currently HCMR) has conducted field surveys in the past (1995-1997, 2001) and therefore benthic and sediment measurements are available through published data (Karakassis et al. 1998, Karakassis et al. 1999, Karakassis & Hatziyanni 2000, Karakassis et al. 2000, Karakassis et al. 2002) and technical reports but only for the area very close to the farm (up to a distance of 100 m from the cages) as well as for a reference site almost 1 km upstream from the fishfarm. The results of those studies indicate the occurrence of the opportunistic polychaete *Capitella capitata* near the cages and up to a distance of 10 m, while further away and at the control site this

species is replaced by other polychaetes, such as *Lumbrineris* and *Glycera*, while bivalves such as *Corbula gibba* and *Mysella bidentata* increase in abundance.

Organic carbon and nitrogen concentrations in the sediment ranged between 1-2 % and 0.08-0.2 % respectively for all the sampled stations in the area except from the area very close to the cages and downstream (within a distance of 5 m from the cages). Likewise, ATP values were much higher, almost 10 times, within a distance of 10 m from the cages towards the main current direction and ranged between 0-50000 ng/g. Chlorophyll values appeared to fluctuate both temporally and spatially within a range of 1-7.5mg/g.

3.5 Marine mammals; seals, cetaceans, otters

The critically endangered mediterranean species of monk seal *Monachus monachus* have been reported to nest in caves at a coastal area which is located southwards to Cephalonia bay (Figure 3.5). The endangered species of loggerhead *Caretta caretta* can be found in Argostoli, where it have been reported to feed on the discarded fish catch (White 2002, 2004). However, neither of these species is a threat to the fish farm and therefore, the company does not use any kind of deterrent.

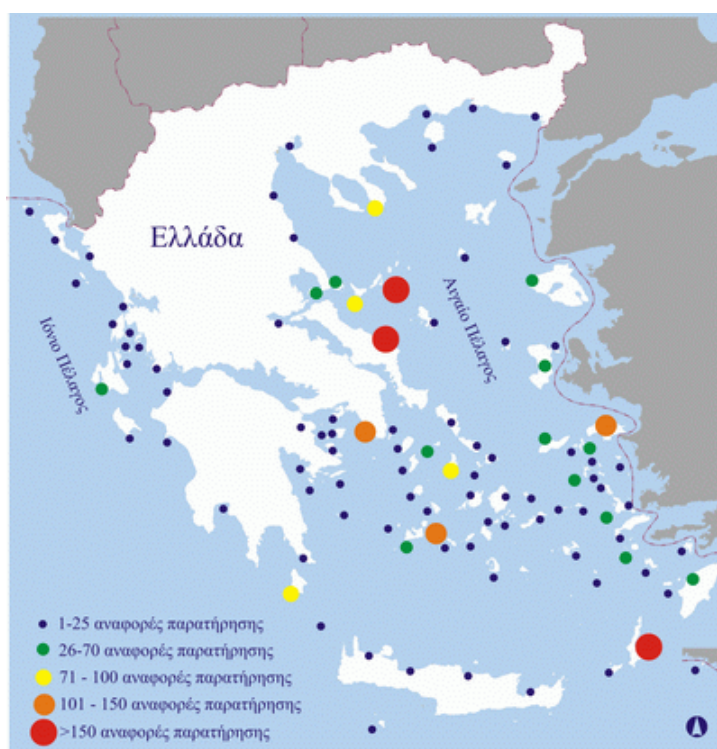


Figure 3.5. Distribution of the critically endangered species *Monachus monachus* (from the website of the N-GO Mom)

3.6 Birds

The mountains Aghia Dhynati and Kokkini Rakhi which are centrally located in the mainland of Cephalonia are important habitats for raptors and a range of passerines associated with a mosaic of forest, scrub and agricultural land.

3.7 Fisheries and wild fish populations.

There is local fishery in the Gulf of Cephalonia but it appears that there is no conflict between the two activities. Fishing is allowed and taking place near the sea cages. An important issue is the fact that the farm attracts dolphins and amberjacks.

Despite the fact that there is no regulation with regard to the recording of diseases and escapes, Cephalonia fishfarms SA keep records of all the diseases and escapes the farm has experienced.

3.8 Noise

The fishfarm site is not located very close to settlements and therefore it is not expected to cause any kind of disturbance to the inhabitants.

3.9 Transport

Company's boats are used for the daily transport of employees to the cages from Argostoli, Lixouri and the marina of Agios Konstantinos. Feed is also delivered by boat, starting from Lixouri. The hatchery and packing plant are very easily reachable by car. The road quality for approaching the ports of Argostoli and Lixouri are very good; however, just before approaching the marina of Agios Konstantinos, the road is turned to a footpath.

3.10 Socio-economic impact

The company offers job to 65 native people that might have moved away from the island along with their families in the absence of a job.

4 Results of ECASA field studies: Indicators and Models applied and evaluated.

4.1 Background to field programme: dates, staff, boats, stations sampled, etc.

During the first week of July 2006 (3-8/7/2006) a field survey was carried out at Cephalonia Fishfarms S.A., during which the field workplan that was established for the greek sites has been followed. More precisely, two transects were established along the direction of the predominant current (160° NW-SE), one for water column measurements and one for sediment sample collection. With regard to the water column transect, five stations were located at the following distances from the edge of the cages: 0, 25, 50, 100, 200 m. The sediment sampling stations were located at 0, 5, 10, 25, 50 m distance from the edge of the cages. Besides the three stations that both transect shared in common (0, 25, 50 m) they also shared the same reference station which was located upstream at a distance of approximately 1 km.

Table 4.2 provides general information on stations and sampling. The list of all the people participated in the fieldwork, their institute and tasks during the survey are presented in **Table 4.1**.

Fieldwork invoked the following activities:

Sediment sample collection (scuba-diving). Plexiglas corers of 4.4 cm internal diameter were used for collecting sediment for TOC, TON, TOP, LOI, chlorophylls and granulometry analyses as well as for the *in situ* measurement of Redox. Sediment cores were sliced in 1 cm layers down to a depth of 12 cm and stored in -20°C. 3 extra sediment cores were collected for meiofauna analysis. 5 replicated sediment cores were collected with bigger diameter corers (Ø 9.4 cm) for use in macrofauna analysis and were sieved in the field through a double set of sieves (upper: 1mm mesh sieve size, lower: 0.5mm mesh sieve size) for testing the BFI index.

Water column sample collection. Water samples were collected using Niskin bottles for measuring concentrations of dissolved nutrients (ammonia, nitrate, phosphate, silicate), POC, PON and chlorophylls.

Secchi depth measurement was made for estimating the water turbidity

Table 4.1. List of participants and Institutes participated in the field campaign

Participant	Institute	Tasks
Dror Angel (WP5 leader)	Haifa University	Diving-Sediment sample collection Bioassay set-up & deployment Laboratory processing of WC & bioassay samples
Katerina Sevastou (chief scientist)	University of Crete	Fieldwork coordination Communication with fishfarm manager and employees WC sample collection Bioassay set-up & deployment CTD deployment Sediment, WC, bioassay sample processing in situ measurements of physicochemical parameters
Sotiris Kiparissis	University of Patras	Diving-Sediment sample collection WC sample collection Bioassay set-up & deployment CTD deployment
Nafsika Papageorgiou	University of Crete	Sediment Incubation Processing of sediment samples
Ioanna Kalantzi	University of Crete	Sediment Incubation Processing of sediment & WC samples
Eugenia Apostolaki	Hellenic Centre for Marine Research	Sediment Incubation, sediment sample processing

CTD was deployed during water column sampling for estimating the vertical profile of water temperature, salinity and chlorophyll at different distances from the cages.

Bioassay experiment set up for assessing nutrients level around the fish farm.

4.2 Sampling methods and materials, analytical methods. (Refer to the book of protocols for detailed methods)

Field and laboratory work was carried out according to the appropriate methodologies described in the Book of Protocols.

4.3 Models used and their parameterization.

4.3.1 The MOM model

The model estimates the environmental effects of fish farming on local scale (zone A). The MOM model can be used to calculate the holding capacity (TPF-Total Fish Production) of an area for fish farming. The model calculations are based on

requirements on the water quality for fin fish in the cages, and for the benthos beneath the cages. The environmental effects of fish farming on the surrounding water and on the water quality in the farm are calculated as oxygen and ammonium concentrations in the farm and oxygen concentrations at the bottom below the farm. The model contains four sub-models; a fish model, a cage water quality model, a dispersion model, and a benthic model. The model also calculates the nutrient release from the farm to the surface water. The holding capacity is expressed as the minimum of the TPF based on oxygen and ammonium concentrations in the cages and oxygen concentration of the bottom water (i.e. of TPFO₂, TPFNH₄, TPFbent). Except for TPF, outputs of the model are also: the theoretical food coefficient, energy content of the food, the length of the production cycle assuming optimal conditions at the site, median weight of the fish during the production cycle, maximal carbon flux to the sediment, outlet of dissolved and particulate matter per tonne fish (expressed as nitrogen and phosphorus). The model results can thus be used to possibly increase the holding capacity at a site. The two basic criteria in the MOM model are:

Table 4.2. Information on stations and sampling during ECASA survey.

