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# ENVIRONMENTAL EFFECTS OF MARINE NORWEGIAN FISH FARMS

by

Arne Ervik (1), Per Johannessen (2) and Jan Aure (1)

1) Institute of Marine Research
Directorate of Fisheries
P.O.Box 1870
5011 Bergen - Nordnes

2) Department of Marine Biology
University of Bergen

## ABSTRACT

Sedimentation rates under fish farms may be very high, and high levels of fish stock may lead to harmful accumulation rates of the nutrient salt ammonia. The environmental effects of the organic load range from minor changes to heavy pollution, depending mostly on the hydrography and topography. Fish farms seem to have a different environmental impact than that of sewage, and it may be inappropriate to measure their outputs in terms of Biological Oxygen Demand.

## INTRODUCTION

With increasing fishfarming activities one has gradually became more aware of pollution problems connected with this industry. The problems include both self pollution and pollution of the surrounding areas.

As discussed by BRAATEN et al. (1983) the difficulties of self-pollution appear after a few years of operation. At this point the fish loses appetite and growth, and resistance to diseases decrease while mortality increase.

Detrimental effects on the surrounding are mainly due to organic enrichment, and have created conflicts with other uses of the same area, such as environmental protection and fisheries. To investigate the impact of fish farming activities, we looked at the levels of nutrient salts, the sedimentation rates and the diversity of the benthic fauna at different farms and at an un-influenced reference station in Western Norway during 1983 and 1984.

## NUTRIENT SALTS

Nutrient salts are released from fish farms by fish excretion and seepage from feed or bottom sediments.

We looked at the levels of nitrate, phosphate and total ammonia at five different depths around six fish farms.

### a) Nitrate (Fig. 1 and Fig. 3)

The concentration of nitrate shows the normal annual variation with little or no nitrate in spring and summer. There is no difference between the surface values and the concentration at 10 m depth. There is also a very close correspondance between concentrations in the fish farms and the reference stations.

b) Phosphate (Fig. 1 and Fig. 3)

Phosphate follows the same pattern of variation as does nitrate. This nutrient does not, however, show the same deficiency in surface waters at the reference stations.

The surface values are higher at the farms than at the reference areas. Phosphate values are higher at 10 m depth than at the surface. This is most pronounced near the farms and clearly indicates leakage from the phosphate-rich sediment.

c) Total Ammonia (Fig. 2A,B and Fig. 3)

The concentration of total ammonia ($NH_3$+$NH_4$+) at the reference areas reflects the normal situation, being low both at surface and at 10 m depth throughout the year. The values at the farms are much higher and strongly inferenced by the fish excretion (BEAMISH and THOMAS 1984), reaching concentrations 8-9 times higher than the reference stations. The highest values are found in autumn when fish biomass and feeding intensity are high and primary production low. Free ammonia ($NH_3$) is toxic even in low concentrations and may reach unhealty levels where fish farming activity is high.

Ammonia may be used as a monitor of water quality in fish farms, as data not presented here indicates that it is sensitive to both fish biomass and water exchange.

d) Primary Production

Primary production around these fish farms is assumed to be limited by nitrogen rather then by phosporus.

Nitrogen is mainly released directly to the water as excretion products (BEAMISH and THOMAS 1984), while the greater part of the phosphorus is sedimented with surplus feeding and faeces (MÄKINEN 1985). Nutrient deficiency in the spring and summer may limit primary production, but the high rates of feeding and excretion from July to December will contribute to the primary production of the following year. Thus continuous removal of the solid waste products have only limited influence on the level of primary production in the region.

## SEDIMENTATION

Sediment from a fishpen was collected in cylindrical traps placed on top of 1.5 m high sediment samplers resting on the seabed. The quadratic fishpen had a volume of 1000 $m^3$, while the traps had an inner diameter of 99 mm and a height of 350 mm. Old traps were replaced by divers usually every 4-5 weeks (Tab. 1 and Fig. 4).

A high density of 40 kg fish per $m^3$ water was reached by the end of August 1983. This was reduced somewhat, but remained above 25 kg per $m^3$ for the rest of the year. In 1984 both the number and size of the fish were smaller, reaching only 13 kg/$m^3$ in the middle of August.

