Muddy odour: a problem associated with extreme eutrophication

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Keywords: flavour, geosmin, 2-methylisoborneol, *Oscillatoria agardhii,* actinomycetes, hypereutrophy

Abstract

The results of a 4-year study in a hypereutrophic bay, Kaupunginselkä Bay at Porvoo on the south coast of Finland, indicated a significant correlation between muddy odour in bream *(Abramis brama)* and the amount of the blue-green alga *Oscillatoria agardhii* in the phytoplankton. This algal strain has previously been shown to produce the muddy-smelling compound geosmin. The numbers of muddy-smelling actinomycetes in the water and sediments of the study area were not clearly related to muddy odour in fish, nor to phytoplankton biomass. In the hypereutrophic L. Tuusulanjärvi, muddy odour in bream and pikeperch *(Stizostedion lucioperca)* was also related to the amounts of blue-green algae in the phytoplankton.

Introduction

Muddy or earthy odours in drinking water supplies and fish for human consumption are a world-wide problem affecting the utilization of aquatic resources. Some species of blue-green algae and actinomycetes (mainly streptomycetes) have been cited as a source of muddy odour in natural waters (Silvey & Roach 1975; Persson 1977; Gerber 1979). These organisms are capable of producing the muddy-smelling compounds geosmin and 2-methylisoborneol. Geosmin and methylisoborneol have been detected in natural waters (see Persson 1979) and in muddy-smelling fish (Yurkowski & Tabachek 1980). Muddy odour has generally been reported from eutrophic or hypereutrophic environments (Cees *et al.* 1974; Tabachek & Yurkowski 1976; Persson 1979).

This paper discusses the causes of muddy odour in some species of fish in two extremely eutrophic waters in southern Finland.

Material and methods

The primary study area during 1976–1979 was an extremely eutrophic brackishwater bay, Kaupunginselkä Bay at Porvoo, on the south coast of Finland. The area and the methods used have been described elsewhere (Persson 1979, 1980a). In 1978, muddy odour in bream, pike *(Esox lucius)* and pikeperch from the hypereutrophic L. Tuusulanjärvi was studied. For a synopsis of the lake, see Ryding (1980) and Vakkuri (1980). Phytoplankton data for the lake were obtained from the Helsinki City Water Works.

Results and discussion

In Kaupunginselkä Bay, there was a significant ($P < 0.05$) correlation between muddy odour in bream and the amount of *Oscillatoria agardhii* in the phytoplankton (Fig. 1). In previous work, geosmin production by this strain has been proved (Persson 1979). Other muddy-smelling strains of this alga are also known (Persson 1980b). Muddy

Hydrobiologia 86, 161–164 (1982). 0018-8158/82/0862-0161/$00.80.

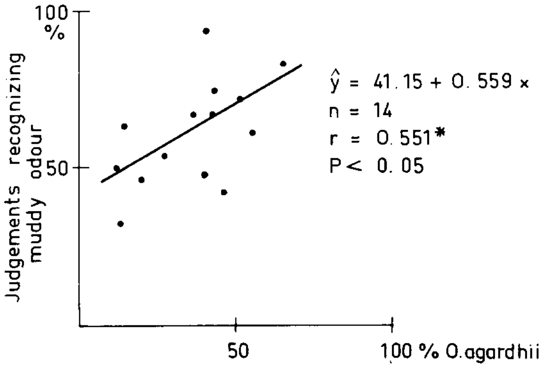

Fig. 1. Relationship between adjudged muddy odour in bream and the percentage *O. agardhii* in the total phytoplankton biomass in Kaupunginselkä Bay at Porvoo. Data from 1976–1979.

odour in bream from the study area did not seem to depend on the absolute biomass of *O. agardhii*, but rather on the proportion of this alga in the phytoplankton. This may have been a result of several factors affecting the uptake of muddy odour by the fish, e.g. sedimentation and adsorption effects (Lovell 1973). Since uptake of muddy odour by fish is facilitated when the fish are feeding (Persson & York 1978), factors affecting the ingestion of algae by the fish would also be important. The results may also reflect a variability in the odour production by *O. agardhii*, as reported for some other species of blue-green algae (Henley 1970; Leventer & Eren 1970), and discussed by Persson (1980b). The phytoplankton data for 1977–1979 (Fig. 2) from the study area indicated that muddy odour in bream occurred during the decline of the biomass peak of *O. agardhii*. However, it should be noted that the fish supply was irregular, and that fish were not always obtained during peak biomasses.

In 1977 and 1978, the numbers of muddy-smelling actinomycetes in the water of the study area were not related to muddy odour in bream (Fig. 2). In 1979, actinomycetes might have contributed to the muddy odour in fish, but it should be noted that during all three years a similar early summer maximum of actinomycetes occurred. Persson (1979, 1980b) interpreted this phenomenon as a result of the spring flood, i.e. wash out from soils. Streptomycetes are soil inhabitants (Lechevalier 1974), and are considered relatively inactive in lakes (Johnston & Cross 1976). In 1977 and 1978, the early summer maxima of actinomycetes probably did not reflect an active growth, as the prevailing water temperatures were low: in 1977, < 12 °C, and in 1978, < 15 °C. At such temperatures, streptomycetes would probably not be actively growing (Silvey & Roach 1975). In 1979, the water temperature in early summer was 17–19 °C, with possible active growth of actinomycetes.