Station (Distance from the cages, m)	Depth (m)			Water Column sampling date	Bioassays deployment	Bioassays retrieval	Sediment sample collection
		Latitude	Longitude				
0	19,7	38 12.260	20 28.754	6/7/2006	3/7/2006	8/7/2006	3/7/2006
5	19,8	38 12.257	20 28.755				7/7/2006
10	20,1	38 12.254	20 28.756				4/7/2006
25	19,8	38 12.238	20 28.758	6/7/2006	3/7/2006	8/7/2006	5/7/2006
50	20,4	38 12.229	20 28.762	6/7/2006	3/7/2006	8/7/2006	7/7/2006
100	20	38 12.199	20 28.771	6/7/2006			
200	20	38 12.137	20 28.788	6/7/2006			
Reference	20,6	38 13,393	20 27,254	6/7/2006	3/7/2006	8/7/2006	5/7/2006

1) The accumulation of organic matter under and in the vicinity of the fish farm must not result in extinction of the benthic macro fauna ($O_2 > 2$ ml/l). This condition is met if the flux of organic matter from the farm is adjusted to local dispersion conditions so that the decomposition capacity of the benthic system is not exceeded.

2) The water quality in the net pens must meet the needs of the fish. This means that the concentration of oxygen is kept above the threshold level and that the concentration of ammonium and other potentially harmful substances are kept below the threshold values. These conditions can be met if the respiration of, and emissions from the fish are adjusted to the rate of water renewal in the net pens.

Current characteristics

Three different characteristics of the current speed are needed to calculate the environmental effects in and below the farm:

1) U_{min} - the dimensioning current speed in the surface water which is calculated based on the longest time it takes for the water to pass through the group of cages. It is estimated from current measurements at the level of the farm. This dimensioning current speed is used to calculate the lowest/highest concentration of oxygen/ammonium expected in the net pens.

If the current measurements are performed before the establishment of the farm or away from the farm, a reduction factor should be applied simulating the effect of current resistance caused by the cages and algae growing on the net pens.

2) U_{std} - the fluctuation component of the current which is calculated as the standard deviation of the current component perpendicular to the farm below the cages. The fluctuation component determines the spreading of organic matter from the farm. The fluctuating component is also used to estimate whether resuspension of sediment will occur in the farm area, which is the case for $U_{std} > 3.5$ cm/s. A value of $U_{std} > 3.5$ cm/s suggests that current speeds of more than 10 cm/s occur in the area (Stigebrandt and Aure 1995), which have been found to be the threshold current speed value for resuspension of organic matter from fish farms (e.g. Cromey et al. 2002).

3) U_{bent} – the dimensioning current in the bottom layer which is calculated as the minimum mean speed determined from the bottom current record. This characteristic is used to estimate the minimum oxygen transport from the water to the sediment below the cages.

Model input data

Background

At the time of the study, five groups of cages were located at Kokkinos Vrachos in the Gulf of Cephalonia. The dominating current is in the NW to SE direction with a mean speed of 2.4 cm/s. Maximum speed was recorded at 17 cm/s. The value of U_{std} at this site is just above 3.5 cm/s at 10 m depth, indicating periods of resuspension of the sediment below the farm. We have no information if sea bream or sea bass dominate

in the farm, therefore we test both species. The MOM model is run on three of the cage groups at the farm and each of them is run with sea bream or sea bass in the net pens, i.e. two runs per cage group. The water depth is 19.5 m. The cage groups are run separately. The number of cages in each group and the farm layouts are presented in **Table 4.3.**

Table 4.3. Farm layout

Site	No. cages	No. rows	Diameter / side length (m)	Spacing (m)	Water depth (m)	Reduction of flow factor (0-1)	Farm direction (deg)
Cephal 1	18	2	15 (d)	4	19.5	0.8	5
Cephal 2	16	2	15 (d)	4	19.5	0.8	5
Cephal 3	18	2	15	2	19.5	0.8	5

The production is 1000 tonnes per year. The highest biomass of the farm is 2000 tonnes, with a production cycle of 3 years and an end weight of 1500 g. The fish are given feed with protein content of 43-56%, and the real food conversion ratio, FCR_{real}, is 1.7-2.4.

Table 4.4. Surrounding water characteristics

Site	Sal. (psu)	Temp. (C)	Ox. (mg/l)	Amm. (mg/l)	Currents (cm/s)	U _{min}	U _{std}	U _{bent}
Cephal 1	38	14-25	5.7	0.0054		0.27	3.9	1.1
Cephal 2	38	14-25	5.7	0.0054		0.30	3.9	1.1
Cephal 3	38	14-25	5.7	0.0054		0.27	3.9	1.1

Table 4.5. Fish data (from Cephalonia, Greece, Magill (Thetmeyer) et al. 2006)

site	Fish	Start weight (g)	End weight (g)	Protein cont. (0-1)	Fat cont. (0-1)	Sinking speed of faeces (cm/s)
Cephal 1	Sea bream	10	1500	0.2	0.04	0.5
Cephal 2	Sea bream	10	1500	0.2	0.04	0.5
Cephal 3	Sea bass	10	1500	0.2	0.04	0.7

Table 4.6. Food data

	Protein cont. (0-1)	Fat cont. (0-1)	Carbohydrate cont. (0-1)	Ash cont. (0-1)	Sinking speed of faeces cm/s	FCR _{teo} /FCR _{real}
Cephal 1	0.43	0.22	0.02	0.07	8	1.29/2.0
Cephal 2	0.43	0.22	0.02	0.07	8	1.21/2.0
Cephal 3	0.43	0.22	0.02	0.07	8	1.25/2.0

4.4 Results

4.4.1 Water

CTD deployments at different distances from the cages indicated higher values of salinity and lower of temperature at the reference station, while particulates were much higher at the station under the cages (**Table 4.7**). The clarity of water, as measured by Secchi disk, was higher at the reference station (9.4 m) and minimum at a distance of 25 m from the cages (7.1 m).

Nutrient, POC, PON and chlorophyll concentrations were measured at three different depths in the water column (**Table 4.8**). With the exception of nitrate, nutrient and PON values were higher at a distance between 50-100m from the farm. Chlorophyll-*a* and nitrate concentrations were higher near the cages and up to a distance of 50m whilst POC spatial trend is rather irregular at all water column depths. With regard to the vertical profile of the water column variables, no obvious trend could be detected apart from phosphates, which appear to be more concentrated at the water body near the bottom at most of the stations (**Figure 4.1**).

Table 4.7. Minimum, average and maximum values of temperature, salinity and particulates in the water column of the sampling stations.

Distance from the farm	FF	25m	50m	100m	200m	Reference
	<i>Temperature (°C)</i>					
Minimum	16,84	16,79	16,45	16,20	16,19	16,08
Average	21,30	21,25	20,85	20,68	20,61	20,72
Maximum	24,25	24,28	24,35	24,26	24,23	23,85
	<i>Salinity (‰)</i>					
Minimum	37,24	37,36	37,11	37,82	37,72	30,85
Average	38,25	38,29	38,28	37,98	38,06	38,35
Maximum	39,07	39,99	39,12	38,89	38,99	43,77
	<i>Particulates (umol/m²)</i>					
Minimum	101,40	94,14	79,38	60,91	67,19	126,50
Average	663,92	588,35	602,26	428,79	475,08	497,78
Maximum	5186,00	5933,00	4853,00	1452,00	2343,00	4867,00

4.4.2 Sediment

Sediment type at the control station seems to differ from that of the stations in the vicinity of the farm with muddy fraction exceeding 94% (**Table 4.9, Figure 4.2**). The sediment of the stations near the farm is less muddy with the percentage of gravels

owing to the existence of a subsurface mussel mat, and sand peaking at a distance of 25 m from the cages (46.51%)

Chlorophyll-a concentrations in the top sediment layer (0-3cm) is much higher near the cages compared to the values reported for the control station (**Table 4.9**), therefore indicating eutrophic conditions at the fish farm site. However, the effect of the fish farm appears to be very local. The same conclusion is reached as well by measuring total organic carbon (TOC), total organic nitrogen (TON) and total organic phosphorous (TOP) concentrations at the surface of the sediment (0-5cm). Similarly, Eh values in the surface of the sediment (0-2) were negative near the cages but become positive at a distance of 25 m from the farm.