Feeding was carried out by hand, the amount varying according to temperature and fish size. From June to November 1983, when the fish were fed moist pellets which relatively easily disintegrated, sedimentation rates were high and the ash content of the sediments low. In 1984 the fewer fish were fed a dry pellet with a better consistency resulting in decreased sedimentation rates and increased ash content relative to the feeding and fish stock (Tab. 1).

The pen was empty during the period between slaughtering the grown fish and introduction of new fish. Solids accumulated in the traps at this time must be due to resuspension of organic material and transport from the other fishpens in the farm.

The thickness of organic sediment on the seabed remained surprisingly constant in spite of the heavy sedimentation. The heights at positions 1, 2 and 3 (Fig. 4) were only about 37, 27 and 17 cm, respectively. It is not known whether this is due to decomposition of sediment, resuspension, concentration of the sediment or horizontal movement of the material on the flat seabed.

In the early days of fishfarming every fishpen was a single unit. At present more permanent constructions containing several fishpens are more common. There is also a trend towards larger fishpens and higher fish densities. This concentration of biomass might lead to a heavier output of organic solids under the fishcages with the usual pollution problems as a result. The location of fish farms and a good feeding regime are consequently more critical with this checkerboard type of fish farms.

## ENVIRONMENTAL EFFECTS

Benthic macrofauna accumulates the effects of organic loadings over time and is a good indicator of the impact of fish farms on the environment. (The response of the fauna to organic enrichment and pollution is discussed by PEARSON & ROSENBERG (1978). A method for data analysis is given by PEARSON, GRAY and JOHANNESSEN (1983)).

The three fish farms were investigated for the number of species present at various distances and depths and the number of individuals per species (Fig. 5). The bottom communities in the vicinity of Fish Farms 1 and 2 clearly indicate high organic input. The species in <u>geometric</u> class X (512←1023 individuals per species) are typical for areas with organic enrichment. At Farm 2 the fauna is dominated by the opportunistic species in geometric class X, and the total number of species is low. The seabed at this site is polluted by organic material. At Farm 1 the species number is relatively high, and the community is stimulated rather than polluted. The seabed close to Fish Farm 3 seems to be only slightly influenced by the farm.

Long range environmental effects of the farms depend greatly on the close range topography and hydrography. Of the four stations taken at Farm 3, the closest lies on a shelf where the organic material is carried away by the tide and deposited deeper in the poll, near the other stations. These have a poor fauna and are heavily polluted although the middle station is less affected than the other two (Fig. 5).

By contrast, the surroundings of Fish Farms 1 and 2, which had both a sufficient water exchange and an absence of shallow sills, showed no signs of pollution. Like other investigations, this study indicates that polls and basins with shallow sills are unsuitable recipients of organic material and should not be used for fishfarming.

## COMPARISON OF SEWAGE AND FISH FARM OUTPUTS

Outputs of organic material from fish farms can be measured as biological oxygen demand (BOD) in the same was as can sewage. BOD per weight fish produced will certainly vary with the size of fish, temperature and the amount and type of feed offered.

It appears that one should be careful when comparing the environmental effects of outputs of equal BOD from sewage and from fish farms. In the latter case, the effect per BOD-unit is smaller as the near zone fauna is rich and biostimulated, while azootic or opportunistic zones are narrow or nonexistent. (PEARSON & ROSENBERG 1978).

Reasons for the apparent differences of environmental effects of waste from sewage and fish farms might be:

1) Organic material from fish farms consists, to a great degree, of larger particles that can be directly used as food for macrofauna, thus giving a quick turnover.
2) Sewage exudes material which is too small for direct uptake in the natural food net and is partly mineralized.
3) Effluents from fish farms do not contain toxins while this is often the case with sewage.

Organic material accumulated on the seabed has little influence on the system. Little is known about the further fate of these organic sediments other than that they represent a threat to the farmed fish. (BRAATEN et al. 1983).

