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IMPACTS OF NET CAGE FISH FARM ON SEDIMENTARY BIOGEOCHEMICAL AND MEIOFAUNAL PROPERTIES OF THE GULF OF TRIESTE

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ABSTRACT

This study provides basic information about the impacts of a fish farm activity on the Slovenian coastal sea. Samples were collected from the fish farm area (sampling site-SS) and away from the cages (control site-CS). Environmental changes were most evident in benthos showing a long-term impact on meiofauna communities. The meiofauna examination and pore water concentrations of hydrogen sulphide and sulphate indicate the greatest impact directly under the cages. The sedimentation of total suspended matter, particulate organic carbon and total particulate nitrogen in the fish farm region was greater than that at unimpacted area. The lower C/N ratio of fish farm suspended matter results from greater supply of proteinaceous material. However, the C/N ratio of sediment under the cages suggests that the system could be in a quasi steady state, where removal processes balance the organic matter loading from the cages. The values of $\delta^{13}C$ and $\delta^{15}N$ of fish were similar to those in dry food pellets fed to the sea bass (Dicentrarchus labrax) *indicating their primary source of food.*

Key words: fish farm, $\delta^{15}N$, $\delta^{13}C$, sediment trap, sediment, meiofauna

IMPATTO DELLA PESCICOLTURA IN GABBIE FLOTTANTI SULLE PROPRIETÀ BIOGEOCHIMICHE DEL SEDIMENTO E SULLA MEIOFAUNA DEL GOLFO DI TRIESTE

SINTESI

Lo studio fornisce informazioni sull'impatto della pescicoltura in acque costiere slovene. I campioni sono stati raccolti nell'area interessata dall'attività (sito SS) e fuori da questa (stazione di controllo CS). I maggiori cambiamenti ambientali sono stati registrati a livello del benthos, con impatti a lungo termine sulle comunità meiofaunistiche. L'analisi della meiofauna e le concentrazioni di idrogeno solforato e di solfato nelle acque interstiziali del sedimento indicano un impatto maggiore direttamente sotto le gabbie. La sedimentazione della materia sospesa totale, del particolato di carbonio organico e del particolato di azoto totale è risultata maggiore nell'area interessata dalla pescicoltura che in quella non affetta. Il minor rapporto C/N della materia sospesa proveniente dalle colture indica un apporto maggiore di materiale proteinaceo. Dal rapporto C/N del sedimento sottostante le gabbie si può ipotizzare che il sistema sia in uno stato semi-stabile, dove i processi di rimozione bilanciano la materia organica proveniente dalle gabbie. I valori di $\delta^{13}C$ e $\delta^{15}N$ nei pesci sono risultati simili a quelli riscontrati nel mangime secco, fonte primaria di nutrimento per la spigola (Dicentrarchus labrax).

Parole chiave: pescicoltura, $\delta^{15}N$, $\delta^{13}C$, trappole per sedimento, sedimento, meiofauna

INTRODUCTION

The rapid development of different aquacultures in the world has resulted in several studies directed towards assessment of the environmental impacts of this activity (Hargrave *et al.*, 1997). During recent years there has been a significant increase in the number of fish farms established in Mediterranean waters. Below the fish cages, organic matter (OM) originating in fish-food remains and the excreta of the cultured fish often accumulates in the sediment. Enhanced and constant sedimentation of particulate organic waste products results in anoxia, high levels of hydrogen sulphide in sediments and subsequently in alteration of the benthic community and a reduction in bioturbation processes. Enhanced aerobic and anaerobic microbial activity in organically rich sediments is resulting in oxygen depletion, production of toxic substances such H_2S, and low oxidation-reduction potentials are characteristic of anaerobic marine sedimentary environments (Weston, 1990). Hydrogen sulphide produced by sulphate-reducing bacteria, through anaerobic respiration stimulated by available substrate and increasing temperature during early summer, could accumulate within sediments to levels that are toxic to benthic macrofauna and heterotrophic microfauna (Hargrave *et al.*, 1993). Oxidation of H_2S, produced during the anaerobic decomposition of organic matter by sulphate-reducing bacteria, is thought to be the major source of the chemical oxygen demand in marine sediments (Findlay & Watling, 1997). Hydrogen sulphide is also toxic to fish and out-gassing of this from sediments beneath fish cages could have a detrimental effect on fish health (Gowen & Bradbury, 1987). Regardless of the pathway of organic matter