Table 4.8. Nutrient, chl-*a*, POC and PON concentrations at three different water column depths (Surface: -1m, Mid: ~ 10m, Bottom: 1m above the bottom) at different distances from the cages.

		Distance from the farm					
		<i>FF</i>	<i>25m</i>	<i>50m</i>	<i>100m</i>	<i>200m</i>	<i>Reference</i>
WATER COLUMN DEPTH	NO₃ (µM)						
	Surface	0,48	0,56	0,54	0,27	0,15	0,11
	Mid	0,37	0,49	0,51	0,49	0,15	0,15
	Bottom	0,66	0,51	0,20	0,22	0,15	0,15
	NH₄ (µM)						
	Surface	0,42	0,32	0,29	0,32	0,05	0,35
	Mid	0,45	0,12	0,52	0,42	0,03	0,25
	Bottom	0,36	0,28	0,56	0,56	0,01	0,26
	PO₄ (µM)						
	Surface	0,01	0,00	0,00	0,02	0,00	0,03
	Mid	0,01	0,00	0,00	0,00	0,00	0,03
	Bottom	0,17	0,14	0,31	0,03	0,00	0,04
	SiO₂ (µM)						
	Surface	1,06	0,98	1,06	1,73	1,58	1,26
	Mid	0,77	0,72	2,16	7,46	1,42	0,86
	Bottom	0,96	0,72	1,13	10,25	1,24	1,22
	Chl <i>a</i> (µg/l)						
	Surface	0,48	0,56	0,54	0,27	0,15	0,11
	Mid	0,37	0,49	0,51	0,49	0,15	0,15
	Bottom	0,66	0,51	0,20	0,22	0,15	0,15
POC (ug/l)							
Surface	203,68	171,33	135,71	139,09	180,92	182,44	
Mid	137,86	157,36	190,60	171,40	163,62	167,00	
Bottom	217,08	142,63	198,16	304,84	177,82	302,18	
PON (µg/l)							
Surface	30,15	26,80	23,03	23,68	30,68	21,32	
Mid	23,86	25,90	32,26	27,44	26,09	21,36	
Bottom	35,72	25,23	34,90	45,22	28,28	36,15	

Organic Material (OM) in the sediment of all stations ranged between 9-17%, in agreement with the values reported by Karakassis et al. (1998) for the same site, with the exception of station 50, where in the top layer an increased value was detected (34.8%) (Table 4.10). That was due to the high levels recorded for refractory organic material at this layer, which was generally lower than 11.5% (Table 4.11). Labile organic material was not exceeding 6 % of the OM (Table 4.12) while Rp values ranged between 0.6-0.86 (Table 4.13), indicating sediments characteristic of protein and polyphenolic compounds (Kristensen 1990).

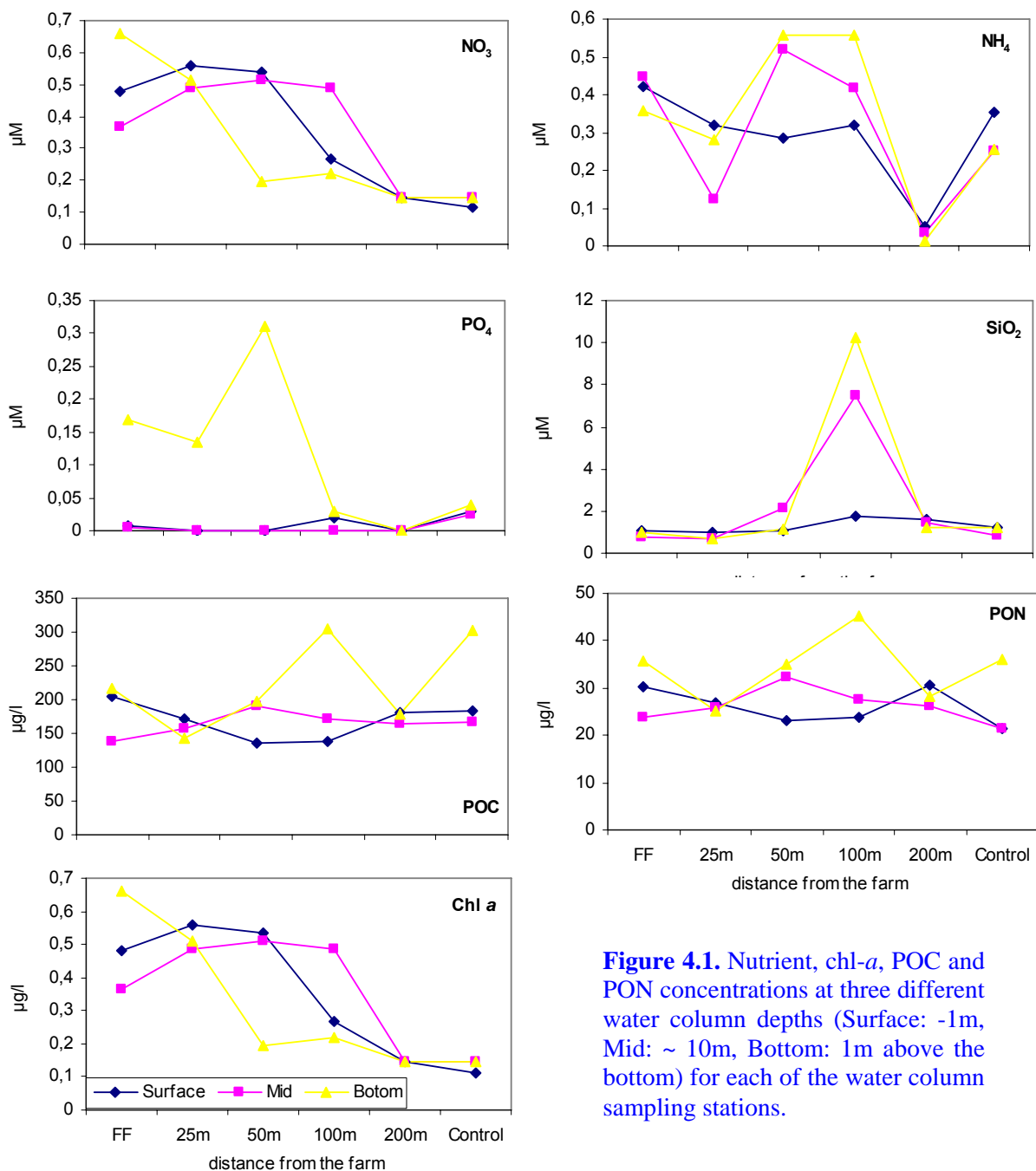


Figure 4.1. Nutrient, chl-a, POC and PON concentrations at three different water column depths (Surface: -1m, Mid: ~ 10m, Bottom: 1m above the bottom) for each of the water column sampling stations.

Table 4.9. Sediment variables

Station	Gravel (%)	Sand (%)	Silt-clay (%)	Eh (0-2cm) (mV)	TOC (0-5cm) (µg/g)	TON (0-5cm) (µg/g)	TOP (0-5cm) (µg/g)	Chl-a (0-3cm) (µg/g)
FF	5,32	16,15	78,53	-57	24,20	3,12	0,54	23,25
5	4,29	26,04	69,67	16	22,90	2,85	0,15	23,61
10	2,54	17,40	80,05	-80,5	20,52	2,67	0,45	17,52
25	4,34	42,17	53,49	27	19,24	2,39	0,22	11,58
50	5,57	10,98	83,45	31,5	21,09	2,76	0,16	13,03
Control	0,40	5,41	94,19	116,5	14,37	1,63	0,08	7,92

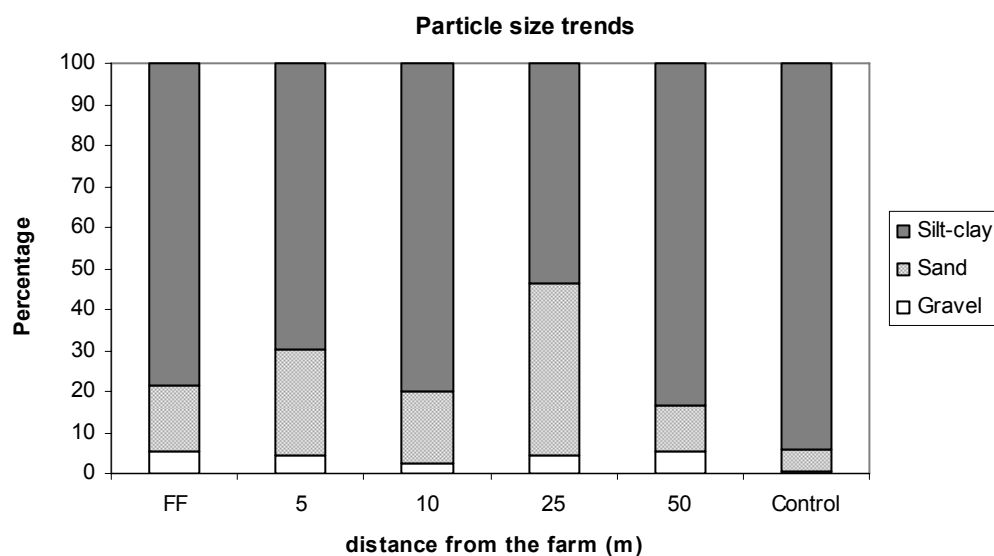


Figure 4.2. Particle size trends across the sampling transect and at the control station.