## CONCLUDING REMARKS

Use of the BOD unit as a measure of the pollutant effects of a fish farm gives an erroneous evaluation of the biological impact when compared to that of sewage. The large particle size of the waste products of fishfarming activities is suitable for uptake by the natural benthos or by wild fish. Only a narrow azootic or opportunistic faunal zone can be observed in the benthos immediately surrounding the farm, although large differences may occur according to the local conditions. Most important are the current regimes and amount of flow-through to the farm which could prevent harmful rates of accumulation of sediments and fish metabolites.

## ACKNOWLEDGEMENTS

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Table 1. Sedimentation from a fishpen in relation to fodder (moist and dry pellet) and fish (size and density).

| Period | Average daily amount feed in kg dry weight | | Fish | | Average temperature | Trap no. | Sedimentation rate Ashfree dry weight $g\,m^{-2}\,d^{-1}$ | Ash % | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Moist pellet | Dry pellet | Average size kg | Total weight in pen, kg | | | | | |
| 1983 | | | | | | | | | |
| 17.06-22.07 | 282 | | 2.1 | 29 400 | 12,2 | 1 | 230 | 47.6 | |
| | | | | | | 2 | 232 | 42.2 | |
| | | | | | | 3 | 176 | 42.7 | |
| 22.07-11.08 | 28 | | 2.5 | 35 000 | 12,3 | 1 | 286 | 42.6 | |
| | | | | | | 2 | 361 | 41.2 | |
| | | | | | | 3 | 192 | 52.3 | |
| 11.08-13.09 | 205 | | 2.8 | 39 200 | 12,4 | 1 | 172 | 42.4 | Pen empty 31.08-15.09 |
| | | | | | | 2 | 180 | 45.2 | |
| | | | | | | 3 | 140 | 49.0 | |
| 13.09-18.10 | 208 | | 2.9 | 25 810 | 12,5 | 1 | 221 | 47.4 | |
| | | | | | | 2 | 220 | 49.1 | |
| | | | | | | 3 | 98 | 51.2 | |
| 18.10-23.11 | 146 | | 3.0 | 26 700 | 9,7 | 1 | 157 | 55.0 | |
| | | | | | | 2 | 166 | 54.3 | |
| | | | | | | 3 | 95 | 53.5 | |
| 1984 | | | | | | | | | |
| 23.11-10.02 | 54 | | 3.1 | 27 590 | 6,2 | 1 | 29 | 51.3 | Feeding stopped 31.12 |
| | | | | | | 2 | 30 | 50.1 | |
| | | | | | | 3 | 8 | 53.2 | |
| 10.02-01.03 | 0 | | | 0 | 3,6 | 1 | 8 | 76.7 | Pen empty |
| | | | | | | 2 | 15 | 78.3 | |
| | | | | | | 3 | 16 | 79.6 | |
| 01.03-13.04 | 13 | 5 | 0.9 | 9 000 | 3,2 | 1 | 24 | 73.7 | New fish into pen 05.03.84 |
| | | | | | | 2 | 14 | 74.3 | |
| | | | | | | 3 | 7 | 76.3 | |
| 13.04-10.05 | 6 | 25 | 1.0 | 8 330 | 5,6 | 1 | 32 | 73.2 | |
| | | | | | | 2 | 40 | 72.3 | |
| | | | | | | 3 | 25 | 72.0 | |
| 10.05-14.06 | | 42 | 1.2 | 10 000 | 10,2 | 1 | 37 | 63.9 | |
| | | | | | | 2 | 27 | 68.6 | |
| | | | | | | 3 | 17 | 63.7 | |
| 14.06-02.07 | | 84 | 1.4 | 11 660 | 11,2 | | | | |
| 02.07-14.08 | | 122 | 1.6 | 13 330 | 11,8 | | | | |

