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Tisvildeleje, Denmark

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1 Introduction

The Workshop on Time Series Data relevant to Eutrophication Ecological Quality Objectives [WKEUT] co-chaired by Ted Smayda, USA, and Gunni Ærtebjerg, Denmark, met on 11–14 September 2006 at Sankt Helene, Tisvildeleje, Denmark. The Terms of Reference are given in Annex 1. In attendance were 21 participants from 12 countries (Annex 2). Peter Henriksen, Denmark, served as Rapporteur. The program of the Workshop is given as Annex 3. The letter of invitation to participants is given in Annex 4.

OSPAR originally co-sponsored the WKEUT Workshop. However, at the ASMO meeting in April 2006 OSPAR suggested changes in the Terms of Reference for WKEUT, suggesting that WKEUT should focus on the application of eutrophication-related ecological quality elements and EcoQOs, instead of undertaking a comparative analysis of the regional and temporal variations exhibited in long-term time series data sets relevant to eutrophication EcoQOs. OSPAR also suggested that WKEUT should analyse zoobenthos time series at the same level as phytoplankton time series (Annex 5). The co-chairs of WKEUT judged that it was not possible at this point to make such changes of the Terms of Reference, given that the expertise of the chairs and invited attendees did not include zoobenthic processes. Evaluation of the application of eutrophication-related ecological quality elements also would have required considerable revision of the already developed program, including invited attendees obliged to find their own funding to allow their participation. The original Terms of Reference were therefore kept, and OSPAR withdrew its co-sponsorship.

The WKEUT workshop was held concurrently with the HELCOM EUTRO-PRO Core Group meeting and workshop on eutrophication indicators. In two common sessions, the objectives of the two parallel workshops and the results were presented and discussed.

WKEUT discussed 17 long-term phytoplankton data sets available from European and relevant North American coastal sites. The criteria used to select the time series for ecological comparison were (1) the data set was to be minimally 10 years in duration, and the sampling frequency of the physical, nutrient and phytoplankton parameters adequate for workshop objectives; (2) the time series habitats and associated phytoplankton processes were to be representative of the different European coastal water environments found; (3) western Atlantic sites of equivalent ecological value were to be included to allow evaluation of possible trans-Atlantic basin similarities in the trends observed at the selected European sites, particularly with regard to climate-driven commonalities. In total, 14 European and 3 North American sites were selected for ecological comparison. The 3 North American sites selected were the Bay of Fundy (Canada), Narragansett Bay (Rhode Island) and the Tampa Bay – Charlotte Bay complex (Florida). European sites included Irish coastal waters, Stonehaven (Scotland), Floedevigen and Gullmar Fjord (Skagerrak), the Kattegat – Oresund – Belt Sea complex, Sylt, Helgoland, the German and Dutch Wadden Sea ecosystem, Belgian coastal waters, Iberian coast and Thau Lagoon in French Mediterranean waters. This selection provided time series data that allowed a comparative analysis of phytoplankton dynamics in response to nutrification and weather-driven changes (proxied by the North Atlantic Oscillation Index) along a latitudinal habitat gradient in European coastal waters that extended from Ireland to the French Mediterranean.

The time series sites group into four general habitats: (1) Large open coastal systems – the Skagerrak, Kattegat; Belgian, Dutch and German coastal waters in the southern North Sea (2) Fjord-like or well-mixed shelf waters – Bay of Fundy, Irish coastal waters, Stonehaven, Spanish rias; (3) Shallow systems – the Dutch and German Wadden Sea, Thau Lagoon; (4) Aquacultural sites – Irish coastal waters, Spanish rias, Thau Lagoon, Bay of Fundy. Narragansett Bay is a coastal estuary which does not have a close counterpart in the European sites selected, but has habitat features and phytoplankton responses that overlap with groups 1, 2 and 3 listed above. Within the habitat groupings, the Wadden Sea ecosystem is under heavy riverine influence, while the Skagerrak and Kattegat systems are open to North Sea and Baltic watermass intrusions, i.e. to farfield effects of Wadden Sea, Southern Bight of the North Sea and Baltic nutrient loading.

The workshop first focused on presentations of the long-term patterns and trends in physical features, nutrients and phytoplankton behavior at the time series locations selected for ecological comparison. This was followed by three invited talks: 1) on the need to evaluate the role of irradiance as a factor regulating the response of phytoplankton to elevated nutrient levels; 2). the influence of time series duration on the detection of the effects of long-term changes in nutrients and climate change on phytoplankton behavior; and 3). the role of modelling in time series analysis, with emphasis on the fact that statistical analyses may reveal parallel trends, but do not explain the underlying mechanisms which are more tractable by mechanistic modelling approaches. The Abstracts and the descriptions of the time series data sets considered are given as Annexes 6 and 7.

The time series descriptions and invited lectures led to various conclusions that influenced the working group responses to the Workshop Terms of Reference (Annex 1) and Workshop Questions: (1) trend analyses should be supported by statistical analyses; (2) the techniques used in time series analyses are not standarized, but should vary with the intended use of the analyses, e.g. correlation, prediction, etc.; (3) time series analyses are vulnerable to interpretive error if the sampling frequency, or length of the time series, does not reflect the system components and dynamics; (4) an interaction between statistical analyses and modellers is required, and time series analysis can help to calibrate models.

The papers presented at the Workshop will be published in a special issue of the Journal of Sea Research kindly being made available by Dr.Katja Philippart, Chief Editor.

2 Questions and answers

Questions addressed generally and specifically at the time series locations considered (Annex 8)

1) *Has the annual abundance or biomass of the different phytoplankton species, functional groups or the ratios between groups, and total abundance/biomass changed over time?*

Excluding the Belgian coastal region and the German Wadden Sea near Büsum (data from Stonehaven, Ireland and Spain was inadequate to address this issue), at all other time series sites there have been long term changes in the annual phytoplankton abundance and/or biomass, in phytoplankton species composition and abundance, in functional groups, and in their ratios. The specific changes in these phytoplankton parameters differed among the time series sites (Table d in Annex 8).

2) *Have the seasonal patterns of abundance or biomass of the different phytoplankton species, functional groups or the ratios between groups, and total abundance/biomass changed over time?*

Excluding the Dutch western Wadden Sea, the German Wadden Sea at Büsum and the Thau Lagoon, where the data are inconclusive, and the Belgian coastal zone, where the seasonal pattern shows no general change over time (data from Stonehaven, Ireland and Spain was inadequate to address this issue), the seasonal patterns of abundance or biomass of the different phytoplankton species, functional groups and the ratios between groups have exhibited long-term changes. The specific changes in this behaviour differed among the time series sites (Table d in Annex 8).

3) *Are the temporal changes in the time series data gradual, or sudden?*

For the most part, observed long-term changes in phytoplankton abundance appeared to be gradual, although sudden changes may also occur, such as in the response of the diatom population compared to that of the flagellates in the Dutch western Wadden Sea (Table d in Annex 8).

4a) Have the seasonal bloom patterns and/or bloom species, including HABs, changed over time?

In the Skagerrak, Kattegat and Belt Sea area, and at Helgoland, in Thau Lagoon and Narragansett Bay the seasonal bloom patterns and/or bloom species, including HABs, have changed over time. The situation in the German and Dutch Wadden Sea area is unclear (Table d in Annex 8).

4b) Is it possible to identify indicator species?

Phytoplankton indicator species and communities having general application are not evident. This does not exclude that indicator species or communities specific to some process or habitat conditions may be unique to a given habitat, and remain to be identified. *Phaeocystis globosa* is considered by some to be a general indicator of elevated nutrient conditions, but this relationship is not robust generally and may be applicable only to the Wadden Sea and in the Belgian coastal waters (Table d in Annex 8).

5) Have the magnitude and seasonal patterns of primary production changed over time?

Where long-term primary production measurements are available, a change in the annual rates has occurred at some locations. In the Kattegat and Belt Sea, an increase was observed up to the late 1980s, followed by a decrease. In the Dutch Wadden Sea a decrease has been observed since the late 1980s, while in the Gullmar Fjord the decrease began around year 2000. There has been no change in annual production in the German Wadden Sea at Sylt or in Narragansett Bay (Table d in Annex 8).

6a) Are the changes observed related to physical variables, such as temperature, salinity, water transparency, wind, NAO, others?

With regard to temperature, there is evidence from Thau Lagoon and Narragansett Bay that changing temperature has modified phytoplankton species and bloom behaviour. There is some evidence from the Helgoland time series that spring grazing on phytoplankton has been influenced by changing temperature (Table d in Annex 8).

NAO effects on various physical parameters and/or phytoplankton behaviour have been reported from the Kattegat and Belt Sea area, German Bight (Helgoland), German Wadden Sea at Sylt, Belgian coastal zone and the western Atlantic at Bay of Fundy, Narragansett Bay and Tampa Bay (AMO) (Table d in Annex 8).

6b) Are the changes observed related to changes in pelagic or benthic grazing (top - down control)?

The data are inadequate to assess this.

7) Are the changes related to eutrophication, e.g. nutrient levels/nutrient loads, or to reduced nutrient loading?

Both long-term increases and decreases in nutrient levels are evident at some of the time series sites, accompanied by parallel changes in phytoplankton abundance, biomass, primary production, and in species or bloom behaviour. This pattern is particularly well developed in the Kattegat – Belt Sea area and in various regions of the Wadden Sea (Table d in Annex 8).

8) Are the changes accompanied by environmental impacts, such as changes in bottom water oxygen concentration, seasonal hypoxia, kills of benthic invertebrates, *fish kills, shellfish poisoning, changed transparency, foam formation, discoloration of seawater, etc.?*

All of the above mentioned impacts have been reported from the long-term sites, although not all have occurred at a given location. Foam formation on the beaches bordering the Belgian, Dutch and German coastal waters and hypoxia in the Kattegat and Belt Sea area have been particularly significant. In Danish coastal waters, fish and, especially, benthic invertebrate kills some times accompany hypoxia (Table d in Annex 8).

9) Is it possible to identify ecological quality objectives, or ecological classes in the sense of the EU Water Framework Directive: high, good, moderate, poor, bad?

The focus of the workshop was to present the long-term observations recorded at 17 geographically different locations in representative habitats for ecological comparison. The workshop, which was primarily descriptive, is the first undertaking of comparisons of long-term data sets that we are aware of. It became evident that the diversity and complexity of the results precluded detailed analysis at the workshop of the type required to identify ecological quality objectives or ecological classes in the sense of the EU Water Framework Directive.

Several data sets on chlorophyll trends were presented at the Workshop that had been used in the implementation work of the WFD and the intercalibration exercise of quality elements to define ecological classes. However, the workshop did not have sufficient time and expertise to undertake the required analysis leading to definitive conclusions, as discussed in the Introduction to this report.

10) Is it possible to identify threshold levels in the driving forces creating different degrees of ecological impact, e.g. to determine the borders between the ecological classes?

The variations in the site- and system-specific differences in the trends, patterns and their rates of change evident in the time series data do not allow identification of threshold levels in the physical, chemical and weather-driven forces useful in serving as borders between ecological classes. There is also no single threshold level or combination of parameter levels evident in the time series data considered that are generally useful as a uniform indicator or predictor of the different modes and degree of ecological impact, either within or among systems.

3 Considerations on climate change, action plans, and the mid- to late-1980s ecosystem behavior at the time series locations

3.1 Climate variations versus climate change

Understanding the possible effects of climate change is a critical requirement in the development of the risk assessments needed for the effective management of eutrophication. The workshop considered the effects of past and present climatic variability on eutrophication. In NW Europe, it is important to distinguish between climate change, which is a global process, and the North Atlantic Oscillation (NAO), which is the expression of natural variation affecting weather at any particular time. The NAO operates on cycles of decadal change affecting temperature, precipitation, wind intensity and direction. For detecting climate changes, much longer time series data sets are needed. The largely decadal records considered by the Workshop showed effects of NAO influence (local increase/decrease in temperature, etc.), but give no basis for assessing broader aspects of climate change. Microfossils from the phytoplankton recovered from the sedimentary record are emerging as a field of research capable of addressing issues of environmental change on the required time scales of 10s to 100s of years (Dale and Dale, 2002). Appropriate model historical reconstruction could be an additional approach to test (Lancelot *et al.*, 2006).

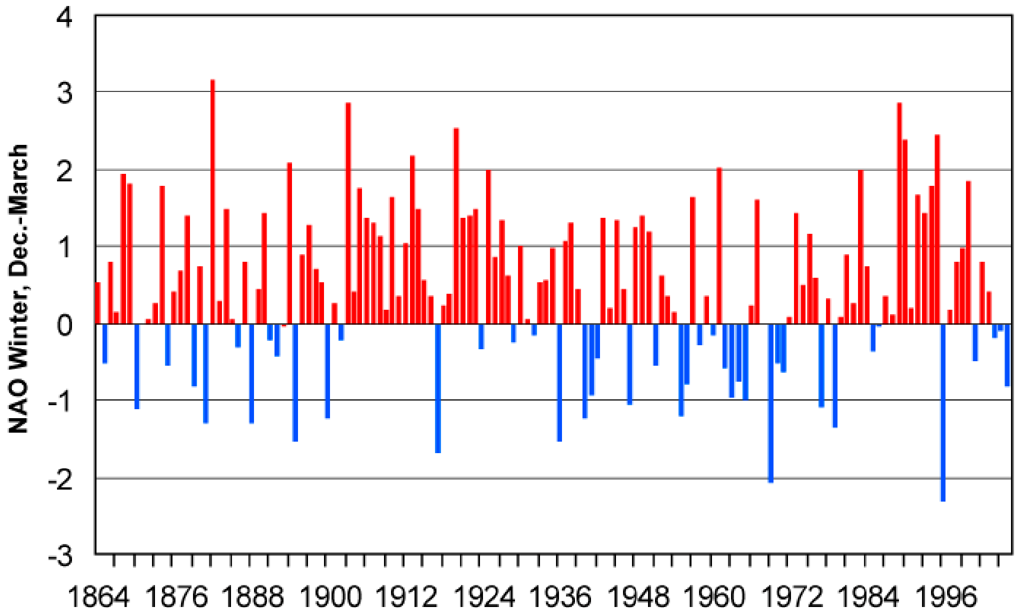

Figure 1. The NAO-index (December – March) 1864–2006. Data source: http://www.cru.uea.ac.uk/~timo/projpages/nao_update.htm

The available phytoplankton time series are not of sufficient duration (length) to document effects from even one NAO cycle. However, the influence of annual to decadal-scale variation in coupled ocean-atmosphere processes, as embodied by the NAO, were apparent in many of the time series. Eight of the plankton time series captured synchronous temperature and/or hydrological signals and biological responses related to NAO variation. Many of these were apparent during the extreme negative NAO year (1996) that occurred during the post-1980 period of extended positive NAO. Four time series captured specific processes and mechanisms describing NAO modification of hydrography (temperature, wind, currents) and watershed processes (precipitation, nutrient runoff) and a response in phytoplankton abundance, seasonal pattern or primary production. Documenting such responses to even short-term environmental variation provides ecological information that may be used for the experimental and modelling research necessary for better understanding climate change.

In the Gullmar Fjord, patterns of primary production and phytoplankton species composition were linked to NAO variations (Belgrano *et al.*, 1999; Belgrano *et al.*, 2004).

In the Danish Kattegat and Belt Sea, the effects of NAO-modulated variation in rainfall (precipitation) were observed in varying nitrogen loading and concomitant variation in phytoplankton and primary production (Carstensen *et al.*, 2006; Rydberg *et al.*, 2006).

In Belgian Coastal waters, the mechanisms linking NAO variation with changes in watershed delivery of nitrate, hydrographic climate and the timing and magnitude of *Phaeocystis* blooms were described (Breton *et al.*, 2006).

The patterns and timing of some events had trans-Atlantic synchrony, with long-term changes in bloom timing and phytoplankton biomass in Narragansett Bay USA showing similar responses to NAO modulated patterns in that system (NAO Chapter in Smayda *et al.*, 2004).

Together, these observations suggest that annual to decadal shifts and trends in phytoplankton abundance, seasonal pattern and primary production are influenced by large, slowly varying changes in ocean-atmosphere patterns.