Table 4.10. Percentage of total organic matter (using LOI methodology).

Layer	Distance from the farm					
	FF	5	10	25	50	Control
1	15,32	16,30	14,14	12,03	34,80	11,72
2	14,45	14,47	13,25	11,27	14,39	11,61
3	13,72	13,22	11,96	10,82	13,69	11,77
4	13,58	13,21	13,08	12,21	14,39	12,04
5	13,01	12,52	12,92	11,58	13,57	11,85
6	12,69	11,79	12,16	11,16	14,53	11,50
7	11,92	10,39	11,09	10,95	12,90	10,59
8	12,07	9,75	9,48	10,95	13,77	10,14
9	12,30	11,11	9,27	10,65	11,22	10,95
10	11,94	12,10	9,78	11,23	13,58	11,05
11	11,81	11,23	9,53	11,03	11,70	9,78
12	11,69	10,00	8,97	10,65	12,65	9,27

Table 4.11. Percentage of refractory organic matter (using LOI methodology)

Layer	Distance from the farm					
	<i>FF</i>	5	10	25	50	<i>Control</i>
1	10,36	10,79	9,95	8,19	30,29	9,24
2	10,88	10,04	9,41	7,66	10,33	9,39
3	10,14	9,97	8,90	7,57	9,97	9,59
4	10,23	9,91	9,90	8,55	10,81	9,90
5	9,35	9,74	10,02	8,62	10,04	9,78
6	9,86	9,04	9,42	8,50	11,11	9,41
7	9,40	8,07	8,69	8,35	9,51	8,61
8	9,66	7,59	7,39	8,37	10,72	8,09
9	9,89	8,82	7,28	8,23	8,40	9,01
10	9,49	9,50	7,71	8,79	10,82	9,31
11	9,44	8,93	7,57	8,60	9,08	8,20
12	9,38	7,96	7,08	8,59	9,85	7,79

Table 4.12. Percentage of labile organic matter (using LOI methodology)

Layer	Distance from the farm					
	<i>FF</i>	5	10	25	50	<i>Control</i>
1	4,95	5,51	4,19	3,83	4,52	2,49
2	3,57	4,43	3,84	3,61	4,07	2,22
3	3,58	3,24	3,06	3,25	3,72	2,18
4	3,35	3,30	3,18	3,65	3,59	2,14
5	3,66	2,78	2,90	2,97	3,53	2,07
6	2,83	2,74	2,74	2,66	3,41	2,09
7	2,52	2,32	2,41	2,61	3,39	1,98
8	2,42	2,16	2,08	2,57	3,06	2,05
9	2,41	2,29	2,00	2,41	2,81	1,94
10	2,45	2,61	2,07	2,44	2,76	1,75
11	2,36	2,30	1,96	2,43	2,62	1,57
12	2,31	2,04	1,89	2,06	2,80	1,48

Table 4.13. Rp index (Kristensen 1990).

Layer	Distance from the farm					
	<i>FF</i>	5	10	25	50	<i>Control</i>
1	0,68	0,66	0,70	0,68	0,80	0,79
2	0,75	0,69	0,71	0,68	0,72	0,81
3	0,74	0,75	0,74	0,70	0,73	0,81
4	0,75	0,75	0,76	0,70		0,82
5	0,72	0,78	0,78	0,74	0,74	0,83
6	0,78	0,77	0,78	0,76	0,76	0,82
7	0,79	0,78	0,78	0,76	0,74	0,81
8	0,80	0,78	0,78	0,76	0,78	0,80
9	0,80	0,79	0,79	0,77	0,75	0,82
10	0,79	0,78	0,79	0,78	0,80	0,84
11	0,80	0,79	0,79	0,78	0,78	0,84
12	0,80	0,79	0,79	0,81	0,78	0,84

Vertical profile

The vertical profiles of Redox, TOC, TON, TOP and organic matter in the sediment were studied at all stations (**Figures 4.3, 4.4**). Higher values of Eh were always recorded at the top layer with the exception of the station under the cages where higher (positive) values are recorded at a sediment depth of 4-6 cm (**Figure 4.3**). That was probably due to the existence of a subsurficial mat of dead mussels. Organic carbon and nitrogen appear to decrease with depth in the sediment at all stations, but no obvious trend was detected for organic phosphorous (**Figure 4.3**) as well as for the different fractions of organic matter (**Figure 4.4**).

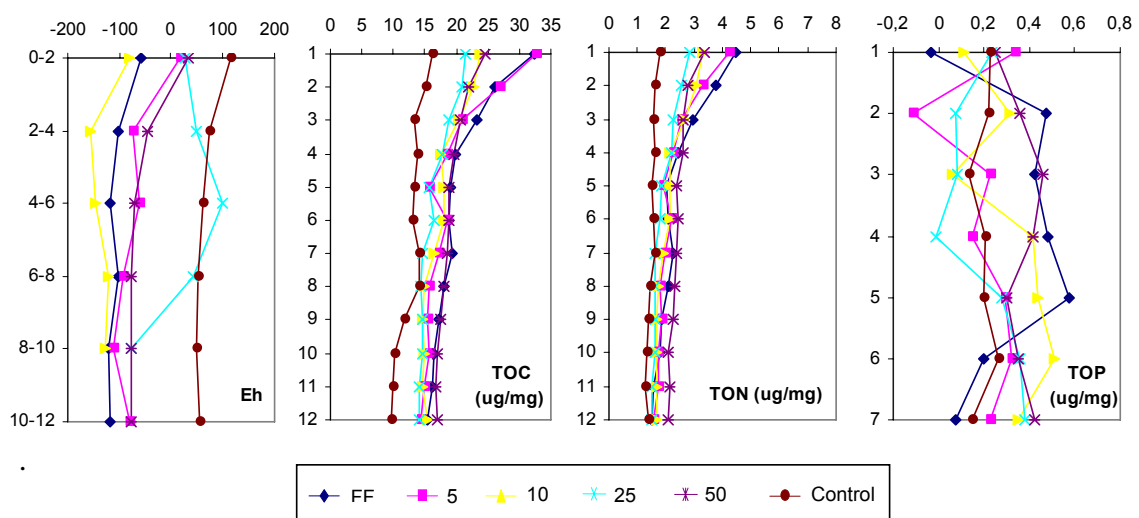


Figure 4.3. Vertical profile of Redox, TOC, TON and TOP for each of the sampling stations.

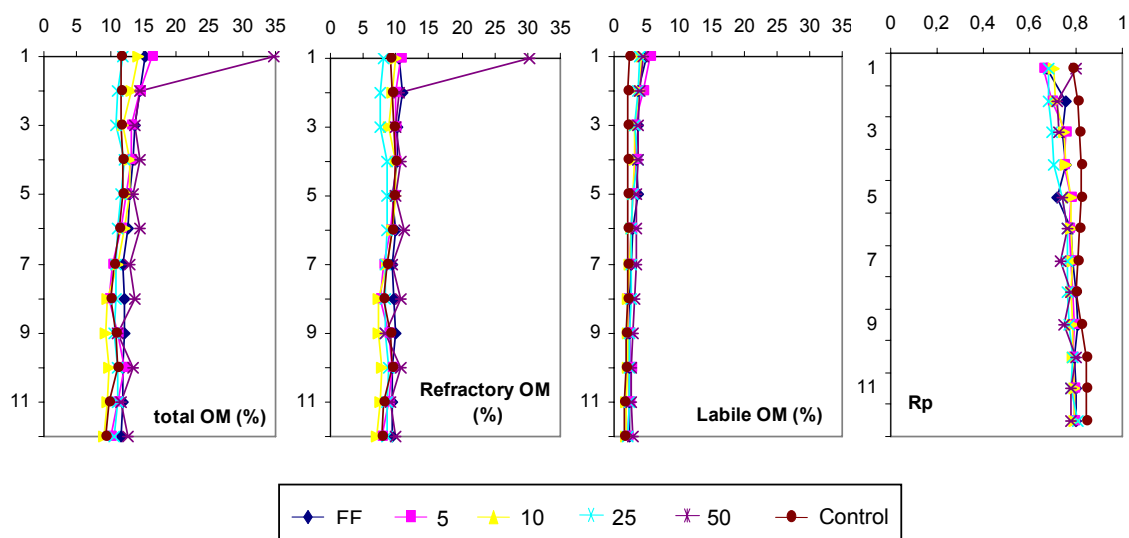


Figure 4.4. Vertical profile of total organic matter, refractory and labile percentages and Rp index for each of the sampling stations.

