Short communication

Establishment of thermophilic phytoplankton species in the North Sea: biological indicators of climatic changes?

Stefan Nehring


Since the beginning of the 20th century, 16 non-indigenous phytoplankton species have become an integrated part of the pelagic system of the North Sea. Among them, 10 thermophilic species were first recorded during the last decade, assumed transported by currents from southern regions. It is suggested that the relatively mild winters during recent years may have been an important factor for their successful establishment. The permanent colonization of the North Sea by species from lower latitudes may be a biological signal of subtle changes in the climate. This issue may be clarified by the analysis of resting stages of plankton organisms in bottom sediments.

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Key words: climate change, German Bight, immigrants, North Atlantic Oscillation index, North Sea, phytoplankton, temperature.

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Introduction

The apparent world-wide increase in frequency and dispersion of exceptional phytoplankton blooms may, through the release of toxins, oxygen depletion, and deteriorating bathing water quality, create significant economic losses in aquaculture, fishery, and tourism. High nutrient inputs in coastal waters are held largely responsible for the successful establishment and enhancement of nuisance species (Smayda, 1990). However, other factors may be involved, and the possible effects of global warming are of particular interest.

The inventories of North Sea phytoplankton made over more than 100 years (e.g. Cleve, 1900) indicate that occasionally ‘new’ species have been identified in the area which were previously only known from other regions. This contribution is aimed at a review of newly recorded phytoplankton species and their origin in order to address the question whether, apart from effects of eutrophication, the observed changes may be related to long-term trends in climate.

Results

The appearance of a new species in plankton samples can have different causes and four categories may be distinguished.

(a) Uncertain taxonomic status: As long as there is taxonomic uncertainty about the status of a particular form, assessing its ecological status and origin is obviously problematic. In this context, the taxonomic status of Gymnodinium catenatum and Gyrodinium aureolum in the North Sea is presently under discussion (Nehring, 1995; Partensky et al., 1991).

(b) Previously overlooked species: Old records may not have documented the existence of a particular species and are thus incomplete, because sampling methods (mesh size) and preservation techniques (strong fixatives) were inadequate. With the increased interest in plankton monitoring, the scientific community is better equipped and more alert for signs and symptoms of plankton blooms. However, because of increased attention for ‘new’ species, a careful check should be made as to whether a species may have occurred in the
area before. For conspicuous species, this is generally no problem, but inconspicuous species like *Chrysochromulina*, *Pseudo-nitzschia*, or * Scrippsia* are suspect for having been overlooked (e.g. Nehring, 1994; Hasle et al., 1996; Vrieling et al., 1996). Absolute certainty can only be obtained by re-examining historic samples. However, there is always the possibility that a species has been overlooked because of extremely low abundance.

(c) **Temporary immigrants:** Atlantic species such as *Dinophysis odioida* and *Rhizosolenia robusta* may be transported irregularly by currents into the North Sea. However, relatively low water temperatures in winter and the absence of particular trace elements, etc., prevent the development of permanent populations. For other species (e.g. *Corynebella aureus*, Gieskes and Kraay, 1986; *Gonyaulax polycydr*, *Phaeopolykrikos hartmannii*, and *Protoperinidium compressum*, Nehring, 1997), it is not yet clear what their status as immigrants is.

(d) **Permanently established immigrants:** A review of the available literature suggests that 16 non-indigenous phytoplankton species have become permanently established immigrants (Table 1). Of these, 13 have colonized the German Bight, corresponding to an increase of about 1% in the number of phytoplankton species found in this area. A detailed discussion of the likely region of origin and the transport vectors involved is given by Nehring (1998). Newcomers may affect the structure and functioning of the pelagic system, for instance by their nutrient uptake characteristics, edibility, repressor of indigenous species, release of toxins, or other properties. So far, only a few studies have addressed the impact of alien species (e.g. Rick and Dürsel, 1995; Hesse et al., 1996). It should be noted that the time span since the establishment of several species in the North Sea is relatively short and therefore the permanent character is still uncertain. For example, mild winters may have enabled *Corethron criophihum* and *Rhizosolenia indica*, also indicators of Atlantic water (e.g., Drebes and Elbrächter, 1976), to colonize coastal areas (Cadée and Hegemann, 1991; Drebes, 1991), although it is questionable whether they will survive a severe winter. The term is used here to indicate that they appear regularly and frequently in samples since their first recordings.

