RECYCLING OF PARTICULATE NITROGEN WASTE FROM THE FISH FARMS: EFFICIENCY OF HARD SUBSTRATE DEPLOYMENTS

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Abstract

The methodology for evaluation of hard substrate deployments for removal of particulate nitrogen waste deriving from aquaculture based upon $^{15}N/^{14}N$ ratios of colonising organisms was developed and tested at four fish farms in N Atlantic, N Adriatic, E Mediterranean and in the Red Sea. The hard substrates were proven efficient in oligotrophic environments, while in turbulent mesotrophic environments with multiple nitrogen sources the effect of farm-derived particulate nitrogen on the fouling organisms could not be traced by environmental isotopes.

Key words: fish farm, nitrogen, stable isotopes, suspension feeders

Introduction

Fish farms release large amounts of soluble inorganic and particulate organic matter (POM) into the environment. In order to capture effluents released from the fish farms, removable hard substrates were deployed in the immediate surroundings of the fish cages, so that these would be colonised by filtering organisms.

The aim of the present study was to examine whether the hard substrate deployment can efficiently reduce the environmental impact of particulate waste deriving from aquaculture. The flow of particulate organic nitrogen from fish farms to the local food web was traced using stable nitrogen isotopes. Nitrogen stable isotope compositions of POM and fouling communities colonising hard substrates (hereafter referred to as biofilters) adjacent to the fish farms and at non-polluted reference locations were determined. Based on differences in $^{15}N/^{14}N$ ratios in POM and organisms at both sites, the contribution of cage-derived particulate nitrogen to the organisms' diet and thus the efficiency of filtering organisms in removing the particulate nitrogen waste were estimated.

Experimental

At four fish farms in Oban (Scotland, N Atlantic), Piran (Slovenia, N Adriatic), Crete (Greece, W Mediterranean) and Eilat (Israel, Red Sea), biofiltering units consisting of several floating arrays of hard substrates were installed in June 2001. Each array was a set of plastic net cylinders (50 cm high, 25 cm in diameter) secured on horizontal frames at 8 m depth. The biofilter arrays were oriented perpendicular to the predominant current direction so as to maximise their exposure to effluents released from the cages. The same structures were installed at reference locations.

Samples of particulate organic matter (POM) and fouling organisms colonising the biofilters at the cages and at reference locations were taken seasonally from July 2001 to May 2003. Individual species and entire fouling communities from randomly selected biofilters were analysed. Faecal material was analysed, too. Stable isotope compositions of nitrogen were determined using a continuous-flow isotope ratio mass spectrometer (Europa 20-20 with ANCA-SL preparation module) and expressed as relative deviation in permil from the $^{15}N/^{14}N$ ratio of atmospheric nitrogen ($\delta^{15}N$). Assuming that the isotope separation between food (i.e. POM) and organisms was the same for the same species at the cages and at the reference locations (1), the fraction of organisms' diet deriving from the farm-derived waste was estimated using a simple mixing equation. As end-members, $\delta^{15}N$ values of POM at reference locations and fish faeces as farm-derived particulate waste were considered (2). Remains of food pellets were considered as negligible since the food conversion ratios have been reduced to ~1.

Results and discussion

In most of the cases, a systematic enrichment in ^{15}N was observed in samples collected at the cages compared to those from reference locations (Table 1). In Oban, d^{15}N of POM and fouling organisms were almost the same at both locations due to the dispersion and mixing in the turbulent environment. In Piran, POM was enriched in ^{15}N at the cages compared to the reference location; however, the organisms at reference location were enriched in ^{15}N compared to the biofilters at the cages. The farm-derived POM was obviously not the only factor affecting the $\delta^{15}N$ of the fouling communities at both sites. The influence of cage-derived POM on the $\delta^{15}N$ of fouling organisms in Crete and in Eilat was detected as an enrichment of fouling organisms at the cages in ^{15}N compared to those at reference locations by about 2‰. Lower $\delta^{15}N$ of the fouling organisms compared to the POM in Crete are due to the taxonomic composition of the fouling community, where bryozoans – relying predominantly on phytoplankton as a food source – prevailed. It was estimated that at the same taxonomic composition of fouling communities colonising the biofilters at the cages and at reference locations, about 76% and 65% of nitrogen consumed by fouling communities on biofilters at the farms in Crete and Eilat, respectively, derived from the fish cages. A big discrepancy in efficiency of removing particulate waste between entire communities and individual species was observed. The most efficient in removing particulate waste from fish farms are annelids (33-48% of recycled N derived from the cages), followed by ascideans (27%), sponge (21%) and bivalves (19%). A mass calculation of N consumption was made for the fish farm in Eilat and Crete. Considering the dry masses of fouling communities (116-575 g/m^2 in Eilat, 106 – 370 g/m^2 in Crete) and concentrations of N in organisms (2.2 and 1% dry weight in Eilat and Crete, respectively), 1.6-7.5 g N from fish cages per m^2 of biofilter was retained in Eilat and 0.8-2.8 g/m^2 in Crete.

Table 1. Nitrogen stable isotope compositions ($\delta^{15}N$) of particulate organic nitrogen and organisms at four selected fish farms and reference locations

	CRETE $\delta^{15}N$ [‰]	EILAT $\delta^{15}N$ [‰]	OBAN $\delta^{15}N$ [‰]	PIRAN $\delta^{15}N$ [‰]
Faeces	9.5 ± 1.2*	7.0 ± 0.3*	4.8 ± 0.9**	6.5±0.3**
POM				
Fish farm	8.0 ± 2.3	4.2 ± 1.0	6.1 ± 2.9	6.0 ± 1.3
Reference	6.6 ± 2.2	3.6 ± 0.8	6.2 ± 1.8	4.6 + 2.4
Fouling communities+				
Fish farm	6.3 ± 0.9	5.6 ± 1.8	10.0 ± 2.0	6.3 ± 1.7
Reference	4.4 ± 0.3	3.5 ± 1.4	9.9 ± 1.4	6.8 ± 0.4

*stripped from fish
** sampled in traps directly under the cages
+homogenised samples of entire communities

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