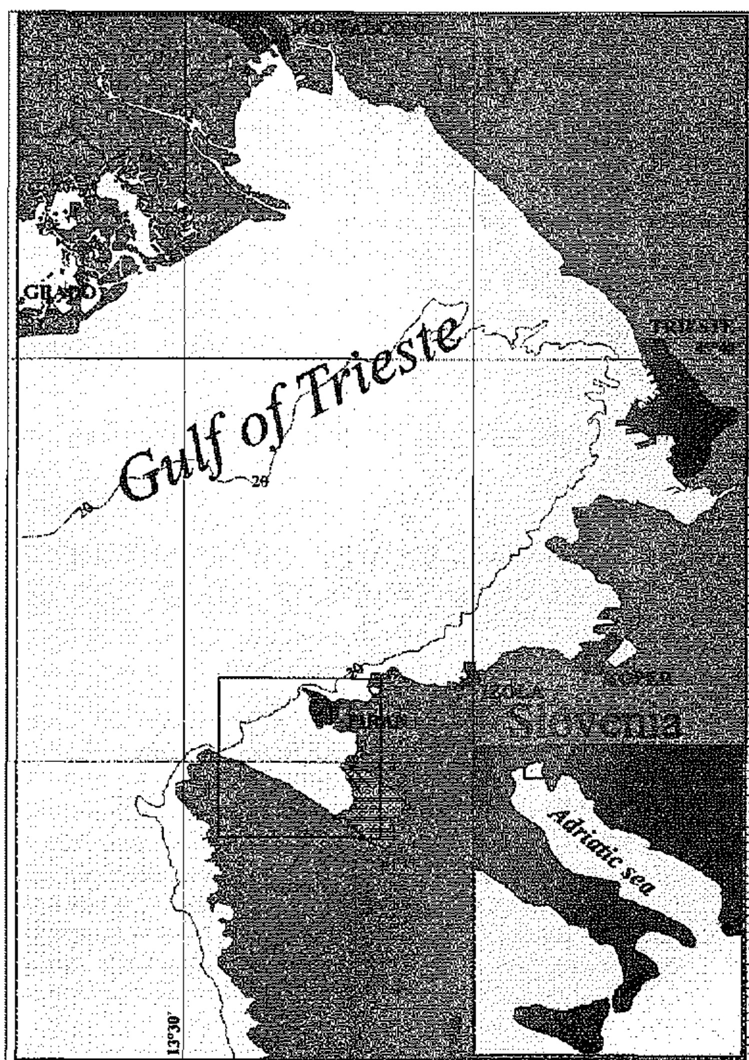

Fig. 1: Map of the Gulf of Trieste (northern Adriatic Sea).
Sl. 1: Lokacija Tržaškega zaliva (severni Jadran).

decomposition, if the supply of oxygen is sufficient then hydrogen sulphide will not accumulate within surficial sediments (Findlay & Watling, 1997).

The degree of impact depends on many factors such as water current speed and direction, sediment composition, resuspension, benthic fauna and organic loading from fish farm activity (Hargrave *et al.*, 1997). Nevertheless, organic output from the fish cages is a serious source of pollution in the affected marine areas. Consequently it is very important to trace organic matter fluxes and estimate their impact on the generally oligotrophic Slovenian marine environment.

In order to provide basic information about the impacts of fish farm area in the Slovenian coastal sea and to collect necessary data for the determination of the carrying capacity of the ecosystem and sustainable management of the investigated area, we performed the preliminary study represented by IAEA Research Contract (Environment Programme - UNEP).

MATERIAL AND METHODS

Study sites

The fish cage farm is located in coastal marine waters in Piran Bay - Gulf of Trieste (Northern Adriatic) (Fig. 1). The pilot cage facilities were established in 1988. From 1989, sea bass *(Dicentrarchus labrax)* and sea bream *(Sparus aurata)* have been the commercially cultivated species. The bottom depth at the fish farm is 12 to 13 m. In the fish farm a series of round cages (eight of 8 m in diameter, and eight of 12 m in diameter) have been used for production of fish. The depth of net cages is about 4.5 m. The fish were fed commercial pelted fish food (Marico Start Premium). There is a minor freshwater input from a local stream discharging into the sea about 1.5 km from the fish farm. The water of the Gulf of Trieste is stratified from the spring to the end of summer. The Gulf is characterized by large temperature variations (6-26°C in the surficial layer and 6-20°C above the bottom). Surface salinity ranges from 33 to 37.5 PSU and bottom water salinity from 36 to 38.5 PSU. Water circulation in the farm area is sufficient to keep the bottom oxygenated throughout the year.

