



Environmental impact of sea bass cage farming in the north Adriatic Sea

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Paper received October 2, 2005; accepted January 12, 2006

ABSTRACT

The main objective of the research was to reduce the organic and nutrient load under the net pen fish farms. An experiment was conducted to study the effects of artificial barriers fixed under a set of sea cages in order to reduce the environmental impact. The artificial barriers were made of four submerged galvanized steel pipes coated with plastic and placed on the sea floor (10 m depth) in the Trieste gulf. The experimental design was as follows: control (C), cages with barriers (B), cages without barriers (WB). Measurements were taken on the surface as well as at 4 and 8 m of depth. The trial lasted from the end of June 2000 to December 2001. Water quality parameters were not significantly influenced by the fish cages. Surface samples were characterised by lower levels of salinity and higher levels of oxygen and nitrate compared to those taken at 4 and 8 m. The artificial barriers favoured the establishment of a rich epiphytic fauna that took advantage of the presence of organic matter derived from fish cages. The two species *Nucula nucleus* and *Neanthes caudata* and the total bacterial counts were identified as potential indicators of pollution under the fish cage farms.

Key words: Sea bass, Sea cages, Environmental impact.

RIASSUNTO

IMPATTO AMBIENTALE DELL'ALLEVAMENTO DI SPIGOLE IN GABBIE GALLEGGIANTI NEL MAR ADRIATICO

*L'obiettivo principale della ricerca era ridurre il carico organico ed inquinante sotto le gabbie galleggianti. È stato realizzato un esperimento per studiare gli effetti di barriere artificiali poste sotto le gabbie per ridurre l'impatto ambientale. Le barriere artificiali erano costituite da quattro tubi d'acciaio ricoperti di plastica e poste ad una profondità di 10 m nel golfo di Trieste. La prova si è svolta da giugno 2000 a dicembre 2001. I parametri di qualità dell'acqua non vennero influenzati significativamente dalla presenza delle gabbie dei pesci. I campioni di superficie erano caratterizzati da livelli più bassi di salinità e da livelli più elevati di ossigeno e nitrati rispetto a quelli rilevati a 4 e 8 m. Le barriere artificiali hanno favorito l'instaurarsi di macrofauna epifitica in relazione alla maggiore presenza di materiale organico. Le due specie *Nucula nucleus* e *Neanthes caudata* ed il numero di batteri totali sono stati identificati come indicatori potenziali di inquinamento sotto le gabbie galleggianti.*

Parole chiave: Spigola, Gabbie galleggianti, Impatto ambientale.

Introduction

The spread of intensive floating cage fish farms along the Italian coastal zones creates serious

problems with respect to the effects of pollution (Brizzi *et al.*, 2002; Porello *et al.*, 2002).

After the feeding of fish, excretory products and solid sediments (uneaten food and faeces) fall into

the sea and are deposited on the sea bottom. The quantity and composition of sediments and released products depend upon several factors, such as the food composition, intake level, water temperature, depth and speed of the water (Silvert, 1992). The chemical water characteristics (oxygen, ammonia, nitrite, nitrate, BOD) are often modified under the cages (Karakassis and Hatziyanni, 2000; Fernandes *et al.*, 2001).

The pollution impact of sea cages can be estimated by means of specific models such as the amount of solid wastes under the cages (Crome *et al.*, 2002), the dispersion of the solid wastes in a marine basin (Doglioli *et al.*, 2002) or the impact of the benthic community (Mehlenbacher, 2002). The identification of bacteria and macrobenthos family groups, which are indicators of pollution, is a very important step in order to carry out large scale monitoring programmes (Read and Fernandes, 2003).

At the same time, the attention of researchers has been focused on several methods to reduce the environmental impact of fish cages. Lupatsh and Kissil (1998) reared detritivorous fish under the cages to reduce the sediments and Spanier *et al.* (2002) used artificial barriers to reduce the environmental impact.

The scope of the present research was to study the environmental impact of intensive fish cages with and without artificial barriers on water quality parameters and macrobenthic communities during an 18-month period.

