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On the impact of a sea bass (*Dicentrarchus labrax L.*) cage farm on water quality and macrobenthic communities*

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In Croatia, the marine fish farming industry has developed over the two decades. Therefore, the floating cages are now located in the majority of semi-enclosed coastal basins. The expected expansion of industry, in terms of new locations and increased production of existing ones asks for the proper assessment of potential impact of the farm in its surrounding environment.

This paper presents the first study on water quality and benthic community in an inshore sea bass cage farm producing around 200 t y^{-1} over almost 15 years. The relationship between feed supply and the effect parameters like nutrient content, phytoplankton biomass, and organic matter in sediments was found rather weak. However, significant changes in the oxygen saturation in the cages during the summer were recorded, when it occasionally may drop bellow 70% in the morning time. Survey on macrobenthic communities showed benthic flora and fauna still quite rich and diverse. On the other hand, with respect to its composition, structure, and distribution, some benthic components were clearly affected by the fish farm. Well-developed Posidonia oceanica *beds have almost disappeared beneath the cages and they are in regression in the entire bay. In the water of farm surroundings, some nitrophilic algal species dominated the biomass, while the number of Chlorophyta exceed the one of Phaeophyta.*

Based on these results, it appears that further enrichment of the bay should include such a monitoring effort, which will ensure that observed ecological changes associated with the farming activities are kept within acceptable levels.

Key words: environmental impact, cage farm, sea bass, water quality, macrobenthos

INTRODUCTION

The majority of cultured marine fish species in Croatia, like in the Mediterranean are ongrown in net cages. Even though, numerous offshore and semi-offshore models have been tested, in most cases farms are of light construction, fabricated of locally available materials, and placed in the semi-enclosed coastal areas.

The intensive production of fish in net cages may generate the considerable amount of nutrients through uneaten feed and feces (GOWEN and BRADBURY, 1987; MAKINEN, 1991; HANDY and POXTON, 1993; ACKEFORS and ENELL, 1994). Nutrients of greatest concern at present are phosphorus and nitrogen compounds. It has been estimated for example, that in Nordic salmon operation organic waste may reach 2500 kg wet weight with 10 kg phosphorus and 60 kg nitrogen per tonne live weight fish (ACKEFORS and ENELL, 1994).

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Diet composition plays a large part in determining input of nutrients to environment (MEDALE *et al.*, 1998). It seems that high values for feed conversion rate can be obtained by under-feeding, as well as by over-feeding (CHO, 1992; AZEVEDO *et al.*, 1998).

Environmental issues relating to the coastal aquaculture wastes are widely discussed in the recent literature. Some studies have concluded that the waste nutrient loadings to coastal areas are comparatively unimportant (WESTON, 1991) or "still of speculative nature" (BARG, 1992). Others have found only weak relationship between nutrient loading and phytoplankton chlorophyll (WALLIN and HAKANSON, 1991). HANSEN *et al.* (1991) has found that only sediments under cages and close to cages are affected. However, in sheltered coastal basins with restricted exchange of waters, changes in the community structure of macrobenthos were recorded (BROWN *et al.*, 1987; RITZ *et al.*, 1990), as well as physical and chemical changes in the sediment (BROWN *et al.*, 1987; HANSEN *et al.*, 1991). Oxygen depletion of the entire water body can be significantly depressed by mariculture and within sheltered farm may fall below safe level (AURE and STIGEBRANDT, 1989).

With the exception of few short-term surveys and unpublished reports, there have been no studies on the effects of effluent from fish-cage farms in Croatian coastal waters. In practice, only big farms are monitoring some basic hydrographic parameters on their own, tending to obtain a suitable basis to maintain the production at a relatively safe level. The aim of these preliminary studies was to elaborate the basic biological and hydrological data in order to assess whether a 15 years cage farm operation levelling production around 200 tonnes per year is still in harmony with the local environment.

MATERIAL AND METHODS

Production records

Production record for a sea bass (*Dicentrarchus labrax* L.) production cycle in the period between June 1994 and December 1995 is shown in Table 1. Fish production was 231 tonnes with a feed consumption of 521 tonnes.

Table 1. Sea bass production records from the farm. Final stocking density in cages was 12 kgm^{-3}

Month-end	Days	Weight (g/fish)	Total biomass (t)	Total feed (t)	FCR[1]	TGC[2]	T (C°)
1994							
Initial (June 15)		3					
December	200	90	80	144	1.9	0.078	16.0*
1995							
January	31	105	93	25	1.9	0.06	12.7
February	28	115	102	22	2.4	0.045	11.5
March	31	123	107	12	2.4	0.033	10.8
April	30	132	111	13	3.2	0.030	13.0
May	31	145	117	27	4.5	0.032	16.3
June	30	160	127	27	2.7	0.030	19.7
July	31	190	145	51	2.8	0.047	21.8
August	31	223	167	53	2.4	0.046	23.0
September	30	260	190	60	2.6	0.052	20.3
October	31	290	207	39	2.3	0.039	19.6
November	30	312	222	29	1.9	0.031	17.5
December	31	330	231	19	2.1	0.027	15.2
TOTAL in 1994/95	565			521	2.3	0.051	

* Average temperature from June to December was 19.5°C

1. Food Conversion Rate (FCR) = amount of food given (t)/fish biomass increase (t)
2. Termal - unit Growth Coefficient (TGR) = $[FBW^{1/3} - IBW^{1/3}] / \Sigma [T \times D] \times 100$
   where FBW is final body weight (g), IBW initial body weight (g), T is water temperature (°C) and D number of days.