4.4.3 Macrofauna

99 macrofauna species were found in Cephalonia, 59% of which belong to Polychaeta (Figure 4.5). This was also the dominant taxon in terms of abundance (Table 4.14). Density ranged between 24 366 ind/m² at 5m distance from the cages and 64 437 ind/m² at 25m from the cages. The most dominant species and their density changes across the sampling transect are presented in Table 4.15. *Capitella capitata* is the dominant species very close to the cages (0m and 5 m), indicating highly enriched conditions near the cages, and although its abundance is reduced as we move away from the fish farm (Figure 4.6) it is still present at all the sampling stations.

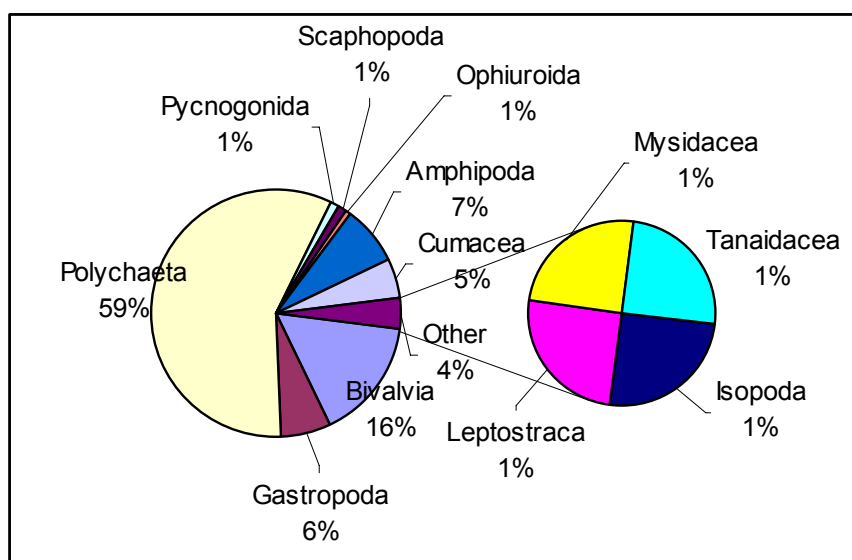


Figure 4.5. Contribution of major taxa encounter in Cephalonia fish farm.

Table 4.14. Density of macrofauna taxa (ind/m², sum of 5 replicates).

Taxon	Distance from the farm						TOTAL
	FF	5m	10m	25m	50m	Control	
Bivalvia	720,88	1441,75	3460,21	24653,98	39359,86	7929,64	77566,32
Gastropoda	144,18	144,18		432,53	144,18	432,53	1297,58
Polychaeta	50605,54	21049,60	40945,79	35034,60	5478,66	23212,23	176326,41
Pycnogonida						144,18	144,18
Scaphopoda					288,35	144,18	432,53
Ophiuroida	144,18		288,35	432,53		1730,10	2595,16
Amphipoda		288,35		1009,23	1297,58	2450,98	5046,14
Cumacea	1297,58	720,88		1297,58	1153,40	432,53	4901,96
Isopoda				144,18			144,18
Leptostraca		144,18					144,18
Mysidacea			144,18	432,53	1441,75	576,70	2595,16
Tanaidacea		576,70			144,18		720,88
TOTAL	52912,34	24365,63	44838,52	63437,14	49307,96	37053,06	271914,65

Table 4.15. Density of the 10 most dominant species at Cephalonia fish farm (ind/m², sum of 5 replicates).

Species	Distance from the farm						TOTAL
	FF	5m	10m	25m	50m	Control	
<i>Abra nitida</i>		144,18	288,35	450,55	164,77	504,61	314,56
<i>Capitella capitata</i> cf.	3503,46	2787,39	2183,23	1169,42	336,41	252,31	2040,64
<i>Ctenodrilus serratus</i>	937,14	384,47	648,79	720,88			634,37
<i>Iphinoe serrata</i>	216,26	180,22		162,20	216,26	144,18	188,05
<i>Mysella bidentata</i>	144,18	360,44	173,01	1329,62	3359,28	648,79	1461,78
<i>Nucula sulcata</i>		144,18	288,35	432,53	432,53	288,35	369,45
<i>Ophyotrocha</i> sp1.	1816,61		2450,98	1960,78	144,18		1955,38
<i>Potamoceros triqueter</i>						4181,08	4181,08
<i>Prionospio fallax</i>	216,26		973,18	552,67	240,29	198,24	432,53
<i>Terebellides stroemi</i>						576,70	576,70

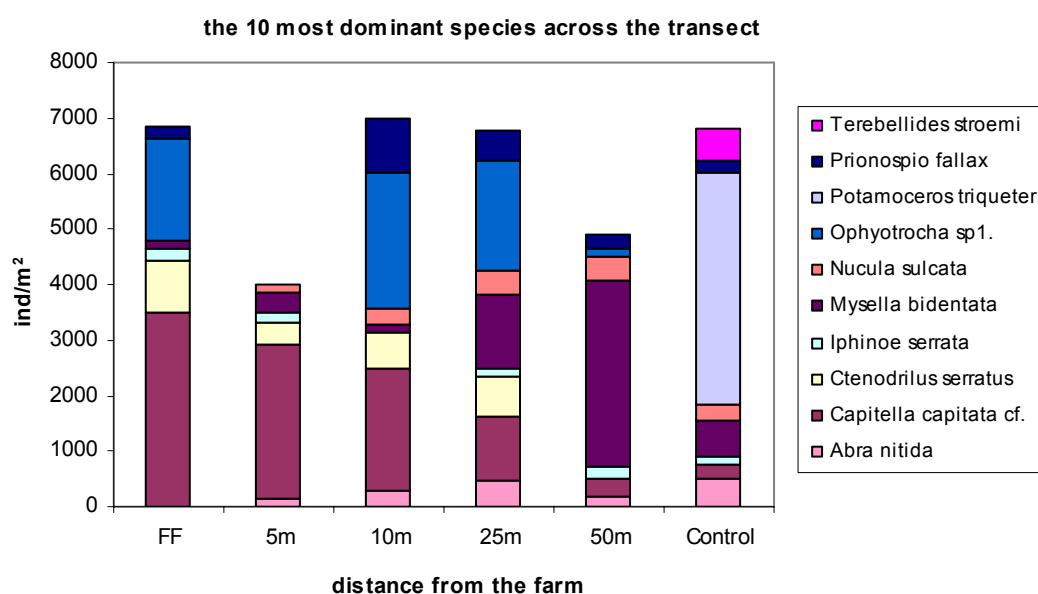


Figure 4.6. Density of the 10 species dominating in Cephalonia fish farm.

All the diversity indices that were calculated for the data set (Richness, Shannon, Margalef) were higher at the reference station and minimum near the cages (**Table 4.16, Figure 4.7**). The same trend was also observed for biomass and the distribution of individuals among species as measured by the evenness index J' , while the opposite was observed for the index BFI (**Table 4.16, Figure 4.7**). AMBI values indicated slightly disturbed conditions even at the control station, however under (0m) and near the cages (5 and 10m) bottom conditions were characterized as heavily and moderately disturbed respectively. It is worth noting the existence of a succession in the macrofauna ecological groups, as the first order opportunistic species (EG-V) dominate the sediment very close to the cages (FF, 5m), near the farm (10m) first and

second order opportunistic species (EG-V, EG-IV) co-dominate, giving their place to second order and tolerant species (EG-IV, EG-III) at a distance of 25 m. Further away (50m), tolerant species predominate, while at the control station the dominant sensitive species (EG-I) coexist with indifferent (EG-II) and tolerant (EG-III) species (Table 4.16, Figure 4.7).

