ZOOLOGICAL INSTITUTE OF RUSSIAN ACADEMY OF SCIENCES
St. Petersburg
1832

Effects of environmental variables on midsummer dinoflagellate community in the Neva Estuary

Mikhail Golubkov, Vera Nikulina, Sergey Golubkov

Introduction

Dinoflagellates are single-celled eukaryotes that are widespread around the world and have a significant variety of types of cellular organization and physiology. It is known that about half of the dinoflagellate species have their own pigment-containing plastids and are capable of photosynthesis. These protists are mixotrophic, that is, organisms, metabolism which combines the features of auto - and heterotrophy (possibility use of organic matter as a nutrients source) (http://tolweb.org/Dinoflagellates/2445).

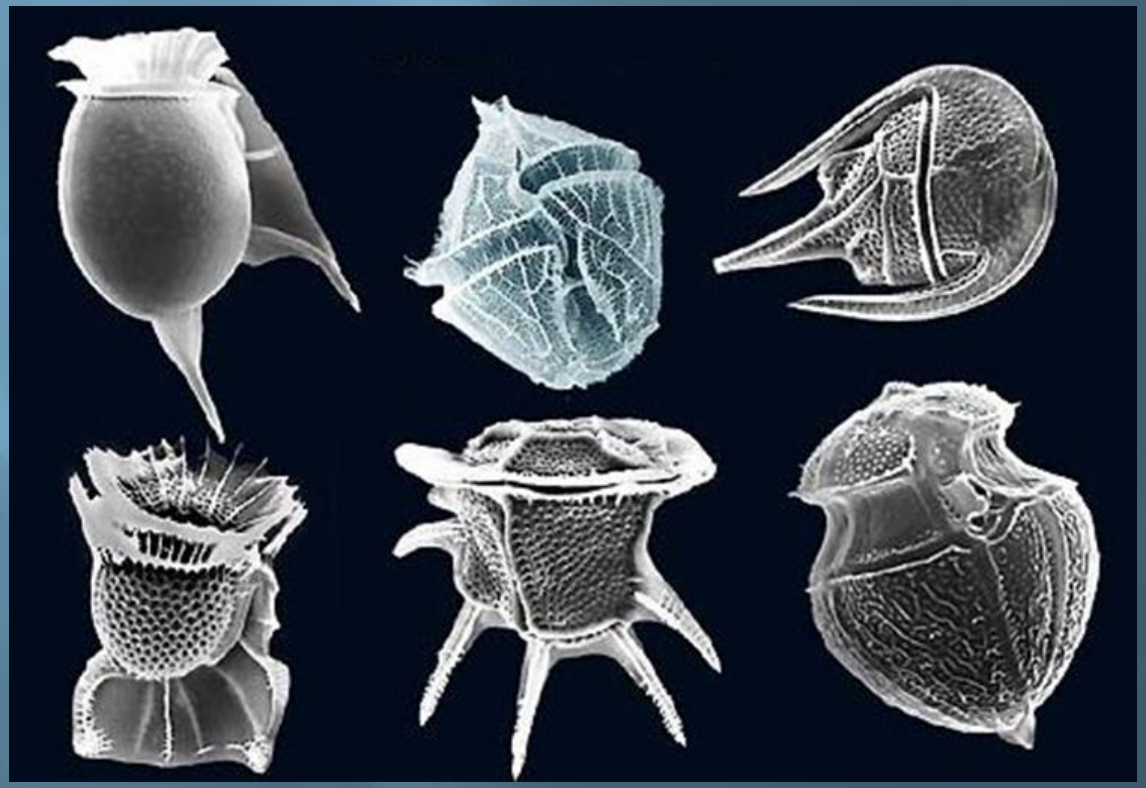


Photo retrieved from: https://www.pinterest.ru/pin/540009811542611329

Introduction

"Red tide" is a common name for a worldwide phenomenon known as an dinoflagellates bloom. Certain species of dinoflagellates found in "red tides" contain photosynthetic pigments that vary in color from brown to red. Red tides occur in oceans, bays, and places where fresh water meets salt water over the world (https://en.wikipedia.org/wiki/Red_tide).