The phosphorus and nitrogen load was approximated according to the recommendation provided by ACKEFORS and ENELL (1990). The estimate was based on a food containing 0.9% phosphorus and 7.2% nitrogen with an average food coefficient (gain/feed) of 2.3%. Total mortality was 30% over 565 days. From the production records the thermal-unit growth coefficient (TGC) was calculated (CHO and BUREAU, 1998; KAUSHIK, 1998).

Salinity was rather stable and throughout a year is in the range of 36 to 37.5 ppt; at surface some dilution were recorded during high runoff. The temperature fluctuates from 10°C in winter to 23°C in summer. The vertical amplitudes (from surface up to 10m depth) were from 0.2°C in autumn to 1.3°C in spring. Daily differences in surface waters were from 0.1°C in September to 0.8°C in May.

Description of the area studied

The study was conducted in the Mala Lamljana Bay, on the island of Ugljan, which is located in the central coast of Croatia, where a relatively large sea bass cage farm was established (Fig. 1). Pilot scale production started in 1981, and from 1983 industrial scale production varied from 150 to 250 tonnes per year. In 1994 the farm was split in a way that four platforms are replaced closer to the entrance of the bay to facilitate better rearing conditions for commercialisation of yearly fish.

The main fish being cultured is the sea bass *(Dicentrarchus labrax)*, which represents about 90% of the population produced. Other species are gilthead sea bream *(Sparus aurata)*, shipnose bream *(Diplodus puntazzo)* and red sea bream (*Pagrus major*). The production of molluscs (*Mytilus galloprovincialis* and *Ostrea edulis)* has never exceeded 50 tons per year.

The bay is about 1.8 km long and 0.3 to 0.7 km wide. The floating platforms are situated in the area where depth is ranging from 15 to 30m, while the depth in the lower central part of the bay and at the communication with the open sea is exceeding 30m. The site has a low public

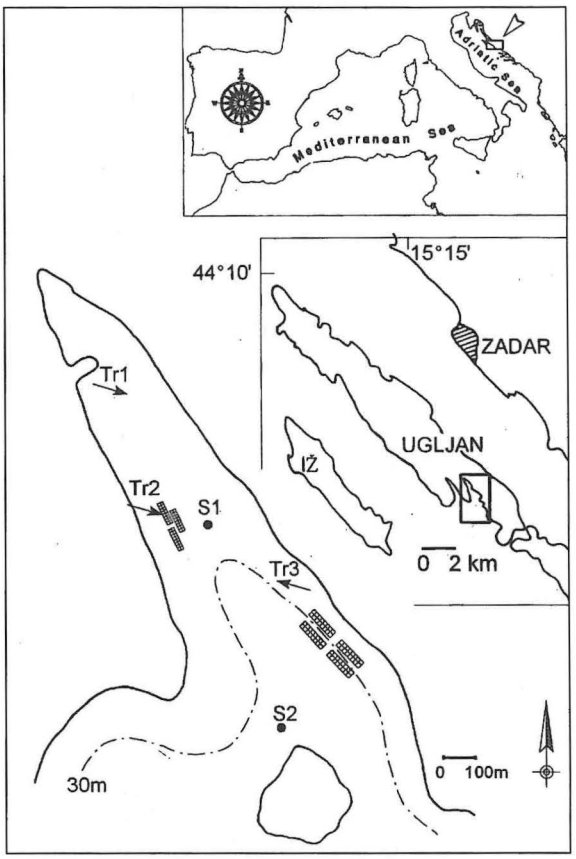


Fig. 1. Diagram of the Mala Lamljana Bay showing the locations of fish cages with the three transect lines (Tr) and two sampling stations (S_1 and S_2) chosen in the sampling programme

access and was chosen because of its shape, which enables a good protection from dominating winds (NE and SW), good flushing and hence good oxygen supply. Currents are predominant tidily driven to the NW. Input of nutrients besides the aquaculture is almost neglectable. The shoreline has a moderate to steep gradient with the rock subtidal area. From a depth of 5m sediments are predominantly sandy with typical feature of mobile bottoms. The *Posidonia* beds used to occupy large areas. NW of the four floating platforms (Fig.1, transect line 3) and below the cages there are some isolated muddy and sandy zones.