Material and methods

The experiment was carried out in the north Adriatic Sea, in the Trieste gulf at about half a mile from the coast (Figure 1). Water depth was about 10 - 11 metres. Six submerged cages of cylindrical shape (diameter 5 m, volume 80 m³) were used. Each cage was connected by means of textile ropes to a previously existing long line used for mollusc production. Both the extremities of each cage were shaped as a funnel. The upper part of the cage was connected to a floating circular collar used for the distribution of the feed. The bottom of each cage was closed with a rope. On the bottom of the sea, five artificial barriers were fixed. Each artificial barrier (Figure 2) was made of four cor-

rugated plastic pipes (diameter 0.4 m, length, 1 m) connected by means of a short galvanized chain to the four corners of a squared plastic coated galvanized steel frame. At each corner a galvanized steel spike was used to fix the barrier on the bottom.

The trial lasted from the end of June 2000 to December 2001 (29/6/2000 - 14/12/2000; 1/01/2001 - 19/12/2001). At the beginning of the trial, 3000 European sea bass for each cage (*Dicentrarchus labrax*) (initial weight: 9.2±0.6 g) were randomly distributed among the cages. The fish were manually fed a commercial diet twice a day according to the estimated live weight and water temperature. Growth rate was estimated periodically using the deep netting technique (Doherty, 1991). The total number of fish was determined at the end of the first and second period. Chemical water analysis and sediments were monitored every two weeks (water salinity, temperature, oxygen, ammonia, nitrate, nitrite and phosphorus concentrations) (APHA, 1995) at the following sites: control (no cages) (C), cages with artificial barriers (B) and cages without artificial barriers (WB), on the surface and at 4 and 8m of depth. Samplings of sediments to measure the number of bacteria were performed by scubas three times per year. The number of sulphate reducing, ammonia producing and proteolytic bacteria (Most Probable Number) (MPN) were measured on the sediment (APHA, 1995).

Species identification and the counting of macrobenthos were carried out on the superficial layer (25 cm).

Visual census of wild fish near the cages was performed by scubas four times per year. Data were subjected to statistical analysis using SAS (1999). The Shannon-Wiener and Margalef indexes were calculated with the INSTAT 2.0.9 package. Multi Dimensional Scaling (MDS) was performed according to Bray-Curtis similarity index on a square root transformed abundance data using the PRIMIER 5.2 software (Clarke and Warwick, 2001).

Results

Final live weight of sea bass was on average

Figure 1. Map of the Trieste gulf showing the location of the marine fish farm.



Figure 2. The artificial barriers showing the four corrugated pipes.

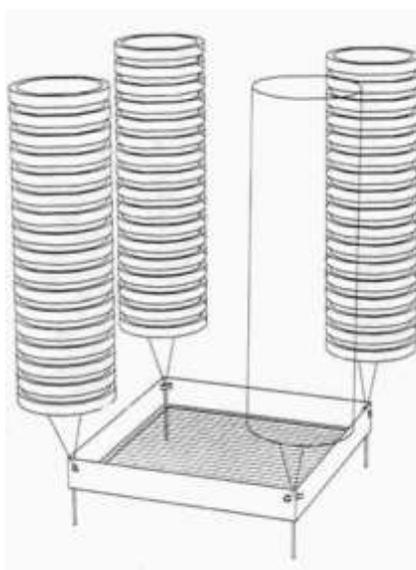
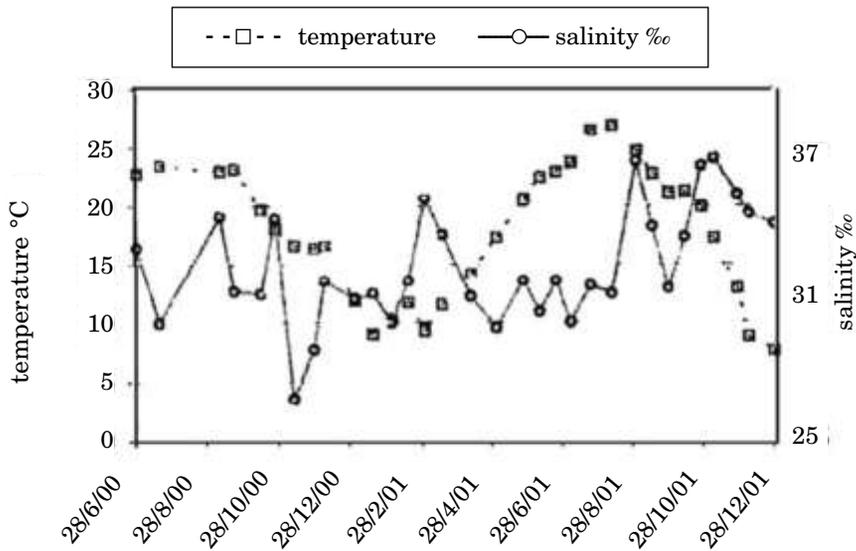