3.2 Action plans and trend reversal

In response to the severe hypoxia event in the Kattegat and Belt Sea area in 1986, the Danish Action Plan for the Aquatic Environment (1987), which aimed at a 50% reduction in nitrogen and 80% reduction in phosphorus load to the aquatic environment, was agreed upon in the parliament. The following year, OSPAR adopted a 50% reduction target for nutrient inputs to marine waters susceptible to eutrophication, and HELCOM adopted a declaration specifying a 50% reduction target for discharges of nutrients, etc. to the aquatic environment over a 10-year period. Thus, since the late 1980s measures have been implemented to reduce the nutrient loads to the HELCOM and OSPAR areas. These action plans appear to be working. For example, over the past 20 years the nitrogen load from Holland and Denmark has decreased 40% to 45%, respectively, and the phosphorus load 65% and 80%. Decreases in nutrient concentrations and primary production have accompanied this decreased nutrient loading. Decreases in inorganic nutrients also appear to be occurring at other European coastal sites.

In the timeframe represented by the long term records considered the trend lines for both NAO and nutrient levels tend to be in parallel, and both have an impact on nutrient cycling. The generally more positive trend in NAO index from the 1970s through the 1980s up to the beginning of the 1990s tended to increase the nutrient load. Subsequently there has been a general decrease in both the NAO and nutrients, but the changes in nutrients appeared to have been more strongly influenced by action plans, with any changes attributable to weather patterns superimposed on the action plan results.

3.3 A mid- to late-1980s regime shift?

A series of unusual events from about 1985 to 1989 that appear to have regional coherence among the European coastal sites compared at the Workshop, and coincident with more or less unique phytoplankton bloom events in the western Atlantic, i.e. in the Bay of Fundy and Narragansett Bay regions, attracted workshop attention.

An unprecedent harmful bloom of *Chrysochromulina polylepis* occurred in 1988 in the Kattegat – Skagerrak over a 75 000 km^2 area which caused catastrophic dieoffs of coastal fish and benthic communities and phytoplankton, along with fish farm losses (see Gjøsæter *et al.*, 2000). Unusual spring weather conditions preceded this event (Maestrini and Granéli, 1991)

- Severe hypoxia occurred in the Kattegat and Belt Sea in 1986 and 1988 (Kronvang *et al.* 1993; Agger and Ærtebjerg 1996)
- A sudden shift occurred around 1986 in residuals from modelling bottom water oxygen concentrations in the Kattegat and Belt Sea area, which indicates a regime shift in the ecosystem (Conley *et al.*, in press)
- Dramatic decreases in the dinoflagellate population in the Kattegat began in the mid- to late-1980s (Edler, 2002).
- Increased reports of toxic shellfish (DSP, PSP) from 1986 – 1989 in Danish coastal waters (Ærtebjerg *et al.*, 2003)
- A regime shift occurred at Sylt following winter-warming that began in 1988 (Diederich *et al.*, 2005; Thieltges *et al.*, 2004; Loebl *et al.*, 2006)
- Nitrogen and phosphorus levels began to decrease in the Dutch Wadden Sea region off Lake Ijssel in 1987/1988 (RWS-DONAR database; Philippart *et al.*, 2000)
- Reversed trends in nutrient loadings in Dutch, German and Danish coastal waters began in the late 1980s (van Beusekom *et al.*, 2005; Carstensen *et al.*, 2006)
- Species composition changes in phytoplankton, macrozoobenthos and birds occurred in the western Dutch Wadden Sea in 1988 (Philippart *et al.*, 2000; Philippart *et al.*, in press).

- Unique blooms of an unidentified flagellate (Flagellate X) occurred in Scottish and Irish coastal waters causing fish farm dieoffs in 1982, and has not reappeared (Smayda, 2006)
- First report of a new shellfish disease – Amnesic Shellfish Poisoning – resulting from a bloom of the pennate diatom *Pseudo-nitzschia multiseries* in 1987, in Cardigan Bay, Prince Edward Island, Canada (Bates *et al.*, 1988)
- Unusual blooms of *Pseudo-nitzschia pseudodelicatissima* 1988, Bay of Fundy, Canada (Martin *et al.*, 1990)
- Novel brown tide blooms of the previously unknown pelagophyte *Aureococcus anophagefferens* in 1985 in Narragansett Bay and contiguous regions (Smayda and Villareal, 1989; Smayda and Fofonoff, 1989)
- Fish decline and composition changes in Narragansett Bay in mid-1980s (Jeffries and Terceiro, 1985; Oviatt *et al.*, 2003)
- Changes in the open Black Sea 1984/85 (Yunev *et al.*, 2005).

4 Conclusions

The time series data presented at the Workshop were determined to be adequate to address the question of whether eutrophication or long-term changes in nutrient levels may have affected phytoplankton dynamics and composition at the time series locations evaluated.

Trends in the time series data indicative of an elevated nutrient effect on phytoplankton species behaviour and biomass, and in response to long-term changes in nutrient concentrations and nutrient type, have occurred at many of the time series locations evaluated.

There is evidence that a regional pattern and temporal synchronization in the altered phytoplankton behaviour is taking place in response to changing nutrient concentrations at the time series collection sites. In systems where the winter nutrient concentrations were less and the systems more well mixed (e.g. Bay of Fundy, Stonehaven, Bantry Bay) changes in the phytoplankton community were less obvious.

There is no convincing evidence, except in Belgian coastal waters, that harmful algal blooms and red tides, either in their intensity or bloom-species selection, are generally linked to eutrophication processes, to elevated nutrient concentrations, or to altered nutrient ratios at the time series locations evaluated. Blooms of *Phaeocystis globosa* in the Belgian coastal waters and in the Wadden Sea are an arguable, and possibly unique exception to this general finding. However, there is evidence that at low or reduced nutrient concentrations harmful algal species may still occur regularly and bloom periodically.

The data sets indicate that action plans to reduce nutrients are having a positive effect. However, no visible effects of nutrient reductions were observed on *Phaeocystis* blooms in the Belgian coastal waters, because the nitrogen load was maintained while the phosphorus load was reduces by 50%.

The data sets at the long-term collection sites considered (n = 15) are inadequate to evaluate long-term climate change effects on phytoplankton behaviour. In a climatic sense, the length of the time series data sets are too short to capture long-term climate change effects on the phytoplankton.

Good correlations with the NAO Index were found at most of the time series locations, and suggest that altered habitat conditions and phytoplankton behaviour are occurring in apparent response to NAO-related changes in short-term weather conditions and patterns.

The observed responses of the phytoplankton to the variations in habitat conditions imposed by the NAO should provide useful information for assessing possible effects of long-term climatic changes on phytoplankton processes. It is emphasized that the NAO, *per se,* is not a measure of climate change, but only a relative measure of local weather patterns in winds, temperature and precipitation.

Long-term changes in phytoplankton responses to altered nutrient conditions and NAO patterns are not uniform, both gradual as well as sudden changes occur within a given habitat, and differ between habitats.

The variations in the site- and system-specific differences in the trends, the patterns and their rates of change evident in the time series data do not allow identification of threshold levels in the physical, chemical and weather-driven forces useful in serving as borders between ecological classes. There is also no single threshold level or combination of parameter levels evident in the time series data considered that are generally useful as a uniform indicator, or predictor of the different modes and degree of ecological impact, either within or among systems.

Phytoplankton indicator species and communities having general application are not evident in the time series data considered. This does not exclude that indicator species or communities specific to some process or habitat conditions may be unique to a given habitat, and remain to be identified. Although *Phaeocystis globosa* is considered by some to be a general indicator of elevated nutrient conditions, this relationship is generally not robust and may be applicable only to the Belgian and Dutch coastal waters and the Wadden Sea, i.e. in areas where huge blooms of large colonies are recorded every year.

5 Recommendations

1) It is essential that long-term time series data be collected, and that time series sites such as those reported on at this workshop be continued, in order to facilitate quantification of eutrophication and climate variation impacts on phytoplankton processes.
2) An inventory of time series sites and locations together with the duration and frequency of sampling, the variables measured, the contact person and information on data availability and web-site addresses should be published in the open literature to guide interested parties in need of long-term data sets.
3) Long-term data sets should be made available on web sites and have open access.
4) Time series analyses are complicated and should be analysed using statistics appropriate to the intended use of the analyses, e.g. for trend determination, for prediction, for use together with modelling, etc. Therefore, there is need for close collaboration between statisticians and biologists in analysing long-term data sets.
5) Species composition analyses require experienced taxonomists to provide good quality control of the species identifications. This is important, among other reasons, because of the unresolved issue of whether indicator species of specific ecological conditions and processes occur.
6) Phytoplankton biomass should be expressed as chlorophyll and/or biovolume. While neither measurement is free of problems, both are preferable to the use of cell numbers only. In biovolume measurements all species present in the sample should be quantified, and not only the dominant species.
7) There is need to complete development of a standardised species code to facilitate the migration of time series data on species abundance and biomass to a common data centre.
8) We recommend that ICES continue to support a working group on phytoplankton ecology, particularly a group to deal with phytoplankton ecological processes. Inclusion of expertise on long term data sets in this WG is also recommended.

9) Given the ecosystem relevance of long-term time series data sets, we recommend the collaboration of phytoplankton scientists with those dealing with higher trophic levels. This includes convening joint ICES workshops and symposia, and dealing with issues such as top-down and bottom-up effects and regime shifts, etc.
10) Our comparative ecological analysis of the time series data considered, together with advances in the knowledge of phytoplankton ecology, indicate the need to re-evaluate the value of using phytoplankton ecological behaviour and abundance/biomass to establish ecological quality objectives (EcoQOs).

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Annex 1: WKEUT Terms of Reference

2ACE04 A **Workshop co-sponsored by OSPAR on Time Series Data relevant to Eutrophication Ecological Quality Objectives [WKEUT]** (Co-Conveners: T. Smayda, USA, and G. Ærtebjerg, Denmark) will be held for four days in mid-November 2005 at a venue to be decided to:

a) examine long-term time series data sets available for European and relevant North American coastal sites and evaluate specific issues relevant to EcoQO premises and standards through a comparative analysis of the regional and temporal variations exhibited in long-term time series observatories;

b) examine the correlations between the patterns in nutrient levels and cycles together with:

i. changes in the abundance, composition, primary production, and dynamics of phytoplankton,

ii. changes in blooms of harmful and novel species, and

iii. changes in oxygen patterns and other water quality parameters. This comparative,
regional analysis will seek to establish the properties of nutrient-regulated behaviour of plankton dynamics, regionally and temporally, and potential mitigation of undesirable changes where they occur.

WKEUT will report to ACE, MHC, and OCC by 15 December 2005.

Supporting information*:*

Priority:	High. To support development of eutrophication-related Ecological Quality elements and EcoQOs as required by OSPAR.
Scientific Justification and relation to Action Plan:	This Workshop is a follow-up to the work of SGEUT to provide an in-depth scientific basis for the development of eutrophication-related Ecological Quality elements and EcoQOs. The Workshop results would also be relevant to WGPE, WGZE, WGHABD, and probably other groups. There is a possibility that the results of the Workshop might be suitable for joint publications by attendees in Marine Pollution Bulletin or the ICES Journal of Marine Science.
Resource Requirements:	No specific requirements beyond the needs of members to prepare for, and participate in, the meeting
Participants:	Participants should include members of SGEUT, together with a selected group of approximately 10–15 investigators who have carried out a relevant time series study of minimally ten years. Participants will be asked to interrogate their data sets to address specific Workshop themes, as formulated by SGEUT members, who will also select the invited participants. Participants will be expected to provide their own funding.
Secretariat Facilities:	Will be required if Copenhagen is selected as a venue
Financial:	None
Linkages to Advisory Committees:	ACE, ACME
Linkages to other Committees or Groups:	OCC
Linkages to other Organisations:	HELCOM, OSPAR
Cost share	Co-sponsored by OSPAR

Annex 2: WKEUT List of Participants

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Annex 3: WKEUT Workshop Programme

Monday 11 Sept.		Tuesday 12 Sept.		Wednesday 13 Sept.		Thursday 14 Sept.	
	Time series		**Time series/Specific topics**		**Specific topics**		**Recommendations**
08:30-09:00	Gunni/TJS Introduction, background, objectives, housekeeping	08:30-09:00	WKEUT/HELCOM	08:30-09:00	Colijn + van Beusekom (nutrients vs irradiance)	08:30-09:00	WKEUT/HELCOM
09:00-09:30	Silke (Ireland)	09:00-09:30	WKEUT/HELCOM	09:00-09:30	Dale (Climate Change)	09:00-09:30	WKEUT/HELCOM
09:30-10:00	Bresnan (Scotland)	09:30-10:00	WKEUT/HELCOM	09:30-10:00	Lancelot (modeling)	09:30-10:00	**Plenary presentations from WG's. Discussion of results and draft recommendations.**
10:00-10:15	**Coffee Break**	10:00-10:15	**Coffee Break**	10:00-10:15	**Coffee Break**	10:00-10:15	**Coffee Break**
				Questions 4, 6, 7, 8 Session			
10:15-10:45	Naustvoll (Flødevigen)	10:15-10:45	Martin (Bay Fundy)	10:15-10:45	**Discussion Question 4 (HABs)**	10:15-10:45	**Draft recommendations (cont.)**
10:45-11:15	Edler (Kattegat)	10:45-11:15	Smayda (Narragansett Bay)	10:45-11:15	**Discussion Questions 6, 7, 8**	10:45-11:15	**Draft recommendations (cont.)**
11:15-11:45	Henriksen (Kattegat-Belt Sea)	11:15-11:45	Dixon (Tampa Bay)	11:15-11:45	**Discussion Questions 6, 7, 8**	11:15-11:45	**Draft recommendations (cont.)**
11:45-12:15	van Beusekom (Sylt)	11:45-12:15	Henriksen (Danish Experience)	11:45-12:15	**Discussion Questions 6, 7, 8**	11:45-12:15	**Draft recommendations (cont.)**
12:15-13:15	**Lunch**	12:15-13:15	**Lunch**	12:15-13:15	**Lunch**	12:15-13:15	**Lunch**
		Questions 1, 2, 3, 4, 5 Session		**Questions 9, 10 Session**			
13:15-13:45	Wiltshire (Heligoland)	13:15-13:45	Borkman - (NBay Experience)	13:15-13:45	Henriksen (monitoring & WFD)	13:15-13:45	**Plenary Discussion**
13:45-14:15	Baretta-Bekker (Wadden Sea)	13:45-14:15	Gunni (Primary production)	13:45-14:15	Bresnan (monitoring & WFD)	13:45-14:15	**Plenary Discussion**
14:15-14:45	Latuhihin (Wadden Sea)	14:15-14:45	Belgrano (Primary production)	14:15-14:45	Franco (monitoring & WFD)	14:15-14:45	**Plenary Discussion**
14:45-15:00	**Coffee Break**	14:45-15:00	**Coffee Break**	14:45-15:00	**Coffee Break**	14:45-15:00	**Coffee Break**
15:00-15:30	Lancelot (Belgian Coast)	15:00-15:30	**Discussion Questions 1, 2, 4**	15:00-15:30	**Discussion Questions 9, 10**	15:00-15:30	**Plenary Discussion**
15:30-16:00	Pazos (Spanish coast)	15:30-16:00	**Discussion Questions 1, 2, 5**	15:30-16:00	**Discussion Questions 9, 10**	15:30-16:00	**Plenary Discussion**
16:00-16:30	Collos (Ytang de Thau)	16:00-16:30	**Discussion Questions 1, 2, 5**	16:00-16:30	**Three working Groups on EQO's for biomass/PP, species groups and indicator species, respectively**	16:00	**Closing**
16:30-16:45	**Pause**	16:30-16:45	**Pause**	16:30-16:45	**Pause**		
16:45-17:45	**Discussion: What have we learned?**	16:45-17:45	**Discussion Questions 1, 2, 5**	16:45-17:45	**Working Groups (cont.) Recommendations**		
18:00-19:30	**Dinner**	18:00-19:30	**Dinner**	18:00-19:30	**Dinner**		
19:30-21:00		19:30- 21:00	**Discussion Questions 1, 2, 5 (cont.) + Question 3**	19:30-21:00	**Working Groups (cont.) Recommendations**		

Annex 4: WKEUT Letter of Invitation

NERI

National Environmental Research Institute

Department of Marine Ecology

File No.: 113/101-0023
Ref.: GÆ

17 March 2006

Dear Colleague,

We have been asked by ICES to convene a Workshop, co-sponsored by OSPAR, on "Time Series Data Relevant to Eutrophication Ecological Quality Objectives [WKEUT]". The primary objective of the Workshop is "to support the development of eutrophication-related Ecological Quality elements and EcoQOs as required by OSPAR" by providing an in-depth scientific basis for these elements. The specific objectives of the Workshop to meet this charge are:

1. Using selected, long-term time series data sets available for European and relevant North American coastal sites, evaluate specific issues relevant to EcoQO premises and standards through a comparative analysis of the regional and temporal variations exhibited at these representative long-term, time series observatories. The focus is to be on European coastal systems.