A red tide off the coast of La Jolla, San Diego, California (https://en.wikipedia.org/wiki/Red_tide)

A red tide near Cape Rodney, New Zealand (https://serc.carleton.edu/microbelife/topics/redtide/general.html)

Introduction

Humans are affected by the red tide species by:

- ingesting improperly harvested shellfish, which one concentrate saxitoxin in their tissues;
- breathing in aerosolized brevetoxins;
- skin irritation after swimming in the ocean during a red tide.

In fact, dinoflagellates account for about 75% of all harmful phytoplankton species (Smayda and Reynolds, 2003). Red tides sometimes caused large-scale mortalities of fin-fish and shellfish and thus great losses to the aquaculture and tourist industries of many countries (Anderson et al., 2002; Heisler et al., 2008; Zhou et al., 2017).

Photos retrieved from:

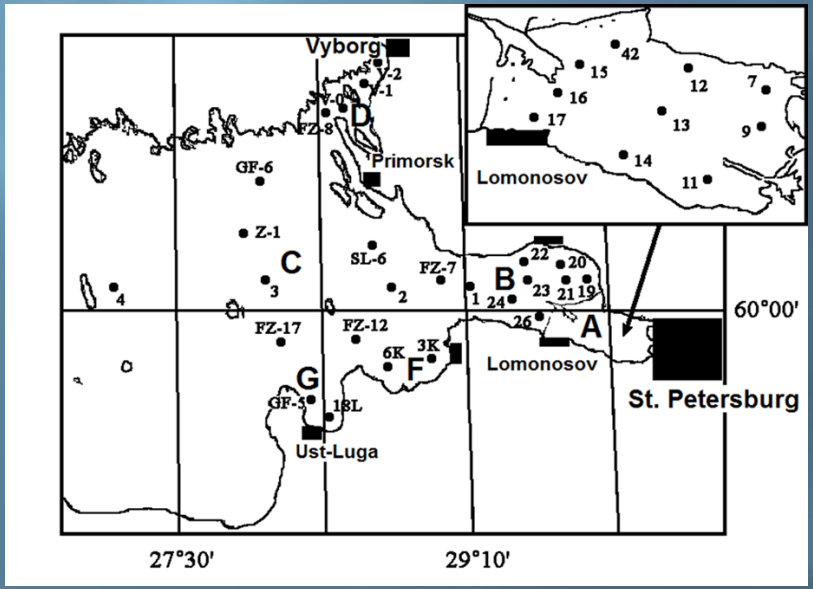
- https://www.abcactionnews.com/news/fwc-releases-red-tide-report-with-minimal-change-in-cell-concentrations-for-most-areas
- https://abcnews.go.com/US/massive-red-tide-off-coast-florida/story?id=24963894

Aim

The aims of this investigation was:

- summarize the results of our 14-year data and previous studies on the composition of the dinoflagellate community in the eastern Gulf of Finland;
- analyze, based on 14-year data, the effects of the environmental variables on biomass of different dinoflagellate species in the Neva Estuary;
- test a hypothesis that biomass of different species may be significantly correlated with environmental variables.

We analyzed environmental conditions such as water temperature, salinity, concentrations of total phosphorus, suspended particulate matter and suspended particulate organic matter, primary production and mineralization of organic matter in order to relate them with dinoflagellate species composition and biomass in the upper, middle and lower parts of the Neva Estuary in midsummer.



Samples were taken at 35 stations at midsummer 2003-2016 in the Neva Estuary.

Species composition of autotrophic dinoflagellates

	1843	1911–1912, 1914	1920–1921	1930–1937	1982–1984	1988	1997	1999–2002	2003–2016
	July-August			All seasons	August	All seasons	All seasons	August	July-August
Amphidinium sp.									+
Ceratium hirundinella		+	+	+	+			+	+
C. longipes				+					
Dinophysis norvegica									+
D. ovum var. baltica				+					
D. rotundata									+
Diplopsalis lenticula									
Glenodinium sp.					+			+	+
Glenodinium paululum								+	
Gymnodinium sp.									+
Gymnodinium simplex									+
Peridinium sp.								+	+
Peridinium aciculiferum									+
P. cinctum					+				+
P. divergens var. oblongum				+					
P. inconspicuum									
Peridiniella catenata				+		+	+		+
Protoperidinium bipes				+	+				+
P. granii				+					
Prorocentrum micans	+								
P. lima									+