Figure 3. Temperature and salinity measurements during the experiment.



76.59 ± 7.0g, in the year 2000 (29/6/2000 – 14/12/2000) and 272 ± 20g in 2001 (1/01/2001 – 19/12/2001, respectively. Feeding rate was: 0.98 ± 0.03 and 1.19 ± 0.04% b.w. in 2000 and 2001, respectively; stocking rate, 0.36 ± 0.01; 2.5 ± 0.10 and 10.33 ± 0.27 kg/m³ at the beginning of the trial, in 2000 and 2001, respectively, and survival rate, 99 ± 0.03% and 97 ± 0.74% in the year 2000 in 2001, respectively.

Quality water parameters measured during the experiment are presented in Figure 3 and Table 1. Results of water analysis showed a significant difference in the salinity, oxygen and nitrate concentrations in the three sites (Surface, 4m, 8m). Surface samples were characterised by lower levels of salinity and higher levels of oxygen and nitrate compared to those taken at 4 and 8 m of depth. Phosphate concentration was higher in the control site than B and WB treatments.

The total number of bacteria (Table 2) was clearly influenced by the fish cages showing a lower number of sulphate, ammonia and proteolytic species in the control site. No differences were noted for sulphate and ammonia bacteria between the sites with and without artificial barriers.

Analyses of macrobenthos showed significant

differences among treatments. The presence of the cages negatively influenced the number of species that were 12.8. (average of all the samplings under the cages) compared to 19 in the control station. The number of species and number of individuals within species decreased in the site with artificial barriers compared to C and WB. The diversity index (Shannon-Wiener and Margalef indexes) and MDS analysis confirmed these data showing a high similarity among the WB samples (Figure 4 and 5) although differences between control and cage without barriers were not always well defined.

The presence of fish in the cages attracted several wild fish species (Table 3). The number of wild fish species and the diversity Shannon-Wiener and Margalef indexes (Table 4) increased during the summer in 2000 and 2001.

Discussion

The production performance of sea bass during the experiment can be considered intermediate considering, above all, the characteristic temperature of the gulf of Trieste showing low temperatures during the winter period. For this reason,

Table 1. Effects of the experimental factors on water quality variables.

		Year		Experimental factors			Depth			Error Variance
		2000	2001	C	WB	B	Surface	4 m	8 m	df = 171
Temperature	°C	20.11	17.14	16.92	17.00	16.90	17.08	17.03	16.69	2.502
Salinity	‰	31.6	32.8	32.3	32.9	32.8	25.9 ^B	35.9 ^A	36.0 ^A	1.19
O ₂	mg/l	5.62	5.57	5.72	5.53	5.56	5.93 ^A	5.56 ^B	5.38 ^B	0.276
NH ₄	"	0.11	0.18	0.12	0.16	0.15	0.10	0.16	0.19	0.057
NO ₂	"	0.03	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.002
NO ₃	"	0.82	2.33	1.65	2.11	1.86	2.10 ^a	1.64 ^b	1.42 ^b	0.002
PO ₄	"	0.36	0.20	0.32 ^A	0.15 ^B	0.17 ^B	0.27	0.22	0.22	1.604

C: Control; WB: Without Barriers; B: Barriers.