2. Examine the correlations between the patterns in nutrient levels and cycles and the:

   a). changes in abundance, composition, primary production and dynamics of phytoplankton,

   b). changes in blooms of harmful and novel species, and

   c). changes in oxygen patterns and water quality parameters.

3, Undertake a comparative regional analysis to evaluate the long-term properties of, and the changes and variability in nutrient-regulated behaviour of plankton dynamics, both regionally and temporally. Also, consider potential mitigation options of undesirable changes where they occur. The influence of climate-change effects and fisheries on the long-term plankton behaviour is also of interest, as is the sedimentary record of long-term changes in plankton.

4. Within this framework, Workshop participants will prior to the Workshop interrogate their data sets to address specific themes/questions. These are presented in the enclosed attach-

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NERI is a research institute within the Danish Ministry of the Environment

ment "WKEUT Workshop Questions". Since not all data sets will be adequate to address each of the proposed questions, participants will select those issues which their data sets can address.

5. Workshop participation is by invitation, restricted to investigators who have a relevant time series of suitable frequency and quantitative measurements, minimally 10 years in duration and at a location relevant to the range of habitat types and long-term variability in conditions and plankton variability found in European coastal waters within OSPAR purview. The inclusion of selected eastern U.S. and Canadian data sets will help to evaluate whether there is a climate-linked, trans-oceanic influence on long-term changes in plankton - habitat conditions in European coastal waters.

6. There will be two products of the Workshop. WKEUT conveners will prepare advisory summaries for submission to OSPAR in a report to be submitted to the ICES committees ACE, MHC and OCC, and due by ultimo September 2006. It is also planned to publish the Workshop presentations and plenary recommendations in a peer reviewed, major journal.

Your research on long-term plankton changes in relationship to habitat and/or climate change and the location of your long-term study site are very relevant to Workshop objectives. We invite your participation in the WKEUT Workshop which is to be convened from September 11 - 14, 2006 at Tisvildeleje, Denmark located on the Kattegat coast about 60 km north of Copenhagen. The Workshop will follow the 12th International Conference on Harmful Algae to be convened in Copenhagen from 4 - 8 September.

Unfortunately, we have not been provided with funds to defray participant expenses, but hope that the importance of developing a sound ecosystem-based understanding, monitoring and management of your nation's coastal waters, independent of OSPAR oversight and regulation, will be of great interest to your institution or other national agency to sponsor your participation in the Workshop. Your contribution to the scientific outcome of the Workshop and plenary recommendations to be made to ICES/OSPAR will help to guide the design and application of future Eutrophication Ecological Quality Objectives to your nation's coastal waters. Aware that we are unable to provide funding, we have scheduled the Workshop to follow the 12th International Conference on Harmful Algae in hopes that, should you have planned to attend that Conference, you would be able to extend your activity to include the WKEUT Workshop under the aegis of your sponsor. The expected cost is 200 Euro per day to include room, meals, coffee breaks; alcoholic beverages will not be included. Further details on the Workshop site will be provided at a later date.

To help us plan the Workshop venue, we would appreciate learning within two weeks of this message whether you would be able to accept our invitation, copying both of us, as Co-conveners, to your response. Please don't hesitate ask any questions concerning the Workshop or your participation. We have space for a limited number of participants, with a backlog of prospective participants, and so your timely response will be helpful. Once we have established Workshop participants and the long-term data sets and sites to be represented and available for presentation and discussion, we will send you further details regarding our wishes for your particular scientific presentation and Workshop activities. A HELCOM Working Group will participate as observers at the Workshop, and we have received inquires from the ICES Working Group on Harmful Algal Bloom Dynamics (WGHABD) about the potential participation of that group as well. There is, thus, lively interest in the WKEUT Workshop which we hope will nurture "cross working group" activities in addition to providing considerable scientific and practical benefit to us, individually, as well as the general scientific and managerial communities.

We are looking forward to hearing from you.

With kind regards,

Co-Conveners:

Gunni Aertebjerg (gae@dmu.dk) and Ted Smayda (tsmayda@gso.uri.edu)

Annex 5: OSPAR WKEUT reservation

Summary record from the ASMO meeting April 2006:

9.5 The Secretariat presented a request from ICES that OSPAR should co-sponsor a workshop on time-series data relevant to eutrophication (ASMO 06/9/3). The purpose of this would be "to provide an in-depth scientific basis for the development of eutrophication-related Ecological Quality elements and EcoQOs".

9.6 ASMO reviewed this invitation. Accepting that "eutrophication-related Ecological Quality elements and EcoQOs" have already been formulated within the OSPAR Comprehensive Procedure and in the EU Water Framework Directive, ASMO considered the scope might better be "to provide an in-depth scientific analysis on the application of eutrophication-related Ecological Quality elements and EcoQOs" and to add to this scope "and to provide advice on the performance and suitability of these elements". Such a workshop would be highly relevant to OSPAR's work on eutrophication assessments, which includes eutrophication EcoQOs related to both phytoplankton and to zoobenthos. There would also be advantage if the zoobenthos indicators which are a current priority could be more visible in the workshop.

9.7 On this basis, ASMO with study reservations from Germany, the Netherlands and the UK agreed to recommend to OSPAR 2006 that it should agree to co-sponsor the workshop on the basis that ICES revised the terms of reference on the lines set out in Annex 11.

ANNEX 11

(Ref. § 9.7)

OSPAR CONVENTION FOR THE PROTECTION OF THE MARINE ENVIRONMENT OF THE NORTH EAST ATLANTIC

MEETING OF THE ENVIRONMENTAL ASSESSMENT AND MONITORING COMMITTEE (ASMO)

HAMBURG: 24-28 APRIL 2006

Proposed amendments to the terms of reference for the ICES Workshop

on Time Series Data relevant to Eutrophication Ecological Quality Objectives (WKEUT)1

1. In the preamble of the terms of reference, the following statements should be added:

   a. both the Comprehensive Procedure established under OSPAR and the EU Water Framework Directive include indicators based on monitoring of plankton and zoobenthos;

   b. in particular, the usefulness of zoobenthos indicators is disputed;

   c. the workshop should consider eutrophication indicators and attempt to conclude on their usefulness in an assessment context.

2. Questions to be generally and specifically addressed at the time series locations should be amended as follows:

Class of question	Convener Proposals	ASMO proposal
Analysis of data	1. Has the annual abundance or biomass of the different phytoplankton species, functional groups or the ratios between groups, and total abundance/biomass changed over time?	1. Has the annual abundance or biomass of the different phytoplankton **and zoobenthos** species, functional groups or the ratios between groups, and total abundance/biomass changed over time and are the trends easily measured?
	2. Have the seasonal patterns of abundance or biomass of the different phytoplankton species, functional groups or the ratios between groups, and total abundance/biomass changed over time?	2. Have the seasonal patterns of abundance or biomass of the different phytoplankton **and zoobenthos** species, functional groups or the ratios between groups, and total abundance/biomass changed over time and are these trends easily measured?
	3. Are the temporal changes in the time series data gradual, or sudden?	

1 Study reservation from Germany, Netherlands and the UK

	4. Have the seasonal bloom patterns and/or bloom species, including HABs, changed over time? Is it possible to identify indicator species?	4. Consider new information on seasonal bloom patterns and/or bloom species, including HABs, changed over time? *Comment: This topic has been discussed on many occasions and should not get a high profile at this workshop, focus should be on new information*
	5. Have the magnitude and seasonal patterns of primary production changed over time?	
Explaining the changes	6. Are the changes observed related to physical variables, such as temperature, salinity, water transparency, wind, NAO, others? To changes in pelagic or benthic grazing (top - down control)?	
	7. Are the changes related to eutrophication, e.g. nutrient levels/nutrient loads, or to reduced nutrient loading?	
Are there other effects	8. Are the changes accompanied by environmental impacts, such as changes in bottom water oxygen concentration, seasonal hypoxia, kills of benthic invertebrates, fish kills, shellfish poisoning, changed transparency, foam formation, discoloration of seawater, etc.?	
Usefulness in an assessment context	9. Is it possible to identify ecological quality objectives, or ecological classes in the sense of the EU Water Framework Directive: high, good, moderate, poor, bad?	9. How do we use information on each ecological quality objective to allow classification under the OSPAR Comprehensive Procedure and the EU Water Framework Directive. The Workshop should consider which of these EcoQOs are useful in an assessment context
	10. Is it possible to identify threshold levels in the driving forces creating different degrees of ecological impact, e.g. to determine the borders between the ecological classes?	

Annex 6: WKEUT Collected Abstracts

Impacts of nutrient reduction on Dutch coastal communities

J.G. Baretta-Bekker[1], T.C. Prins[2], C.J.M. Philippart[3]

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Dutch coastal waters are considered to be eutrophicated, as a consequence of high anthropogenic nutrient loadings. During the 1970’s and 1980’s the nutrient loadings steadily increased. During the period 1990–2004 riverine phosphate loadings to Dutch coastal waters have decreased considerably (50%) as a consequence of sanitation measures. Discharges of nitrogen also show some decrease. The reduced loadings are reflected in decreasing concentrations of nutrients in the estuaries and the coastal zone.

Two datasets are presented:

1) 1987–2004 An extensive monitoring programme at stations in the estuaries and coastal waters and at offshore stations in the Dutch part of the North Sea provides data on abiotic conditions and phytoplankton biomass and composition. An analysis of the responses of various indicators of eutrophication responses (viz. chlorophyll-a and Phaeocystis blooms) to changing nutrient loadings over almost two recent decades will be presented.
2) 1974–2004 A series of 30-year concurrent field observations on phytoplankton, macrozoobenthos and estuarine birds in the Dutch Wadden Sea, which has been subject to decades of nutrient enrichment and subsequent nutrient reduction. The long-term variations in limiting nutrients (phosphate and silicon) were weakly correlated with biomass and more strongly with community structures of phytoplankton, macrozoobenthos and estuarine birds. The data hint that the nutrient enrichment and subsequent nutrient reduction are at least partly responsible for the concurrent trends in these communities.

References

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Primary Productivity in the Gullmar Fjord (Sweden): 1985-2005

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We have analyzed the ongoing primary productivity (PP) time series from the Gullmar Fjord on the Swedish west coast covering the time period 1985–2005. We tested the magnitude and seasonal patterns of (PP) over time. The results of a piecewise linear regression (PLR) analysis of the annual time series for this time period showed an overall decrease in PP from 2000. We also tested monthly time series for the same time period using (PLR) to assess whether there are any seasonal differences in the (PP) patterns. The results showed a clear decrease in PP in the spring and summer months beginning either 1999 (May or June) or 2001 (July or August), and a decrease in April starting in 1995. These observed patterns in (PP) need to be related to environmental/climate forcing and may also reflect shifts in the phytoplankton species composition.

Long-term Changes in *Skeletonema costatum* Abundance and Seasonal Pattern in Narragansett Bay

David Borkman and Ted Smayda

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A 38-year (1959–1996) time series based on weekly observations in lower Narragansett Bay was analyzed to identify long-term abundance and seasonal pattern changes in the diatom *Skeletonema costatum*, the most abundant NBay diatom, and to identify drivers of these changes. A ca. 45% decline in *Skeletonema* abundance occurred, from 2292 cells ml^{-1} (before 1974) to 1263 cells ml^{-1} (1980–1996). Subsequent observations have indicated that *Skeletonema* abundance has remained at reduced levels of 1000–1500 cells ml^{-1} during 2000–2006. Winter-spring decreases were greatest; March abundance of *Skeletonema* declined from ca. 3400 cells ml^{-1} prior to a 1977 change-point, to ca. 1000 cells ml^{-1} after 1977. Three types of *Skeletonema* annual abundance patterns were found: winter-spring, summer, or autumn maxima. The frequency of winter-spring dominated annual cycles has decreased in the later portion of the time series.

Winter-spring *Skeletonema* bloom years tended to be bright, windy, cold, and had reduced first quarter zooplankton (*Acartia hudsonica)* abundance. Summer and fall *Skeletonema* bloom years were dark, warm, and had calm winds and elevated *A. hudsonica* abundance in the first quarter. Years in which the North Atlantic Oscillation Index (NAOI) was low had colder winter water temperature and an annual cycle dominated by the winter-spring bloom. In elevated NAOI years (1980s and 1990s), winters were warmer and summer or autumn blooms prevailed. Linear regression models suggested that Narragansett Bay *Skeletonema* annual patterns were strongly influenced by farfield (= climate) forces, with both the NAOI and the position of the Gulf Stream north-wall explaining significant portions of the long-term variation in *Skeletonema's* bloom pattern and abundance.

Threshold levels for *Skeletonema's* response to environmental variables were established. Most discerning threshold variables were operative in the first quarter of the year (winter). A threshold winter (1Q) water temperature of + 2°C was identified as discerning between a *Skeletonema* annual pattern dominated by a winter-spring bloom (1Q T <2°C) versus a

summer bloom (1Q T > 2°C). An NAOI threshold of -0.7 which discriminated between a winter-spring *Skeletonema* pattern (NAOI < -0.7) versus a summer bloom pattern (NAOI > -0.7) was also identified. *A Skeletonema* growth model investigated the effects of altered temperature on its abundance and annual pattern. Consistent with the temperature threshold analysis, water temperature simulations indicated that winter-spring *Skeletonema* abundance increased up to three-fold in response to 1–5°C decreases in winter temperature, while 1–5°C increases repressed the winter-spring bloom, mainly because of increased grazing losses. The analyses suggest that the long-term *Skeletonema* decline and altered annual pattern were associated with an extended positive NAOI phase and a period of warming winter temperature.

Stonehaven time series (NE Scotland)

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The phytoplankton community at this site is characterised by a diatom spring bloom dominated by *Pseudo-nitzschia*, *Skeletonema*, *Thalassiosira* and laterally *Chaetoceros* species. This progresses into a summer dinoflagellate community which can be dominated by the genera *Ceratium* and *Dinophysis.* During late summer, early autumn the phytoplankton population is dominated by *Pseudo-nitzschia* spp. and other chain forming diatoms. Chlorophyll measurements have never exceeded 10 µg chl '*a*'.l^{-1}.

Phytoplankton data from this site is reported from this site as cell counts only. The annual abundance of dinoflagellates observed at this site shows a decreasing trend between 1997 and 2005. This trend is particularly observed by selected genera that dominate the summer dinoflagellate population such as *Dinophysis* and *Ceratium*. The average annual abundance of diatoms decreased during 2001–2004 however numbers appeared to increase in 2005. There was no observed marked shift in the average annual diatom:dinoflagellate ratio. The annual average concentration of chlorophyll measured at this site showed a similar pattern to diatom cell densities with an observed decrease during 2000–2004.

The seasonal pattern of dinoflagellate cells at this site shows a reduction in cell densities during the spring and summer months particularly from dominant genera that were once common. Whereas high cell densities of *Chaetoceros* have been observed in May from 1997–2000, lower numbers have been observed during this period since 2001. *Skeletonema* spp. cells observed an earlier occurance during 2005. These changes are reflected in the diatom:dinoflagellate ratio. This time series is relatively short and these changes appear gradual over the course of the 10 years monitored.

Members of the potential shellfish toxin producing genera *Pseudo-nitzschia, Dinophysis* and *Alexandrium* have been routinely observed at this site. *Dinophysis* cell densities have declined between 1997 and 2005. *Pseudo-nitzschia* show a characteristic seasonal distribution with a bloom of the *P delicatissima* type cells in the spring and *P. seriata* type cells in late summer/autumn. High cell densities of *Alexandrium* species are now observed in the water column during June; during 1997–2000 high cell densities were observed during April/May.

Temperature, salinity and nutrient concentrations were all variable over the time series and their influence on the phytoplankton community is being assessed. Surface temperature at this site ranges from 5°C (Mar) to 16°C (July/Aug). Winter nitrate concentrations vary from 11µmol $NO_3^-.l^{-1}$ to the limit of detection in summer. Of particular interest has been a marked increase in copepod numbers at this site over the duration of this time series.

Shellfish toxins have been detected in King Scallops (*Pecten maximus)* from this site however this data is not collected at a frequency sufficient to allow for any trend to be assessed. Due to the offshore location of this site it is difficult to detect and assess benthic kills. Events such as foam formation are not routinely recorded.