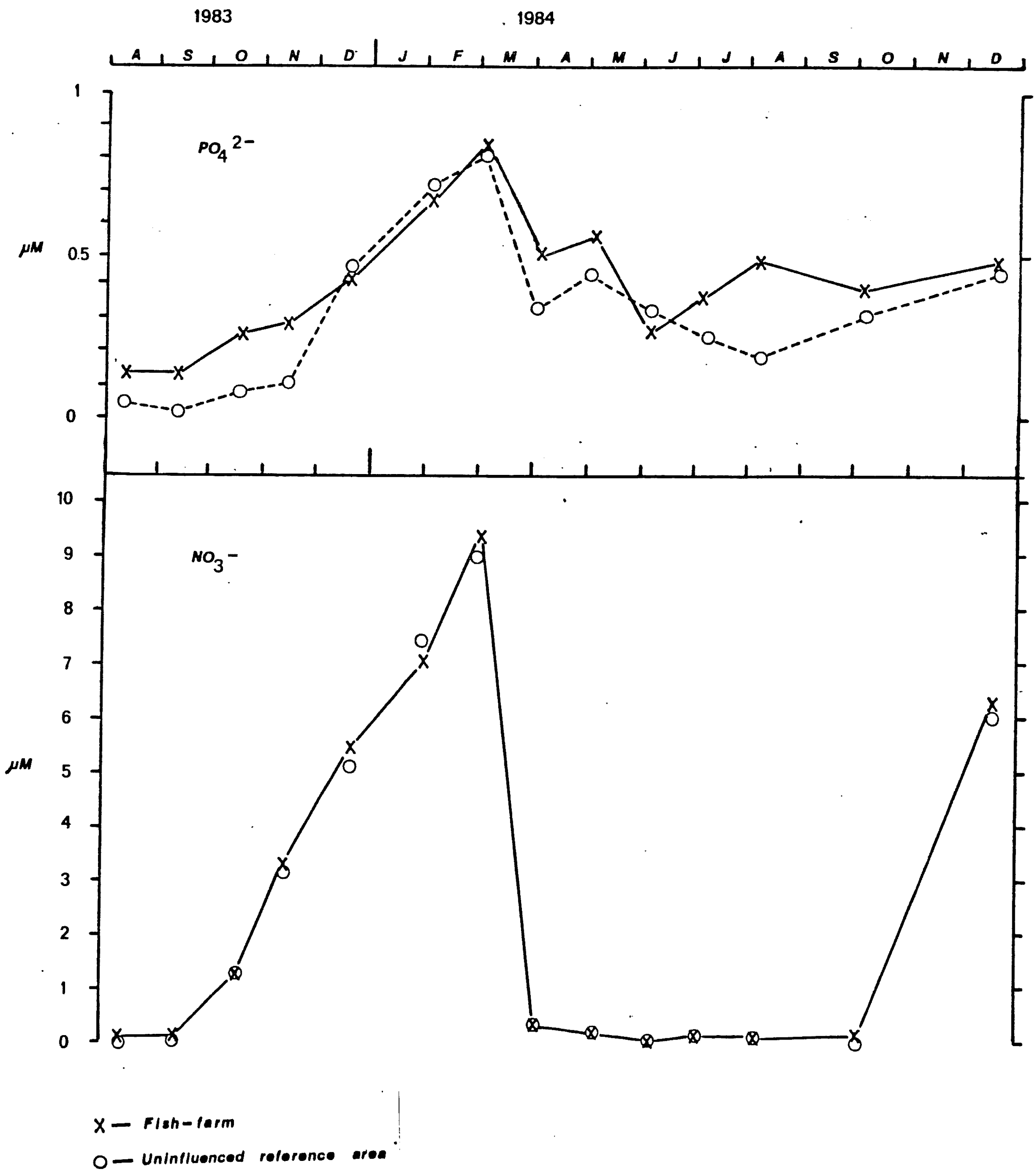


Fig. 1. Mean concentration of phosphate and nitrate (0-5 m depth) at six marine fish farms and three uninfluenced reference areas in Western Norway in 1983-84.