Means within the same row not shearing a common superscript are significantly different (A,B : $P < 0.01$; a,b : $P < 0.05$).

Table 2. Effects of the experimental factors on the number of bacteria (Most Probable Number).

Bacteria	Years		Experimental treatments			Error Variance
	2000	2001	C	WB	B	df = 14
Sulphate reducing	3018	2296	792 ^B	3350 ^A	3630 ^A	3,000,000
Ammonia producing (x 1000)	10,945 ^a	5251 ^b	1123 ^B	9841 ^A	13,329 ^A	3,700,000
Proteolytic	6622	3967	3417 ^b	4012 ^b	8456 ^a	14,766,537

Means within the same row not sharing a common superscript are significantly different (A,B : $P < 0.01$; a,b : $P < 0.05$).

the effective feeding period was not very long. During the experiment, feed was distributed to fish for 132 days in 2000 and 214 days in 2001.

The salinity concentrations were lower on the sea surface due to the water coming from the Isonzo river while oxygen and nitrate contents were higher. The other water quality characteristics (with the exception of phosphate concentrations) were not significantly influenced by cages and experimental treatments. Changes at marine sites of the water quality characteristics, where dilution is much more rapid, are often transitory (Weston, 1991). Lefebvre *et al.* (2001) observed a continuous phosphorus and nitrogen exchange between the sediment and the water.

The number of bacteria (MPN) found in the sediment was lower in the control site indicating a smaller presence of organic substances. Similarly, La Rosa *et al.* (2001) showed an increase in the number of bacteria within the food web as a consequence of the organic matter load. Sediments (food and faeces) stimulate microbial production and changes are correlated with waste loadings and accumulation (Beveridge, 1996). This in turn leads to the anaerobic generation of hydrogen sulphide and methane changing the wild benthic populations (Beveridge, 1996).

A clear difference was shown for macrobenthos in sediments under cages with artificial barriers. These were quickly colonized by many species.

Figure 4. Dendrogram of grouping of the experimental factors utilizing the similarity index (Shannon-Wiener) based on the number of benthic species in the sediments.

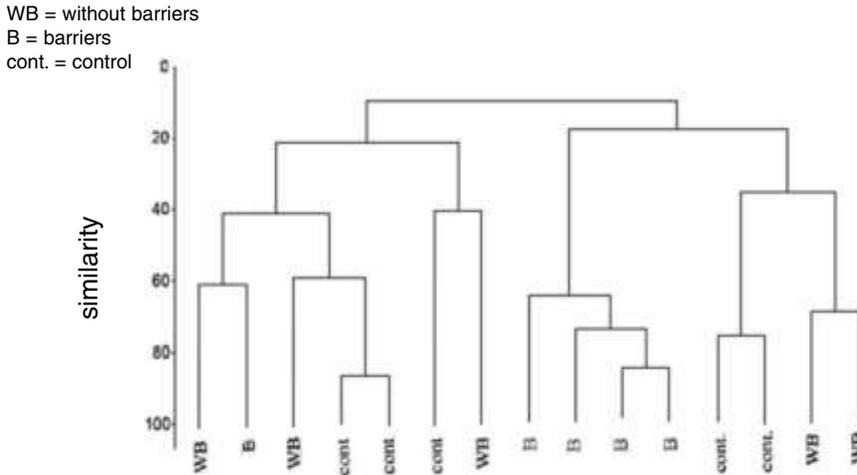
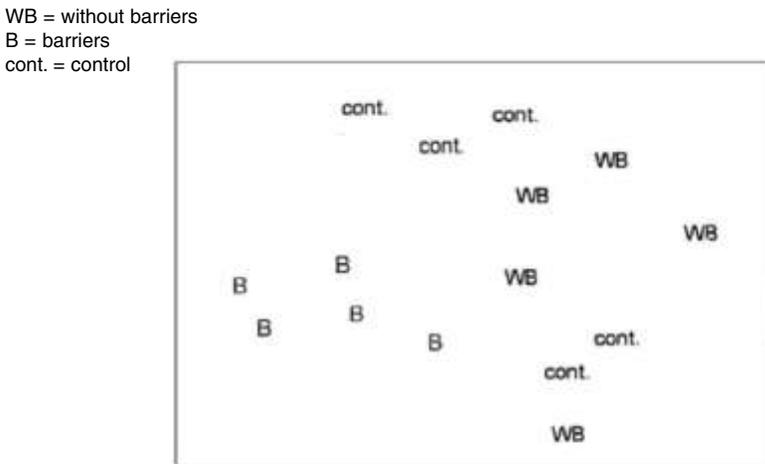