**Discussion**

The factors enabling alien species to establish permanent populations cannot easily be identified because of the large number of factors determining the ecological niche of a species. Besides chemical factors (e.g., shifts in nutrients), physical factors may be involved which are related to local or global climatic conditions. Changes in the North Atlantic current system may affect temperature and salinity conditions in the North Sea and changes in wind conditions may influence dispersal of organisms (e.g. Aebisher et al., 1990; Aurich, 1953). However, changes in species composition might reflect potential effects of global warming.

Prognoses of faunal shifts in aquatic systems as a consequence of the greenhouse effect (e.g., a suggested increase by 20–40% in macrozoobenthos species number in the Wadden Sea in response to a 2–4°C increase in temperature; Reise, 1993) still have a hypothetical character. Nevertheless, the establishment of 10 non-indigenous ‘thermophilic’ (i.e., species that are normally found in more southerly and warmer waters) phytoplankton species in the North Sea during recent years coincides with a period of slightly increased sea surface temperature anomalies in the northern oceans (Houghton et al., 1992; Fig. 1). A comprehensive analysis by Becker and Pauly (1996) did not identify a distinct trend in mean temperature in the North Sea, but the mildest winters of the past 50, and perhaps even 130, years in the North Sea area occurred between 1899 and 1994. A time series of water temperature measured in the German Bight shows an overall increase by 1°C over the period 1962–1984 (Radach et al., 1990). However, the observed increases are within the expected natural variability and therefore a warming trend cannot be ascertained. Nevertheless, the establishment of an unusual number of thermophilic phytoplankton species in the North Sea ecosystem may be a sensitive indicator of changes that are not evident in the temperature record. The winters of 1983, 1989, and 1990 were marked by the highest positive values of the North Atlantic Oscillation (NAO) index recorded since 1864 (Hurrell, 1995). A positive NAO index indicates that the wind across the North Atlantic had a strong westerly component, resulting in higher winter temperatures in Europe than normal (Hurrell, 1995).

The increased influx of Atlantic Water through the English Channel in 1989–1991 (Becker and Dooley, 1995), through its effects on initial population abundance, may be a further factor that has contributed to the establishment of non-indigenous plankton species from more southerly regions. In addition, temperatures during the cold season seem a crucial factor for their prolonged presence.

The results confirm that long-term studies of phytoplankton species diversity provide an important contribution to climate impact research (cf. Lange et al., 1992; Robinson and Hunt, 1986), because species composition appears to be a sensitive indicator of subtle changes in the temperature conditions. A climatic indicator function has also been attributed to other key pelagic organisms. In recent years, the thermophilic siphophore *Mugiaea atlantica* and the cladoceran *Penilia avirostris* have entered the North Sea (Greve et al., 1996). Also, several southern fish species have shown increased abundance in the southern North Sea (Corten and van de Kamp, 1996).
Table 1. Permanently established phytoplankton species with indication of supposed year of settlement in the North Sea (N.S.) and the German Bight (G.B.), supposed region of origin, suggested transport vector, and occurrence in the German Bight (†thermophilic; *potentially toxic).

<table>
<thead>
<tr>
<th>Species</th>
<th>Year</th>
<th>N.S.</th>
<th>G.B.</th>
<th>Origin</th>
<th>Transport vector</th>
<th>Occurrence G.B.</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coscinodiscus wailesii</td>
<td>1977/78</td>
<td>1978</td>
<td></td>
<td>Indo-pacific</td>
<td>Aquaculture</td>
<td>Regular with outbreaks</td>
<td>Boakh and Harbour (1977)</td>
</tr>
<tr>
<td>Odontella sinensis</td>
<td>1903</td>
<td>1903</td>
<td></td>
<td>Indo-pacific</td>
<td>Ballast water</td>
<td>Frequent</td>
<td>Ostenfeld (1908)</td>
</tr>
<tr>
<td>Rhizosolenia indicata†</td>
<td>1989</td>
<td>1989</td>
<td></td>
<td>Atlantic</td>
<td>Currents</td>
<td>Frequent</td>
<td>Cadée and Hegeman (1991)</td>
</tr>
<tr>
<td>Thalassiosira henleyi†</td>
<td>1978</td>
<td>1995</td>
<td></td>
<td>South Atlantic</td>
<td>Currents</td>
<td>Frequent</td>
<td>U. Tillmann (pers. comm.)</td>
</tr>
</tbody>
</table>

