SEASONALITY IN UPWARD AND REGENERATED FLUXES OF INORGANIC NITROGEN AND PHOSPHORUS IN EUPHOTIC ZONE OF THE DEEP-WATER AREAS OF THE BLACK SEA

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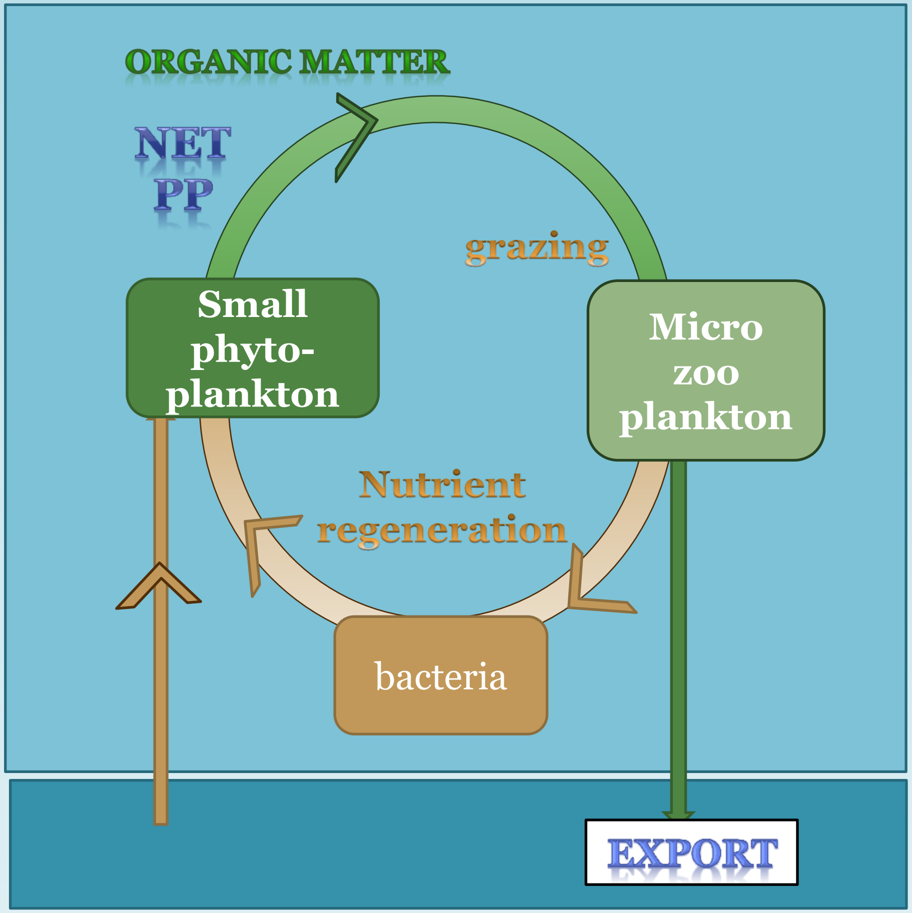
Introduction

- Part of primary production exported from the surface to entire waters is one of the important productivity characteristics of marine ecosystems because determines the amount of atmospheric carbon dioxide which absorbed by the ocean
- Many investigation have been conducted in the World Ocean for the last decades with aim to assess an organic matter exported to entire waters.
- Direct method uses sediment trap which is rather complicated and results are inconsistent. Indirect approaches are more common and one of them is based on the measures of nitrogen uptake rates by phytoplankton using ^{15}N isotope.