The surficial sediment at the study site is dark grey sandy clayey silt (Ogorelec *et al.*, 1991) containing up to 20% of sand and up to 35% of clay. With respect to the control site (CS), it is slightly richer in sand and contains less clay, due to the near mouth of the river Dragonja. The carbonate content is above 30%. Ostracods, molluscs and foraminifers are the most frequent biogenic components of the sediment. The majority of carbonate minerals is of detrital origin. This is true for quartz, too, and is the third most abundant mineral; its content reaches up to 20%. The clay minerals at the study site are composed of chlorite and mixed structure illite/montmorillonite. Pyrite observed in the sediment at about 4% indicates reducing conditions and it is normally present in up to 200 μm large framboids few millimetres below the surface.

Sampling

The samples were collected during a 24 hour long sampling period on 21 and 22 June 2000 at the sampling site (three samplings: morning of first day - sampling I, midnight sampling II and morning of second day - sampling III) and at the control station (two samplings: morning of first day - sampling I and second day - sampling III). The sampling site (SS) was located under the cages of sea bass and the control site (CS) at a similar depth was established 1.5 kilometres from the fish farm (Fig. 2).

Sediment cores (5 cm in diameter) were collected by SCUBA divers at sampling and control sites. Cores were inserted into the sediment to preserve an intact sediment-water interface and plastic rubber stoppers were used to close the top and bottom of each core. Surficial sediment (0-2 cm) was used for subsequent analyses. For meiofauna analyses three replicate tube core samples (3.2 cm in diameter) were used.

The sedimentation rates were measured over a period of 24 hours using moored sediment traps, which were designed to collect 3 samples simultaneously. Cylindrical sediment traps with a diameter of 7 cm and an aspect ratio of 7 were used to collect sinking particles from the cages (positioned below the cages approx. 1 m above the bottom). At the same time, sedimentation rates were also measured at the control site (1.5 km from the influenced area). After collection, three aliquots of homogenized suspension from each cylinder were filtered through precombusted Whatman GF/F glass micro-fibre filters. All samples were freeze-dried for 24 hours and weighed. Dried samples were used for analysis of total suspended matter (TSM), particulate organic carbon (POC), particulate nitrogen (PN) and isotopic composition (^{13}C and ^{15}N).

Samples of fish, fish food, fish cage fouling were also collected for stable isotope analysis (^{13}C and ^{15}N). Different fish tissues (liver, muscle, bone) were carefully dissected and deep frozen. Before isotopic analysis, all samples were freeze-dried and powdered with mortar and pestle.

During sampling periods, large quantities of mucous macroaggregates were present in the water column. Hyperproduction of this mucilaginous material in the northern Adriatic has been known for more than 250 years and recently occurred during the summers of 1988, 1989, 1991, 1997 and this year. These macroaggregates are found in a variety of stages or forms - small flocs, macroflocs, stringers, tapes, clouds, creamy surface and gelatinous layers (Stachowitsch *et al.*, 1990). These mucous events were previously described by several authors (Degobbis *et al.*, 1995; Herndl, 1992; Mingazzini & Thake, 1995; Kovač *et al.*, 1998; Degobbis, 1999).

Analytical methods

Total particulate matter was determined gravimetrically. Organic carbon (POC) and total nitrogen (N) content of freeze-dried filters and sediment samples were determined after acid pretreatment with a commercial Carlo Erba 1108 elemental analyser.

The water content of the sediment was determined as a weight loss after drying at 80°C until constant weight (approximately 20-30 hrs).

Analyses of the ^{13}C and ^{15}N isotopic composition of freeze-dried samples were performed with a Europa 20-20 (Europa Scientific) mass spectrometer. Stable-isotope ratios were expressed in δ notation as parts per mill (‰) according to the following relationship:

$\delta X = [(R_{sample}/R_{standard}) - 1] \times 10^3$

where X is ^{13}C or ^{15}N and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{14}N$. Standards for ^{13}C and ^{15}N are V-PDB and atmospheric N_2 (air), respectively.

