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CASE HISTORIES AND NEW APPROACHES TO PLANNING AND MODELLING FOR NORWEGIAN MARICULTURE

by

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ABSTRACT

To promote a sustainable mariculture industry the environmental impact of the individual fish farm must be adjusted to the holding capacity of the site. The present regulation systems seems insufficient in achieving this. We present a new regulation system consisting of two integrated parts; 1) a monitoring program which is adjusted to the degree of exploitation of the site, and 2) a model which simulates the local impact. The system will be helpful in maintaining satisfactory water quality within the fish farms by reducing pollution and be useful in coastal zone management.

INTRODUCTION

The main environmental objectives of a sustainable mariculture industry are to fulfil the environmental requirements of the cultured organisms and to keep the environmental quality standards defined by society. The production in Norwegian mariculture has increased rapidly during the last decade. In 1993 it reached a total of approximately 170 000 metric tonnes Atlantic salmon and rainbow trout and further growth is expected. The present system for regulating mariculture is insufficient in handling this situation, representing a challenge with regard to both coastal zone planning and site management. This is the case in many ICES countries and different approaches have been chosen (Rosenthal et al. 1993). The different regulations seems to cover juridical and economical aspects while the environmental ones receive less attention. A more comprehensive approach to planning and regulation of mariculture is therefore needed. This paper presents a system for planning and management of mariculture at site level.

CASE HISTORIES

The Norwegian legislation regarding mariculture limits the size of the individual fish farm by setting a maximum rearing volume of 12 000 m^3 down to 5 m depth. The stocking density must be kept below 25 kg fish per m^3. Thus, the maximum joint cage area of one farm is 2 400 m^2, and the maximum biomass is 300 metric tonnes. There are no guidelines regarding clustering or scattering of pens, but the fish farm must not give rise to pollution. The following two case histories illustrates the insufficiency of the existing regulation.

Case one.

The fish farm was established in 1980 in a sheltered tidal area on the rocky coast of Western Norway. Average depth was 14 m under the farm and the average current velocity was 2 cm/s with frequent periods of velocities below 0.5 cm/s. After four years of operation 10 to 30 cm of organic waste from the farm had accumulated under the cages. The sediment under the cages was azoic and the fauna in the vicinity of the farm was absent or dominated by *Capitella capitata* (Aure et al. 1988). The sediment was rich in metabolites from anaerobic degradation of feed and spontaneous outgassing of methane, carbon dioxide and hydrogen sulphide occurred (Samuelsen et al. 1988). The farm experienced several outbreaks of infectious diseases and after treatment with oxytetracycline up to 300 ppm of the drug was found in the sediment (Samuelsen et al. 1988). Following a medication with oxolinic acid 100 % of the wild fish caught in the vicinity of the farm contained this drug (Samuelsen et al. 1992). The site and the adjacent area were heavily affected by the farming operation, and in

1991 the farm was moved to a more exposed location.

Case two.

This farm was located in a small bay and in operation for five years. Depth under the cages varied from 7 to 15 m and the average current velocity was 2.1 cm/s. After four years the accumulation of organic waste under the cages was up to 40 cm and severe outgassing occurred (Ervik et al. 1985). The impact on the fauna was narrowly restricted to the immediate vicinity of the farm, but under the cages the sediment was azoic (Aure et al. 1988). The site was abandoned in 1985. In 1990 the fauna in the sediment where the farm used to be was still poor and dominated by *Capitella capitata* despite low organic content. This was probably due to copper concentrations above 400 ppm in the sediment, a residual from the antifouling treatment of the net pens (Grønnestad 1994).

The two case histories reveals the type of local impact experienced in Norwegian fish farming first described by Braaten et al. (1983), which results in abandonment of many sites after a few years of operation. Production losses due to self pollution are difficult to estimate, but no doubt some of the health problems in mariculture have resulted from poor environmental conditions. Some environmental impact must be tolerated if one wants a mariculture industry, while other effects such as outgassing, azoic sediments and accumulation of antibacterial agents are unacceptable.

The pollution problems are partly a consequence of the current legislation which has several deficiencies: restriction of the rearing volume may lead to high stocking densities relative to water renewal; concentration of a large biomass within a small area may lead to a very high load and subsequent accumulation of organic sediments on the seabed below the cages; effluents from the individual farms can not be quantified making overall estimation of the impact of several farms within an area difficult. In addition, the environmental quality standards are too vague, and no standardized monitoring program exists.