Nutrient fluxes in the euphotic zone and fate of net primary production

According to Falkowsky, 2006



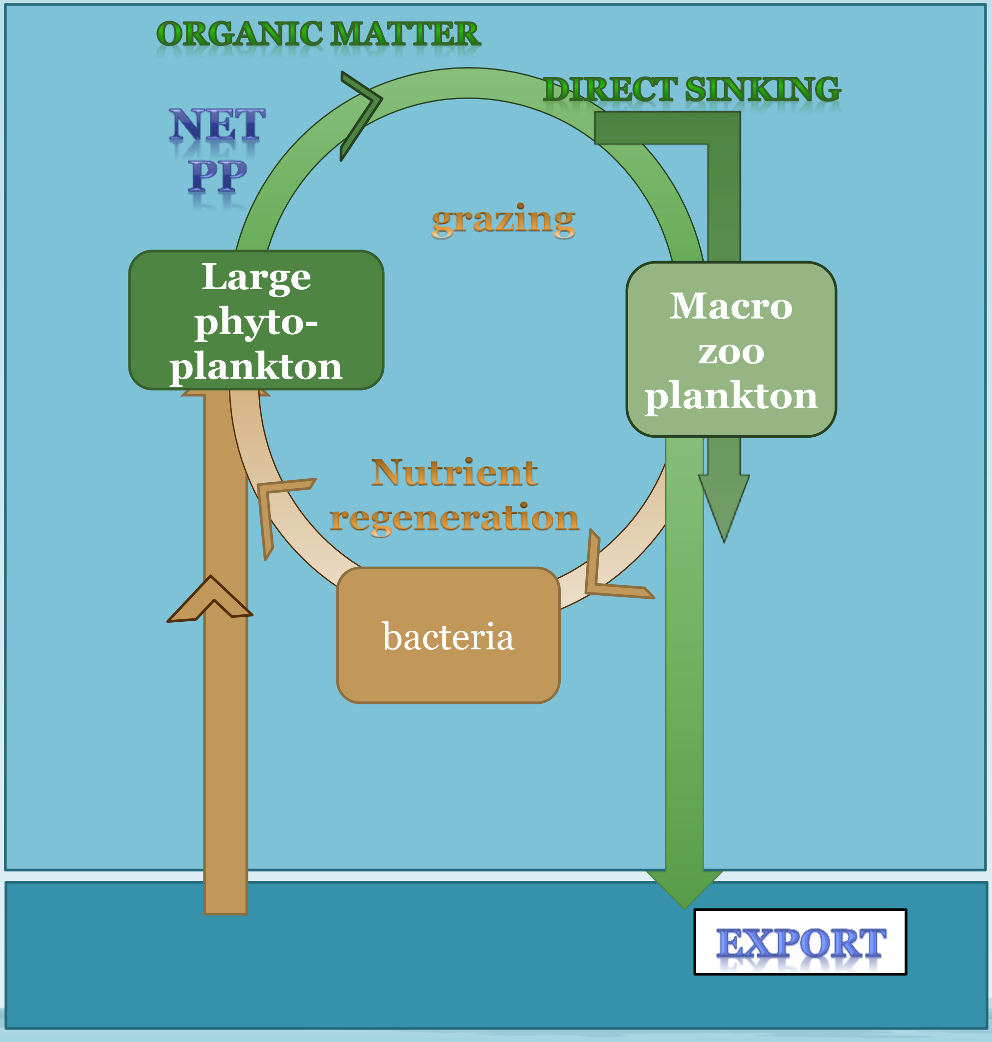
"Balanced" state

- Upward nutrient flux is strong limited by stratification
- Temporal forces that provide nutrient supply is stable
- Low nutrient concentration in the surface layer is observed
- Small part of Net PP exported from euphotic zone.
- As result nutrient regeneration via grazing supports almost all phytoplankton nutrient demands.
- Pico/nano phytoplankton and microzoplankton/protist dominate in the community.

Nutrient fluxes in the euphotic zone and fate of net primary production

According to Falkowsky, 2006

"Perturbed" state



- Temporal forces that provide nutrient supply is episodic
- Vertical mixing becomes more intensive and upward nutrient flux increase
- Which results in increasing of inorganic N and P concentration in the upper layers.
- most phytoplankton nutrient demands are supported by the endogenous sources.
- The exported part of NPP is significantly higher than in the first case
- Diatom/coccolithofores and macrozoplankton dominate in the community.