The role of light and nutrient limitation for the growth of phytoplankton: long term developments in the Northern German Wadden Sea.

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Data from two long term stations (Büsum, 1991–2002 and Sylt, 2000–2004) were used to analyse the limitation status of phytoplankton during these years. We used the method developed by Cloern (1999) to compare the nutrient concentrations and underwater light conditions as important limiting factors for phytoplankton growth. Both sites show different nutrient – light relations probably because the nutrient concentration levels as well as the turbidity are different: The Büsum Mole station is closer to the coast and the Elbe estuary and therefore shows higher turbidity levels and higher nutrient concentrations for silicate and phosphate. At Sylt, nutrient concentrations are generally lower and turbidity is less due to a stronger influence from the North Sea and a larger distance from the main nutrient input sources such as the river Elbe. The limitation periods for nutrients differ accordingly: At Büsum, DIN hardly ever limits growth, PO4 showed a limitation period of up to three months in the first half of the 1990's, but showed later on no limitation. Silicate showed a variable pattern with years without limitation periods to up to four months per year.

Near Sylt, all five years showed much longer nutrient limitation periods with about three months for DIN, and five to six months for PO4 and Silicate respectively. The data for List reveal a consistent pattern as opposed to the Büsum data which showed a stronger inter-annual variability. During the presentation, we will propose explanations for the different nutrient- and light limitations between the two sites. The potential role of the Elbe inputs and consequences for the biomass of phytoplankton will be discussed.

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A 30 year time series of biogeochemical variables in a coastal lagoon recently invaded by cyanobacteria and a toxic dinoflagellate

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Time series data on water temperature, salinity, nutrients and phytoplankton have been examined in Thau lagoon (Southern France) from 1972 to 2004. The main trends identified are an increase in water temperature and a large decrease in soluble reactive phosphorus concentration over the 30 year period (summer values decreased from 10 µM to 1 µM while winter values decreased from 3 µM to undetectable at present). Seasonal hypoxia events with discoloration of seawater due to bacteria proliferation usually occur in the summer and are associated with shellfish kills. On a longer time scale, such events are more and more due to positive temperature anomalies than eutrophication. *Alexandrium catenella* blooms always occur either in the spring or the fall and are associated with shellfish bans. The recent and almost simultaneous appearance of both cyanobacteria and the toxic dinoflagellate *A. catenella* seems to be related to reduced nutrient loading and the increase in temperature after the year 2000.

Time series data from the sedimentary record of dinoflagellate cysts: relevance to eutrophication studies

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The paucity of adequate time series data is one of the main factors limiting our understanding of the effects of eutrophication on the phytoplankton. Available data often suggests significant variation in the amounts and species composition to be found in phytoplankton from different water depths, and on the full range of time-scales from one tidal cycle to several days, months and years. Gathering time series data from the phytoplankton with coverage for this extent of variation has rarely been attempted so far, and is not expected to feature in future research. Without such data it is difficult to document changes in the phytoplankton over time and to relate these to eutrophication, climate change, etc.

Some of the main groups within the phytoplankton (diatoms, dinoflagellates, and coccolithophorids) produce fossil remains that accumulate in bottom sediments, offering an alternative source of long time series of up to many thousands of years of variation. In this presentation I will describe records of several hundreds of years of variation in one such group, the fossil resting cysts of dinoflagellates recovered from cored bottom sediments from:

- The Oslofjord, including a well-documented period of cultural eutrophication from the early 1900s to the 1970s;
- Several fjords along the southern coast of Norway relating the “eutrophication signals” from the cysts to the collapse of local fisheries previously documented by Tore Johannessen (Inst. for Marine Research in Norway);
- Off the Tagus estuary, Portugal, relating the “eutrophication signals” to the establishment of the toxic *Gymnodinium catenatum* as a regular component of the phytoplankton.

Decadal patterns of water quality and phytoplankton response in the major estuaries of southwest Florida, U.S.A.

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Analyses have emphasized the two phytoplankton data bases of the longest duration from the southwest coast of Florida, U.S.A., collected in the two largest estuaries of the region, Tampa Bay and Charlotte Harbor. Seasonal hydrographic signals are strong in the region, with a warm summer wet season when riverine flows and CDOM concentrations of terrestrial origin are typically at a maximum. Climatic trends in both regions include increasing temperatures. The two estuaries vary in character. Tampa Bay with a 6:1 watershed:bay area ratio experiences generally more stable salinities than Charlotte Harbor, whose water shed ratio is 12:1. High flows to Charlotte Harbor during warmer months can result in extensive density stratification and extended periods of hypoxia and anoxia as the result of sediment oxygen demands. Hypoxia is less prevalent in Tampa Bay.

Nutrient supplies to the regions differ as well. Anthropogenic influences have been greatest on Tampa Bay, with high nutrients (both inorganic and total) present in the early 1970's as the result of domestic wastes and phosphate mining and shipping. Reduction in these impacts and concentrations was accompanied by a decline in chlorophyll concentrations from the 1974–2005 time period. The most recent decade has experienced relatively stable total and inorganic nutrient concentrations. A shorter period of record exists for Charlotte Harbor, where human development is not as extensive or long-standing. The water quality effects from phosphate mining have improved and have resulted in declines in total and inorganic phosphorus. Total nitrogen, however, is increasing, while chlorophyll has first declined and then increased over the 1983–2001 period. For both estuaries, trends in nutrient concentrations are present even after climatic changes in salinity are accounted for. Both estuaries are nitrogen limited based on nutrient concentration ratios and biomass changes have been gradual overall.

Seasonal and salinity based patterns are present in the major groups of phytoplankton. High flows are often associated with low phytoplankton biomass, particularly for low salinity environs. Seasonal maxima of phytoplankton at higher salinities also occur during late summer and fall wet season, but high flow years are not always matched by high abundances. The timing and relative abundance of dominant species groups vary by estuary, and exhibit high interannual variability. Elevated silica concentrations are typical for both estuaries leading to an overall dominance by diatoms in the mesohaline and marine regions of each estuary. Export of silica to coastal areas also supports high seasonal diatom biomass and can be used as an indicator of estuarine flux to coastal waters and the location of fronts associated with accumulations of the red tide dinoflagellate, *Karenia brevis*. Changes in patterns of abundance are not monotonic and are not highly correlated either with riverine flows, or with nutrient concentrations. For Charlotte Harbor, declines in chlorophyte abundances over time have been accompanied by increases in cyanophytes. Chlorophyll concentrations for both Charlotte Harbor and Tampa Bay display varying correlations with the abundance of individual or combined species groupings.

Temporal variability of phytoplankton species and biomass, chlorophyll and primary production in the Kattegat and Öresund

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In the Kattegat and Öresund – the transitional area between the Baltic and the North Sea – time series of different phytoplankton parameters show obvious changes over the last 35 years. Phytoplankton species being rare or absent previously, are now present and even blooming (e.g. *Prorocentrum minimum, Peridiniella danica, Chrysochromulina polylepis, Chattonella* cf. *verruculosa* and *Heterosigma* sp.). Some of these species develops large populations every year, whereas others show an irregular presence. Since 1996 there seems to be a shift towards earlier spring blooms, sometimes starting as early as December-January.

Chlorophyll and the Primary Production has increased weakly since the 1970-ies, but seen over the last 10–15 year period there is an obvious decrease. Secchi depths have decreased considerably over a long period of time in both the Kattegat and Öresund. Autumn deep water oxygen deficiency, which was most obvious during the 1980-ies, is not as frequent any more. Assessment according to the EU Water Frame Directive reveals moderate-good conditions the last 10 years judging from chlorophyll. Phytoplankton biovolume shows a more varied picture, with some good, some moderate and a few poor years.

Monitoring Programme of Phytoplankton in the Basque Country according to the Water Framework Directive requirements

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1. Introduction

In 2000 the Water Framework Directive (WFD; Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000) came into force with its publication in the Official Journal of the European Communities. This Directive establishes a framework for Community action in the field of water policy. Overall, the directive aims at achieving good water status' for all waters, by 2015. The WFD requires member states to assess the ecological quality status (EcoQ) of water bodies. The EcoQ will be based upon the status of the biological, hydromorphological and physico-chemical quality elements, with the biological elements being especially important. In coastal and transitional waters, the biological elements to be considered are phytoplankton, macroalgae, benthos and fishes (the latter only in transitional waters).

In the Basque Country (N. Spain) there is a monitoring programme in operation since 1994 for the assessment of the quality of the marine environment, for the establishment of cause-effect relationships and, overall, for contributing to the management of the marine environment. However, phytoplankton abundance was not included in this monitoring programme. In 2002, in order to fulfil the requirements of the WFD in the assessment of the EcoQ, phytoplankton abundance and composition began to be monitored in the coastal waters and estuaries of the Basque Country. This contribution shows the most relevant aspects regarding the methodological approaches of this monitoring programme, some results and some insights on future developments of classification tools.

2. Geographical Context

The Basque coast is located on the eastern part of the Cantabrian Sea (Bay of Biscay). Although very close to the French coast, the Basque waters, as well as other Cantabrian waters, present specific features. First, the Cantabrian shelf is narrower compared to the Atlantic French shelf. Second, continental water inputs (and hence, nutrients) are of less magnitude in the Cantabrian coast, as rivers are comparatively smaller (OSPAR Commission 2000). The mean annual flow of the main river discharging at the Basque Coast is 150 $m^3 s^{-1}$ (Valencia *et al.*, 2004).

Seasonal natural inflows of deep nutrient-rich waters characterize the coast of Galicia (NW Spain). The upwelling activity, however, decreases eastward along the Cantabrian coast and affects only slightly the Basque coast (Valencia *et al.*, 2004; Lavín *et al.*, 2006).

The differences in morphology and hydrology with the neighbour coasts (NW Spain and France) must be taken into account when discussing the phytoplankton data presented here.

3. Field and laboratory methods

The Basque monitoring network comprises 19 stations in coastal waters and 32 stations in transitional waters. For chlorophyll "a", 11-year time series are available in some stations. For phytoplankton abundance, the monitoring has been conducted since 2002 (although some data from other projects are also available).

Samples are collected at surface, every 3 months for chlorophyll and in spring and summer for phytoplankton abundance. Standard methods are used for field and laboratory work: Van-Dorn bottle sampling; fluorescence measurements (CTD) for chlorophyll "a" (calibrated with spectrophotometric measurements); inverted microscopy and Utermöhl for cell counts.

Also, chlorophyll data are estimated almost monthly by CTD profiles in one offshore station.

4. Classification tools

The methodology developed by AZTI for the Basque coastal and transitional waters integrates measurements of chlorophyll concentration and phytoplankton abundance to derive the quality status of the phytoplankton community (see Borja *et al.*, 2004). This method uses 4 indicators: (i) chlorophyll "a" concentration; (ii) abundance of phytoplankton species harmful for the human health; (iii) abundance of phytoplankton species harmful for the ecosystems; (iv) total phytoplankton abundance. The list of toxic species is based upon that of Ifremer for France (Vincent *et al.*, 2002), adapted for the Basque Country.

For the classification, a 5-year running period is considered. Therefore, data sets comprise 20 measurements of chlorophyll and 10 measurements of abundance. The number of cases with chlorophyll concentration higher than 8 $\mu g\ l^{-1}$, or with cell counts higher than 10^6 cells l^{-1} is computed. The classification of each indicator is established by the number of events above the threshold levels, as summarized in Table 1. The final classification corresponds to the worst status among the 4 indicators. By this method, five categories are established following the status classification typology of the Water Framework Directive (from high to bad status).

Table 1. Indicators and proposed levels used in establishing the phytoplankton biological quality in the Basque Country (modified from Borja *et al.*, 2004).

INDICATOR	LEVEL	CLASSES AND NUMBER OF EVENTS				
		High	**Good**	**Moderate**	**Poor**	**Bad**
Chlorophyll *a* (i)	8 μg.L^{-1}	<2	2-5	6-10	11-15	>15
Blooms (ii)	>10^{6} cel.L^{-1}	0	1-2	3-5	6-8	>8
Blooms (iii)	>10^{6} cel.L^{-1}	0	1-2	3-5	6-8	>8
Blooms (iv)	>10^{6} cel.L^{-1}	<2	2-4	5-7	7-9	>9

(i) Chlorophyll in coastal waters; (ii) Human health toxic phytoplanktonic species (producing DSP, PSP and ASP toxins, such as *Dinophysis* spp., *Alexandrium minutum*, *Gymnodinium catenatum*, *G. breve*, *Prorocentrum minimum* and the Diatom genus *Pseudo-Nitzchia*; (iii) Flora and fauna toxic phytoplanktonic species (*Gymnodinium* cf. *nagasakiense* (= *G. nagasakiense*, *G. aureolus*, *G. mikimotoi*), *G. splendens* (= *G. sanguineum*), *G. breve* (=*Ptychodiscus brevis*), *Gyrodinium spirale*, *Prorocentrum micans* (=*P. arcuatum* =*P. gibbosum*)(main species)+*P. minimum* (=*P. balticum* =*P. cordatum*)(high proportion of species), *P. gracile*, *P. lima* (=*P. marinum*), *P. triestum* (=*P. redfieldii*) (low proportion of species) + *P. compressum*, *P. mexicanum* (sporadic species), *Dictyocha* sp., *Heterosigma carterae*, *Fibrocapsa japonica*, *Chrysochromulina* spp.), *Dinophysis* spp., *Phaeocystis* spp., *Distephanus* spp., *Dictyocha* spp. and *Pfiesteria piscicida*; and (iv) Eutrophication indicator species (all).

In transitional waters (estuaries) a different methodology for phytoplankton biomass is used. In this case, samples are taken both at low and high tide (data sets comprise 40 measurements of chlorophyll). Water samples are filtered on GF/C filters, extracted in acetone and analyzed by spectrophotometry. The threshold for chlorophyll "a" is 16 µg l^{-1} and the number of events corresponding to each status are <4 (High), 4–10 (Good), 11–20 (Moderate), 21–30 (Poor) and >30 (Bad). The criteria used in transitional waters for phytoplankton abundance is similar than in coastal waters (Table 1).

5. Intercalibration results and discussion

For the intercalibration exercise required by the WFD the 90th percentile was used. This has been made with the chlorophyll data. About 15 chlorophyll data per station within a 5-year period (2000–2004) were used for this calibration exercise. Winter measurements were not included.

Results show that the 90th percentile values were in the lowest range of those obtained in France, Portugal and UK and much lower than those of the Netherlands (see scale of the figures).

In the Basque coastal waters the 90th percentile was usually close to 1–1.5 µg l^{-1}, never higher than 3 µg l^{-1}. These values are very similar to the 2.2–2.3 µg l^{-1} presented by the Asturias team (N Spain, Central Cantabrian Sea). In agreement with them, and considering the specific hydrographical conditions of the Cantabrian coast indicated above, our values seem realistic.

Data from the literature also support the differences found between the Eastern Cantabrian coast and the French coast. The chlorophyll sub-surface maximum in Basque shelf waters is usually 2–4 µg l^{-1} (Orive *et al.*, 2004), whereas in French shelf waters (Loire plume) it is ~10 µg l^{-1} (Lunven *et al.*, 2005).

Taking into account the specific hydrographical conditions of the Cantabrian coast in relation to other northerly Atlantic areas and the low levels of phytoplankton biomass recorded both at the Basque Country and Asturias, specific thresholds are proposed for the eastern and central Cantabrian coasts. In this regard, a value of 3 µg l^{-1} for the limit between the high and good status was set based on the 90th percentile. The limit between the good and moderate status was set at 6 µg l^{-1}, which accounts for a 100% increase in biomass from the first to the second boundary. A similar percentage of change between boundaries has been adopted by other

European Atlantic regions where chlorophyll levels are relatively low (e. g. Scandinavian countries).

As for phytoplankton abundance, the value of 5 10^5 cells l^{-1} has been chosen as the threshold to identify a bloom event in the Basque waters. Phytoplankton cell counts could be an indicator of eutrophication when the community composition is dominated by small size cells, and therefore, the chlorophyll signal is not so evident. For example, in the highly eutrophied Nervion estuary (E Cantabrian coast) peaks of 10^7 cells l^{-1} have been observed, consisting of small diatoms (*Cyclotella* cf. *atomus* and *Skeletonema costatum*), small cryptophytes and chlorophyceans, in areas with relatively low chlorophyll levels (Seoane *et al.*, 2005).