Table 4.16. Macrofaunal variables for Cephalonia fish farm. (EG: Ecological group)

Index	Distance from the farm					
	FF	5m	10m	25m	50m	Control
Density (ind/m ²)	10611,30	4873,13	9083,04	12918,11	9976,93	7987,31
Biomass (4,14	0,78	15,71	10,28	8,96	33,73
Richness	28	24	24	48	39	61
Margalef	2,05	2,16	2,22	4,95	3,32	5,44
Evenness	0,51	0,61	0,72	0,82	0,54	0,88
Shannon	1,15	1,28	1,66	2,58	1,45	2,73
BFI	0,39	0,48	0,13	0,26	0,43	0,04
AMBI	5,20	4,91	4,45	3,25	2,62	1,97
EG-I (%)	5,10	7,00	5,50	17,80	14,30	18,20
EG-II (%)	1,70	5,10	4,10	5,60	3,00	48,20
EG-III (%)	3,10	10,80	14,40	33,50	77,50	23,70
EG-IV (%)	21,20	3,20	39,50	26,00	3,00	7,10
EG-V (%)	68,80	74,10	36,40	17,10	2,10	2,80

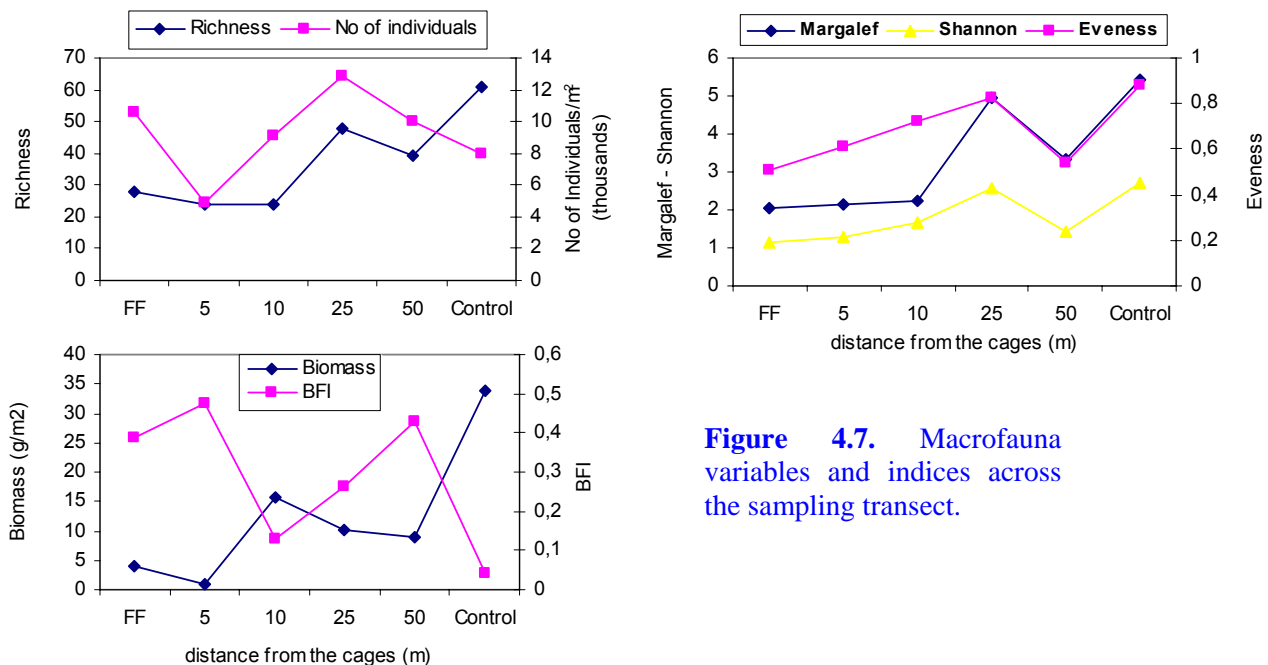


Figure 4.7. Macrofauna variables and indices across the sampling transect.

4.4.4 Meiofauna

The abundance of the major meiofaunal metazoan taxa as well as the Kinoryncha density and the Nematodes/Copepods ratio (N/C ratio), which have been suggested by some researchers as tools for assessing organic pollution (Raffaelli et al. 1991, Mazzola et al. 2000) are presented in **Table 4.17**. As it was expected, meiofaunal density showed the same spatial pattern as nematode abundance (**Figure 4.8**), having low values near the cages; however, meiofauna peaks at a distance of 25m from the cages, similarly to copepod density. Density of Kinoryncha is quite low along the transect being absent at 5 and 10 m from the cages, whilst at the reference station they appear to significantly increase. N/C ratio is higher near the cages (0-10m) exceeding 100 at 5m distance from the farm.

Table 4.17. Meiofauna variables across the sampling transect.

Abundance (ind/cm ²)	Distance from the farm						Total
	FF	5m	10m	25m	50m	Control	
Nematodes	1346,49	1845,18	3231,36	2864,04	2199,56	2369,52	2309,36
Copepods	37,28	46,27	99,78	483,55	279,61	236,84	197,22
Copepod nauplii	30,70	3,29	10,96	97,59	85,53	109,65	56,29
Kinoryncha	2,19	0,00	0,00	1,10	2,19	28,51	5,67
N/C	37,95	115,78	81,20	8,82	9,52	10,84	44,02
Meiofaunal metazoan	1688,60	2229,39	3549,34	3768,64	2836,62	2922,15	2832,46

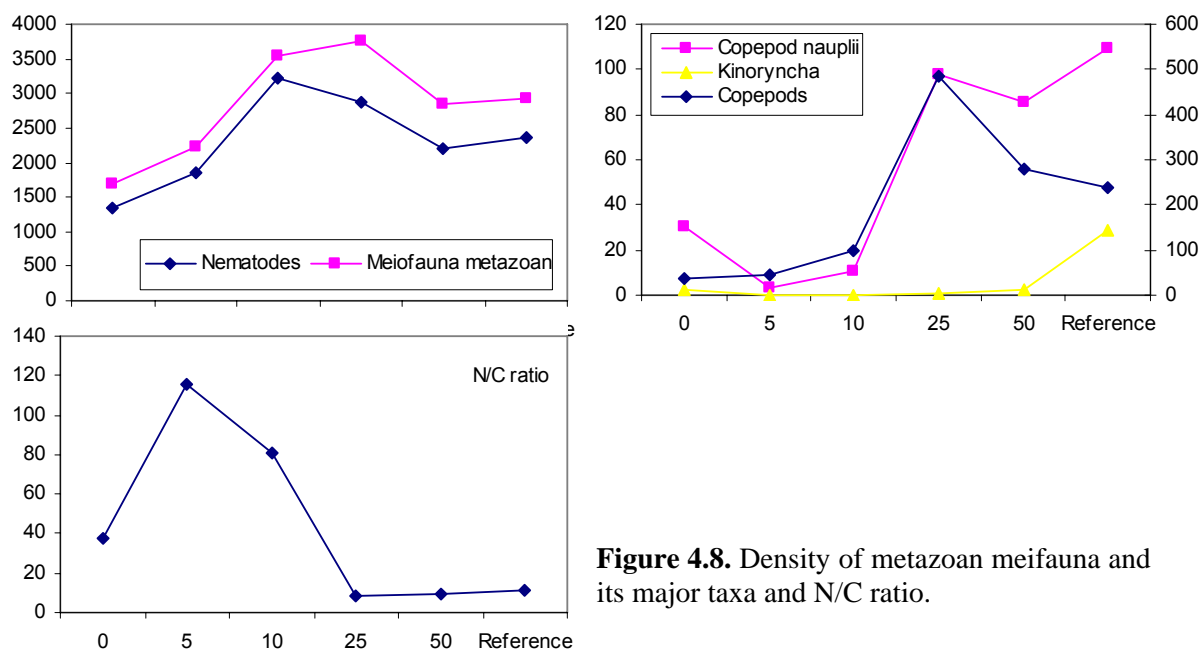


Figure 4.8. Density of metazoan meiofauna and its major taxa and N/C ratio.

4.4.5 Bioassay experiment

Two treatments of bioassays were deployed *in situ*, one for which the water used in the dialysis bags was filtered through a mesh size of 25 μm to remove grazers and one with untreated water. For both treatments, Chl-a and Total Particulate Phosphorous (TPP) values have increased compared to the initial concentrations and appeared to decrease with increasing distance from the cages (**Figure 4.9**) indicating, therefore, an effect of fish farm nutrient release on the water column primary production that could not be detected straightforward through the measuring of the water column variables presented above.