Evaluation of organic matter export

In the Ocean

- “New” production assessments
  - Determination of inorganic nitrogen uptake rates using trace ^{15}N method
- Sedimentation rate assessments
  - Sediment trap
  - U/Th radiochemical method
- Modeling of new and export production as portion of NPP
  - f-ratio
  - *e*-ratio

In the Black Sea

- ✓ Kryvenko et al 1998; McCarthy et al., 2007
- ✓ Hay et al., 1990; Kempe et al., 1993
- ✓ Gulin et al., 1995
- ✓ Oguz, 1999; Gregoire et al., 2008

There are some estimates, **produced** with the variety of approaches in the Black Sea, **but** there are no long-term and well spatial resolution studies providing accurate assessment of seasonality in upward nutrient flux or organic matter export

Objectives

- To calculate mean monthly rate of the fluxes of dissolved inorganic nitrogen and phosphorus in the euphotic layer of the Black Sea deep-waters;
- To identify the seasonal dynamics of the upward and regenerated fluxes and their relative contribution to total nutrient supply into the euphotic zone;
- To reveal relationship between the relative contribution of monthly mean upward flux to total nutrient supply ratio and some monthly averaged environmental characteristics

Upward fluxes calculations

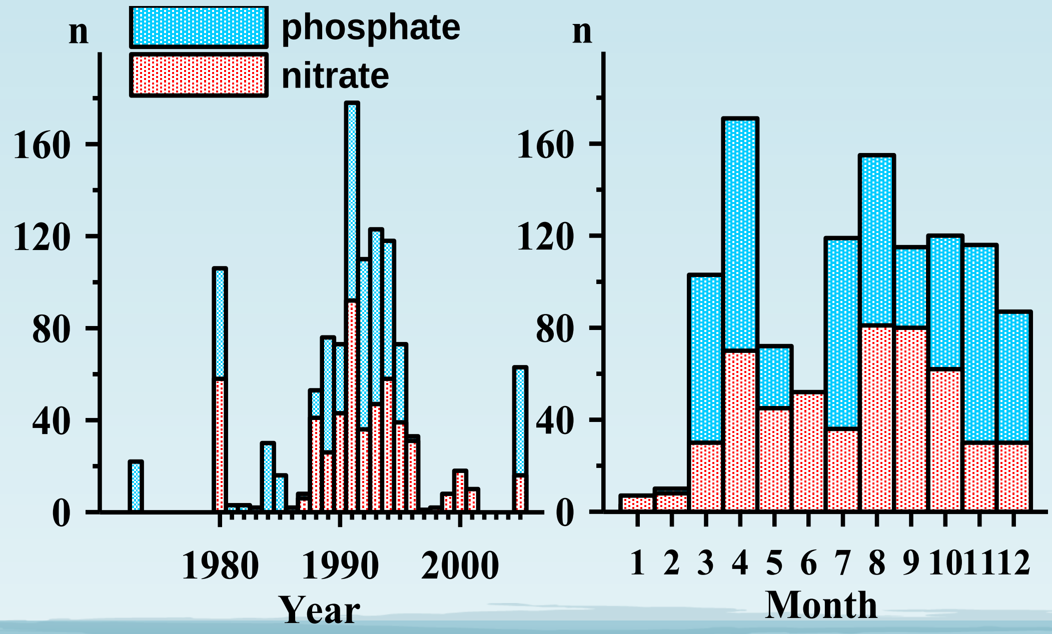
based on averaging of long-term data of the vertical profiles of water density, nitrate and phosphate concentration in the upper 150-m layer of the deep-water area (bounded by 200 m isobath)

Data sources :

- NATO-TU Black Sea Project database;
- Dataset of Department of EFA (IBSS)