In 1977 and 1978, the number of actinomycetes in the study area was not related to phytoplankton biomass (Fig. 2). In 1979, the concurrence of maximal phytoplankton biomass and actinomycetes may have been coincidental, the number of acti-

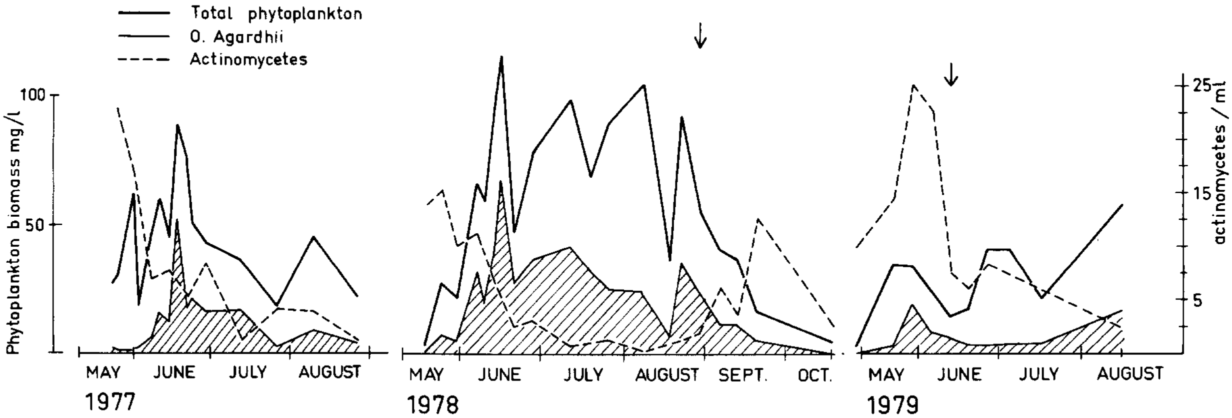

Fig. 2. Biomass of total phytoplankton and *O. agardhii*, and the concentration of actinomycetes in Kaupunginselkä Bay at Porvoo during the summers of 1977, 1978 and 1979. The arrows indicate occurrence of muddy odour in bream. Data for 1977 compiled from Persson (1979), data for 1978 partly from Persson (1980b).

nomycetes reflecting the spring flood as discussed above. However, a causal relationship between algae and actinomycetes in this year cannot be excluded (cf. Silvey & Roach 1964). The number of actinomycetes in the shore sediments of the study area bore no relationship to muddy odour in fish, nor to phytoplankton biomass (Fig. 2).

The concentrations of actinomycetes in the study area were low compared to the concentrations associated with muddy odour episodes elsewhere. Several studies have indicated that odour production by actinomycetes is inhibited in unsterilized natural water, but proceeds in sterilized water (Seppänen & Jokinen 1969; Leventer & Eren 1970; Persson & Sivonen 1979). Much of the evidence brought up in favour of actinomycetes as a source of muddy odour in natural waters is based on work with laboratory cultures (Gerber 1979). Mere isolation of a muddy-smelling actinomycete from an area does not constitute evidence for actual odour production *in situ* (Persson 1979). The data from Kaupunginselkä Bay indicate that the role of actinomycetes as a source of muddy odour in this area is insignificant compared to that of *O. agardhii.* However, actinomycetes can still be a major source of muddy odour in natural waters in warmer climates (Raschke *et al.* 1975; Silvey & Roach 1975; Weete *et al.* 1977).

In L. Tuusulanjärvi, the muddy odour in bream and pikeperch was related to the amount of blue-green algae in the phytoplankton (table 1), but for pike no such relationship could be established. However, different susceptibilities to muddy odour should be expected for different species of fish. As the intestinal tract seems to be a major route for uptake of muddy odour by fish (Persson & York 1978), the trophic positions of the fish are important, and so is the habitat of the fish compared to the odorous algae. Vakkuri (1980) indicated a relationship between blue-green algae (*Anabaena* sp.) and the odour of the lake water in L. Tuusulanjärvi. Persson (1980b) found a correlation between muddy odour in pikeperch and the amount of *O. agardhii* in the phytoplankton of the lake. Thus, several species of blue-green algae may contribute to the muddy odour in the lake, and moreover, different species may assume importance in different compartments of the ecosystem.

Table 1. Correlations between muddy odour in fish and the amount of blue-green algae in the phytoplankton of L. Tuusulanjärvi in 1978 (y = % of judgements recognizing muddy odour, x = biomass of blue-green algae, mg/l).

Regression line	r	Significance level
Pike		
$y = -2.82x + 64.95$	-0.348	n.s.
Pikeperch		
$y = 4.45x + 7.95$	0.569	$P < 0.10$
Bream		
$y = 3.74x + 38.11$	0.607	$P < 0.05$

Acknowledgements

Financial support by the following institutions during different periods of the study is gratefully acknowledged: University of Helsinki, The Academy of Finland, The Finnish Culture Foundation, The Maj and Tor Nessling Foundation, The Finnish Research Foundation for Natural Resources, and the Environmental Protection Board of the Rural Municipality of Borgå.

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