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Assessment of the local environmental impact of intensive marine shellfish and seaweed farming—Application of the MOM system in the Sungo Bay, China

Jihong Zhang [a,*], Pia Kupka Hansen [b], Jianguang Fang [a,*], Wei Wang [a], Zengjie Jiang [a]

[a] Department of Mariculture Ecology and Carrying Capacity Laboratory, Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Nanhai Road 7#, Qingdao City, Shandong Province, 266071, PR China
[b] Institute of Marine Research, P. O. Box 1870, Nordnes, N-5817 Bergen, Norway

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ABSTRACT

The impact of large scale shellfish (*Crassostrea gigas*, *Chlamys farreri*) and seaweed (*Laminaria japonica*) culture on the benthic environment at the Sungo Bay, China was assessed using the B-investigation of the MOM system. The MOM system (Modelling-Ongrowing fish farms-Monitoring) was developed to control the impact of organic waste from marine fish farms in Norway, but it is based on a general concept of environmental management and may be adapted to other fish species and longline shellfish or seaweed farming by adjusting parameters and techniques. 10 sampling station were set and a total of 66 sediment samples were collected. Seasonal variations in three groups of parameters were compared, but no significant differences were detected between the different culture species sites. Benthic animals were found in all samples, and the redox potential stayed above +50 mV. The sediment conditions according to the Groups 2 and 3 parameters of the MOM-system were compared. The results suggest that the Sungou Bay benthic environment belong to condition 1 or 2, which means that the effects of long term shellfish and seaweed farming activities on the benthic environment of Sungou Bay were low. But the result also showed that the impacts in summer and autumn are likely to be greater than in winter and spring. More studies need to be performed to adjust the investigation to Chinese conditions and to shellfish farming, so as to form an adequate system for China. The reasons that keep the Sungo Bay benthic environment in good condition were analysed.

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1. Introduction

China is the biggest marine shellfish and seaweed producer in the world, and the annual production of shellfish and seaweed were 11,135,000 tonnes and 1,502,000 tonnes respectively in 2006. The aquaculture history of some shellfish culture areas is more than 20 years old. The biodeposit excreted by shellfish or the fall-off of the seaweed has accumulated in the seabed, which may not only affect the benthos organisation, but may also deteriorate the environmental conditions. So far there has been no simple effective method to evaluate the influence of shellfish and seaweed aquaculture on the environment.

With the increasing of the large intensive mariculture of Atlantic salmon, Norway has developed regulatory frameworks to ensure a sustainable mariculture industry. Achievements in fish health have led to vaccination programmes and to the development of standardised practices and regulations, which minimise the risk and effects of diseases. A vital part of the Norwegian environmental regulation is a system called MOM (Monitoring, Ongrowing fish farms, Modelling), which ensures that the environmental conditions of the surrounding environment does not deteriorate beyond predetermined levels (Ervik et al., 1997). MOM consists of a model and a monitoring programme including Environmental Quality Standards (EQS) so changes in the environmental conditions of sites can be followed closely with relatively low costs. The monitoring programme consists of three types of investigations (A, B and C), the A-investigation is a simple measurement of the rate of sedimentation of organic material below the fish farm; the B-investigation is performed in the local impact zone and combines three groups of parameters; the C-investigation is a study of the benthic community structure along a transect drawn from the fish farm towards sedimentation areas to sensitive parts of the intermediate and regional impact zones (Hansen et al., 2001). Based on the MOM monitoring program a Norwegian standard for the monitoring of fish farm sites has been made (Norwegian Standards Association, 2000), which is now a part of the legislation (Anonymous, 2004). Environmental quality standards of Norway is the foundation of MOM system, and MOM system is a relative successful monitoring programme which is helpful for the sustainable development of salmon farming in Norway. Therefore, in this paper, we try to use the MOM B-investigation system for reference at shellfish aquaculture in Sungo Bay.

Sungo bay is located in Shandong Province of People's Republic of China. With an area of 144 km^2, it has been used for aquaculture for

* Corresponding authors. Tel.: +86 532 85822957; fax: +86 532 85811514.
E-mail addresses: zhangjh@ysfri.ac.cn (J. Zhang), fangjg@ysfri.ac.cn (J. Fang).

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Table 1
Annual productions and culture areas of dominant species in Sungo Bay from 1996 to 2007

Species		1996	1999	2004	2005	2006	2007
Scallop	Yield ($\times 10^4$ tonnes)	4.5	1.3	0.4	0.2	1.2	1.7
	Culture area (km^2)	31.3	13.5	4.2	2.7	7.7	7.9
	Unit yield (kg/m^2)	1.4	0.9	1.0	0.7	1.5	2.1
Oyster	Yield ($\times 10^4$ tonnes)	1.2	1.6	15.0	9.1	9.9	9.7
	Culture area (km^2)	5.9	7.2	41.7	35.6	33.5	38.3
	Unit yield (kg/m^2)	2.0	2.2	3.6	2.5	2.9	2.5
Kelp	Yield ($\times 10^4$ tonnes)	5.4	2.9	5.6	5.9	5.8	6.0
	Culture area (km^2)	37.4	37.9	58.1	54.8	54.9	55.6
	Unit yield (kg/m^2)	1.5	0.8	1.0	1.1	1.1	1.1

more than 20 years (Guo et al., 1999). The main cultivation method is longline culture and mainly cultivated species include seaweed (*Laminaria japonica*), scallop (*Chlamys farreri*) and oyster (*Crassostrea gigas*). As one of the most important aquaculture bases for shellfish and seaweed in the north of China, the annual yields of kelp, oyster and scallop were 5.4×10^4, 1.2×10^4 and 4.5×10^4 tonnes, respectively in 1996. From then on, high summer mortalities for scallops in the bay had led to changed aquaculture practices, including shifting from mainly culture species of scallop to oyster. In 2005, the annual yields of scallops were in the lowest situation (annual yields was only about 2000 tonnes) (Table 1).