Figure 5. MDS plots for the experimental factors based on the number of benthic species in the sediments.



Number of species was higher than in the control and WB treatment. Angel and Spanier (2002) reported a noticeable increase in invertebrates and fish after six months of using an artificial reef situated under a commercial net cage farm.

Bombace *et al.* (1994) constructed along the Italian Adriatic coast artificial reefs of different sizes that were rapidly colonized by different organisms, mainly mussels (*Mytilus galloprovincialis*) and other sessile organisms. Most of these

Table 3. Number and abundance of wild fish species observed near the cages.

Species	Family	Sampling dates							
		06/00	08/00	09/00	12/00	05/01	08/01	09/01	10/01
<i>Atherina hepsetus</i>	<i>Atherinidae</i>			3		3	3	3	
<i>Belone belone</i>	<i>Belonidae</i>		1	1			1		
<i>Chrisophris aurata</i>	<i>Sparidae</i>		1	2			2		
<i>Dicentrarchus labrax</i>	<i>Serranidae</i>			2	2	2	2	3	
<i>Diplodus annularis</i>	<i>Sparidae</i>	1	1					1	1
<i>Diplodus puntazzo</i>	<i>Sparidae</i>		1						
<i>Diplodus vulgaris</i>	<i>Sparidae</i>	1	1				2		
<i>Lichia ama</i>	<i>Carangidae</i>			1			1	1	1
<i>Mugil cephalus</i>	<i>Mugilidae</i>			2			3	3	3
<i>Sargus rondeletii</i>	<i>Sparidae</i>		1				2		
<i>Crenilabrus griseus</i>	<i>Labridae</i>	1	2	2		2			
<i>Crenilabrus tinca</i>	<i>Labridae</i>		1	2		2	2		3
<i>Gobius exanth</i>	<i>Gobiidae</i>			1		1	1	2	1
<i>Lepadogaster lep.lepadogaster</i>	<i>Gobiesocidae</i>					1			
<i>Lipophrys adriaticus</i>	<i>Blenniidae</i>			2	2	2	3	2	
<i>Lipophrys dalmatinus</i>	<i>Blenniidae</i>			1	2	2	2	1	
<i>Parablennius gattorugine</i>	<i>Blenniidae</i>		1	1					
<i>Parablennius incognitus</i>	<i>Blenniidae</i>				2	2	2	1	1
<i>Parablennius rouxi</i>	<i>Blenniidae</i>	1	1	1	1	1	1		1
<i>Parablennius tentacularis</i>	<i>Blenniidae</i>	1	1	1	1	1	1		1
<i>Serranus hepatus</i>	<i>Serranidae</i>	1	2	2	1	1	1	2	
<i>Gobius jozo</i>	<i>Gobiidae</i>		2	2		3	3	1	1
<i>Hippocampus ramulosus</i>	<i>Syngnathidae</i>	1				1			
<i>Phrynorhombus unimaculatus</i>	<i>Bothidae</i>			1	1	1			
<i>Solea kleinii</i>	<i>Soleidae</i>	1							2
<i>Solea lascaris</i>	<i>Soleidae</i>	1						1	2
<i>Syngnatus acus</i>	<i>Syngnathidae</i>	1							
N. of species		10	13	17	8	15	17	12	11
Abundance		10	16	27	12	25	32	21	17

sessile organisms are filtering animals that utilize the organic output from the fish cages.