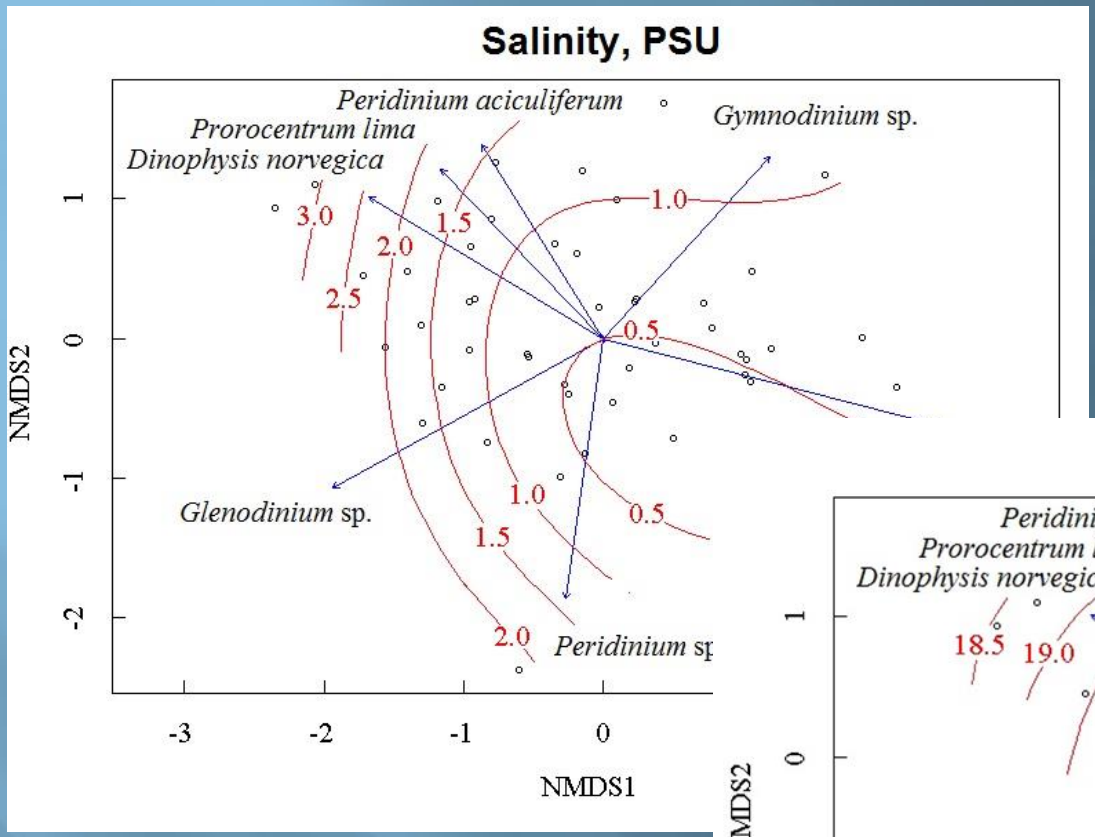
- 21 taxa of dinoflagellate were noted in open waters in the Russian part of the Gulf of Finland since the mid-19th century;
- 13 distinct species were observed in the midsummer 2003-2016 and 9 of them could be identified to species level;
- *Peridinium aciculiferum* was first time found in the Baltic Sea. This common species for the Neva Estuary was not in the list of dinoflagellates found in the Baltic Sea published by HELCOM (2004);
- *Prorocentrum lima* was first time found in the Gulf of Finland. This marine dinoflagellate is interesting because it releases toxins, which are dangerous for humans.