Sampling and analytical methods

Water samples for the nutrient components, nitrogen (N) and phosphorus (P) were collected

once per month, at two locations; one was at the cage site (S1), while the second one was about 300m further away from the most exposed cage (S2) (Fig. 1). Samples were preserved by freezing and thawed rapidly before a standard oceanographic methods for N and P analyses was performed (GRASSHOFF, 1976).

Dissolved oxygen concentration (DO) and temperature were recorded daily using YSI dissolved oxygen-temperature meter and salinity by an optical refractometer. These measurements were made at the same stations as the nutrients, but with the daily intervals. Water samples for estimation of chlorophyll related phytoplankton biomass were collected monthly from May to July 1995 at S1. A standard fluorescence method with an acidification step (HOLM-HANSEN *et al.*, 1965) was applied to estimate the concentration of chlorophyll. A 54 micron nylon phytoplankton net (Nansen type) was used during May and June 1995 in order to determine dominant species in the bay. Samples were fixed with 2% neutralised formaldehyde and analysed under the Olympus IMT-2 microscope.

The benthic surveys were limited to summer season only. Methodology used in collecting the benthos involved classical ecological methods on the three line transects (Fig. 1). Samples were collected by SCUBA diving (direct method) from hard and mobile substrata of the mediolitoral and infralitoral at different depth intervals along each transect (0-0.5m; 0.5-1m; 5-10m; 15-20m; 20-25m). The settlements of benthic flora were analysed from 400cm^2 quadratus (20x20 cm). The faunal samples were collected from mobile infralitoral substrata by dredging, in fact by a small beam trawl known as "musular". Such a gear mostly sampled animals of greater size, so that only presence and number of species were recorded along each transect.

The material collected preserved in 4% formaldehyde and determination was carried out by a binocular microscope. Ichthyofauna was visually observed and recorded throughout the entire sampling period.

The possible inter-relationship of benthic components among transects was examined by the SØRENSEN's similarity quotient (SØRENSEN, 1948).

RESULTS

Nutrient loading from fish farm

An increased feed dosage from June to September is directly related to the temperature increase; the great portion of the feed was taken during the optimal summer temperature (above 20°C) as shown in Table 1. Based on the daily farm records the environmental load was estimated with 16.5 kg phosphorus and 60 kg nitrogen per tonne of fish produced.

The relationships between ambient temperature, feed supply, and possible eutrophication effects were analysed. There were no clear relationships between nutrient supply and concentration of phosphorus and nitrogen component in the water (Fig. 2). The concentration of phosphate is not considerable different in the surface and near bottom waters throughout the year, except a peak in near bottom waters at the outer station in July, and less pronounced increase in surface waters in June. There were also no appreciable differences in the concentration of the nitrate in the water column as well as between inner and outer station.

Table 2. Percentage of water content and organic matter from surface sediments of transect 2, and at different distance from sea bass farm

Distance (m)	Water content (%)	Organic matter (%)
0	21.20	3.58
100	19.35	2.56
300	18.54	2.40

