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Prorocentrum minimum (Dinophyceae) in the Baltic Sea: morphology, occurrence—a review

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Abstract

The potentially toxic dinoflagellate *Prorocentrum minimum* (Pavillard) Schiller has successfully established in the Baltic Sea in the last two decades. A review of the invasion history is presented as well as new data on the spatial and inter-annual variability of this species and its relation to salinity, temperature, and nutrient concentrations. A short literature review of the morphological characters of the Baltic *P. minimum* is also included.

From 1993 to 2002, *P. minimum* was a regular component of the summer and autumn plankton flora of the Baltic Sea proper and the Gulf of Finland. Its abundance varied considerably inter-annually and did not show any clear trends during the period. Abundance of *P. minimum* was significantly higher in the nutrient-enriched Bay of Mecklenburg (German coast) and the southern Baltic proper than in the central and northern Baltic proper and the Gulf of Finland, where its abundance was mostly sparse. In coastal waters *P. minimum* occasionally reached densities of several million cells per litre and dominated phytoplankton biomass (>90%).

Abundance of the Baltic *P. minimum* was generally not related to salinity or temperature. It could be a dominant species at both high and low salinity (over 15 and 4.8 PSU), and its temperature range was broad (from 2.7 to 26.4 °C). However, dense populations usually occurred from July to October at temperatures above 10 °C.

Further, there appears to be a positive correlation between the success of *P. minimum* in the Baltic Sea and high concentrations of total phosphorus and nitrogen.

This tolerant and morphologically variable dinoflagellate seems to be a morphospecies without subtaxa, which can expand its range in the Baltic Sea, especially in nutrient-rich coastal waters.

Keywords: Baltic Sea; Harmful dinoflagellate; *Prorocentrum minimum*; Total nutrients

1. Introduction

Increasing intensity and spreading of toxic and non-toxic blooms, as well as global transport of non-

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indigenous marine species, have been documented for many areas including Scandinavian waters (e.g., Smayda, 1990; Carlton and Geller, 1993; Sellner et al., 2003; Hajdu et al., 2000). According to Gollasch and Mecke (1996), the Baltic Sea is inhabited by at least 10 non-indigenous phytoplankton species. The potentially toxic dinoflagellate *Prorocentrum minimum* (Pavillard) Schiller (1933) is one. This morphologically variable, euryhaline, and eurythermal red tide species is common in many coastal and estuarine areas worldwide (Tangen, 1980; Tyler and Seliger, 1978; Grzebyk et al., 1997; Hajdu et al., 2000; Pertola et al., 2003). The origin of the Baltic *P. minimum* is unclear. It could have been transported by ballast water (Gollasch et al., 2002) or alternatively it could have spread successively by currents from the Skagerrak into the brackish Baltic Sea. According to Tyler and Seliger (1981), the species is able to survive long-distance subsurface transport.

The first bloom of *P. minimum* in Scandinavian waters (Oslo fjord, Norway) was probably toxic (Tangen, 1980), but the species has not been reported to produce toxins in the Baltic Sea.

Since the early 1980s blooms of *P. minimum* have been reported from many eutrophic coastal areas of the Baltic Sea (Hajdu et al., 2000). Knowledge of the spreading and establishment, and the spatial and temporal variability of *P. minimum*in the Baltic Sea, are mainly based on bloom reports and low frequency monitoring data from a few offshore stations (Hajdu et al., 2000; HELCOM, 1996). Confirmations based on more frequently sampled data, especially from the open sea, are still needed.

The reason for the success of *P. minimum* in the Baltic Sea is not known, because in earlier studies the field data of abundance and environmental factors was not frequent enough for statistical evaluation. A laboratory experiment by Hajdu et al. (2000) revealed that the species had optimum growth at 15 PSU, but it could also grow well at salinity below 5 PSU. The growth rate ranged from 0.13 to 0.6 μ day^{-1} below 10 PSU (Fig. 3 in Hajdu et al., 2000).

The cell shape of *P. minimum* varies considerably, which has led to several synonyms and varieties of the species and a need for further taxonomic revision (Hulburt, 1965; Faust et al., 1999). The morphology of the Baltic *P. minimum* has been studied thoroughly and a short review of the results is included below.

The aim of this paper is to

(i) review the invasion history and the morphology of the Baltic *P. minimum*,
(ii) confirm its expansion and establishment in different areas and show the spatial and inter-annual variability of the species, based on high frequency semi-quantitative data collected during a 10 years period,
(iii) explore relationships between the abundance of *P. minimum* and environmental factors (temperature, salinity, and nutrients), and
(iv) to seek some explanation for its successful expansion in the Baltic Sea.

2. Material and methods

The Baltic Sea is a large, semi-enclosed non-tidal estuary, comprised of a series of large basins (Fig. 1.), where salinity ranges from 20 PSU in the Kattegat to 5 PSU in the northern Baltic proper and to 2 PSU northward in the Gulf of Bothnia (Voipio, 1981). During the study years 1993–2002, a maximum salinity of 17 PSU was measured in the Bay of Mecklenburg and a minimum of 4.7 PSU in the Gulf of Finland.

Data on spatial and inter-annual occurrence of *P. minimum* was provided by the Alg@line project (Finnish Institute of Marine Research, Helsinki, Finland), which has monitored phytoplankton communities in the Baltic Sea since 1993 using automated, flow-through equipments installed on a merchant ship (Leppänen and Rantajärvi, 1995). The sampling route extended from the Bay of Mecklenburg in German coastal waters, across the Baltic Sea, to the Gulf of Finland (Fig. 1). Most of the samples thus represented the open sea, but the samples from the Bay of Mecklenburg and the northernmost parts of the Gulf of Finland were taken near the coast.

The active monitoring period usually lasted from April to September, while fewer samples were taken during the other months (none in December). The annual number of the samples varied from 181 to 312 (total $n = 2374$). Unfortunately, the number of the samples per month varied in different years, and in 1998 and 2000 no samples were obtained in