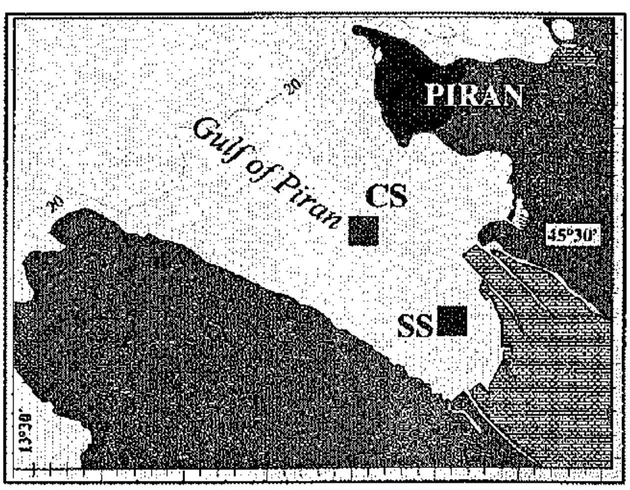

Fig. 2: Location of sampling (SS) and control (CS) stations in Piran Bay, Gulf of Trieste.
Sl. 2: Lokacija vzorčevalne (SS) in kontrolne (CS) postaje v Piranskem zalivu (Tržaški zaliv).

After extraction from the sediment in inert atmosphere, pore waters (0-2 cm depth in sediment, at each sampling point) were used to determine pH and concentration of hydrogen sulphide (H_2S) and total carbon dioxide (CO_2) (Grasshoff, 1983). Concentration of sulphate (SO_4^{2-}) was determined turbidimetrically (Tabatabai, 1974).

Surficial sediment (0-5 cm) containing meiofauna was taken using a core sampler, always with three replicates. Meiofauna was extracted from fixed surficial samples (5% formalin) by sieving and decantation (Wieser, 1960), identified as to major taxa and counted.

RESULTS AND DISCUSSION

Composition and sedimentation of suspended particulate matter

Differences in the composition of sedimented particulate matter from sampling (SS) and control (CS) sites are presented in Table 1. During the investigation period, the composition of particulate matter was affected by presence of macroaggregates with high content of carbohydrates and high atomic C/N ratio of 14.7 (mean value of macroaggregates sampled in June 2000). Nevertheless, based on the elemental analyses of the material collected during 24 hours in a trap placed under the fish cages the portion of organic carbon and total nitrogen was higher than that measured at the control site. The particulate matter originating from fish farm was enriched for 43% with organic carbon and about 66% with nitrogen. The higher input of proteinaceous material (organic waste originating in uneaten fish food) was in that case evident also from the lower C/N ratio (7.28, at.) in the sediment trap samples from the sampling station.

Tab. 1: Analyses performed in the sedimented particulate matter at sampling (SS) and control (CS) sites.
Tab. 1: Analize sedimentirane suspendirane snovi vzorčevalne (SS) in kontrolne (CS) postaje.

PARAMETER	SEDIMENT TRAP SAMPLES (mean values)	
	Sampling site (SS)	*Control site (CS)*
Content of organic carbon (%)	5.50	3.13
Content of total nitrogen (%)	0.90	0.35
C/N ratio (atomic)	7.28	10.60
Sedimentation ratio of total suspended matter ($g\ m^{-2}d^{-1}$)	73.19	36.16
Sedimentation ratio of total particulate nitrogen ($g\ m^{-2}d^{-1}$)	0.58	0.13
Sedimentation ratio of particulate organic carbon ($g\ m^{-2}d^{-1}$)	3.57	1.19

The comparison of measured sedimentation rates showed higher values in fish farm area. At the control site (CS), sedimentation rates of total suspended matter, particulate organic carbon and total particulate nitrogen were 36.16 g $m^{-2}d^{-1}$, 1.19 g $m^{-2}d^{-1}$ and 0.13 g $m^{-2}d^{-1}$. These sedimentation rates from the control station were similar to the rates previously reported for the unimpacted area of the Gulf of Trieste (Faganeli, 1989; Faganeli *et al.*, 1995). Sedimentation rates of total suspended matter, particulate organic carbon and total particulate nitrogen were about 51%, 67% and 78% higher under the fish cages and amounted 73.19 g $m^{-2}d^{-1}$, 3.5 g $m^{-2}d^{-1}$ and 0.58 g $m^{-2}d^{-1}$ respectively. Measured sedimentation rates showed higher input of organic matter below the cages. However, the measured sedimentation with mean carbon flux = 3.57 g $m^{-2}d^{-1}$ measured in our fish farm area was approximately 50% lower than the level of organic matter reported elsewhere (Angel *et al.*, 1992).