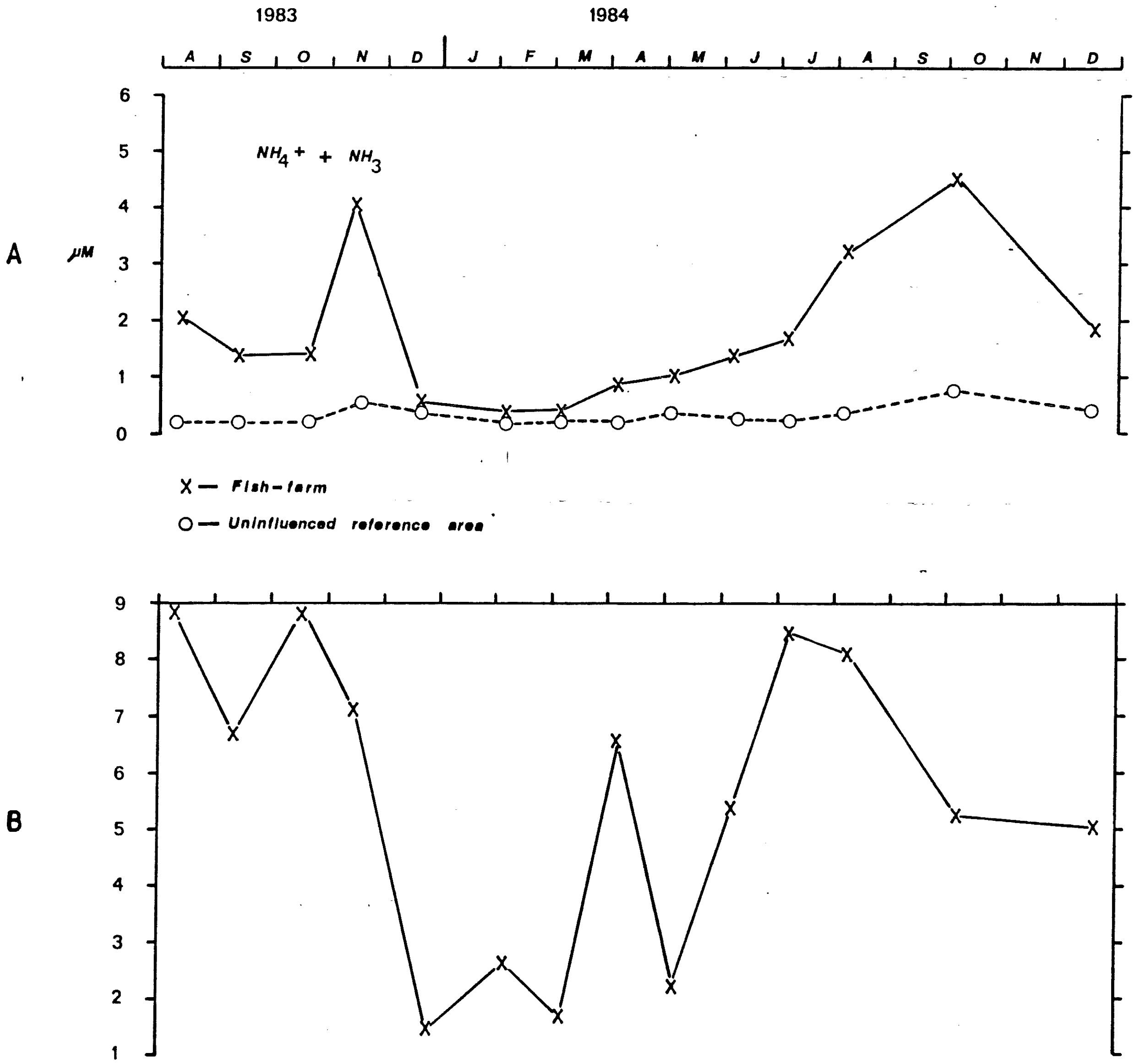


Fig. 2. A. Mean concentration of total ammonia ($NH_3$+$NH_4$+) (0-5 m depth) at six marine farms and three uninfluenced reference areas in Western Norway in 1983-84.