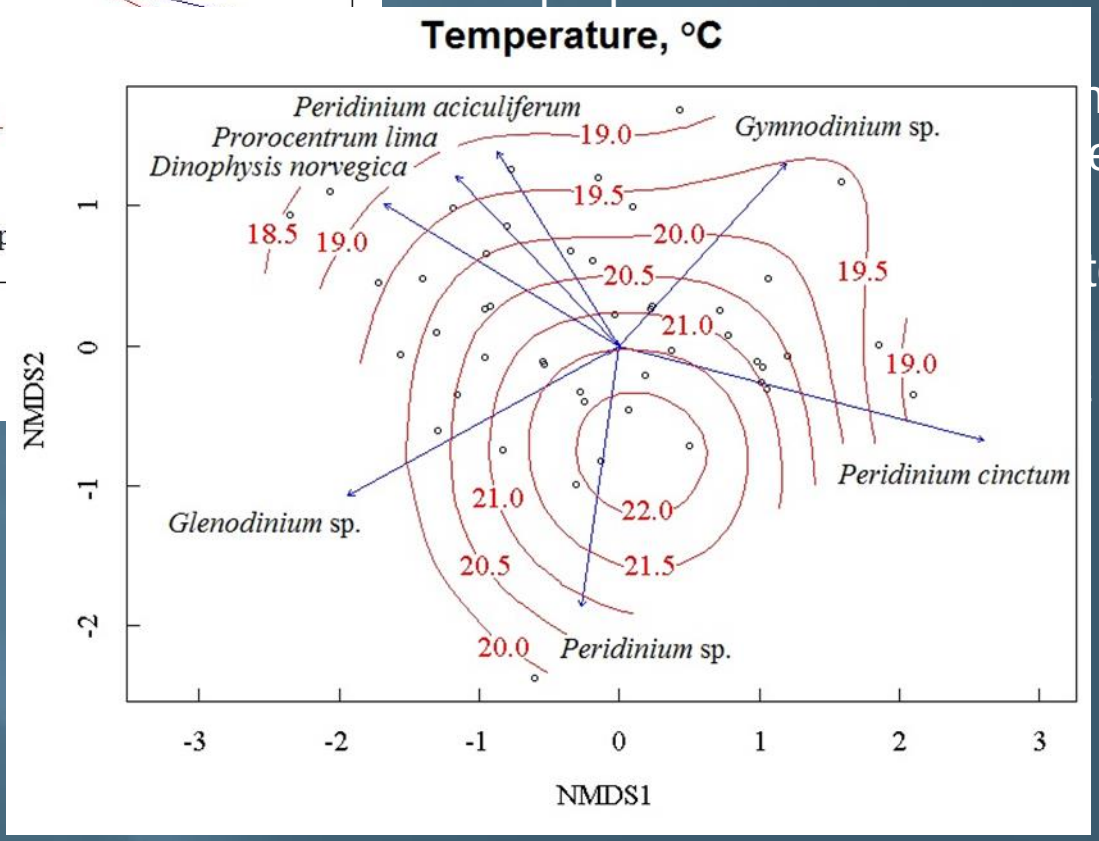
according to Brandt, 1845; Kiselev, 1924, 1948; Lange, 2006; Nikulina, 1987; Shishkin et al., 1989; Tereshenkova, 2006; Vislouh, 1913, 1921 and own data .

Statistical analysis

- Statistical analyses were performed using the R software (www.r-project.org/), community ecology package “vegan” **(**Oksanen et al., 2017);
- Non-metric Multidimensional Scaling (NMDS) was used to analyze changes within the dinoflagellate communities by ordinating samples based on the dissimilarities of environmental conditions;
- The range of data values was so large that the data were square root transformed, and then submitted to Wisconsin double standardization, or species divided by their maxima, and stands standardized to equal totals;
- We used the Bray-Curtis dissimilarity as the distance metric in the NMDS;
- In the NMDS ordination space, the samples position themselves based on their taxon specific biomass. To overlaying environmental information onto ordination diagrams we use function “envfit” (R package “vegan”, Oksanen et al., 2017).