The relation of Harmful Algal Blooms with the anthropogenic eutrophication of marine waters is still a discussion topic in the scientific community (Smayda, 2004). As this issue has not been elucidated yet, the method applied in the Basque Country by AZTI takes into account not only the total cell counts, but also, the abundance of harmful species. For transitional waters, which are subjected to stronger anthropogenic nutrient inputs, indicators based on harmful species could be of particular interest.

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Hydroclimatic modulation of 1988–2001 diatom/*Phaeocystis* blooms in the eutrophicated Belgian coastal waters

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Time series Station 330 (Southern North Sea)

Lation

The 20-m-deep Station 330 (N 51°26.00; E 02°48.50; Figure 2.1), located in the central BCZ (Belgian Coastal Zone) is representative of the Southern Bight of the North Sea, as its physico-chemical (depth, temperature, salinity, nutrient enrichment level) and ecological characteristics (early spring diatom bloom, spring *Phaeocystis* bloom, over fished top predators) are similar to those present in large part of the region. The strong along-shore tidal currents (1 m s-1) combined with the shallow water depth ensures a permanent vertical mixing of the water column. This area is highly dynamic, with water masses resulting from the variable mixing of the English Channel water inflow coming from the Atlantic and freshwater input from the river Scheldt which results in nutrient enrichment of the area (Figure 1). The inflowing Atlantic waters are themselves enriched with nutrients from the river Seine.

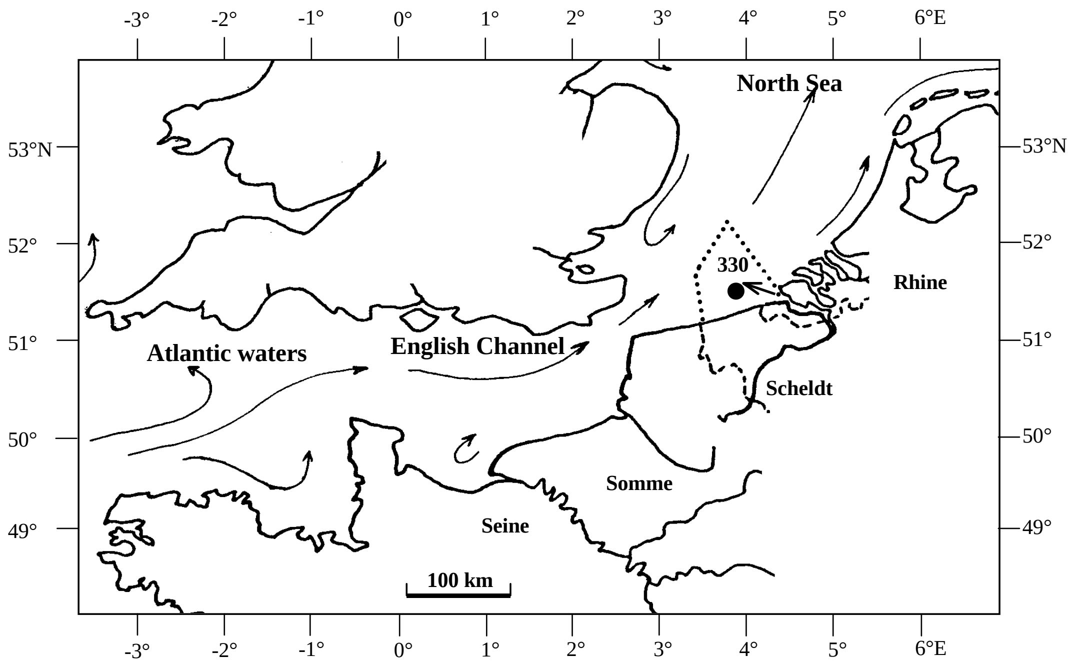

Figure 1. Map showing the borders of BCZ (dotted lines) and location of station 330.

Sampling

Between 1988 and 2001 subsurface seawater was collected throughout the year at station 330 (Figure 1) at weekly intervals except during winter and summer, when the interval was 2 weeks. From 1988 to 1991 and in 2001, the survey period only ran from February to mid-June.

Measured parameters

Sub-samples were analyzed for salinity, temperature, major nutrients (NO3, NH4, PO4, Si(OH)4), Chlorophyll a (Chl a), dissolved organic carbon (DOC) and main phytoplankton groups [diatoms, nanophytoplankton and *Phaeocystis* colonies (cell number and carbon biomass)].

For some years, bacteria, heterotrophic nanoflagellates, microprotozooplankton and Noctiluca were also measured (cell number and carbon biomass)

Statistical analysis of diatom/*Phaeocystis* blooms at St.330 over 1988-2001: response to Q1-4 and Q6-7

Over 1988–2001, diatoms were recorded year-round while *Phaeocystis* colonies occurred as a spring event lasting between 4 and 13 weeks. The diatom-*Phaeocystis* succession was observed every year, but the magnitude of the blooms showed important interannual fluctuations with most years clearly dominated by *Phaeocystis*, but a few by diatoms. Over this period, P loads by the Scheldt river were reduced by about 77% with respect to the level in the early 1980s, but N loads remained unchanged. Yet, the phytoplankton time series collected at station 330 did not reveal any corresponding trend in diatom-*Phaeocystis* blooms. The hypothesis of the additional influence of NAO-driven hydroclimatic factors was explored.

The statistical analysis of the fourteen-year (1988–2001) of intensive phytoplankton monitoring at station 330 in the central Belgian Coastal Zone (BCZ, Southern Bight of the North Sea) suggested that the long-term diatom biomass trend and the spring dominance of *Phaeocystis* colonies over diatoms were determined by the combined effect of the North Atlantic Oscillation (NAO) together with freshwater and continental nitrate carried by the Scheldt. The strong correlation between diatoms and the NAO index was largely explained by the modulating effect of the latter on the water budget at the monitoring station. The relationship between *Phaeocystis* spring blooms and winter NAO (NAOw) was indirect, better expressed by springtime *Phaeocystis* dominance over diatoms due the higher response of the latter to the NAO. The spring *Phaeocystis*:diatom bloom ratio was negatively (or positively) linked to positive (or negative) NAOw values. A complex cascade of events linked large-scale NAO index variations to the local meteorological conditions (wind strength and direction, rainfall) that drived the hydrography and water budget of the BCZ. Local meteorological conditions in turn were modulating the geographical spread of Scheldt nutrient loads in the coastal zone and ultimately regulated the magnitude of *Phaeocystis* spring blooms by determining winter nitrate enrichment. Hence, the absence of a linear relationship between *Phaeocystis* spring blooms and NAOw was explained by the nonlinear response of river-based nitrate pulses to NAO due to local wind-driven hydrodynamical forcing.

Response to Q8-10

Phaeocystis blooms are accompanied by foam deposition on beaches. This foam deposition is due to the wind-driven mechanical action of waves on ungrazed *Phaeocystis* colonies accumulated in the water. Thresholds are under study based on a combination of natural science (e.g. thresholds for food web disruption) and environmental socio-economy.

Trends and patterns in phytoplankton community data – a review on more than 10 years monitoring of Dutch coastal waters

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Monitoring of trends in biological communities in the Netherlands is part of the National environmental monitoring programme (MWTL), which also includes monitoring of chemical substances, physical and morphological parameters. The Directorate-General Rijkswaterstaat of the Ministry of Transport, Public Works and Water Management is in charge of executing this monitoring programme.

Within the framework of the biological monitoring programme, phytoplankton is sampled on a regular basis in the Dutch coastal waters since 1990. Thirty-one stations are sampled monthly during winter and fortnightly during summer. The dataset presented contains 600 different taxa, from which 440 are at species level. An analysis of changes in phytoplankton composition over the period 1990–2004 will be presented, and it will be discussed to what extent this variability can be related to environmental changes.

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Phytoplankton long term monitoring in the Bay of Fundy, eastern Canada – are there linkages between salmon culture and HABs?

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A monitoring program was initiated in May 1987 to study phytoplankton populations in the Bay of Fundy, southwest New Brunswick, eastern Canada. The purposes of the phytoplankton study when it was initiated were: to establish baseline data on phytoplankton populations since little detailed work had been published since studies by Gran and Braarud in the early 1930's; to identify harmful algal species that could potentially cause harm to the salmonid aquaculture industry; to provide an early warning to the salmon aquaculture industries by sorting and identifying samples soon after collection; and to determine patterns and trends in phytoplankton populations. Another purpose of the study was to determine whether there were environmental changes, such as changing trends in phytoplankton populations or nutrient loads, as a result of the salmon industry. In addition, it could provide an early warning to regulatory agencies such as the Canadian Food Inspection Agency (CFIA) for the occurrences of species that produce toxins resulting in shellfish toxicities and closures of shellfish beds to harvesting.

Samples are collected for phytoplankton at five locations in the Bay of Fundy. Other parameters measured include plant nutrients (ammonia, nitrate, phosphate and silicate), secchi depth, and depth profiles for fluorescence, temperature and salinity.

Alexandrium fundyense abundance from the 5 sites and between years is compared to physical and chemical properties of seawater using principle component analyses (PCA) to identify factors showing the greatest amount of variance in temporal and spatial distribution patterns. Analysis of *A. fundyense* abundance from the 18 yr period 1987–2005 indicates that cell abundance from one year does not reflect the following year and nitrate values and cell densities appear to have a negative relationship. A further comparison between the 2 years, 2004 and '05 (years with very different intensities of *A. fundyense* maximum cell concentrations) further supported these findings.

Preliminary analyses indicate that *A. fundyense* abundance and intensity appears to be more climate related than nutrient flux related. Various analytical approaches to examine relationships between *Alexandrium*, nutrients and environmental variables as well as trends from a programme initiated in 1943 to monitor paralytic shellfish toxins in blue mussels and soft-shell clams from the Bay of Fundy will be presented.

Time series of *Dinophysis acuminata* at one station in Ría de Pontevedra (NW Spain)

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Chronic persistent blooms of *Dinophysis acuminata* in the Galician Rías Baixas cause prolonged closures of shellfish harvesting and constitute the main threat to the mussel industry. Closures of mussel harvesting may occur at concentrations of *Dinophysis acuminata* as low as 200 cells L^{-1}. Forecast of accumulation and detoxification times is essential to mitigate the negative impact to mussel growers. Cell counts are necessary but the relationship between *Dinophysis* cell concentrations and toxin-levels in shellfish is quite complex. Since 1992 to date, the Galician monitoring programme includes weekly sampling of 32 oceanographic stations within the Rías. Time series of cell counts have shown that *Dinophysis acuminata* is an autochthonous species that grows during the upwelling season and gets accumulated during downwelling events, is present under a broad range of environmental conditions, and exhibits a large inter-annual variability. Here we explore a time series of *D. acuminata* in Bueu (Ría de Pontevedra), a station in the *hot-spot* of diarrhetic shellfish poisoning (DSP) outbreaks of the Galician Rías. The use of the Brunt-Väisälä component due to temperature in relation to *Dinophysis acuminata* populations, during the upwelling season, was explored. Vertical density gradients influenced bloom development, but significant differences between years were observed that could not be explained by temperature and/or salinity driven stratification. Very low values of *Dinophysis acuminata* ($\approx 10^2$ cell L^{-1}) coincided with years when upwelling was not detected in April. Threshold levels for innoculum populations appeared also as a crucial factor to consider in population dynamic studies of *Dinophysis acuminata*.

Irish Phytoplankton Dataset, 1990–2005.

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The ultimate use to which long term datasets will be put is not usually envisaged when the collection of the data is commenced. In Ireland, the Marine Institute has carried out a phytoplankton-monitoring programme since the mid 1980's. This high frequency data set includes 28 000 samples which were analysed in the period between 1990 and 2005. The samples were generally collected from a range of aquaculture sites because the primary purpose of the programme was to observe the presence of species that occurred with deleterious effect to fish farms. The samples were analysed in most cases for complete phytoplankton counts, to genus and where possible to species level. The results from these analyses were used routinely in order to explain, and in some cases prevent harmful affects from phytoplankton species. In addition, the results were entered onto a database for archival and querying purposes, and when combined with GIS, to analyse spatial-temporal trends and unusual occurrences within the phytoplankton populations.

This presentation will firstly concentrate on observations on the annual patterns of abundance, seasonal change and temporal change within selected sites. The inter-annual variability of blooms of selected species will be also discussed. The environmental and oceanographic context for these trends of abundance will be investigated in the areas of temperature, salinity, transparency, wind and NAO. Change related to nutrients will also be shown. Issues dealing with data gaps and quality are a problem when data is collected for one purpose and subsequently used for another. For this reason only the data that meets a defined quality standard will be used in this analysis.

The second part of this presentation will show how this dataset has been used extensively for the development of EU Water Quality Framework (WFD) tool development in Ireland and the UK. The requirement for a phytoplankton quality index has been proposed as one of several biological elements under the WFD in order to investigate and develop reference values, intercalibration requirements and classification tools. A consistent implementation of WFD across the EU involves the establishment of an inter-calibrated process which will ensure that a common understanding of 'high' and 'good' status is used in making water body status assessments. This work is being taken forward through a number of Geographical Intercalibration Groups (GIG), of which the Marine Institute has participated. Key to the intercalibration process is the determination of where the boundaries between the various status classes lie, and through involvement with the UK-Ireland Marine Plants Task Team (MPTT) and North East Atlantic GIG this task is greatly facilitated by having at its disposal long term datasets, such as the Marine Institute phytoplankton data.

The classification tools that have been developed by the MPPT list the composition, abundance and biomass of the phytoplankton community as part of the biological quality elements that need to be considered for transitional and coastal waters. Specifically, it outlines the criteria that need to be related to type specific, undisturbed conditions for phytoplankton, in other words reference conditions. These reference conditions once established and have quantifiable biological quality elements are then used to compare against selected intercalibration sites to establish moderate/good and good/high thresholds. The development of these tools and their role in future monitoring will be described.

The Multi-decadal Narragansett Time Series: Evidence for a Regime Shift

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The results of a 38 year study on physical, chemical, phytoplankton and zooplankton behavior in Narragansett Bay located in the biogeographical transitional region between Temperate and Boreal waters along the eastern coast of the U.S. are presented. Major changes and trends have occurred in temperature, watermass transparency, in macronutrient concentrations and their ratios, in phytoplankton biomass, production, bloom cycles and species dynamics, and in copepod and ctenophore abundance and seasonal behavior. There is strong evidence that the observed plankton dynamics are sensitive to altered nutrient and temperature conditions. Two primary, confluent mechanisms are identified as driving the observed changes: an internal and an external forcing stimulus. The internal forcing functions identified are changes in nutrient supply and their ratios, and in altered copepod abundance. The external forcing function is a change in watermass temperature associated with long-term changes and patterns in the North Atlantic Oscillation Index. Functional group shifts, along with a major shift in the annual bloom period from winter to summer have accompanied the long-term trends observed. It is suggested that a regime shift has occurred, or is in process, in Narragansett Bay.

Long-term pelagic dynamics in the List tidal basin (northern Wadden Sea) near Sylt

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We present time series data from the entrance of a shallow coastal tidal basin in the northern Wadden Sea between Germany and Denmark. First regular (weekly) measurements are from 1973–1976. From 1979–1982 focus was on tidal variation at a shallow subtidal station. Since 1984 two stations –one at a shallow subtidal station and one in the main tidal channel- are monitored twice a week. The time series include hydrographic parameters (salinity, temperature, pH), nutrients, chlorophyll (since 1984), suspended matter. Diversity of net phytoplankton catches is monitored weekly since 1989, phytoplankton abundance since 1993.

Hydrography of the area is driven by climatic factors. Interannual differences in salinity significantly correlate with riverine discharge. Interannual temperature differences fit within the so-called regime shifts observed in the North Sea. Notable changes have been the relatively cold and wet winters of the 1980's, the relatively warm winters of the 1990's and the extreme warm summers since the mid-1990's.

Suspended matter dynamics show a strong seasonal pattern with low values during summer and high values during winter. The seasonality is driven by biological processes. Interannual differences can be attributed to differences in wind (resuspension) and riverine nitrogen loads. The latter factor is probably involved in a more efficient import of SPM from the North Sea. A gradual decrease in winter and summer SPM levels is evident and is related to riverine nitrogen loads.