^{13}C and ^{15}N isotopic composition

The stable carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotope analyses were used to investigate the sources of sedimentary matter and to provide basic information about trophic relationships within the fish farm area. The mean values of terrigenous POM from the riverine inputs (-28.0‰), marine (-21.0‰) POM and net-zooplankton (-20.9 ‰ from the Gulf of Trieste (northern Adriatic) were previously reported by Faganeli *et al.* (1988). The mucous macroaggregates, which appeared in the Gulf of Trieste in summer 1997, were characterized by $\delta^{15}N$ value of 7‰ and $\delta^{13}C$ value of -19‰, which is typical of the phytoplankton of the Gulf of Trieste (Faganeli *et al.*, 1995). Additional average $\delta^{13}C$ and $\delta^{15}N$ values and elemental composition for selected components at sampling *(SS)* and control *(CS)* sites were measured (Tab. 2). The average $\delta^{13}C$ and $\delta^{15}N$ data obtained for different tissues of fishes varied between -20.52 and -24.66‰ and between 10.27 to 13.21‰. The highest $\delta^{13}C$ was found in fish muscle, followed by fish bone and fish liver. In the natural environment, sea bass *(Dicentrarchus labrax)* feeds on other fish and crustacea, but in the fish farm they are fed with artificial food. The values of $\delta^{13}C$ and $\delta^{15}N$ of fish were similar to those in dry food pellets fed to sea bass indicating their primary source of food. Unfortunately, fish tissue was not enriched in the $\delta^{13}C$ sufficiently over other measured components (with only slightly different values), suggesting that this parameter is not very suitable for the study of trophic relationships in this case. $\delta^{15}N$ values seem to be more appropriate but in any case some additional data of isotopic composition of other components are needed.

However, the $\delta^{13}C$ and $\delta^{15}N$ values of trap samples from the sampling site (-20.90‰ and 8.37‰) were more positive than those of samples from control site (-21.94‰ and 6.88‰), the former most probably reflecting the presence of waste products from fish farming. When the average $\delta^{13}C$ and $\delta^{15}N$ values obtained for surficial sediments under the fish cages were compared, we did not find significant differences between the sampling (-21.42‰, 3.93‰) and control sites (-21.58‰, 4.40‰).

Tab. 2: Average $\delta^{13}C$ and $\delta^{15}N$ values and elemental composition for selected components at sampling (SS) and control (CS) sites.
Tab. 2: Povprečne $\delta^{13}C$ in $\delta^{15}N$ vrednosti in elementna sestava izbranih sestavin iz vzorčevalne (SS) in kontrolne (CS) postaje.

SAMPLE	$\delta^{13}C_{PDB}$ (‰)	$\delta^{15}N_{air}$ (‰)	C_{org} (%)	N (%)	C/N (atomic)
Food for juvenile fish	-20.13	11.24	45.63	8.99	5.92
Food for adult fish	-22.22	9.08	42.79	7.39	6.75
Fish liver	-24.66	13.21	/	/	/
Fish muscle	-20.52	11.42	47.04	12.92	4.24
Fish bone	-23.46	10.27	/	/	/
Net-cage fouling	-21.41	5.50	10.01	1.78	7.10
Sediment trap samples *(SS)*	-20.90	8.37	5.50	0.90	7.28
Sediment trap samples *(CS)*	-21.94	6.88	3.13	0.35	10.43
Sediment *(SS)*	-21.42	3.93	1.11	0.12	10.43
Sediment *(CS)*	-21.58	4.40	1.26	0.13	11.04

Benthic impact of fish farming

Organic matter accumulates in surficial sediment under cage due to direct sedimentation of particulate matter as waste food, feces, unconsumed fish food pellets and enhanced sedimentation of fine particulate matter from the water column through flocculation (Hargrave *et al.*, 1997), furthermore adsorption on mucous macroaggregates. In order to assess the horizontal extent of the impact, surficial sediment samples were taken under the sea bass cage *i.e.* directly below the cage (SS1), beneath the edge of cage (SS2: 6 m from the centre of cage) and 6 m from the cage edge (SS3) as well as at the control site (CS) (Fig. 3) and analysed (Tab. 3).