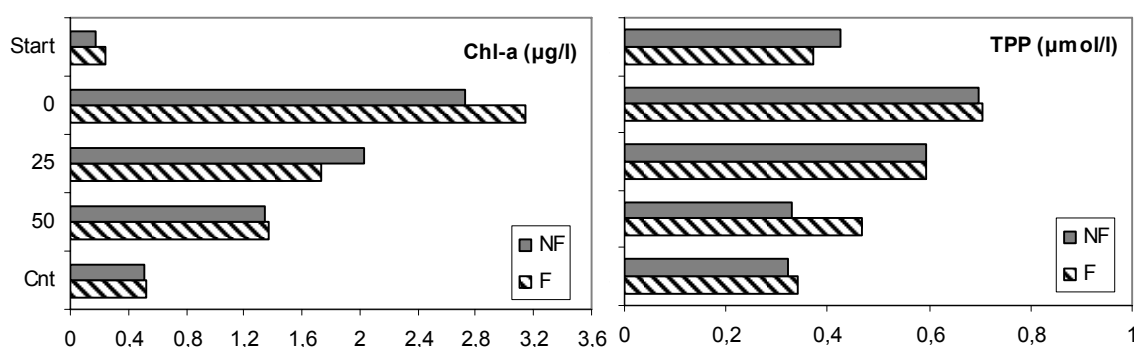


Figure 4.9. Chl-a and Total Particulate Phosphorous concentrations at the time of deployment (Start) and after retrieval for different distances from the fish farm site.

4.4.6 The MOM model

The water quality at this site is good but since the cage groups are placed along the direction of the main current the through flow is not optimised and the limiting criterion is in fact the water quality in the cages at this site. With the values of the dimensioning current (U_{min}) shown in **Table 4.4**, the longest flushing times are above 3 hours for all groups, and the longest flushing time occurs rather frequently. The oxygen concentration of the surrounding water is 5.7 mg/l, and with the configuration of *Cephalonia* 1-3, the maximum holding capacity is about 300 tonnes/year for each cage group, with a biomass of about 300 tonnes. Together the tree cage groups tested have a holding capacity of about 900 tonnes/year. Two cages groups that were not tested are somewhat smaller. The estimated total holding capacity of the farm is thus above the present production of the site of 1000 tonnes per year. The conditions in the groups with circular net pens is somewhat better due to

longer distance between the net pens, and the holding capacity can be increased further with even more separated net pens, which will increase the through flow and thereby the holding capacity of the site. There are only minor differences in the holding capacity keeping sea bream or sea bass in the cage groups. From the above results it seems that the fish farm at Kokkinos Vrakhos can increase the production with the present configuration of the farm.

The outlet of dissolved nutrients from the cage groups per 1 tonne of fish production are 10 kg of phosphorus (P), and 58 kg of nitrogen (N) for Cephalonia 1-3, and are calculated based on the requirement of the fish and the amount of protein in the food, where most of the nutrients are tied up (REF). About the same but less outlet of dissolved nutrients were found for sea bass than sea bream, with the same food. The excessive nutrients can be reduced by reducing the fraction of protein in the feed. The outlet of dissolved nutrients is hard to validate, but at this site bioassay studies showed a local increase in the chl *a* concentrations at and in the vicinity of the farm (0-50 m) compared to the reference station, but no effects on B or C scale were shown (Pitta et al. 1999, Cephalonia bioassay study).

The outlet of particulate matter from the farm per 1 tonne of fish production is 13 kg (P), 78 kg (N), 147 kg of faeces, and 977 kg of wasted food at Cephalonia 1-3. The wasted food was calculated based on the theoretical food conversion ration FCR_{teo} and the food conversion ratio given by the farmer FCR_{real} (see **Table 4.6**). FCR_{teo} is based on the requirement of the fish and type of feed given. The figures show a slightly smaller sedimentation rate with sea bream than with sea bass in the cages. The model results show that most of the outlet of particulate matter from the cages does not settle at the bottom below or near the farm due to the large current speed and the oxygen concentration at the bottom is above the critical level of 3 mg/l. ECASA observations at the site show that both the density (no. of individuals) and the diversity decreases below the cages. This indicates an enrichment of organic matter below the cages compared to the surrounding bottoms, but a well oxygenated bottom, which agree with the model result.

The production cycle for the fish to reach the weight of 1500 g with an initial weight of 10 g at this site is about 3 years and the model predicts 2.7 years for sea bream and 2.4 years for sea bass, with a median weight of 300 and 370 g during the production

cycle. We do not know which species dominates at the site, but the model results point to sea bream, or that the condition for the fish are not optimal.

4.5 Evaluation of Indicator Performance

Water column Indicators

As it was expected, most of the water column variables do not seem to be efficient estimators of the fish farm impact on the surrounding environment when measured through the traditionally analysis of water column nutrient and particulates concentrations, as their fluctuation was quite irregular over space. Chl *a* and NO₃ concentrations of near the bottom water seem to be the only two exceptions as their spatial trend revealed an impact on the water body, which was evident for the stations very close to the farm (up to a distance of 25m from the cages). The impact of the fish farm on the water body was very clearly demonstrated when bioassay experiments were set up and TPP and in particular chl *a* concentrations were measured. Therefore, and in agreement with Dalsgaard & Krause-Jensen (2006), it is concluded that the study of primary production through the deployment of bioassay experiments is a more appropriate tool for assessing the water column impact from fish farms.

Sediment Indicators

The widely used in monitoring studies Redox potential did not reveal any trend of impact at the studied site. Similarly, no obvious gradient of impact could be detected by measuring organic matter after LOI methodology. On the contrary, the traditionally measured concentrations in the sediment of TOC, TON and chl *a* as well as the less studied Phosphorus did show the existence of an impact gradient along the studied transect.

Benthic indicators

All benthic univariate indicators used in this study were useful for detecting environmental differences between the reference area and the site of the cages, however, most of them could not be used for detecting a gradient of environmental impact, the only indicators performing well on that being AMBI, its components EG-I and EG-V and the abundance of the opportunistic species *Capitella capitata*. It seems, therefore, that it is still inevitable to resort to benthic community analysis for assessing the scale of impact of a fish farm.

With regard to meiofauna, the overall conclusion seems to be that there is no distinguishable and uniform pattern of response for the meiofauna univariate variables that have been proposed for the monitoring of organic pollution. Nonetheless, the highly criticized N/C ratio as well as the abundance of the copepods nauplii seem to detect the fish farm impact and therefore could be used as an indicator for detecting fish farms effects.

4.6 Evaluation of Model Performance

Indicators used by the model to estimate the effect of the farm activity on the water column are nutrient output. The outlet of dissolved nutrients is hard to validate in this type of environment with rather short residence time as pointed out in section 4.5 above. An exact evaluation of the performance of the model can not be done but at this site bioassay studies showed a local increase in the chl *a* concentrations at and in the vicinity of the farm (0-50 m) compared to the reference station, but minor or no effects on B and C scale were shown (Pitta et al. 1999, Cephalonia bioassay study). And this agrees with the model results.

The model results show that most of the outlet of particulate matter from the cages does not settle at the bottom below or near the farm due to the high current speed and the oxygen concentration at the bottom is above the critical level of 3 mg/l. ECASA observations at the site show that both the density (no. of individuals) and the diversity decreases below the cages. This indicates an enrichment of organic matter below the cages compared to the surrounding bottoms, but a well oxygenated bottom, which agree with the model results.

4.7 Site specific conclusions

All the indicators that have been used for assessing the environmental state of the studied site indicated that there is an evident impact of the farm very close to the cages (Zone A), which is extending up to a distance of 25 to 50 m from the edge of the cages. Nonetheless, a couple of those indicators, namely AMBI and chl *a* concentrations as determined after deployment of bioassay experiments, indicated that the reference station, which fall within Zone B scale, is slightly disturbed. However, this fact can not be attributed directly to the presence of the farm in the area since other activities (e.g. tourism, fisheries, agriculture) might synergistically contribute to

the observed minor disturbance. No effects resulting from the fish farm are anticipated for Zone C.