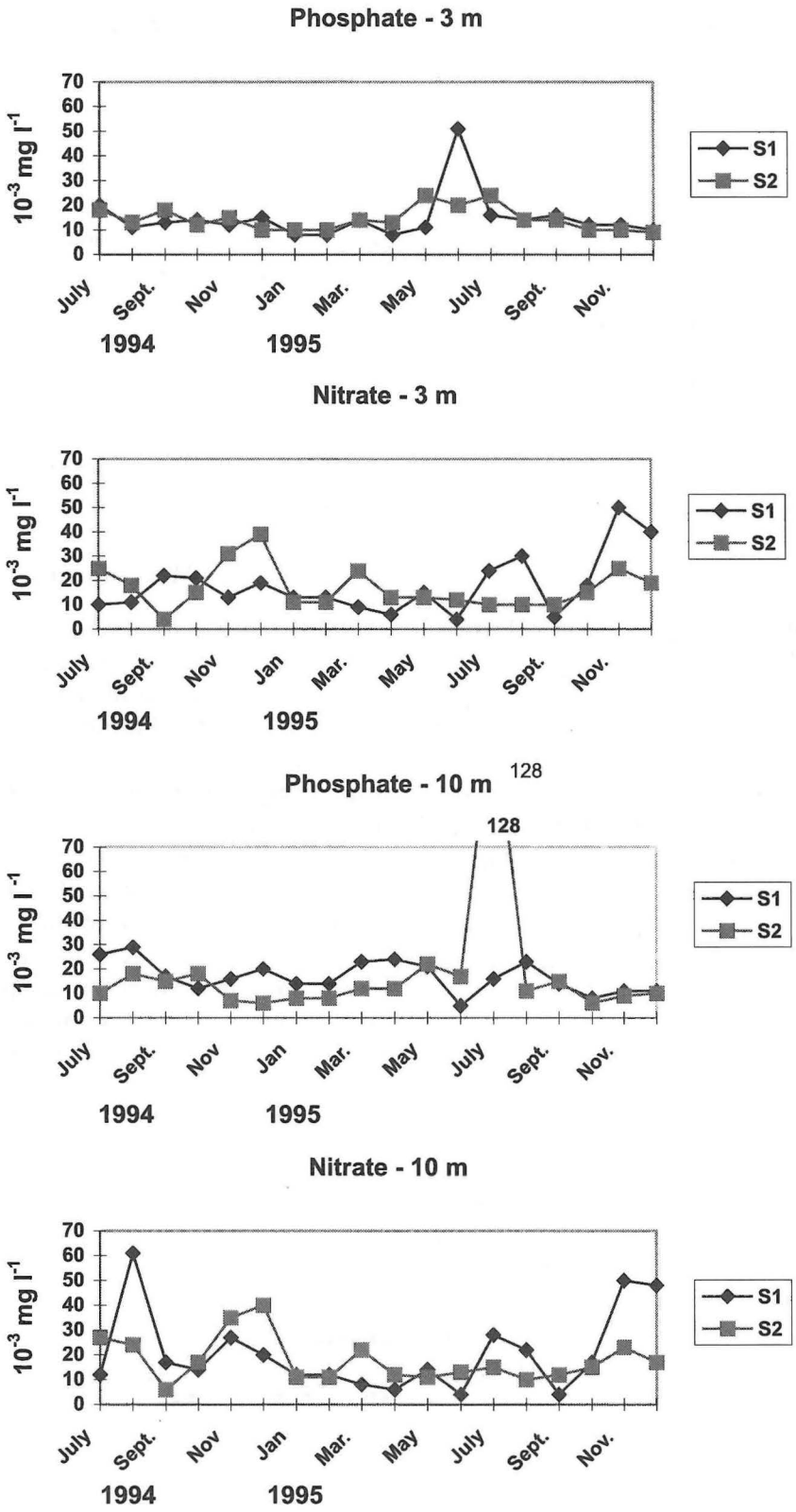


Fig. 2. The changes of phosphate and nitrate concentrations (mgl^{-1}) in the near surface (3 m) and near bottom (10 m) waters of the inner (S_1) and outer station (S_2). Data are collected from July 1994 to December 1995

Sediment

Sediment was not grossly enriched by organic meter beneath the fish cages. Within 100m and 300m respectively of the floating cages the organic content from surfacial sediment along a transect 2 was slightly reduced (Table 2).

Phytoplankton

The phytoplankton biomass has showed slight increase from May on, but hardly reaching 1mg m^{-3} in July (Table 3).

Table 3. Chlorophyll a content (mg m^{-3}) in Mala Lamljana Bay from May to July 1995 at station S1

	Surface	5 m	10 m	Bottom
May	0.30	0.28	0.24	-
June	0.59	0.42	0.37	0.25
July	0.95	0.76	0.59	0.40

The phytoplankton community was still diverse with 37 species identified. The qualitative structure was typical for Eastern-Adriatic coastal waters. Most of the summer chlorophyll was quantitatively contributed by diatoms, among which 90% were *Skeletonema costatum* and *Chaetoceros compressus*.

Oxygen

Oxygen levels fluctuated throughout a year and there appeared to be seasonal variations with a decrease in dissolved oxygen from June, reaching a minimum during September. Average oxygen summer saturation was around 80% but without undesirable consequences for farmed fish (Table 4).

The only serious problem associated with high summer temperature has occurred in the morning when occasionally surface oxygen saturation in the cages may drop below 75% (Table 5). Horizontally, a decrease of the oxygen levels resulting from fish farming activities seems to be restricted to 10m only from the cages.

Macroflora

A total of 128 taxa of benthic algae and one marine phanerogam (*Posidonia oceanica*) were collected. Rhodophyta dominated with 72 taxa or 56%, followed by Phaeophyta with 29 taxa or 23%, and Chlorophyta with 27 taxa and 21% respectively. An overal ratio of Rhodophyta to that of Phaeophyta was 2.5.