Organic carbon and total nitrogen content in the surficial sediments at the station under the fish cages show some variations but the range of values under cages were similar to that at control site (see Tab. 3). Samples of dry food pellets fed to fish during the sampling time contained 42.79% C and 7.38% N by weight (C/N atomic ratio of 6.75). Even though no input of wastes from the fish farm occurred at the control station, the C/N ratio was only slightly higher. The atomic ratio

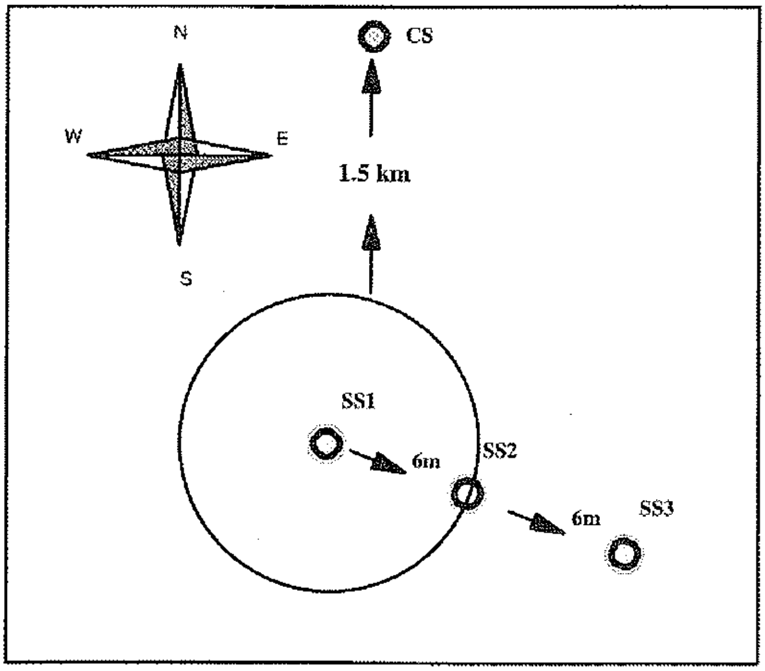

Fig. 3: Location of sampling points (SS1, SS2, SS3) in sediment under the fish farm and at control site (CS).
Fig. 3: Lokacije vzorčevalnih točk sedimenta na vzorčevalni (SS1, SS2, SS3) in kontrolni (CS) postaji.

Tab. 3: Parameters measured in sediment at the three sampling points (SS1, SS2, SS3) located under the fish farm and one point (CS) at control site.
Tab. 3: Analize sedimenta treh vzorčevalnih točk (SS1, SS2, SS3), lociranih pod gojiščem rib in na kontrolni postaji (CS).

PARAMETER	SEDIMENT			
	Sampling site (SS)			*Control site (CS)*
	SS1	*SS2*	*SS3*	*CS*
Water content (%)	51.26	57.02	56.68	66.46
N (%)	0.14	0.16	0.08	0.13
$C_{org.}$ (%)	1.19	1.44	0.70	1.26
C/N (at.)	9.87	10.77	10.77	11.04
$\delta^{13}C_{PDB}$ (‰)	-21.87	-21.32	-21.53	-21.58
$\delta^{15}N_{air}$ (‰)	3.8	3.8	4.2	4.4

Tab. 4: Concentrations of sulphate, hydrogen sulphide, total CO_2 and pH values measured in sediment (SS1, SS2, SS3) under the fish farm and at control site (CS).
Tab. 4: Koncentracije sulfata, vodikovega sulfida, celotnega CO_2 in pH vrednosti izmerjene v pornih vodah sedimenta (SS1, SS2, SS3) pod ribjimi kletkami in na kontrolni postaji (CS).