### Bacillariophyceae

- **Alexandrium minutum†**
  - 1985/92
  - Mediterranean
  - Currents
  - Occasional
  - TRIPOS (1993)

- **Gymnodinium catenatum**
  - 1983/91
  - Northern Spain
  - Currents
  - Living cysts only
  - Nehring (1995)

- **Gymnodinium chlorophorum†**
  - 1990
  - River Loire estuary
  - Currents
  - Outbreak
  - Nehring et al. (1995)

- **Gyrodinium aureolum**
  - 1966
  - ? West Atlantic
  - Ballast water?
  - Frequent
  - Braarud and Heimdahl (1970)

- **Prorocentrum redfieldii**
  - 1961
  - 1992
  - ?
  - ?
  - Frequent
  - Kat (1979)

### Dinophyceae

- **Chattonella antiqua**
  - 1991
  - 1991
  - ?
  - ?
  - Occasional
  - Peperzak et al. (1996)

- **Chattonella marina**
  - 1991
  - 1991
  - ?
  - ?
  - Occasional
  - Peperzak et al. (1996)

- **Fibrocapsa japonica**
  - 1991
  - 1992
  - ?
  - ?
  - Occasional
  - Vrieling et al. (1995b)

- **Heterosigma akashiwo**
  - ?
  - 1993
  - ?
  - ?
  - Frequent
  - Rademaker et al. (1995)

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1. For expanded list of references, see Nehring (1998).
2. First year indicates record from the English Channel.
3. Years of establishment in the German Bight refer to Dutch waters, directly west of the German Bight.
4. Taxonomic status uncertain (see text).
A better understanding of the impacts of climate on the development of plankton populations and species composition on time scales of some decades to several thousands of years might be gained from the analysis of fossilized resting forms in dated sediment depth cores. Dale et al. (1993) found subfossil cysts of Gymnodinium catenatum in Kattegat/Skagerrak sediments from a period between \(26000\) and \(300\) BP and suggested that inflow of warmer waters in prehistoric times contributed to the occurrence of ‘fossil blooms’ of the species. Cooling during the ‘Little Ice Age’ \(2300\) BP may have been the cause of its disappearance (Dale and Nordberg, 1993). In recent years, the appearance of living cysts and/or vegetative cells in surveys off Danish, Dutch, French, German, and Swedish coasts (e.g. Nehring, 1995, 1996; Peperzak et al., 1996) suggest that northern European waters have been recolonized.

However, because vegetative cells and also cysts show small morphological variations compared to the organisms from the type locality in northern Spain, the taxonomic status of G. catenatum found in the North Sea is uncertain (Nehring, 1995): (i) if it is the same species, its recent establishment is likely due to immigration by current transport from Spanish waters, or (ii) if it is a different species, it is probably a relict that survived somewhere in areas adjacent to the North Sea from prehistoric times (cf. Dale et al., 1993). In both cases, changed environmental conditions may have enabled this thermophilic species to (re-)colonize the North Sea and adjacent waters.

Partensky et al. (1991) questioned the taxonomic identity of G. aureolum described from the western North Atlantic by Hulburt (1957) and the species recorded in the eastern Atlantic in 1966 on the SW coast of Norway (Braarud and Heimdal, 1970). The European form appears to have a stronger affinity with G. mikimotoi (synonym G. nagasakiense), a toxic bloom-forming species from the Pacific (e.g. Takayama and Adachi, 1984), than with the original description of G. aureolum by Hulburt (Steidinger and Tangen, 1996). Immunochemical studies show that the European form and G. mikimotoi cannot be distinguished (Vrieling et al., 1995a), but other results suggest that the American and European forms might be different morphotypes of the same species (Blasco et al., 1996).

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References


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