It was determined 93 taxa of epilythic algae; (Rhodophyta, 51 taxa or 54.3%, Phaeophyta, 23 taxa or 24.5% and Chlorophyta, 19 taxa or 22% respectively. The vegetation in the shallow waters (dawn to 5m depth) is composed of common litophytic forms that are growing on the surface of rocks such are *Padina pavonica,*

Table 4. An average monthly oxygen saturation (range) in the fish cages as compared to 10 m distance from the cages. The oxygen was measured daily at 09 a.m. from April through September 1995 in near surface waters (about 0.5 m depth)

	Oxygen saturation (%)					
	in cage			out cage		
Month	**min**	**max**	**average**	**min**	**max**	**average**
April	93	101	97.0	95	103	100.8
May	92	100	94.1	96	101	98.5
June	82	94	86.1	94	98	96.5
July	74	84	78.2	92	101	95.3
August	76	88	82.9	91	99	94.8
September	72	85	75.5	93	98	94.5

Table 5. Daily changes in dissolved oxygen saturation (%) in cages at three depths (0 m - surface, 5 m, 10 m). An average was calculated from 10 measurements during the three consecutive days of July 1995

Depth (m)		Oxygen saturation (%) at time (hrs)				
		07,00	10,00	13,00	16,00	20,00
0.5	min	65	75	78	94	96
	max	80	91	101	108	100
	average	74.5	80.4	94.3	105.1	91.6
5	min	84	83	82	95	89
	max	95	107	105	110	106
	average	89.6	102.1	99.0	103.2	98.5
10	min	98	96	98	94	91
	max	107	113	115	109	108
	average	105.1	108.2	109.6	101.8	104.1

Ceramium ciliatum, Entereomorpha flexuosa, Cladophora sp., Cystoseira barbata, C. compressa, and *Litophyllum incrustans*. The vegetation on the next bank, which is characterised with mixed-rocky to sandy bottom is becoming scarce, with over domination of several *Cystoseira* species. From 10 m to 15 m, well-developed *Posidonia* beds were found on the bottom that is characterised by sandy to muddy sediments. Along the transect 2 which has 15 years long history of fish production, a domination of some nitrophilic species such as *Ulva rigida, Enteromorpha intestinalis, E. compressa, Dictyopteris polypodioides, Dictyota dichotoma var. intricata* and *Gigartina acicularis* are indicating some changes that occurred in the benthic vegetation structure. Along this, transect Chlorophyta dominated the number of species over Phaeophyta in the total and in particular their epilithic component (Fig.3B.).

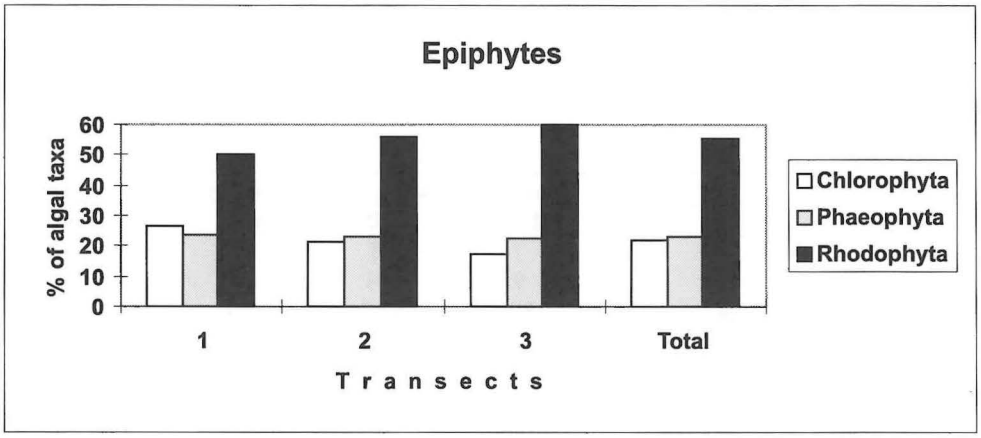
Posidonia oceanica was found in regression and the process of its degradation is of various degrees. The total disappearance was found beneath the cages and around their edge all along transect 2, whilst at transect 3, which is in vicinity of recently replaced floating cages degradation is also visible. Dead rhizomes inhabited with epiphytes are in most cases the only remaining traces of former well-developed *Posidonia* beds bellow cages. However, at transect 1, which is about 500 m far away from nearest floating platforms the *Posidonia* beds are still vital.

From 87 epiphytes determined, the Rhodophyta were best represented with 55% in average, while Phaeophyta and Chlorophyta represented 23% and 21.8% respectively. The most frequent epiphytes found upon *Posidonia* leaves were *Dictyota linearis* and *Sphacelaria cirrosa*, and their rhizomes are also invaded with *S. cirrosa, S. plumula* and *Cladophora sp.*

Similarity quotient (QS) for the three main taxonomic divisions was quite different in the study area. When compare the three transects, the highest QS was obtained for Chlorophyta, The highest similarity in total flora composition was found between transect 2 and transect 3 (Table 6)

Table 6. SØRENSEN's similarity quotient (QS as percentage) of three floral divisions (Rhodophyta, Phaeophyta, Chlorophyta) and total flora along the three transects (Tr) in Mala Lamljana Bay

Transects	QS Rhodophyta	QS Phaeophyta	QS Chlorophyta	QS Flora
Tr1 - Tr2	52	55	75	52.3
Tr1 - Tr3	45	58	68	46.7
Tr2 - Tr3	51	53	70	68.1