Total *profiles*:
NO_3 – 530; *PO_4 – 1050 were analyzed to determine:*

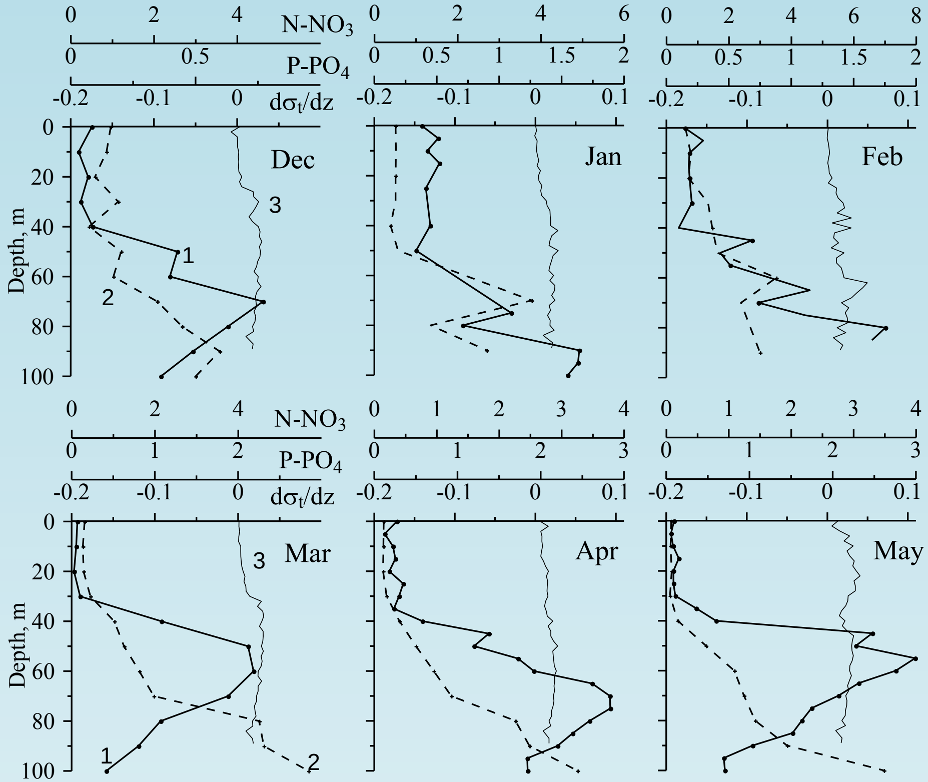
- *Nutricline position;*
- NO3/PO4 concentration at the upper boundary of nutricline;
- NO3/PO4 *gradient of concentration at this boundary;*