Nutrient cycles also show a clear seasonality. Nutrient dynamics in winter reflect salinity (riverine nutrient loads). (NO_3: ~55 µM; PO_4~1.2 µM; Si: ~23 µM). During the spring bloom Si, PO4 and NH_4 are depleted (<0.1 µM). PO_4 starts to increase immediately after the bloom. NO_3 reaches its minimum between May-July. Nowadays, large *Phaeocystis* blooms may be limited by NO_3. Between August and October, nutrient increase again. The timing is probably related to weather conditions. The start of the autumnal increase has gradually shifted from mid-August to late September and is probably related to a combination of lower SPM dynamics and local wind conditions.

Phytoplankton dynamics are characterized by a spring bloom around the first week of April, and followed by a *Phaeocystis* bloom in May. The maximum of the spring bloom is related to winter temperature and biomass up to 90 µg chlorophyll a/l may be reached after cold winters. Summer chlorophyll levels are around 6 µg chlorophyll a /l. Summer chlorophyll is significantly correlated with riverine nitrogen loads.

Phytoplankton composition is still under investigation. Preliminary analysis suggests that the diatom biodiversity (net phytoplankton) shifts between a summer composition and a winter composition. Similarity (Bray-Curtis) between consecutive summers and winters is high (about 80%).

The Helgoland Roads Long-Term Data Series: 40 years of views and new perspectives

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The Island of Helgoland is situated in the North Sea, 70 Km off the coast in the German Bight. Historically it has always been a hub for seafaring peoples and, in the last two centuries, of great interest to scientists. This is because of its placement as a rocky shore environment surrounded by water and off a coast of mudflats which has resulted in a very special flora and faunal assemblage. The island has increased in importance as a unique long-term monitoring programme was started in 1962 at the Biologische Anstalt Helgoland.

This involved monitoring pelagic nutrients, salinity, light penetration and plankton species composition at the Kabel-Tonne (54° 11,3`N, 7° 54,0`E) on a work-daily basis. (Figure 1) This resulted in a produced an enormous data base of great potential.

However, whereas the chemical and physical data and methods of detection resulting from this monitoring were analysed and modernised to some degree over the years this was severely lacking for the data and monitoring of planktonic species of algae. In the last year we have rectified this (Wiltshire and Dürselen, 2004). This involved a three-pronged strategy: 1) inventory and quality control of 40 years of existing daily algal species counts, 2) modernisation of taxonomic recognition and archiving of current algal species (including culture collection) and 3) introduction of new monitoring strategies and technology.

Our new evaluation and quality control allowed us to analyze the data properly for system changes, for example, potentially induced by climate change.As a result we could show that there has been an obvious warming of 1.1^{o}C since 1962 and that the algal spring bloom and high diatom counts are occurring later in spring (Wiltshire and Manly, 2004). We showed both by analyses of the data series as well as in experiments that this is related to a warming of the autumn and the continued grazing of zooplankton. We also analyzed the shifts in species and reveal a change in phytoplankton succession which shows a shift to warmer species. This data is the first indication of a warming-related shift in phytoplankton succession, timing of the spring bloom and food web changes. The consequences of this will be life cycle/ food resource mismatches, through to regime shifts in the North Sea system (Wirtz and Wiltshire, 2005). The very evident changes elsewhere in the fish/ invertebrate/ macroalgal populations and also bird migratory patterns at Helgoland underpin our investigations on change at Helgoland Roads an allow us to place our work into a global perspective.

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Annex 7: WKEUT Time Series Overviews

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Stonehaven (NE Scotland) dataset

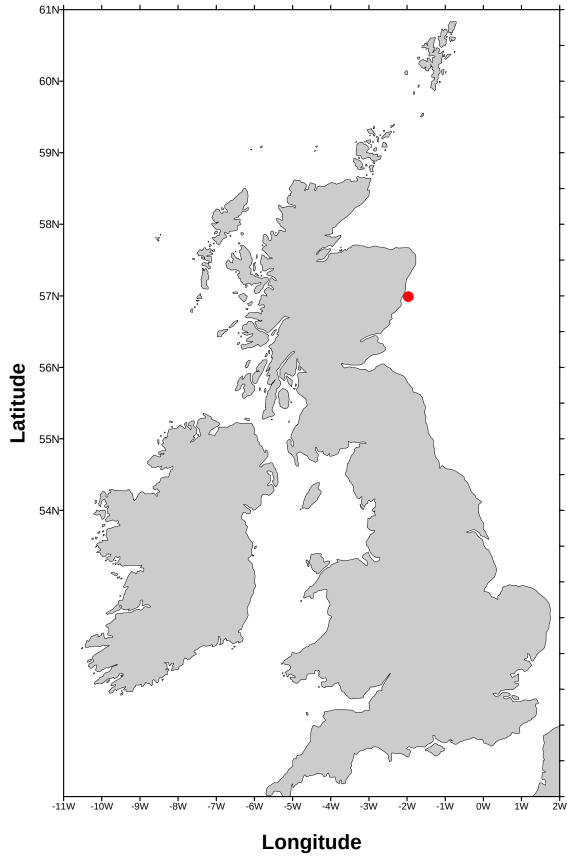
The Stonehaven coastal ecosystem monitoring site is located 3 km offshore of Stonehaven, which is approximately 15 miles south of Aberdeen. The station (56 °57.8'N 02°06.2'W) has a water depth of approximately 50 meters with a southerly water flow. This site been sampled weekly (weather permitting) since January 1997. The present and long term objective of this study is to monitor and assess the state of the ecosystem in the eastern coastal waters of Scotland and to consider variations in relation to broader measures of ocean climate. Samples taken routinely include salinity and temperature at near surface and seabed, nutrient concentrations (inorganic nitrate, ammonia, phosphate and silicate) at surface and seabed, chlorophyll 'a', phytoplankton species concentration (10 m integrated sample) and zooplankton species concentration (200 µm mesh net). This site has also been included in a number of studies examining different aspects of plankton ecology. During 2007–2008 primary production measurements will be made at this site to validate production values estimated through mathematical models.

Data from this site can be found at:

http://www.frs-scotland.gov.uk/Delivery/standalone.aspx?contentid=1144

Contact person: Eileen Bresnan (Bresnane@marlab.ac.uk)

Location of Stonehaven monitoring site (●)



Overview of Thau lagoon (France) time series

Location: Thau lagoon (Southern France), first oyster production center on the Mediterranean Sea.

Position: 43°20'/43°28'N 3°31'/3°43'E

Dimensions: 15 km x 4 km

sampling period: 1972–2004

measurements made:

temperature: every month
salinity: every month
nitrate: every month
nitrite: every month
soluble reactive phosphorus: every month
silicate: every month
phytoplankton counts: variable frequency depending on toxic blooms

Contact person: Yves Collos, Laboratoire Ecosystèmes Lagunaires, Université Montpellier II, CC093, 34095 Montpellier Cedex 5, France, tel: 33-4 67144744, fax: 33-4 67143719, email: collos@univ-montp2.fr

Long term monitoring data for the southwest coast of Florida, U.S.A.

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The waters off of the southwest coast of Florida (Figure 1) are the site of nearly annual occurrences of the toxic dinoflagellate, *Karenia brevis*. Kills of marine life, respiratory irritation, economic damage, and neurotoxic shellfish poisoning can all result. Blooms typically begin offshore and prevailing winds and currents move the organisms onshore and into the relatively high salinity estuaries behind the generally residentially-developed barrier islands. Larger estuaries with riverine inflows, nutrient loads, and strong salinity gradients are not immune, as well, but the organism does not typically persist in the lower salinity environments.

Of the three major estuaries on the west coast of Florida (Tampa Bay, Charlotte Harbor, and the Caloosahatchee River/San Carlos Bay, Figure 2), Tampa Bay has the longest history of anthropogenic alterations to hydrology and nutrient loads and the combined urban area houses a population of 2.7M, the second largest in the state. Waste treatment improvements over the years can be documented but population growth continues and local governments have united to control nitrogen loads and maintain at present day levels. Some of the rivers to the Bay have comparatively high phosphorus loads due to both phosphate mining activity in the basins as well as natural geology. Charlotte Harbor has high phosphorus loads as well for similar reasons, but population densities are much reduced compared to Tampa Bay. The Caloosahatchee River on the other hand receives discharges from the highly managed Lake Okeechobee and intensive agricultural influences are coupled with increasing urbanization at the mouth of the river. Data sets available to describe these estuaries are described below.

EPCHC

The Environmental Protection commission of Hillsborough County (EPCHC) has collected approximately monthly water quality data in both the watershed and in Tampa Bay. Parameters include inorganic N and P species, total Kjeldahl nitrogen, total phosphorus, chlorophyll, color, turbidity, total suspended solids, salinity and temperature since 1974. The program continues today. Numerous stations capture strong salinity gradients from the numerous river inflows and monthly samplings capture seasonal variations. The data have been used over the years for numerous wasteload allocation and reduction efforts, for the determination of seagrass light requirements, and for implementing nitrogen reduction goals and as such have received much scrutiny and review for quality. Current data are generated under a rigorous laboratory certification program designed to ensure continued high quality. Data are available on-line from the link below and sampled stations appear in Figure 3.

http://www.epchc.org/surface_water_maps.htm

U.S. Environmental Protection Agency

Many other agencies sample and report data from stations within Tampa Bay as well, and submit data to the USEPA STORET (STOrage and RETrieval) as a condition of permits, monitoring programs, and the like. These data are available from the government sites listed below and can be retrieved based on station name, a latitude/longitude "box", a county name, etc. depending on need. Parameters include those listed for the EPCHC data, and may also include dissolved quantities of the same parameters. Stations include both surface water and groundwater stations, as well as industrial discharges. Trace organics, metals, major and minor ion data are also available. Quality of data can be more problematic due to the large number of users supplying data and the use of these data should include a thorough review process to screen for station locations, unlikely units, and unreasonable values.

Some stations in the data base experience a long history of sampling, others are sampled for a few years and are then discontinued. Sampling frequency varies widely. These data are generally best used from a restricted geographic area and examined as a function of general parameter:salinity trends. In general, agency budgets for sampling and analyses under routine monitoring programs began in the 1970's in response to legislation and have declined exponentially since then. Most sampling programs today are designed to investigate targeted questions, or in support of specific operation permits. Data prior to about 1999 reside in the Legacy system, and more recent data appear in the new STORET. Electronic formats a very different between the two systems. Federal government support for both storage systems is scheduled for termination in the next few years.

http://www.epa.gov/STORET/legacy/gateway.htm

http://www.epa.gov/storet/dbtop.html

U.S. Geological Survey

The USGS operates a similar data storage and retrieval system to the USEPA STORET system described above. Data can be retrieved by station name, latitude/longitude, or other criteria. Fewer data submitters generally result in a more consistent data product. Water quality parameters are varied and include both dissolved and total nutrients, chlorophyll, and numerous synthetic organic compounds, trace metals, ions, etc. Groundwater as well as surface water stations are included. In addition, river flow data are also available from most of the major freshwater sources to the major estuaries. Flow gaging stations are generally located above the head of the tide for technical reasons and may only capture 40–60% of the watershed. Nutrient data often accompany these flow data but, except in rare instances, is usually monthly in frequency or less, making loading estimates difficult.

http://waterdata.usgs.gov/nwis

Other Agencies

Sampling of the three major estuaries is supported by numerous agencies. Local County governments have similar programs to those described for EPCHC. The County sampling programs participate in a Regional Ambient Monitoring Program (RAMP) which addresses potential gaps in spatial or parameter coverage, regulatory issues, and participates in routine split-sampling exercises to ensure quality and comparability. Formal National Estuary Programs (Tampa, Sarasota, and Charlotte Harbor) were begun with Federal monies and continue today under local government support. They have variously sponsored water quality sampling programs, as well as targeted investigations of water quality and biota of nearly the entire regions' estuarine waters, and are active in watershed investigations as well. Water management districts (Southwest Florida Water Management District and South Florida Water Management District) also sponsor water quality sampling programs, either internally or through funding of local entities. These data generally begin in the mid 1990's and are available through the STORET system described above.

Coastal Water Quality Data

Logistic and budgetary constraints result in very few data being collected outside the mouths of estuaries although some do exist in the data bases described above. Coastal water sampling programs typically consist of a year or two of a single transect, often conducted by universities or private entities. Frequency is seldom more often than monthly and may be less. On the other hand parameter coverage is generally more extensive, dissolved nutrient quantities are typically determined, and other less common parameters may be included (iron, urea, etc.).

Data are not generally available except from the individual investigators. Much of the coastal water quality data has been collected in concert with investigations into *K. brevis* blooms. These data, both cell counts and physical and chemical water quality data, have been compiled by the State of Florida Fish and Wildlife Conservation Commission (FWCC). A long term, fixed frequency, fixed location sampling program in the Gulf does not exist at this time.

Phytoplankton Data

Phytoplankton taxonomic data is less well represented in spatial coverage, frequency and duration, with the marked exception of a few locations in Tampa Bay and in the Peace River (Charlotte Harbor). Monthly species enumeration data have been collected by the City of Tampa at one to three stations from 1978 to present, and are available digitally since 1995. Weekly data on cyanophytes at selected stations from 1989 to present are also collected by this organization. For the Peace River, species counts are available at four selected salinities from 1983–2001 and are coupled with water quality and chemistry data. Smaller species-specific data sets, on the order to two to three years in length, are also available for several other rivers discharging to Tampa Bay.

More recent offshore *K. brevis* investigations utilize HPLC/Chemtax approaches to describe community composition, coupled with visual identification and enumeration of *K. brevis* and notes of other dominant species. These sampling programs do not extend more than a few years at this time. The data on *K. brevis* presence and associated water quality assembled by FWCC include other species information on occasion, but station frequency and reproducibility make these data generally unsuitable for trend analyses.

Figure 1. North America, and the southwest coast of Florida..

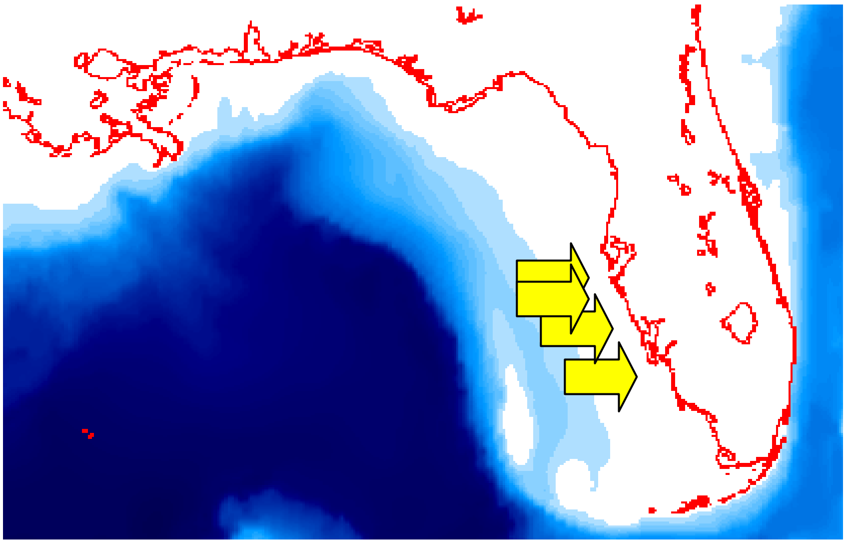

Figure 2. Southwest coast of Florida illustrating, from north to south, Tampa Bay(A), Charlotte Harbor (B), and the Caloosahatchee River/San Carlos Bay (C) estuaries.