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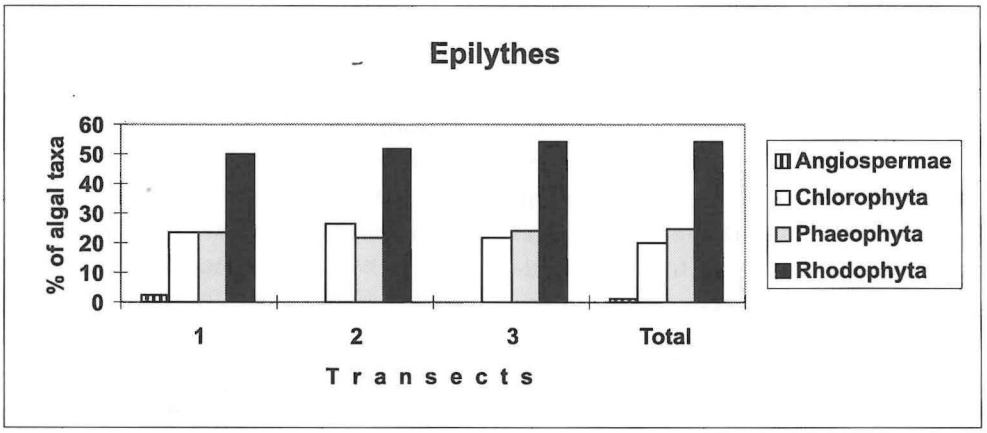

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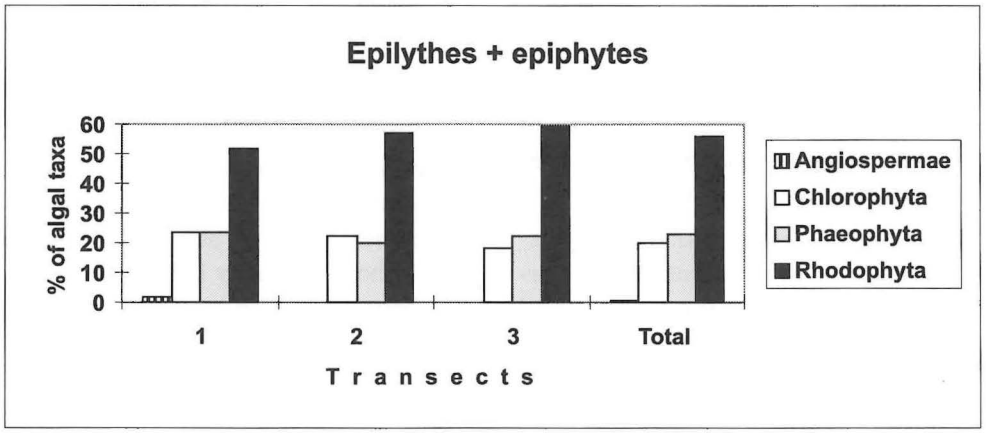

C

Fig. 3. Dominant division of benthic flora (A-epiphytes; B-epilithes: C-epiphytes and epilithes together) expressed as percentage of the total number of species. The sampling was performed at three transects in Mala Lamljana Bay during June 1995

Macrofauna

The benthic macrofauna was represented with 84 species (Fig. 4). Mollusca were predominant in the number of species (33), being followed by Arthropoda (12), Annelida (9), Tunicata (7), Echinodermata (6), Cnidaria (6), and Porifera (5) respectively. Tentaculata, Echiurida, and Sipunculida together were presented with 6 species only. Filtrating organisms such as Molluscs were predominant in the number of species. Among the most abundant up to 5 m depth are mussels *(Mytilus galloprovincialis)* and European flat oysters *(Ostrea edulis)*.

Sea urchins (Echinoidea) and some ascidians (Thaliacea) dominated biomass on the next bank characterised by rocks, while detritus eating sea cucumber *Holothuria tubulosa* dominate in term of biomass bellow the cages and in their vicinity.

Concerning the differences between the three transects the highest QS in macrobenthic fauna was found between transect 2 and transect 3 (Table 7).

Table 7. SØRENSEN's similarity quotient (QS as percentage) of the macrobenthic fauna along the three transects (Tr) in Mala Lamljana Bay

Transects	QS Fauna
Tr1 - Tr2	52.3
Tr1 - Tr3	46.7
Tr2 - Tr3	68.1

Ichthyofauna

Abundant shoals of commercial-size grey mullets *(Liza aurata)* dominate upper layers in between cages. The biomass was estimated at up to 10 tons. This fish seems to be a species that makes the best use of the uneaten food available. From the bottom feeders, the striped sea bream *Lithognathus mormyrus* was most abundant. From other sparids, most common species recorded were *Boops salpa* and *Diplodus sp.* and from non-sparids species the most frequent are *Mullus sp., Trachurus sp., Sardina sp., Engraulis sp., Seriola sp.*, and *Lichia sp.* respectively. Fish recruitment has been occurred near farm where juvenile *Pagellus erythrinus, Diplodus puntazzo, and Diplodus annularis* were attracted by the shelters and the rich food supply.