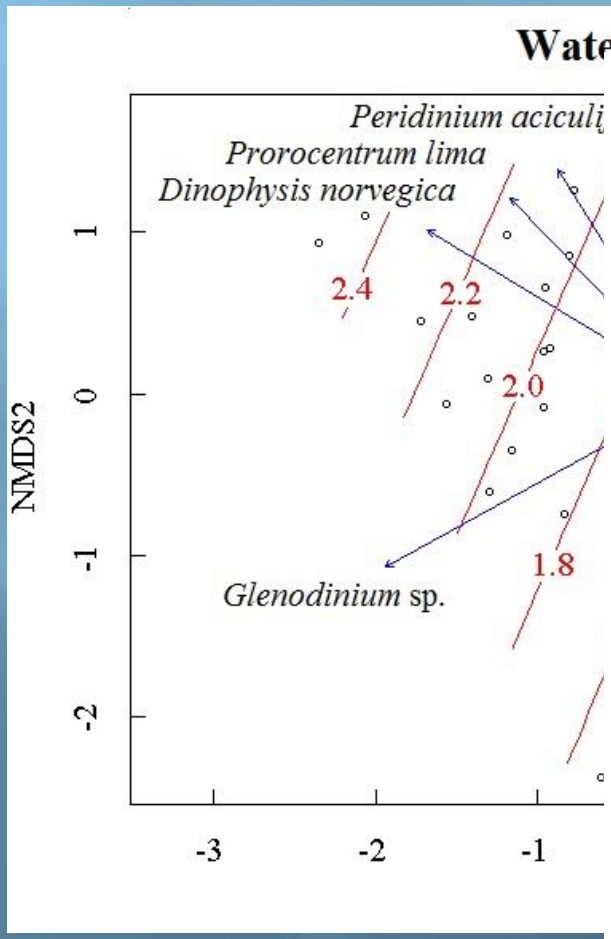
Salinity and temperature

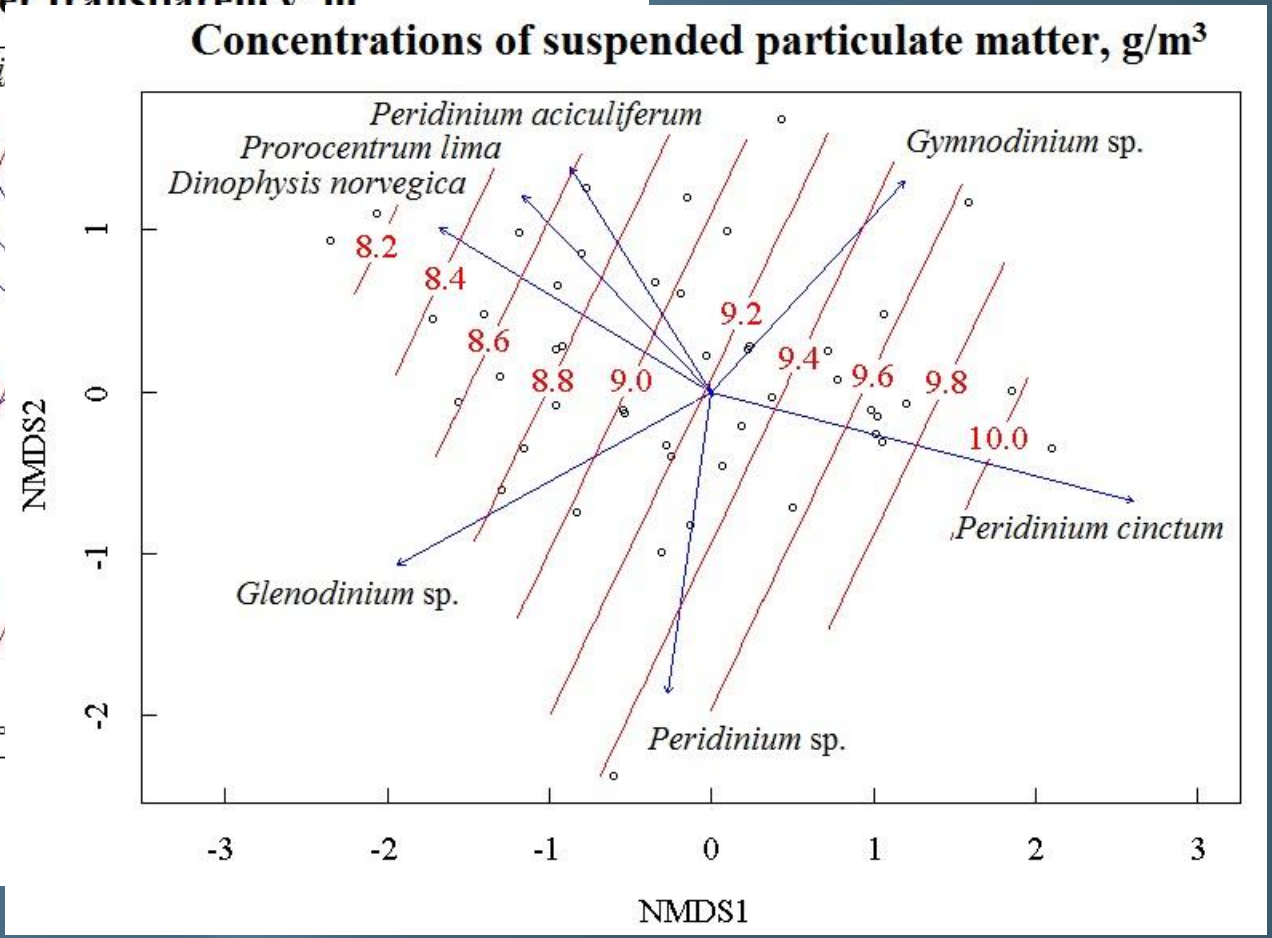




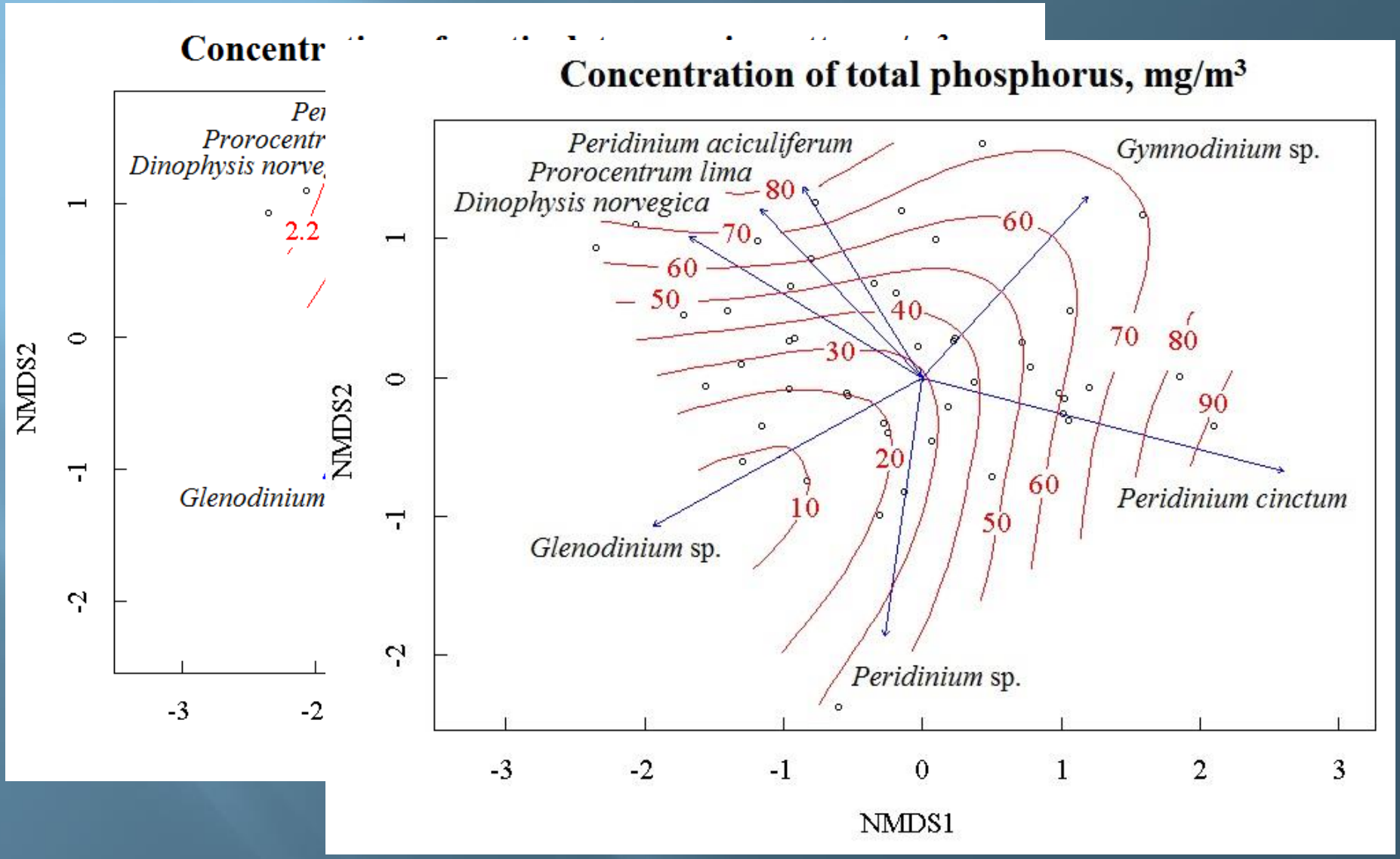
- The arrow points to the direction of most rapid change in the environmental variable. This is called the direction of the gradient.
- The length of the arrow is proportional to the correlation