More obvious are the effects caused by sea cages compared to the control. In fact, the greater amount of organic substances under the cages

determined a reduction of the number of species (12.8, average of all the samplings under the cages, compared to 19 in the control station) with a simultaneous decrement in the number of organisms per surface unit. Marine benthic communi-

Table 4. Total number of species, Shannon and Margalef indexes of wild fish species observed near the cages by visual census.

	Sampling dates							
	06/00	08/00	09/00	12/00	05/01	08/01	09/01	10/01
N. species	10	13	17	8	15	17	12	11
Shannon index	1.00	1.09	1.19	0.96	1.14	1.24	1.03	0.79
Margalef index	3.91	4.33	4.85	2.81	4.35	4.62	3.62	3.53

ties often showed similar patterns of response. Beveridge (1996) also reported an increase of the anoxic organic matter under the cages with a reduction of benthic infaunal density and diversity. In Australia, McGhie *et al.* (2000) observed the accumulation of uneaten food under the cages and a period of rest of one year was not sufficient to totally restore the quality of the marine bottom under the cages. Pawar *et al.* (2001, 2002) reported the formation of a layer of anoxic organic material under the cages with modest seasonal variations. They observed a tight relationship between the amount of food distributed and the accumulation phenomenon. Yokoyama (2002) studying the benthic macrofauna observed their disappearance during the summer in relation to the feeding of fish. Similar studies were carried out in Korea by Park and Kim (2002) showing the presence of rich opportunistic fauna under the cages, by Brizzi *et al.* (2002) in the gulf of Trieste where they observed lower modifications in the macrobenthos, and by Porrello *et al.* (2002) along the coast of Tuscany.

The most abundant group were molluscs and anellidae. Concerning the former group, this was more abundant in the sediment of the control compared to the cages (4.66 vs 2.77). The most represented species was *Mytilus galloprovincialis* and *Nucula nucleus*, while the number of individuals turned out to be similar (C, 13.2 vs under cages, 14.5). Also for the anellidae, the situation was similar with an average number of species of 12.2 with respect to a value of 6.4 for the sediments under the cages. The most represented species under the cages was the *Neanthes caudate*, while it was not found in the control site. The opportunistic species

Capitella capitata reported by other authors was not found in the present study. The analysis of similarity utilizing the Shannon index showed that the experimental samples (B and WB) can be classified in two distinguished subgroups.

The visual census of the wild fish near the artificial barrier showed a remarkable change in the type of wild fish. Although, there is a clear seasonal effect, particularly on the nektonic fish whose number shows a decrease following the reduction of the water temperature, the presence of cages has undoubtedly favoured the presence of wild fish. Moreover, the artificial barriers located under the cages favoured the development of species that usually inhabit rocky substrates, while the number of species typical of sandy substrates was reduced. Spanier *et al.* (1985) and Spanier (2000) reported a similar increase in the number of wild fish under cages rearing *Sparus aurata*

Conclusions

Several conclusive remarks can be drawn from this experiment. First of all, water analyses due to the high variability observed among the periods of samplings, did not show a clear effect of the fish cages, at least in the area selected for the trial. On the other hand, the bacterial counts performed on the sediment can detect the presence of cages as their number showed a higher level for increasing amounts of organic matter in the sediment. Also, the analyses on fauna that colonized the superficial layer of the sea bottom are able to clearly respond to a fish farm presence. Artificial barriers favoured the establishment of a rich epithetic fauna that takes advantage of the presence of organic matter

derived from fish cages and they have a positive effect in reducing the environmental impact of fish farms. Moreover, artificial barriers can contribute to favour the establishment of wild fish that usually colonize rocky substances, taking advantage of the large amounts of shelter offered by barriers. On the other hand, the presence of cages also attracts pelagic fish, contributing in this way to reduce the impact of cages.

This work was funded by a grant from the Ministry of Agricultural and Forestry Policies (MIPAF) Italy, Project 5 C56, Fifth Plan of Fishery and Aquaculture.

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