The use of MOM model at Cephalonia site indicated that this site is suited for fish farming due to the rather high current speed. The holding capacity of the farm with the configurations of Cephalonia 1-3 and with both MOM criteria fulfilled (see above) is 300 tonnes/year for each of the groups tested by the model. Two cage groups that were not tested are somewhat smaller. Together the three cage groups tested have a holding capacity of about 900 tonnes/year. The estimated total holding capacity of the farm is thus above the present production of 1000 tonnes per year and the production may be increased. The estimated total holding capacity of the farm is thus below the present production of the site with a maximum biomass of 2000 tonnes. The limiting criteria at this site is the water quality in the cages, where the oxygen levels seem too low occasionally due to the rather long maximum flushing time of about 3 hours occurring in periods of weak current speed. The configuration of the farm is not optimal and the holding capacity of the site may be increased by separating the net pens further and place them in single rows perpendicular to the main current direction. One may also decrease FCR_{real} at this site. The protein retention of the fish with $FCR_{real}=2.0$ is only 23 %, therefore the protein content in the fish food can be reduced considerably as well.

Currently, there are no conflicts between the fish farm at Kokkinos Vrakhos and other human activities. As it has already been stated, the company offers employment to people that might otherwise have moved away from the island and therefore, local people and stakeholders have turned to be very supportive of the company. However, this attitude could change in case there was an increase in fish farming companies in the specific area, since an increase in fish farming could alter significantly the landscape from an aesthetic point of view, an aspect which is very crucial especially for the tourism industry.

Apart from a possible negative reaction that an increase in fish farming in the bay could create, there are a few more important reasons for being sceptical towards that option. First, there is a lack of oceanographic and in particular hydrographic studies in the area, which are essential for estimating the capacity of the site in terms of aquaculture development. Furthermore, at the moment there are no environmental

guidelines in Greece for establishing and monitoring aquaculture, while trained personnel and consultants that could provide the environmental services needed are very scarce. Unless, the above issues are resolved it would not be wise to further develop aquaculture in the area.

4.8 Culture type and environment type conclusions

In agreement with the findings of previous studies in the area (Pitta et al. 1999, Karakassis et al. 2005, Pitta et al. 2005), most water column indicators employed for the study of Cephalonia site (nutrient concentrations, POC and PON concentrations analysed with CHN analyzer, Secchi depth) were not efficient in detecting impact due to fish farm effluents. On the contrary, the recently developed approach of using phytoplankton bioassays for detecting the scale of fish farming effect on primary production (Dalsgaard & Krause-Jensen 2006) seems to be a very promising tool in monitoring fish farm effects.

With regard to the sediment chemistry indicators, the traditionally used Redox Potential failed to reveal any impact due to farming and so did the indicator LOI. Organic carbon and nitrogen measured by CHN analyzer as well as chl *a* concentrations were more powerful and therefore is suggested to be used instead.

From the benthic set of indicators, AMBI was the one that detected a clear gradient of impact along the sampling transect, whilst the rest of them could only separate heavily from slightly impacted stations. Meiofauna variables, such as N/C ratio and copepod nauplii showed a slight gradient of impact away from the cages, but they need to be further tested.

According to the index AMBI, the selected reference station is characterized as slightly disturbed. This fact points out the difficult task of selecting reference conditions. However, the greatest difficulty in the field of environmental monitoring of fish farms in Greece remains the absence of sound hydrographic data which would facilitate the appropriate selection of station grids and would help in the assessment of the observed patterns.

Taking into consideration all the above we conclude that:

- phytoplankton bioassays should be deployed for estimating the extent of fish farm effects on water column
- LOI can not replace the determination of organic carbon and nitrogen by CHN analyzer
- Chl *a* concentrations can provide an estimation of the level of eutrophication near to and in the sea bottom.
- AMBI is pointed out as the best indicator of environmental impact from the operation of the fish farm and should therefore be calculated when possible
- an appropriate model e.g. MOM gives valuable information of the effect of fish farming, i.e. the most important type (water column, benthic) of indicators to be measured, and also possible improvements to be made in the configuration of the farm.
- hydrographic data are needed urgently for applying an efficient monitoring system
- reference conditions should be very carefully selected
- a multicontrol monitoring strategy may help overcoming the problems related to appropriate selection of reference conditions.

5 Acknowledgements

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7 Appendices

7.1 Appendix 1: Environmental data.

Produce a metadata table with references to electronic files (e.g. spread sheets etc) containing the data collected and analyzed. Separate data clearly into water column, sediments and benthos...

Metadata table

Study environment	File type	Parameter(s)	Headings	Location	Prepared by
water column	Excel	CTD	ST_CODE; DATE; TIME_GT; LAT_DEGR; LAT_MIN; LON_DEGR; LON_MIN; SPINDLE; DATUM; Z_DEPTH; Z_SAMPLE; TEMP; SAL; PAR; CHLA	C:\Katerina\ECASA\Data\water\CTD.xls	Katerina Sevastou
	Excel	CHN	ST_CODE; DATE; TIME_GT; LAT_DEGR; LAT_MIN; LON_DEGR; LON_MIN; SPINDLE; DATUM; Z_DEPTH; Z_SECCHI; Z_SAMPLE; NITRITE; NITRATE; AMMONIUM; PHOSPHATE; SILICATE; CHLA; POC; PON; C/N	C:\Katerina\ECASA\Data\water\water column variables.xls	Katerina Sevastou
	Excel	Nutrins			
	Excel	Secchi depth			
Bioassay experiment	Excel	CHN	Code; A/A; Site; Distance; Replicate; Treatment; Volume; N (ug); C (ug); C (ug) transformed; N (ug/l); C (ug/l); N (mol/kg); C (mol/kg); Chla (mg/l); Phaeop. (mg/l); CPE; TPP (umol/l); PIP (umol/l); POP (umol/l)	C:\Katerina\ECASA\Data\water\data_bioassay.xls	Katerina Sevastou
	Excel	Chl a			
	Excel	TPP			
	Excel	TOP			
Sediment	Excel	Eh	Code; Season; Site; Distance; Replicate; Layer; T (°C); Eh (mV); Eh standardised	C:\Katerina\ECASA\Data\raw data\Redox.xls	Katerina Sevastou
	Excel	CHN	Code; Season; Site; Distance (m); Replicate; Layer; sample weight; ug N; ug C; ug N/mg; ug C/mg; C/N; ug N/kg; ug C/kg; N (mol/kg); C (mol/kg); CN; remarks	C:\Katerina\ECASA\Data\sediment\sediment_over all variables.xls (Worksheet CHN)	Katerina Sevastou
	Excel	LOI	Code; Season; Site; Distance (m); Replicate; Layer; Wc; W0; W 250; W 500; PI; PII; Rp; % labile OM; % refractory OM; total OM; Ws	C:\Katerina\ECASA\Data\sediment\sediment_over all variables.xls (Worksheet LOI)	Katerina Sevastou
	Excel	Phosphorus	Code; Season; Site; Distance (m); Replicate; Layer; TP (mg/g); IP (mg/g); OP (mg/g); TP (mol/kg); IP (mol/kg); OP (mol/kg); Notes	C:\Katerina\ECASA\Data\sediment\sediment_over all variables.xls (Worksheet P)	Katerina Sevastou
	Excel	Chl a	Code; Season; Site; Distance (m); Replicate; Layer; Chla (ug/g); Phaeop. (ug/g); CPE (ug/g)	C:\Katerina\ECASA\Data\sediment\sediment_over all variables.xls (Worksheet Chl-a)	Katerina Sevastou
Benthos	Excel	macrofauna abundance	sample code; site; distance (m); replicate; sieve; phylum; subphylum; class; order; family; Genus; GenusSpecies; abundance (raw data); density (in/m ²)	C:\Katerina\ECASA\Data\raw data\1EA2macrofauna.xls	Nafsika Papageorgiou
	Excel	macrofauna biomass	code; site; distance (m); replicate; sieve; phylum; class; family; Genus; GenusSpecies; abundance; biomass	C:\Katerina\ECASA\Data\raw data\Species (abundance+biomass).xls	Nafsika Papageorgiou
	Excel	macrofauna biomass	site; distance (m); replicate; g(0,5mm); g(1mm); Total; BFI	C:\Katerina\ECASA\Data\raw data\Total biomass.xls	Nafsika Papageorgiou
	Excel	macrofauna diversity indices	station; S; N; d; J'; H'(loge); H'(log2); 1-lambda; N1; N2; Ninf	C:\Katerina\ECASA\Data\macrofauna\indices_Cep halonia.xls	Katerina Sevastou
	Excel	meiofauna	sample code; participant; location; year of study; month; site; sampling gear; sample size; distance from cages (m); replicate; Nematoda; Soft bodied; Copepoda; Copepodites; Copepoda nauplii; Cops; Total Cops; Polychaeta; Oligochaeta; Ostracoda; Kinoryncha; Tardigrada; Halacaroidea; Amphipoda; Cnidaria; Tanaidacea; Notes	C:\Katerina\ECASA\Data\meiofauna\meiofauna.xls	Katerina Sevastou