A NEW APPROACH

The weaknesses of the present regulatory system has led to the development of a new concept, where the main emphasis is on adjusting the local environmental impact of the fish farm to the holding capacity of the site. The concept is thus based on regulating the environmental effects of the farming activity, rather than controlling the amount of effluents from the farm. Benthic degradation has been chosen as the main impact, since it has relevance to both fish health and the environment, some information exists on the relationship between effluents and effects, it is quantifiable and integrates the impact from the farm over time and is therefore suitable for regulatory purposes. The holding capacity of a site is defined as its ability to receive organic effluents without the benthic impact exceeding predefined levels. In addition to the regulation of benthic impact water quality in the fish pens and in the adjacent water bodies are also included.

A regulatory system for the individual sites based on the above concept is being developed. The system is called MOM, which is an acronym for Monitoring-On growout fish farms-Modelling. It consists of two integrated parts, a monitoring program and a simulation model. A fundamental element of the system is the degree of exploitation, which is the relation between the benthic impact of the farm and the holding capacity of the site, both determined by the simulation model. MOM operates with three degrees of exploitation, each corresponding to a level of surveillance, which defines the extent the monitoring required to avoid exceeding the predefined environmental quality standards (Fig 1).

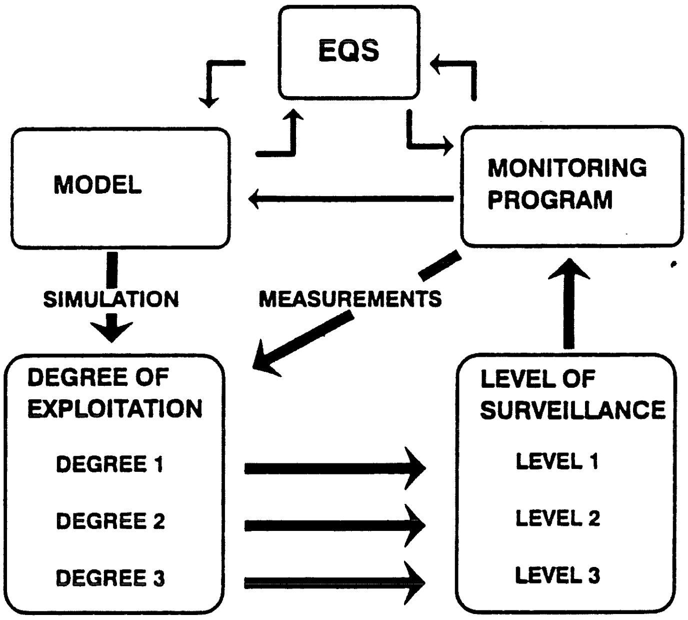

Fig. 1. An outline of the MOM system showing the relation between the model, the degree of exploitation, the level of surveillance, the monitoring program and the environmental quality standards (EQS). Degree 1 is equivalent to low exploitation, degree 3 to high exploitation.

The higher the degree of exploitation the higher the level of surveillance and the more frequent monitoring is needed on the site. In cases where the calculated degree of exploitation diverge from the results of the monitoring, the degree of exploitation is altered in accordance with the observed values. We are trying to keep the system simple and practical, and flexible enough to incorporate new knowledge as such is gained.

In connection with MOM the following environmental objectives have been proposed as guidelines for assuring a sustainable mariculture: safeguarding long term utilization of sites; preventing accumulation of organic waste leading to depletion of benthic infauna under the cages, and keeping drug residues below predefined levels.

The monitoring program consists of three types of investigations (A, B and C) which are carried out on each level of surveillance, but with different frequencies. Investigation A is an observation of smell, colour, consistency and presence of fauna in sediment samples taken from under the farm. It will give the fish farmer and the authorities a simple and qualitative mean of following the impact from the farm. Investigation B is a quantitative study of the same parameters as in investigation A and additional measurements of chemical sediment parameters. Investigation C is a faunal study to follow a possible long term deterioration of the areas adjacent to the farm. The frequencies of the different investigations in relation to the levels of surveillance is shown i Table 1.