There were a number of studies on the pelagic environment (Song et al., 2007), carrying capacity of shellfish mariculture in Sungo Bay (Grant and Bacher, 2001; Hawkins et al., 2002; Nunes et al., 2003; Duarte et al., 2003; Bacher et al., 2003), the re-suspension and fluxes of nutrients at sediment-water in the Bay (Chen et al., 2007; Jiang et al., 2007). But reports on the effects of biodeposits from suspended longline culture on the local benthic environment were lacking. Though less serious than finfish farming, sedimentation of faeces, pseudofaeces and fall-off seaweeds beneath shellfish and seaweed farms could effectively lead to organic enrichment, which is generally similar to finfish mariculture. The MOM system was developed for marine fish culture but is based on a general concept of environmental management and may be adapted to other species by adapting parameters and techniques. Therefore, in this paper, the MOM B-investigation was tried out in the Sungo Bay to assess the impacts of shellfish and seaweed culture on the environment.

2. Materials and methods

2.1. Study site

The Sungo Bay is a semi-enclosed bay located at the northwest coast of Yellow Sea, China, with maximum depth of 21 m in the mouth, and the average depth is 7.5 m. The total area of the bay is about 144 km^2, and nearly 2/3 of the area is used for bivalves and seaweed aquaculture since 1983. The species pattern of mariculture is shown in Fig. 1. The bottom sediments are predominantly composed of clayey silty sand (over 70%). In this paper, the total bay is considered as one site and 10 sampling stations were chosen in the bay to cover the various aquaculture species, which were measured in April, July, November, 2006 and January, 2007 (Fig. 1). There were 4 sampling stations (#7, #8, #9, #10) within the shellfish culture areas, 3 sampling stations (#3, #4 , #5) within the polyculture areas, 2 sampling stations (#2 and #6) within kelp culture areas and 1 sampling station (#1) at the no-culture areas.

2.2. Sample collection and measurement

Sediment samples were collected by a small gravity core sampler with transparent corers (diameter is 6.6 cm) or by a modified Van Veen grab (250 cm^2). At least 2 samples were collected at each station. In accordance with the MOM-B guidelines, during sampling, if the grab is empty on retrieval, another attempt was made. If the second attempt was also unsuccessful, the sea bottom was likely to be hard bottom, without accumulation of organic material.

After sampling the sediment, the following procedure was applied.

First, the chemical parameters (pH and redox potential) were measured at 2-cm depth intervals in the core samples (from the surface to 8 cm of sediment). The parameters of pH and redox potential were measured by the instruments of SENTRON pH-System 1001 (accuracy ±0.01) and Meterlab PHM 201 (accuracy: ±1 mv), respectively. If cores could not be collected, the electrodes might be inserted directly into the grab samples. The pH values were read when the given values were stable, and the Eh values were read when the drift was less than 0.2 mV/s.

Second, the sensory parameters were observed, which included sediment colour, odour and consistency, gas ebullition, and thickness of sludge accumulated on top of the original sediment.

Final, the sediment samples were sieved through a 1-mm mesh sieve and the materials remaining on the mesh screen were

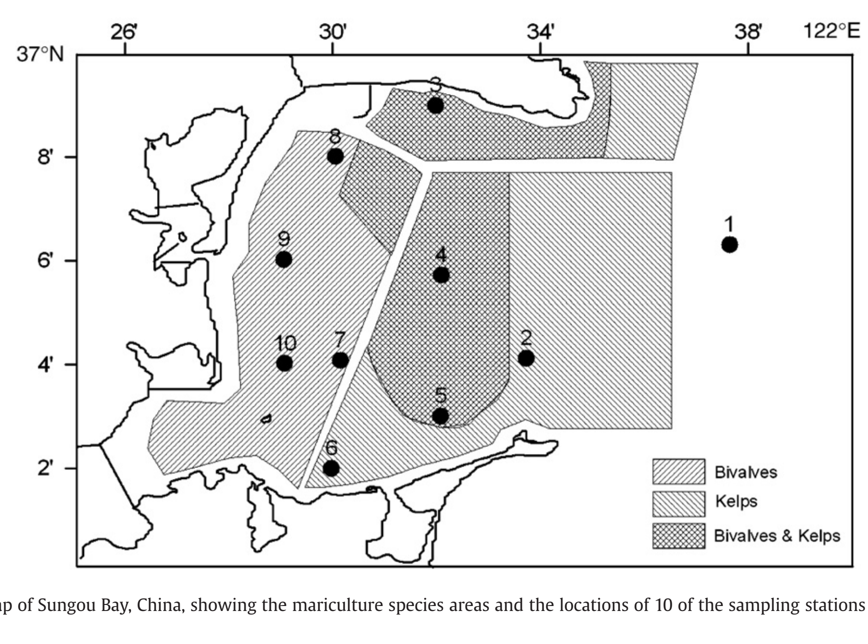

Fig. 1. Map of Sungou Bay, China, showing the mariculture species areas and the locations of 10 of the sampling stations (#1–#10).

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