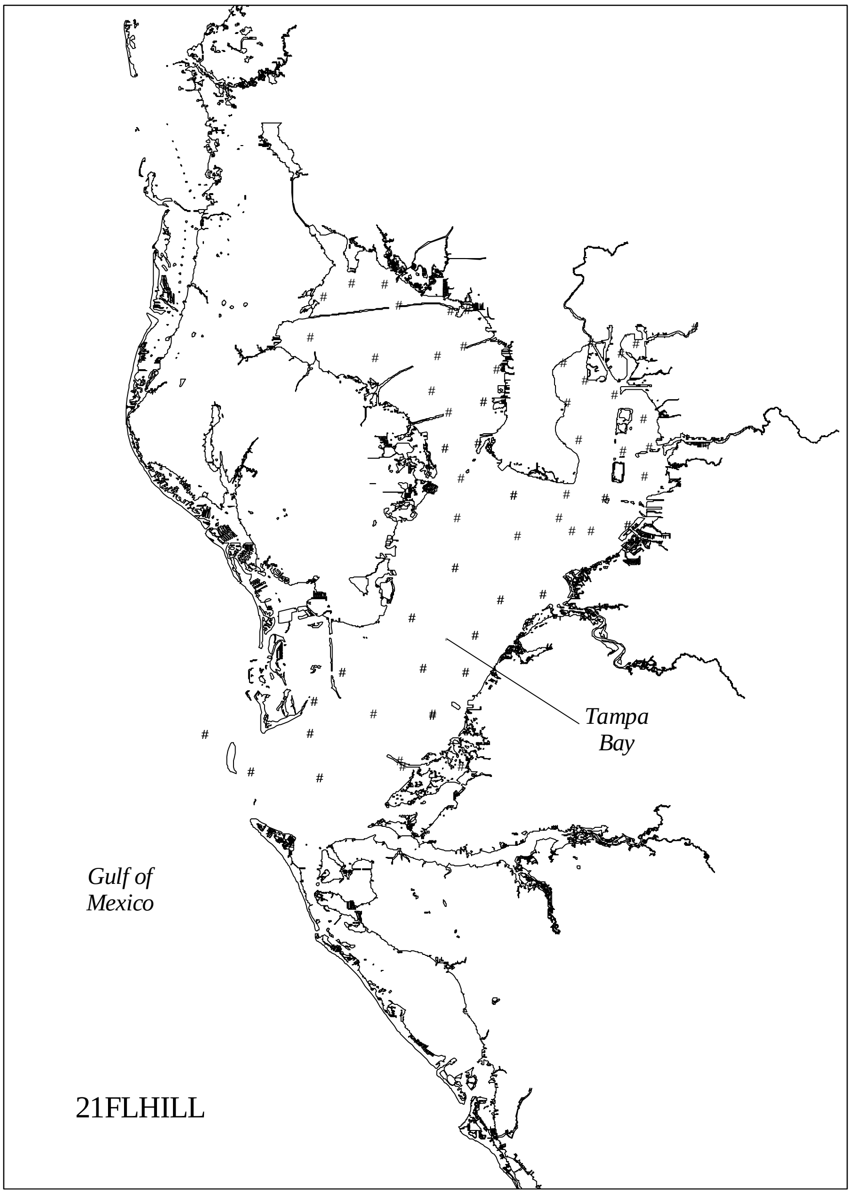

Figure 3. Station coverage of the EPCHC water quality monitoring program in Tampa Bay, Florida.

Overview of phytoplankton time series in the Kattegat and Öresund

Lars Edler, WEAQ Hb

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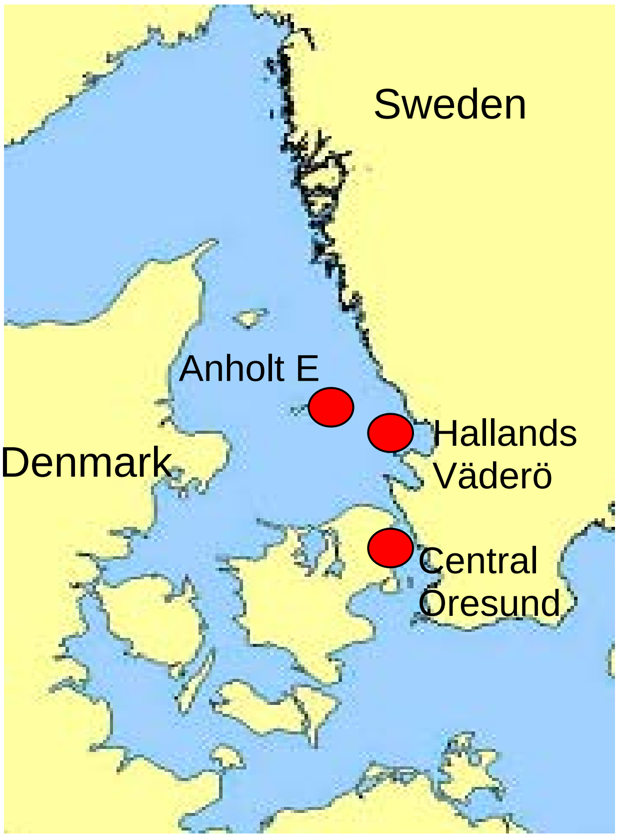
Kattegatt

Station:	Anholt E, N56.40, E12.07.
Sampling period:	1979 – 2005
Measurements:	Phytoplankton cell density, biomass, carbon. Chlorophyll a. Primary production. Nutrients
Frequency:	Infrequent 1979-1994, 1995-2005 24 times per year
Contact person:	Lars Edler, lars.edler@telia.com

Station:	Hallands Väderö, N56.29, E 12.32
Sampling period:	1989–1996
Measurements:	Phytoplankton cell density, biomass, carbon. Chlorophyll a. Primary production. Nutrients
Frequency:	25 times per year
Contact person:	Lars Edler, lars.edler@telia.com

Öresund

Station:	Central Öresund, N55.40, E12.25.
Sampling period:	1972–2005
Measurements:	Phytoplankton cell density. Chlorophyll a. Primary production. Nutrients
Frequency:	monthly
Contact person:	Lars Edler, lars.edler@telia.com



Phytoplankton and shellfish toxicity datasets from the Bay of Fundy, eastern Canada

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Fisheries and Oceans Canada, Biological Station, St. Andrews, NB Canada E5B 2L9

Phytoplankton

A monitoring program was initiated in May 1987 to study phytoplankton populations in the Bay of Fundy, southwest New Brunswick, eastern Canada. The purposes of the phytoplankton study when it was initiated were: to establish baseline data on phytoplankton populations since little detailed work had been published since studies by Gran and Braarud in the early 1930's; to identify harmful algal species that could potentially cause harm to the salmonid aquaculture industry; to provide an early warning to the salmon aquaculture industries by sorting and identifying samples soon after collection; and to determine patterns and trends in phytoplankton populations. Another purpose of the study was to determine whether there were environmental changes, such as changing trends in phytoplankton populations or nutrient loads, as a result of the salmon industry. In addition, it could provide an early warning to regulatory agencies such as the Canadian Food Inspection Agency (CFIA) for the occurrences of species that produce toxins resulting in shellfish toxicities and closures of shellfish beds to harvesting.

Samples are collected weekly from early May to the end of September, biweekly in the month of October and monthly during all other months for phytoplankton distribution and abundance at five locations – Brandy Cove, Lime Kiln Bay, Deadmans Harbour, the Wolves Islands and mid-Passamaquoddy Bay. Other parameters measured include plant nutrients (ammonia, nitrate, phosphate and silicate), secchi depth, and depth profiles for fluorescence, temperature and salinity. Samples are collected at the surface from all locations and additional discrete depths of 10 m, 25 m, and 50 m at the Wolves Islands.

PSP shellfish toxicity

A programme was initiated in 1943 to monitor shellfish from the Bay of Fundy for paralytic shellfish toxins and represents the longest continuous data base for shellfish toxicity in the world. It includes results from more than 35 000 shellfish samples (the majority of which are soft-shell clams and blue mussels) that have been assayed by mouse bioassay according to the A.O.A.C. PSP method. Although shellfish monitoring has been ongoing, continuous data is available for only a few locations. Shellfish have been collected on a weekly basis from areas with detectable levels of toxins and bi-weekly from areas that are permanently closed to harvesting.

Overview of IMR, Flødevigen (No) time series relevant for coastal systems - Skagerrak.

Lars Naustvoll, and Tore Johannessen

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PROGRAM	PARAMETERS	PERIOD	FREQUENCY	CONTACT
Flødevigen Bay	Phytoplankton	1984 -	3 a week	Einar Dahl, Lars Naustvoll
	Chl - a	1984 -	3 a week	
	Salinity	1924 -	Daily	
	Temperature	1924 -	Daily	
	Metrological	1957 -	Daily	
Coastal Monitoring	Phytoplankton	1990 -	~24 a year	Einar Dahl, Lars Naustvoll
	Chl – a	1990 -	~24 a year	
	Zooplankton	1990 –	~24 a year	
	Nutrients	1990 -	~24 a year	
	Oxygen	1990 -		
	Salinity	1990 -	~24 a year	
	Temperature	1990 -	~24 a year	
	Particulate matter	1990 -	~24 a year	
Torunge - Hirtshals	Phytoplankton	1980 -	~12 a year	Einar Dahl, Lars Naustvoll
	Chl – a	1980 -	~12 a year	
	Nutrients	1980 -	~12 a year	
	Salinity	1951 -	~12 a year	
	Temperature	1951 -	~12 a year	
	Oxygen	1951 -	~12 a year	
Fjords Skagerrak	Nutrients	1995 -	~9 a year	Einar Dahl, Lars Naustvoll
	Oxygen	1995 -	~9 a year	
	Salinity	1995 -	~9 a year	
	Temperature	1995 -	~9 a year	
	Chl –a	1995 -	~9 a year	
Beach Seine sampling, Skagerrak	Fish recruitment	1919 -	1 a year	Tore Johannessen
	Oxygen	1920 -	1 a year	

THE 38-YEAR NARRAGANSETT BAY TIME SERIES

Ted Smayda and Dave Borkman

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A long-term, *quantitative* data set (1959 - 1996) based on weekly measurements is available at a station located (41°34’07”N, 71°23.3”W) in the unpolluted waters of lower Narragansett Bay, a phytoplankton-based ecosystem characterized by tight pelagic-benthic coupling. Weekly samples were collected at three depths (0, 4 and 8 m) at this 9 m-deep station excluding zooplankton and ctenophores which were sampled throughout the water column. River runoff, meteorological (wind speed, precipitation) and irradiance data are based on daily measurements undertaken by the U.S. Army Corp of Engineers, or the U.S. Weather Bureau at Providence Airport located about 20 km north of the monitoring site, and irradiance measured at a site located in Newport about 10 km from this station. Irradiance measurements were supplemented by daily measurements at the Campus of the Graduate School of Oceanography. The time-series is a spinoff from a series of research grants awarded to study various aspects of phytoplankton bloom and succession ecology in Narragansett Bay. Upgraded to a process-oriented study in mid-1963, weekly measurements of 28 variables and processes at three depths were made during maximum activity using quantitative techniques routinely used in oceanographic research (Table 1). This effort has produced the longest known, continuous quantitative time-series (38-yr) on plankton-environment relationships available for U.S. coastal waters. Lack of funds terminated the field program in 1997, but sampling was resumed again in 2000 at a reduced scale.

Table 1. Narragansett Bay Time Series Variables

Meteorological + Physical		***Nutrients***	
VARIABLE	TIME SERIES	VARIABLE	TIME SERIES
River runoff	1959 - 98	NO_3	1959 - 63; 1969 - 96
Precipitation	1959 - 98	NH_3	1972 - 1996
Wind speed	1959 - 98	PO_4	1959 - 63; 1969 - 96
Irradiance	1959 - 98	SiO_3	1959 - 63; 1969 - 96
Temperature	1959 - 98	Urea	1972 - 78
Salinity	1959 - 98	NO_3 Reductase 1975-7 7; 1986	
Secchi Disc	1972 - 96	Alkaline Phosphatase 1976 - 77	
NAOI*1	1959 - 98		
Ground Water Index	1973 - 98*2		
Palmer Drought Index	1959 - 96		
Gulf Stream Index	1966 - 1993*3		

Phytoplankton	***Zooplankton**** *4
Species Composition 1959–96	Species Composition 1972–90*5
Numerical Abundance 1959–96	Numerical Abundance 1972–90
Chlorophyll 1968–69; 1972–96	Dry Weight Biomass 1972–96
ATP-C Biomass 1972–86	C,N Biomass 1972–96
Primary Production 1979 - 90	Ctenophore Abundance 1973–96

*1 = North Atlantic Oscillation Index; *2 Potential for pre-1973; *3 Data available from 1964–; *4 Zooplankton data available also for 1959–61 (Martin, 1965) and ctenophore data for 1971–72 (Kremer, 1975); *5 Samples from 1991–96 archived for species identifications and abundance.

The Narragansett Bay data set considerably exceeds the 38-yr time-series of field measurements. It has been supplemented by the publication of numerous physical and chemical studies, descriptive and experimental field studies at all trophic levels; experimental and process-oriented studies on the dominant phytoplankton and zooplankton species in Narragansett Bay, and modeling of specific ecosystem events carried out in Dr. Smayda's laboratory and by colleagues.

The contact person for this time series is Dr. Theodore J. Smayda (tsmayda@gso.uri.edu).

The data are currently being migrated to an electronic web site for open access.

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Description of the Sylt and the time series and a short summary of the Wadden Sea eutrophication status.

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The island of Sylt is located in the Northern Wadden Sea (North Sea, Europe), a shallow tidal coastal sea protected from the North Sea by barrier islands. The tidal range near Sylt is about 2 meters and at low tide about 30% of the area is exposed. Salinity ranges between 27.5 in winter to about 31 in summer. Temperature ranges on average between 2°C in February and 17°C in August. Sediments are predominantly sand.

First regular (weekly) measurements are from 1973–1976. From 1979–1982 focus was on tidal variation at a shallow subtidal station. In monthly intervals, a half tidal cycle was monitored. Since 1984 two stations –one at a shallow subtidal station (55°2.26N, 8°26.3E) and one in the main tidal channel (55°1.3N, 8°27.1E) - are monitored twice a week.

The time series include hydrographic parameters (salinity, temperature, pH), nutrients, chlorophyll (since 1984), suspended matter. Phytoplankton diversity of net phytoplankton catches is monitored weekly since 1988, phytoplankton abundance weekly since 1993 but are partly digitized. Samples for zooplankton abundance have been taken weekly since 1979 and have been partly analysed.

Little has been published so far on temporal aspects of the time series. Hickel (1984) reported on the suspended matter composition. The same author described a long term change in phosphate dynamics (Hickel, 1989). Drebes and Elbrächter (1976) published a phytoplankton species list. Elbrächter and Martens (1998) summarized the temporal patterns of dominating phytoplankton species and zooplankton species.

Recent evaluations of the Sylt time series were carried out within an international Wadden Sea framework. Van Beusekom *et al.* (2001) proposed Wadden Sea Eutrophication Criteria, based on the OSPAR comprehensive procedure. The evaluation of winter nutrient concentrations was not appropriate as the eutrophication is mainly driven by organic import from the adjacent North Sea (van Beusekom and de Jonge, 2002). The main criterion was based on the seasonal dynamics of ammonium and nitrite. These nutrients are typical remineralisation products. For the Dutch and Lower Saxonian Wadden Sea a linear relation was found between riverine nutrient input during winter and the concentrations of these remineralisation products during the following autumn. The criterion did not give satisfactory results for the northern Wadden Sea. In a follow up study, the eutrophication study was assessed for the 2004 Wadden Sea Quality Status Report. In addition the seasonal dynamics of ammonium and nitrite, a second criterion was found, based on summer chlorophyll levels, which correlated significantly with riverine nitrogen input during the winter and early summer. The latter correlation was only found for the longer time series including the Sylt series (van Beusekom *et al*., 2005). Both proxies correlate, supporting that they are useful eutrophication indicators (van Beusekom, 2006). These proxies indicate that the Wadden Sea has to be separated in a more eutrophic southern part and a less eutrophic northern part. At present, the Wadden Sea is about 5 times more eutrophic then during pre-industrial conditions (van Beusekom, 2005).