B. Ratio between the concentrations of total ammonia at fish farms and reference areas (shown in Fig. 2A).

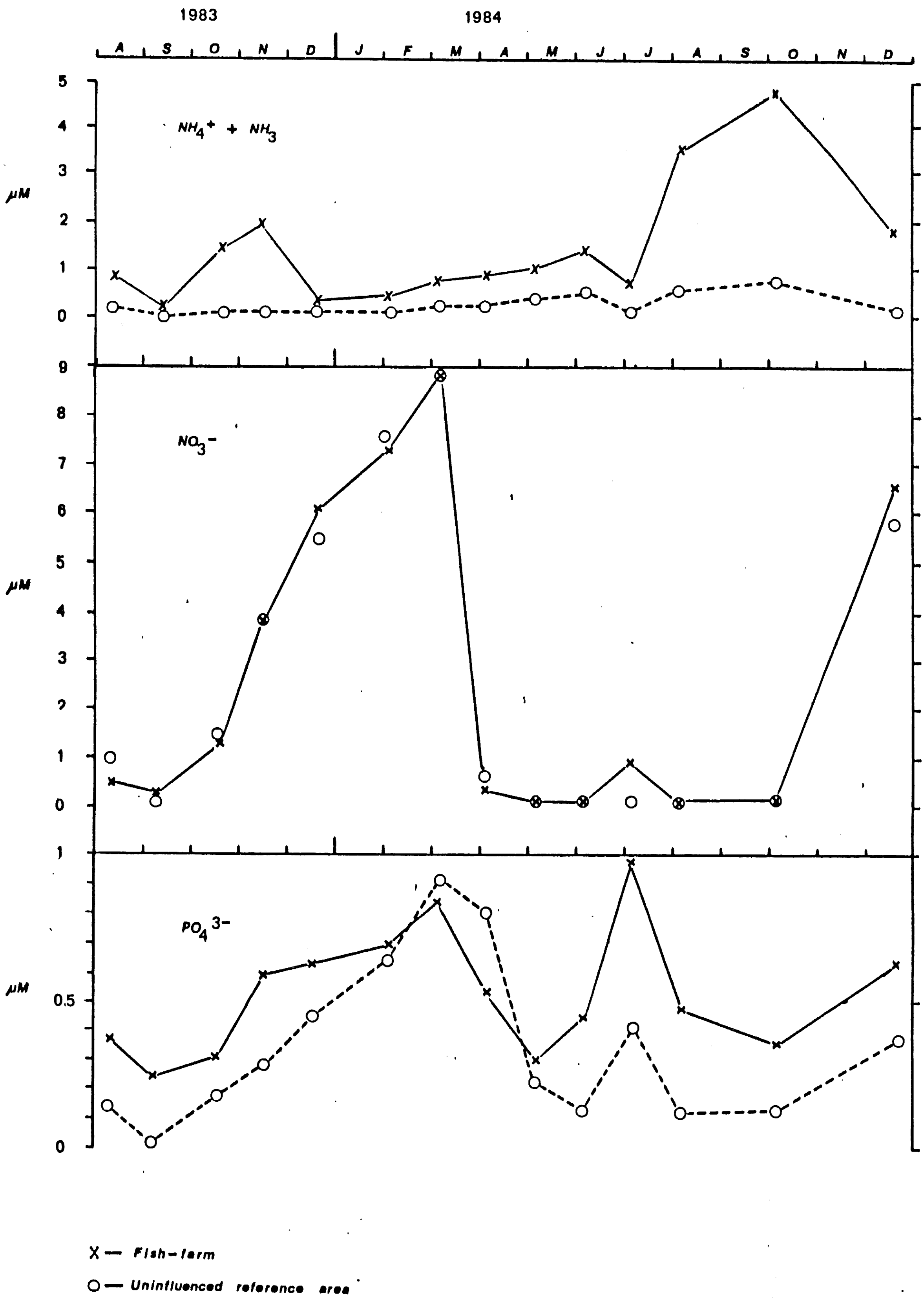


Fig. 3. Mean concentration of total ammonia ($NH_3$+$NH_4^+$), nitrate and phosphate (10 m depth) at six marine fish farms and three uninfluenced reference areas in Western Norway in 1983-84.

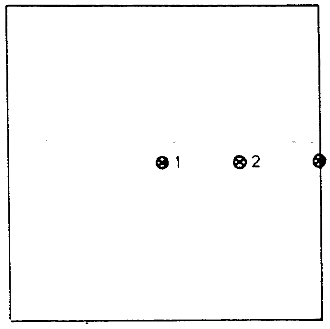


Fig. 4. Lokation of sediment traps and sediment depth observations.