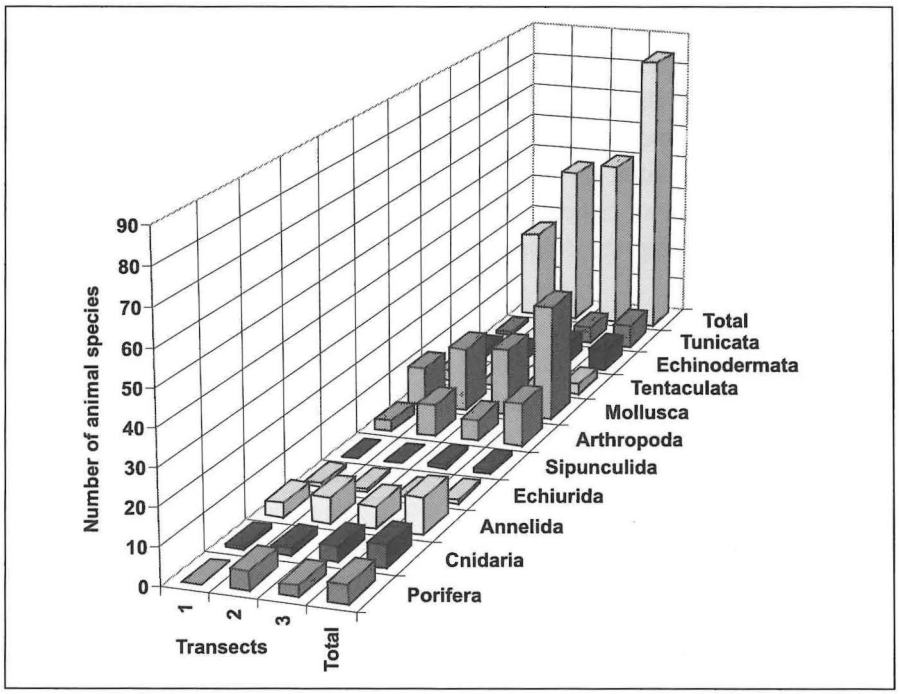

Fig. 4. Dominant benthic macrofauna expressed as percentage of the total number of species at three transects in Mala Lamljana Bay during June 1995

DISCUSSION

Following the production records as a starting point and estimated nutrient load per ton of the fish produced it was assumed that the total load of nutrients in the Mala Lamljana Bay was 3.8 t y^{-1} of phosphorus and 29.3 t y^{-1} of nitrogen. Since the nutrients released consists of a dissolved fraction and the particulate fraction, the available amount of nutrients for biological production is much lower. For salmon farming ACKEFORS and ENELL (1990) showed that about a quarter of the supplied nitrogen and phosphorus is incorporated into the fish for their growth. About a quarter of the phosphorus is excreted in a dissolved form and about 50 % sinks to the bottom in a particulate form. In contrast to the phosphorus, about 50 % of the nitrogen load is in dissolved form and minor portion is in particulate form (about a quarter of N supplied). These figures may depend on fish species and vary greatly from farm to farm, but in general could be considered as averages for fish reared in cages (WALLIN and HAKANSON, 1991).

The concentration of nutrients measured in Mala Lamljana Bay, and their relative homogeneity in the water body are suggesting good dispersion of the load and good exchange of the water between the bay and the main basin throughout the year. This statement is also supporting relatively low accumulation of the organic matter in the sediment beneath the cages and low difference along the transects established.

The phytoplankton community of markedly diatom type with low contribution of dinoflagellates. This is a typical feature of the Middle Adriatic coastal waters (MARASOVIĆ and PUCHER-PETKOVIĆ, 1991). With respect to phytoplankton chlorophyll there was an adequate increase with the nutrient loading increase. This is in accordance with the general theories of the relationship between nutrient loading and the primary production in the relatively shallow and sheltered aquatic systems. However, some authors were not able to confirm such a clear relationship between nutrient levels and primary production in marine systems (LEE and JONES, 1979; O'CONNOR, 1979; SCHINDLER, 1979). GOWEN and EZZI (1992) concluded that nutrient enrichment would stimulate phytoplankton growth only when the particular nutrient is limited. PRIDMORE and RUTHERFORD (1992) found that when nitrogen is not limiting phytoplankton growth, other factors such as grazing and sedimentation controlling phytoplankton biomass.

As for oxygen it was found that surrounding waters were not much depressed by the farming operations. Morning depletion of the oxygen in the summer is because it is rapidly taken by the fish over the night while exchange of the water is reduced. It was observed that low oxygen saturation in the cages is usually associated with heavy fouling. In the standard intensive cage culture practice, the morning is a time when the feed is regularly distributed to the fish. If feed distribution is associated with abnormally low water exchange it may stress the fish and cause further increase in their oxygen demand (GOWEN *et al.*, 1990).