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Annex 8: Data series

Data series A				Phytoplankton data (y = yes / n = no)		
Area	Time period covered	Samples year^{-1}	Nutrient trend reversal (if relevant)	All species - Cell counts	All species - Biomass	Other data available
Belgium Coastal Zone	1988-2000 P, NH4, Si decrease		1985	y	y	n
Dutch Coastal Zone (RWS, 9 stations)	1977-2004 TP, TN decrease		1980 (P) 1989 (N)	y	n	n
Dutch Western Wadden Sea (NIOZ, 1 station)	1978-1987 TN, TP increase			y	n	Macrozoobenthos, birds
	1988-2004 TN, TP decrease		1988 DIP decrease	y	n	n
German Wadden Sea (Büsum, 1 station)	1991-2005			n	n	n
German Wadden Sea (Sylt, 1 station)	1984-2004			y	y	n
German Bight (Helgoland, 1 station)	1962-2004		1982-1985	y	y	n
Bantry Bay (51º30´36" N, 9º56´04"W) to (51º44´24"N , 9º28´36")	1989-2002 NO3 increase	~830		n	n	Diatoms and dinoflagellates counted
Stonehaven NE, Scotland (57º00´00" N, 02º00´00"W)	1997 - 2006	45 - 52		y	n	Zooplankton /microciliates
Bay of Fundy (44.50 N, 65.00 W to 45.00-67.00W)	1988-2006	~350		y	n	Zooplankton /microciliates
Nervion Estuary, Basque Country (43º23'-43º14''N, 03º07'-02º55'W)	1993-2005	120-190		y (2000-2005)	n	
Basque Coast (43º 17' 16 ''N, 01º 55' 00''W)	1986-2006	8-10		y	n	
Galician coast (43º31'39''N, 07º02'42''W) to (41º36'00''N, 8º30'00''W)	1992-2006	1924-2912		y	n	Microciliates
Gullmar Fjord, Sweden	1985-	12-24		y (4 depths)	n	Oxygen
IMR Flødevigen Bay, Norway	1984 -			y	n	
Kattegat Anholt E, Sweden/Denmark	1979 - 1997	5-7		y	y	Zooplankton, macrozoobenthos
	1997 -	20-25		y	y	Zooplankton, macrozoobenthos
Kattegat, Belt Sea and the Sound, Denmark (St. 409, 431, 925, 937)	1953 - 1985 N increase	6-50	Mid 80ies	n	n	Primary production
	1986 - N decrease	6-50	Mid 80ies	n	n	Primary production
Kattegat, Belt Sea and the Sound, Denmark (St. 409, 431, 925, 937)	1979/81 - 1985	5-8	Mid 80ies	y	y	Zooplankton, macrozoobenthos
	1986 - 1997/prese	5-26	Mid 80ies	y	y	Zooplankton, macrozoobenthos
The Sound (Vestlandskrona + Barsebäck)	1985-	12+		y	y	
Arkona st. 444, Denmark	1979 - 1997	5-8		y	y	Zooplankton, macrozoobenthos
Narraganset Bay	1959 - 1997 + 1999-	52	P decline from early 70ies	y	n	Zooplankton 1972-90
Tampa Bay, Florida	1981-1994		load decrease in 1979	Groups only Species on paper files	n	
Tampa Bay, Florida	1995-2003	60		y	n	
Charlotte Harbor, Florida	1989-2001	48		species 1989-2001	n	
Thau, France	1972-2004	12-144		n	n	Species>10um (unavailable) 1972-1985 GF/C chl-a data, 1985-present GF/F chl data

Data series **B**				Ranges of parameters in data sets For nutrient ranges 0 = detection limit								
Area	**Time period covered**	**Samples year[1]**	**Time of Nutrient trend reversal (if relevant)**	**Salinity**	**temperature (°C)**	**Chl a (µg L^{-1})**	**NO_3 (µM)**	**NH_4 (µM)**	**PO_4 (µM)**	**Si (µM)**	**O_2 (mg L^{-1})**	**Secchi depth (m)**
Belgium Coastal Zone	1988-2000 P, NH4, Si decrease		1985	32-34.5	+2-19	1 - 35	0 - 45	0 - 8	0 - 2	0 - 17		
Dutch Coastal Zone (RWS, 9 stations)	1977-2004 TP, TN decrease		1980 (P) 1989 (N)	19-35	-1.5 - 22	0.1 - 150	0 - 137	0.6 - 62	0.2 - 4.5	2.5 - 56	4 - 16.5	0.2-3.5
Dutch Western Wadden Sea (NIOZ, 1 station)	1978-1987 TN, TP increase			3 - 36	-1.8 - 24	0.1 - 85	0.7 - 270	1.6 - 113	0.3 - 2.3	6 - 88	4.5 - 14.6	0.05 - 3.5
	1988-2004 TN, TP decrease		1988 DIP decrease									
German Wadden Sea (Büsum, 1 station)	1991-2005			14 - 30	-1.5 - 24	0 - 30	0 - 160		0.5 - 6	1 - 120		0.05 - 2
German Wadden Sea (Sylt, 1 station)	1984-2004			25 - 32	-2 - 22	0 - 90	0 - 80	0 - 12	0 - 1.2	0 - 35		0.2 - 5.9
German Bight (Helgoland, 1 station)	1962-2004		1982-1985				0 - 120	0 - 20	0 - 2.5			
Bantry Bay (51º30´36" N, 9º56´04"W) to (51º44´24"N , 9º28´36")	1989-2002 NO3 increase PO4 increase	~830		33.5 - 35-5	7-17	0.1 - 6.1	< 16	< 5	< 1	< 15		
Stonehaven NE Scotland (57º00´00" N, 02º00´00"W)	1997 - 2006	45 - 52		33-34.9	4.8 - 16	0.01 - 9.5	0 - 11	0 - 3.8	0 - 1.2	0 - 11		
Bay of Fundy (44.50 N, 65.00 W to 45.00- 67.00W	1988-2006	~350		15 - 33	1.5 - 16		0.09 - 11.7	0.5 - 8.1	0.15 - 1.6	0.3 - 14.9		
Nervion Estuary, Basque Country (43º23'-43º14"N, 03º07'-02º55'W)	1993-2005	120-190		no		0 - 38		0.5 - 600				
Basque Coast (43º 17' 16 "N, 01º 55' 00"W)	1986-2006	8-10		no								
Galician coast (43º31'39"N, 07º02'42"W) to (41º36'00"N, 8º30'00"W)	1992-2006	1924-2912		(0-) 32 - 35.8		< 20	9.7	4.6	1.2	6.1		

Data series B - continued				**Ranges of parameters in data sets** For nutrient ranges 0 = detection limit								
Area	**Time period covered**	**Samples year^{-1}**	**Time of Nutrient trend reversal (if relevant)**	**Salinity**	**temperature (^{o}C)**	**Chl a ($\mu g\ L^{-1}$)**	**NO_3 (μM)**	**NH_4 (μM)**	**PO_4 (μM)**	**Si (μM)**	**O_2 ($mg\ L^{-1}$)**	**Secchi depth (m)**
Gullmar Fjord	1985-	12-24		?								
IMR Flødevigen Bay	1984 -			15 - 35	-1 - 22	0.5 - 11	0 - 13	?	0.04 - 0.7	0 - 15	?	5 - 13
Kattegat Anholt E SE/DK	1979 - 1997	5-7					0 - 12					
Kattegat Anholt E SE/DK	1997 -	20-25		?			0 - 12					
Kattegat, Belt Sea and the Sound St. 409, 431, 925, 937	1979/81 - 1985	5-8	Mid 80ies	10-30	-0.9 - 21	0.1 - 18	0 - 10					
Kattegat, Belt Sea and the Sound St. 409, 431, 925, 937	1986 - 1997/present	5-26	Mid 80ies	10-30	-0.1 - 23	0.2 - 30	0-10		0 - 1.3			
The Sound (Vestlandskrona + Barsebäck)	1985-	12+					0 - 15					
Arkona st. 444	1979 - 1997	5-8		8-10	0.1 - 23	0.4 - 9.3						
Narraganset Bay	1959 - 1997 + 1999-	52	P decline from early 70ies	25-32			0 - >20		0 - 2			
Tampa Bay, FL	1981-1994 load decrease in 1979			12-37	10 - 33	2 - 100	0 - 140	0 - 42	5 - 65		3 - 15	0.5 - 3
Tampa Bay, FL	1995-2003	60		12-37 - related to flow and SST	10 - 33	2 - 100	0 - 140	0 - 42	5 - 65	?	3 - 15	0.5 - 3
Charlotte Harbor, FL	1989-2001 natural geology varied	48		0-20 - related to flow and SST	10 - 33	2 - 50	0 - 100	0 - 15	5 - 30	?	4 - 13	?
Thau	1972-2004	12-144		25-42	2 - 27	0.1 - 40	0 - 30	0 - 15	0 - 10 (0.2-0.9 DOP)	1-43	?	nd

Data series **C**

Trends (no = no trend, + = increase, - = decrease, ? = in progress)

▨ = no data

Area	Time period covered	Samples year[1]	Time of Nutrient trend reversal (if relevant)	Cell counts/ biomass	Ratios between groups	Chl a	Primary production	N_NO3	N_NH4	PO4	Si	O2	Secchi depth	Temperature
Belgium Coastal Zone	1988-2000 P, NH4, Si decrease		1985	no	no	no	?	▨	-	-	-	no	no	no
Dutch Coastal Zone (RWS, 9 stations)	1977-2004 TP, TN decrease		1980 (P) 1989 (N)	+ (counts diatoms)	?	no	?	- (DIN)		-	no	?	?	?
Dutch Western Wadden Sea (NIOZ, 1 station)	1978-1987 TN, TP increase			?	?	no	▨	no (DIN)		no	no	?	?	?
	1988-2004 TN, TP decrease		1988 DIP decrease	?	?	no	-	no (DIN)		-	+	?	?	?
German Wadden Sea (Büsum, 1 station)	1991-2005			▨	▨	no	?	no (DIN)		no	no	▨	?	?
German Wadden Sea (Sylt, 1 station)	1984-2004			?	?	-	▨	no	no	▨	no	▨	(+)	+
German Bight (Helgoland, 1 station)	1962-2004		1982-1985	no	no	▨	▨	+, no	-	+, -	no	▨	-, +	+
Bantry Bay (51º30´36" N, 9º56´04"W) to (51º44´24"N , 9º28´36")	1989-2002 NO3 increase PO4 increase	~830		no	Slight, Diatom:Dino	(Chl drops in late 90s increase since 2000)	▨	?	no	Slight +	+	▨	no	+ (winter)
Stonehaven NE Scotland (57º00´00" N, 02º00´00"W)	1997 - 2006	45 - 52		very variable no linear trend	very variable no linear trend	yes but non linear	▨	?	?	?	?	▨	▨	?
Bay of Fundy (44.50 N, 65.00 W to 45.00- 67.00W	1988-2006	~350		yes - cyclical	Diatoms 1995-2002	?	▨	no	no	no	no	?	?	no
Nervion Estuary, Basque Country (43º23'-43º14"N, 03º07'-02º55'W)	1993-2005	120-190		?	?	no			-			+	+	no
Basque Coast (43º 17' 16 "N, 01º 55' 00"W)	1986-2006	8-10				no						no		no
Galician coast (43º31'39"N, 07º02'42"W) to (41º36'00"N, 8º30'00"W)	1992-2006	1924-2912		?	?	?	▨	+ (one station)	?	Slight +	no	?	▨	+ (summer)

Data series C - continued				Trends (no = no trend, + = increase, - = decrease, ? = in progress) = no data										
Area	Time period covered	Samples year [1]	Time of Nutrient trend reversal (if relevant)	Cell counts/ biomass	Ratios between groups	Chl a	Primary production	N_NO3	N_NH4	PO4	Si	O2	Secchi depth	Temperature
Gullmar Fjord, Sweden	1985-	12-24		?	?	?	?	?	?	?	?	?	?	?
IMR Flødevigen Bay, Norway	1984 -			+ / -	?	-		?	?	?	?	no	no	+ winter
Kattegat Anholt E, Sweden/Denmark	1979 - 1997	5-7		-	no									?
	1997 -	20-25		-	?	-	?	-	-	-	-	?	?	?
Kattegat, Belt Sea and the Sound St. 409, 431, 925, 937	1953 - 1985 N increase	6-50	Mid 80ies				+						-	?
	1986 - N decrease	6-50	Mid 80ies				-						+	+
Kattegat, Belt Sea and the Sound St. 409, 431, 925, 937	1979/81 - 1985	5-8	Mid 80ies	no	?	no		?	?	-	no	-	no	+
	1986 - 1997/present	5-26	Mid 80ies	-	Diatoms: dinos	+ / -		-	?	-	no	-	+ since 1997	+
The Sound (Vestlandskrona + Barsebäck)	1985-	12+		+ / -	?	-	no	-	?	?	?	?	- (6 cm/y)	?
Arkona st. 444, Denmark	1979 - 1997	5-8		-	?	?		?	?	?	?	?	-	+
Narraganset Bay	1959 - 1997 + 1999-	52	P decline from early 1970ies,	+ (cycle)	+ (cycle)	-	no (72-90)	no	?	- (from early 70ies)	+ (since late 80ies)	?	+ / -	+
Tampa Bay, Florida	1981-1994 load decrease in 1979			-	?	Since 1983		-	-	-		minima increase, maxima decrease	+	+
Tampa Bay, Florida	1995-2003	60		Declining blue greens	?	Since 1983		-	-	-		minima increase, maxima decrease	+	+
Charlotte Harbor, Florida	1989-2001 natural geology varied	48		Varied years of high cyanobacteria counts	?	(1997)		-	(assoc with high temp, lower DO)	-		nearly annual flow-related hypoxic events	?	+
Thau	1972-2004	12-144		?	?	transient chl, removed by oysters		no trend (rainfall driven)	no trend (seasonal fall peak, summer hypoxia-related release)	-	no	Occasional anoxia (summer)		+ (0.05 Deg C/year)

Data series D		Answers to questions 1-10 np = not possible									
Area	**Time period covered**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
Irish estuaries	1990-2005										
Stonehaven West Scotland	1996-2005	Variable no linear trend	Variable no linear trend	?	Variable no linear trend	np	?	?	?	?	?
Skagerrak, Flødevigen, IMR	1984- 2006	Yes (Chl a)	Yes (Chl a since 2003, species)	Sudden (02, Fish recruit.)	Yes (Karenia & Chrysochr. Decrease, Chattonella - new)	np	?	No? Chryso? Chattonella?	Yes (Fish mortality - Chattonella)	Yes (Chl a)	?
Prim.Prod. Gullmar Fjord, Sweden	1985-2005					Yes, decrease after 2000					
Kattegat E, Sweden	1997-05	Yes	(Yes)	Gradual	Yes	Yes	?	Yes	?	Yes (Chl a, bio vol))	?
The Sound, Sweden	1985-05	Yes	(Yes)	Gradual	Yes	(Yes)	?	Yes	?	Yes (Chl a, bio vol))	?
Kattegat W & Belt Sea, Denmark	Prim. Prod. 1953-1997, Plankton 1980-2005	Yes	Yes	Both gradual and sudden	Yes	Yes	?	Yes	Yes	Yes (Chl-a)	Yes (Chl-a)
German Bight (Helgoland, 1 station)	1962-2004	Yes	Yes	?	Yes	np	Yes	Yes	Yes	Yes	Yes
German Wadden Sea (Sylt, 1 station)	1984-2004	Yes (summer chlorophyl)	Yes (longer growth period)	gradual	nd	No	Temp: yes (spring grazing) Riverine TN discharge: yes: Summer >Chla Wind: yes (SPM)	Yes	Yes only transparency and foam	?	?
German Wadden Sea (Büsum, 1 station)	1991-2005	no	?	np	np	np	np	np	No	?	?

Data series **D continued** **Answers to questions 1-10**

np = not possible

Area	Time period covered	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Dutch Western Wadden Sea (NIOZ, 1 station)	1978-1987 TN, TP increase	Yes flagellates & diatoms	?	flagellates gradual, diatoms sudden	?	np	?	?	No	?	?
	1988-2004 TN, TP decrease		?		?	Yes, decreasing	?	Yes	No	?	?
Dutch Coastal Zone (RWS, 9 stations)	1977-2004 TP, TN decrease	Yes diatoms	?	sudden (diatom counts)	?	np	?	No	(foam)	?	?
Belgium Coastal Zone	1988-2000 P, NH4, Si decrease	No	No	gradual	Phaeocystis colonies related to N	np	Yes NAO	Yes NO3	foam	?	?
Basque Coast, Spain	2002-2005										
Ria de Pontevedra, Galicia, Spain	1002-2005										
Thau Lagoon, Southern France	1972-2004	Yes Cyanobacteria + *Alexandrium cattenella*	?	Sudden	Yes	np	Yes, increasing temperature	Yes, reduced nutrient loading	Yes, fish kills and shellfish poisoning	Yes, Pico-eucariotes	Yes, Temperature
Bay of Fundy, southeastern Canada	1987-2005	Yes	Yes	?	No	np	Yes	No	?	?	?
Narragansett Bay, northeast USA	1959-1997	Yes	Yes	?	Yes	No	Yes	?	?	?	Yes
Tampa Bay and Charlotte Harbor, Florida	Tampa 1974-2005, Charlotte 1989-2002	Tampa Yes, Charlotte ?	Tampa Yes, Charlotte ?	Tampa Gradual, Charlotte ?	Slightly, Indicators ?	np	Links of rainfall/flow loads to SST and AMO. Tampa: Temp. increasing	Tampa correlated, Charlotte less clear, light limitation?	Tampa improved DO and macroalgae, Charlotte not apparent	Tampa Yes Chl-a based, Charlotte Future transparency based	No