PARAMETER	SEDIMENT PORE WATER			
	Sampling site (SS)			*Control site (CS)*
	SS1	*SS2*	*SS3*	*CS*
SO_4^{2-}(mmol/L)	19.48	26.92	36.27	22.90
H_2S (µmol/L)	0.25	0.55	0.17	0.68
Total CO_2 (mmol/L)	2.93	4.40	4.55	2.80
pH	8.17	8.06	7.80	7.97

Tab. 5: Taxa and their mean abundances (No. ind./10 cm^2) determined at the three sampling points (SS1, SS2, SS3) in sediment under the fish farm and at control site (CS).
Tab. 5: Glavne skupine meiofaune in njihove srednje abundance (št. oseb./10 cm^2), določene na treh vzorčevalnih točkah (SS1, SS2, SS3) sedimenta pod ribjimi kletkami in na kontrolni postaji (CS).

	MEAN ABUNDANCES (No.ind./10 cm^2)			
TAXA	Sampling site *(SS)*			Control site *(CS)*
	SS1	*SS2*	*SS3*	*CS*
Nematoda	374.3	897	1180.3	1183.6
Harpacticoida	16	35.6	106	255.6
Polychaeta	32.3	34.3	48.3	125
Turbellaria	6.3	17.3	28.3	21.6
Gastropoda	0.6	0	1.3	5
Bivalvia	0	2	6	7
Kinorhyncha	0	0	0.6	22.3
Acarina	0	0	0	1.3
Hydroidea	0	0.3	2.3	1.6
Ostracoda	1.6	1.6	3.3	6.6
Ascidiacea	0	0	0	44.6
Amphipoda	0.3	0.6	0.3	0.6
Total	431	989	1377	1675

for organic carbon/nitrogen varied from 9.87 to 10.77 in sediment under the cages and at the control site was 11.04. Higher C/N ratio of organic matters in the surficial sediment of sampling site probably reflects the preferential degradation of N versus C or/and transportation of organic matter. These results suggest that the system could be in a quasi steady state, where removal processes balance the constant and enhanced organic matter loading from the cages.

Sediment water content in surficial sediment (0 to 2 cm layer) varied slightly (51.2% to 56.7%) with no consistent pattern in values between the sampling points under the fish farm. Higher sediment water content (Tab. 3) at the control station (66.4%) most likely reflects the finer grained texture of the sediment.

The results presented in Table 4 show low concentrations of dissolved H_2S in the intersticial water of the surficial sediment at all sampling points, almost at the limit of detection. Obviously all dissolved H_2S escapes out of the system. This is most probably due to the diffusion of H_2S out of the sediment and consequent oxidation in the water column. However, the low sulphate concentration and pH values above 8.1 below the centre of the fish cages might indicate H_2S precipitation in a form of pyrite as well (Ben-Yaakov, 1973).

Sulphate concentrations decrease from SS3 to SS1 indicating strong impact (similar to the results of meiofauna examination) directly under the centre of cages. Organic matter decomposition and consequently nutrient production in the surficial sediment is vice versa increasing in the opposite direction, with highest nutrient concentrations at SS3. Therefore it is obvious that the fish farming impact is spread over at least three times larger area then the cage settlement.

The meiofauna revealed differences in abundances and diversity with distance. A list of meiofauna taxa and their abundance at all sites is presented in Table 5. The densities of the total meiofauna were approximately 66% lower at SS1 point and 33% lower at the SS2 point than at the control site, but the difference was not evident for SS3 sample point.

In addition to lower abundances of both total meiofauna and their leading groups (Nematoda, Harpacticoida, Polycheta, Turbellaria) at the more impacted zone (SS1, SS2), we observed also absence of some typical meiofaunal groups (Gastropoda, Bivalvia, Kinorhyncha, Hyroidea). According to the data, the meiofauna from the control site reflects typical (normal) summer community of unimpacted area (Vrišer, 1997). The same variation in meiofauna could be due to differences in ecological factors (such as particle size distribution of sediment) at sampling and control sites.

Few particular studies regarding the fish farming impacts on benthic communities were found in the literature before 1999. Lower abundance and biomass (up to 37% of the normal community) of macrofauna at the fish cages sites are reported by Weston (1990) and Hargrave *et al.* (1997), though these results are presented in the context of the different methodological and/or ecological aspects. Our results (*i. e.* a 66% reduction of the total abundance and disappearance of some sensitive groups as Mollusca and Kinorhyncha) are highly consistent with the last published studies (Mazzola *et al.*, 1999, 2000; La Rosa *et al.*, 2000; Mirto *et al.*, 2000) on fish mariculture effects on meiofauna.