Our results show that floristic component in the major part of the bay is still balancing three systematic divisions: Rhodophyta, Phaeophyta, and Chlorophyta respectively. One of the first and basic characteristics of coastal Adriatic flora is the domination of Rhodophyta over Phaeophyta and Chlorophyta. The next feature is that in the non affected coastal areas of Adriatic Pheophyta usually dominate Chlorophyta (ERCEGOVIĆ, 1957; ŠPAN, 1980a, 1980b; ŠPAN and ANTOLIĆ, 1994; ŠPAN and ANTOLIĆ, 1999). An overall Rhodophyta/Phaeophyta ratio in the bay was 2.4, and is slightly in excess of 2.2. determined for coastal benthic flora of the central eastern Adriatic (ŠPAN and ANTOLIĆ, 1989). Chlorophyta showed very high recruitment and densities, and as for the number of species there were their domination over Phaeophyta in the most affected zone of the bay (Transect 2). This may suggest some changes in the environment

that turn to be in favours for Chlorophyta development (ŠPAN and ANTOLIĆ, 1997). The changes in the vegetation structure along the transect 2 and abundance of *Ulva rigida, Enteromorpha intestinalis, E. compressa, Dictyopteris polypodioides, Dictyota dichotoma var. intricata,* and *Gigartina acicularis* respectively are indicating process of eutrophication in which these nitrophilic species (BOUDOURESQUE, 1984) are apparently benefiting from the increased nutrient load.

Disappearance of the *Posidonia oceanica* below the cages and heavily damaged beds in the vicinity of the cages can be explained by several reasons. The floating cages themselves prevent penetration of the light, while further reason may be low transparency of sea water due to culturing activities, (uneaten feed and faeces that covering levels). Abundant shoals of wild fish visually observed around the farm were apparently attracted by uneaten food, but also by *in situ* net cleaning, dead animals and other organic material that come from harvesting operation (e.g. blood). The floating structure itself may provide shelter for many fish population, while sediment fauna may attract some bottom feeders. Such an abundant wild fish population may play an important role in functioning of entire ecosystem in the bay as they increase the capacity of the environment to assimilate organic loading being released.

CONCLUSION

The studied location does not show signs of significant eutrofication as it can be concluded from the high nutrient load during such a long farming history. Most probably, this comes out from the bottom morphology and flushing rate that is higher than the potential of the nutrient to accumulate and cause a stronger biological response. The changes observed in the benthic communities in the immediate environment of the farm should be subjected to the increased attention in the next coming years. Further monitoring programme may require inclusion of chemical measures of enrichment, studies on temporal variability of macrobenthos and sediment fauna respectively.

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Utjecaj kaveznog uzgoja lubina (*Dicentrarchus labrax* L.) na kvalitetu mora i makrobentoske zajednice

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SAŽETAK

Industrijska se marikultura u Hrvatskoj razvijala tijekom dvije posljednje dekade. Plutajući su kavezi za uzgoj ribe smještani uglavnom u poluzatvorene uzobalne zone. Očekivani razvitak ove industrije s obzirom na povećanje proizvodnje i potrebu za novim lokacijama zahtijeva sagledavanje potencijalnog utjecaja uzgajališta na prirodni okoliš.

Ovaj rad donosi prve rezultate praćenja promjena u kvaliteti mora i bentosu na uzgajalištu lubina čija se proizvodnja u posljednjih 15 godina kretala oko 200 t godišnje. Utvrđeno je da su koncentracije hranjivih soli, fitoplanktonska biomasa i organska komponenta sedimenta razmjerno slabo korelirana s količinom hrane. S druge strane, uočene su značajne promjene u sadržaju otopljenog kisika u kavezima tijekom ljetnih mjeseci kada se u jutarnjim satima zasićenost spuštala ispod 70%. Studijem makrobentoskih zajednica utvrđena je razmjerno bogata i raznolika pridnena flora i fauna. Međutim, s obzirom na sastav, strukturu i prostornu raspodjelu, vidljivo je da su neki elementi bentoske zajednice izmijenjeni pod utjecajem uzgojnih aktivnosti. Dobro razvijena ležišta morske cvjetnice *Posidonia oceanica* su gotovo iščezla ispod kaveza, a primjetno je njeno uzmicanje u cjelokupnom zaljevu. Oko kaveza biomasom dominiraju nitrofilne alge, a brojčana zastupljenost Chlorophyta nadmašuje Phaeophyta.

Temeljem iznesenih rezultata nameće se potreba uključivanja programa daljnjeg praćenja stanja okoliša kako bi se opažene ekološke promjene kao posljedica uzgojnih aktivnosti održale na prihvatljivoj razini.