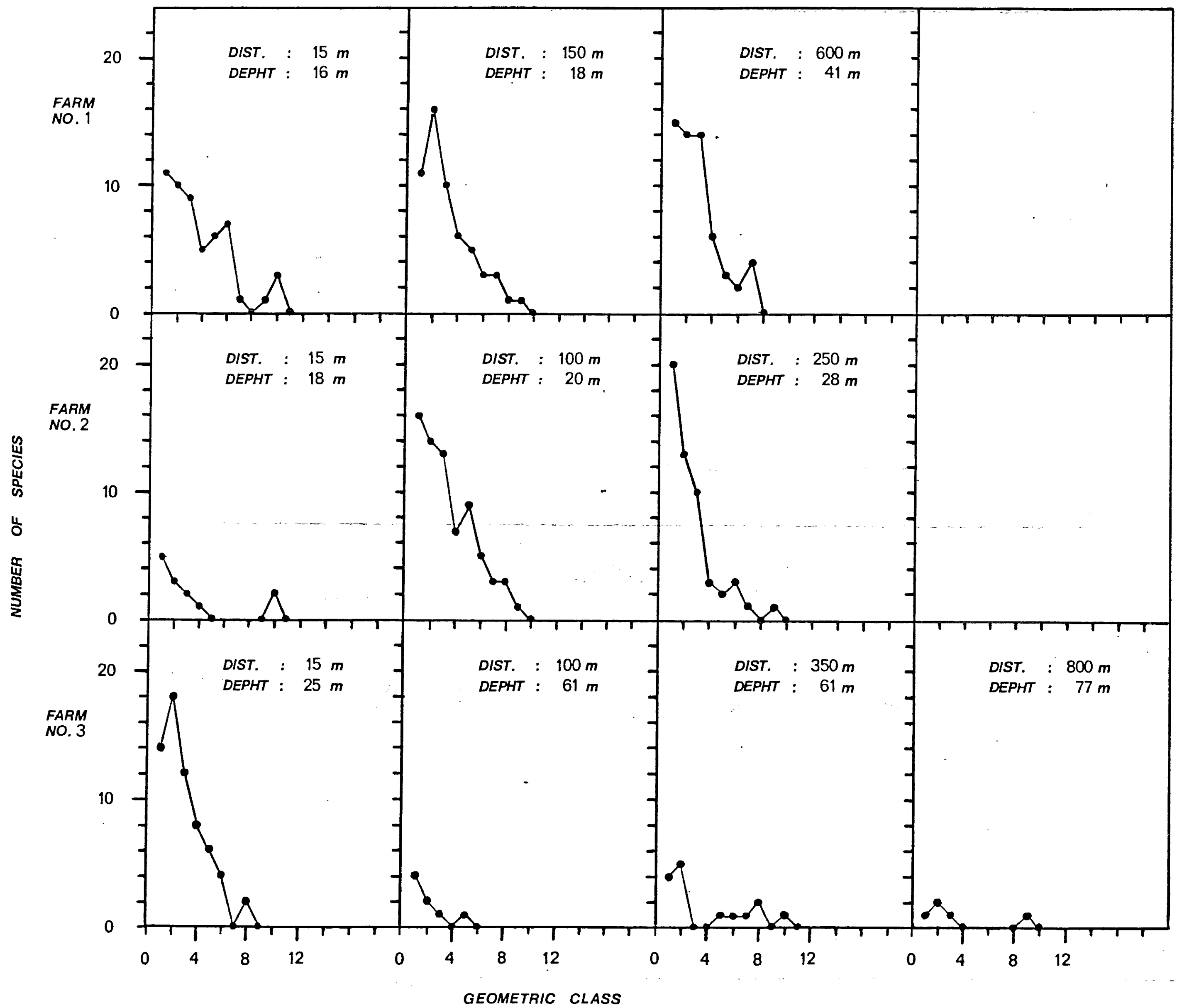


Fig. 5. Number of species in different geometric class at various depths and distances from three fish farms.