CONCLUSIONS

Environmental changes were most evident in benthos showing a long-term impact of fish farming on meiofauna communities. Settling of unconsumed food and constant deposition of waste and fish feces under and adjacent to fish cages has been found to reduce diversity and abundance of benthic meiofauna. The impact, *i.e.* impoverishment of meiofauna, was local and most pronounced in the sediment directly below the cages.

Pore water concentrations of hydrogen sulphide, sulphate and elemental composition of sediment also indicate the greatest impact directly under the cages. However, despite continuous organic loading on the sediments below the fish cages, the measured concentrations were within variability of the background levels of the Bay of Piran.

The sedimentation of total suspended matter, particulate organic carbon and total particulate nitrogen in the fish farm region was greater than that at the control station because of the higher deposition of organic waste in the form of feces and uneaten food beneath the fish farm. In comparison to the control site, the lower C/N ratio of sedimented suspended matter in the fish farm accounted 7.3 (at.), indicating a greater supply of proteinaceous material.

The values of $\delta^{13}C$ and $\delta^{15}N$ of fish were similar to those in dry food pellets fed to sea bass (*Dicentrarchus labrax)* indicating their primary source of food. The highest values of $\delta^{13}C$ and $\delta^{15}N$ were observed in the sediment trap samples resulting from heterogeneous sedimented material, such as particulate matter, waste food, feces and mucous macroaggregates.

Results of this preliminary study suggest that the system could be in a *quasi* steady state, where removal processes balance the organic matter loading from the cages. Several mechanisms could be responsible for this situation, including site-specific properties such as bottom currents, water exchange and bottom topography, rapid OM decomposition rates, sediment characteristics and bioturbation. Nevertheless, additional analyses concerning the impact on sediment, such as quantification of decomposition of organic matter by benthic flux chamber, observation of bacterial mats and determination of more detailed sediment profiles (biological and chemical parameters) under the fish farm, must be performed in the future.

The database from this study provides useful information for the better planning of future investigations of the fish farm impact and for reduction of the organic matter overload in the shallow coastal ecosystem of the northern Adriatic.

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VPLIVI GOJENJA RIB NA MEIOFAUNO TER BIOGEOKEMIČNE LASTNOSTI SEDIMENTA TRŽAŠKEGA ZALIVA

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POVZETEK

V območju marikulture se kopiči neporabljena hrana, potrebna za intenzivno gojenje morskih organizmov, presnovni produkti organizmov, kot so feces in različni eksekreti ter različni kemijski dodatki, kot so antibiotiki in protiobrastna zaščitna sredstva. Konstanten in povečan vnos organske snovi posledično vodi do sprememb ekoloških lastnosti obremenjenih območij te vrste, zato smo v okviru te študije opravili preliminarne raziskave območja marikulture rib v Piranskem zalivu.

Vzorčevanje je potekalo v okviru 24-urnega terenskega dela (21. in 22. junija 2000) na vzorčevalni postaji v območju gojišča rib ter na kontrolni postaji, locirani zunaj neposrednega vpliva marikulture. Preliminarni rezultati te študije so pokazali največje spremembe v bentoški združbi (spremembe v sestavi populacije meiofaune), ki so odsev dolgotrajnega vpliva marikulture. Osiromašnje meiofaune in višje koncentracije vodikovega sulfida v pornih vodah je bilo najbolj izraženo v sedimentu neposredno pod ribjimi kletkami. V območju gojišča rib smo zabeležili tudi višje vrednosti celotne suspendirane snovi, suspendiranega organskega ogljika in celotnega dušika, kar je verjetno posledica večjega vnosa organske snovi. Nižje vrednosti C/N razmerij suspendirane snovi vzorčevalne postaje pa potrjujejo večji vnos proteinske snovi (odpadne snovi gojenja rib) glede na kontrolno postajo. Izotopska sestava, tj. vrednosti $\delta^{13}C$ in $\delta^{15}N$ analiziranih gojenih rib, je bila podobna tistim, določenim v hranilnih peletih, s katerimi hranijo ribe, kar kaže, da so le-ti njihov primarni vir prehrane.

Rezultati te študije so podlaga in izhodišče za nadaljnje raziskave vplivov marikulture na obalno slovensko morje.

Ključne besede: ribje kletke, $\delta^{15}N$, $\delta^{13}C$, sedimentacijske pasti, sediment, meiofauna

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