Water transparency and concentrations of suspended particulate matter

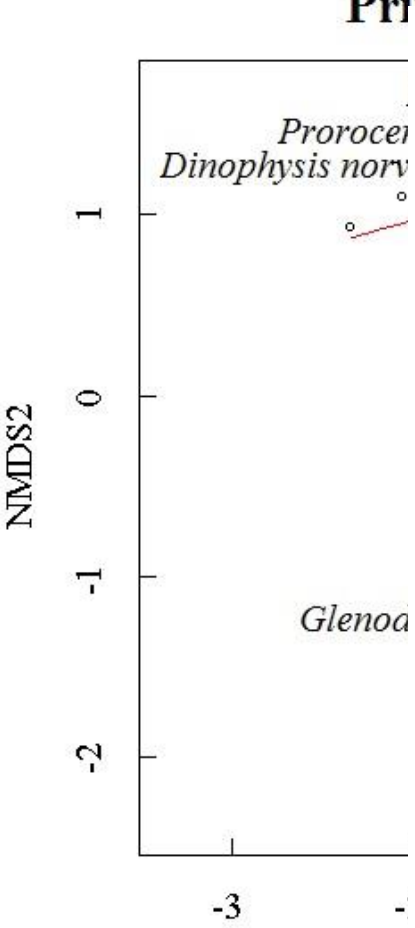


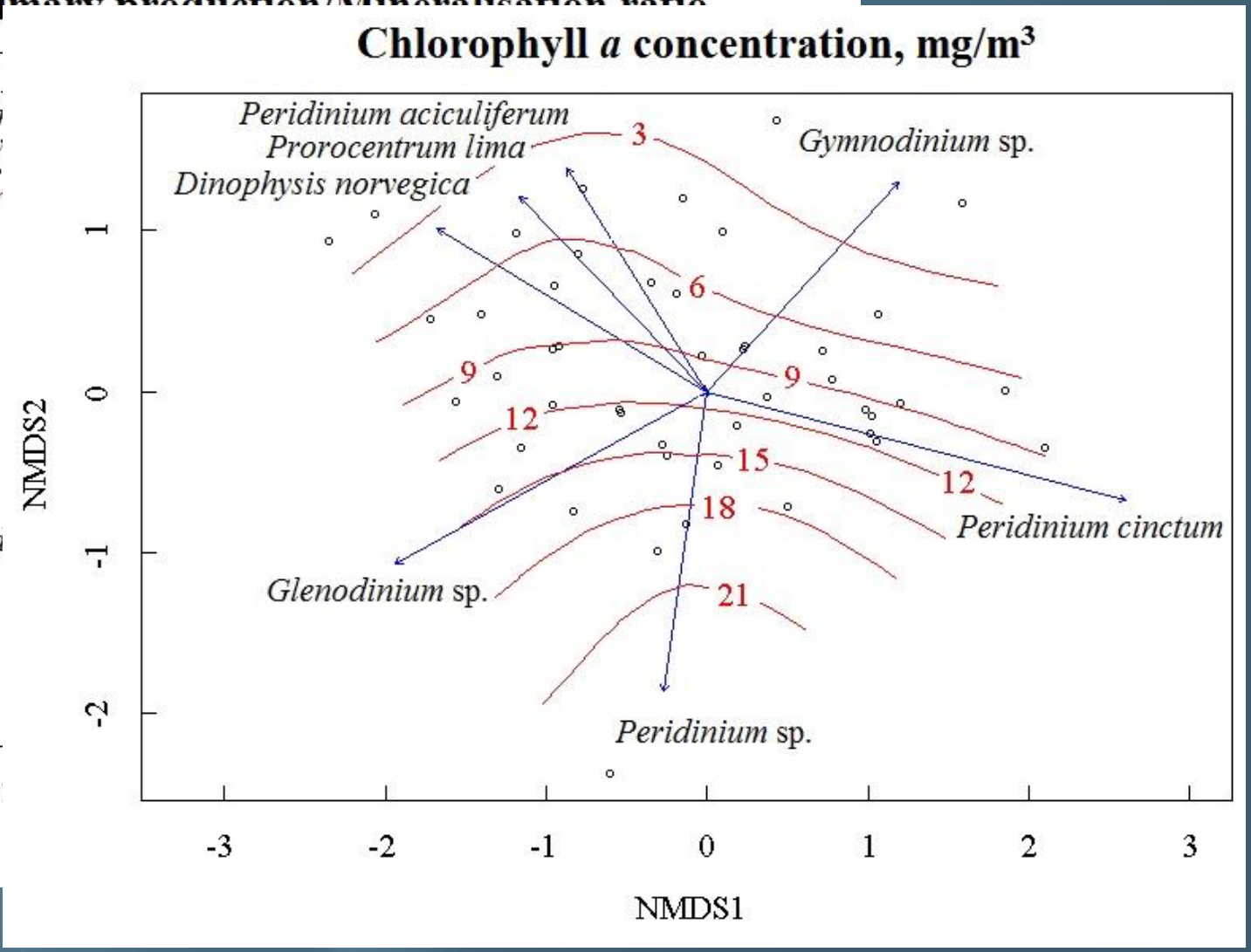


Concentrations of particulate organic matter and total phosphorus



Primary production/Mineralisation ratio and chlorophyll *a* concentration





Conclusion

1. The statistical analysis showed that different species of dinoflagellates differ in relation to changes in environmental factors. Biomasses of *D. norvegica*, *P. lima* and *P. aciculiferum* had very similar relationships with investigated environmental variables that included salinity, temperature, phosphorus and suspended particulate organic matter concentrations;
2. Biomass of *Glenodinium* sp. and *Peridinium* sp. positively correlated with primary production, and biomass of *Peridinium* sp. also positively reacted to an increase in the concentration of chlorophyll. However, these species did not show a positive relationship with phosphorus. This may be due to the fact that *Glenodinium* sp. and *Peridinium* sp. in the conditions of the Neva Estuary, apparently, are more consumers than producers of organic matter, feeding on algae and cyanobacteria of phytoplankton;
3. Current climate fluctuations leading to changes in temperature, salinity, nutrient and organic matter runoff from the catchment area could significantly affect the composition and productivity of the dinoflagellate community;
4. At the same time, when interpreting the results of the analysis, it should be taken into account that the species of this group is characterized by mixotrophy and, consequently, their biomass may depend not only on the conditions of autotrophic, but also heterotrophic nutrition.

+ Models
OCEANO-190; No. of Pages 11
ARTICLE IN PRESS

Oceanologia (2018) xxx, xxx–xxx

Available online at www.sciencedirect.com

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ORIGINAL RESEARCH ARTICLE

Effects of environmental variables on midsummer dinoflagellate community in the Neva Estuary (Baltic Sea)

Mikhail Golubkov *, **Vera Nikulina, Sergey Golubkov**