Table I. Frequencies of the different investigations applied at different levels of surveillance

	Investigation		
	A	B	C
Surveillance level 1	*	0.5/PC	8. years
Surveillance level 2	*	1/PC	5. years
Surveillance level 3	*	2/PC	2. years

* Monthly
PC: Production Cycle

The model has two tasks; one, to simulate the degree of exploitation given farm and site specifics, and two, to calculate the maximum loading from a farm when the degree of exploitation and site specifics are given. The model consists of four modules (Fig. 2).

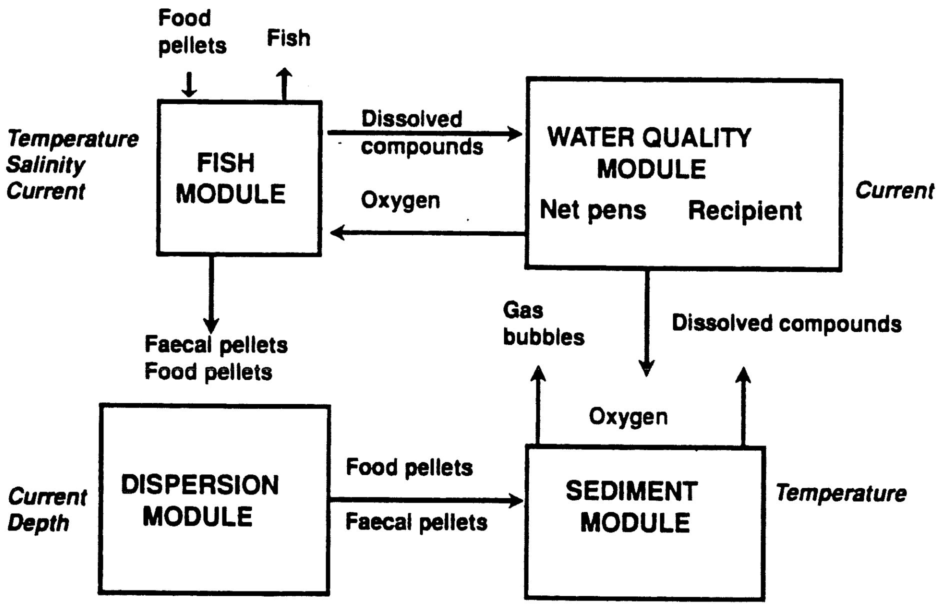

Fig. 2. A flow diagram of the MOM model showing the connection between the four modules, the input to each module and the factors affecting them.

The *Fish module* simulates effluent of dissolved and particulate material and the oxygen demand of the fish in relation to composition and amount of feed, fish size and biomass, temperature, and uptake, incorporation and excretion of food by the fish. The *dispersion module* simulates the dispersion and sedimentation rates of food and faecal pellets in relation to farm area, current velocity and direction and depth. The *sediment module* simulates the accumulation and degradation of organic material in relation to loading, temperature and benthic fauna. The *water quality module* simulates oxygen and ammonia concentrations and primary production in the cages and the recipient in relation to hydrodynamic and topographic factors.

APPLICATION OF MOM

In MOM a new principle is introduced where environmental impact is regulated rather than amounts of effluent or rearing volumes. The principle is general and can be applied to other enterprises provided a clear relationship between the load and the effect exists.

The environmental impact of mariculture must be regulated at both local and regional levels. We consider benthic impact to be the most important at the local level, whilst oxygen depletion in land locked basins is the dominant regional impact in Norway (Aure & Stigebrandt 1990). Eutrophication seems not to be a problem unless in restricted areas. For the Norwegian conditions, a coastal zone management system, called LENKA, has been developed, which integrates socia-economic and environmental aspects of mariculture (Pedersen et al. 1988). MOM operates at site level but can be integrated into this more comprehensive management system which operates at a higher geographical level.

The adjustment of the impact from the farming activity to the holding capacity may open new sites for mariculture and give a more flexible use of the coastal areas. By dispersing the fish over larger areas accumulation of organic matter at the seabed is prevented and water quality improved. This will optimize fish production and improve the quality of the product. Furthermore, documentation of good rearing conditions could be used for marketing purposes. Development of new farming procedures and devises reducing output from the farms may be accelerated as a result of the application of the MOM system.

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