Zoological Institute of Russian Academy of Sciences, St. Petersburg, Russian Federation

Received 13 June 2018; accepted 19 September 2018

KEYWORDS
Gulf of Finland;
Phytoplankton;
Mixotrophy;
Eutrophication;
Climate change

Summary Dinoflagellates account for most of the harmful phytoplankton species but relatively little is known about the specific responses of different species to environmental variables. 21 dinoflagellate species were recorded in the plankton of the Neva Estuary since the mid-19th century. 14-year long data of midsummer dinoflagellate biomass was statistically analyzed in the Neva Estuary to show the changes in dinoflagellate species in relation to environmental factors. Biomasses of *Dinophysis norvegica* (Clapared & Lachmann 1859), *Prorocentrum lima* ((Ehrenberg) F.Stein 1878) and *Peridinium aciculiferum* (Lemmermann 1900) had very similar positive relationships with salinity, temperature, phosphorus and suspended particulate organic matter concentrations while the biomass of the other common species *Peridinium cinctum* ((Müller) Ehrenberg 1832) and *Peridinium* sp. mostly showed quite opposite trends. Climate fluctuations leading to changes in the environmental variables could significantly affect the composition and productivity of the dinoflagellate community. Biomass of *Glenodinium* sp. and *Peridinium* sp. positively correlated with primary production and biomass and chlorophyll *a* concentration, but did not show a positive relationship with phosphorus. This may be due to the fact that these species in the conditions of the Neva Estuary, apparently, are more consumers than producers of organic matter, feeding on algae and cyanobacteria of phytoplankton. Therefore, to interpret the relationships between the dinoflagellate biomass and environmental variables one should take into account that the species of this group is characterized by mixotrophy and, consequently, their biomass may depend not only on the conditions of autotrophic, but also heterotrophic nutrition.

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