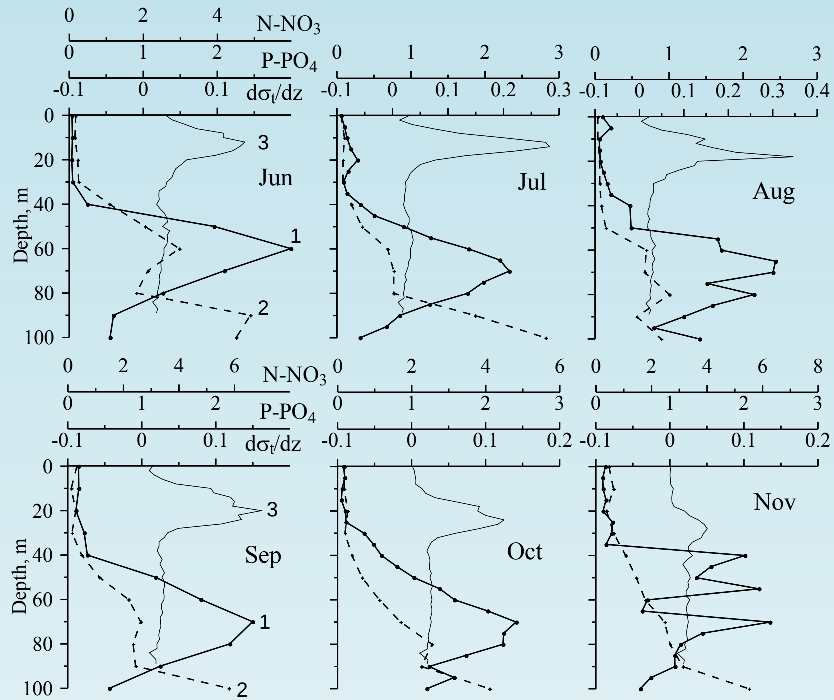


Number of profiles per the year and the month

Upward fluxes calculations

Mean monthly profiles of water density gradient and nitrate and phosphate concentration





Common peculiarity: location of the upper boundary of the nutricline at the depth of 30 - 50 m in or directly above the layer of the density gradient that corresponding to the upper boundary of the main pycnocline.

Assumptions:

- vertical transport of nitrate and phosphate are controlled by the density gradient at the upper layer of the main pycnocline during the year;

- the upward fluxes could be calculated using standard equation of vertical transport in a stratified waters;

- because spatial variability of the coefficients using for calculation (water turbulent mixing (Kz), nitrate and phosphate concentration and their gradients beneath the euphotic layer) in the areas with the opposite water dynamics is compensated on the sea scale average monthly values could be used ;
- Monthly mean Kz values in the 40 – 60 m layer averaged for entire deep-water area characterize seasonality in the turbulent mixing processes which supported upward nutrient fluxes; Data from (Bohuslavsky et al, 1979, 1989, Bohuslavsky, Ivashchenko, 1990) have been used for calculation;
- Vertical velocity coefficient is assumed constant over the year and equal to the - 10^{-4} m · h^{-1} (Ivanov, Samodurov, 2001).

Upward fluxes calculations

$$V_P = C_{PO4} \cdot W - K_Z \cdot dP/dz \quad \text{and} \quad V_N = C_{NO3} \cdot W - K_Z \cdot dN/dz,$$

- V_P and V_N – upward phosphate/nitrate flux, mg-at·m^{-2}·day^{-1};
- C_{PO4} and C_{NO3} - phosphate/nitrate concentration in the upper boundary of the layer with the highest values of the concentration gradient , mg-at·m^{-3};
- dP/dz and dN/dz - vertical gradients of phosphate/nitrate concentration, mg-at·m^{-4};
- K_Z - coefficient of vertical turbulent diffusion, $m^2 \cdot h^{-1}$
- W - vertical velocity, m·h^{-1};

Monthly mean values of the parameter used for calculation

C_{PO4} /C_{NO3} - phosphate/nitrate concentration; , mg-at·m^{-3}; S_P /S_N – depth of upper boundary of the layer with the highest values of the concentration gradient; dP/dz and dN/dz - vertical gradients of phosphate/nitrate concentration, mg-at·m^{-4}; K_Z - coefficient of vertical mixing, m^2·h^{-1}.

Month	1	2	3	4	5	6	7	8	9	10	11	12
S_P, m	50-60	40-50	30-40	40-50	40-50	30-40	40-50	50-60	40-50	40-50	40-50	40-50
dP/dz	0.04	0.07	0.06	0.05	0.04	0.06	0.05	0.03	0.04	0.04	0.04	0.04
C_{PO4}	0.19	0.21	0.33	0.33	0.31	0.22	0.29	0.21	0.30	0.34	0.39	0.44
S_N, m	50-60	40-50	30-40	40-50	30-40	30-40	40-50	40-50	40-50	30-40	40-50	40-50
dN/dz	0.25	0.30	0.47	0.25	0.26	0.49	0.43	0.19	0.30	0.29	0.29	0.21
C_{NO3}	1.60	0.36	0.55	1.06	1.09	1.41	1.43	0.57	0.90	1.10	0.89	0.70
K_Z	0.16	0.16	0.16	0.11	0.11	0.07	0.03	0.03	0.08	0.08	0.11	0.16

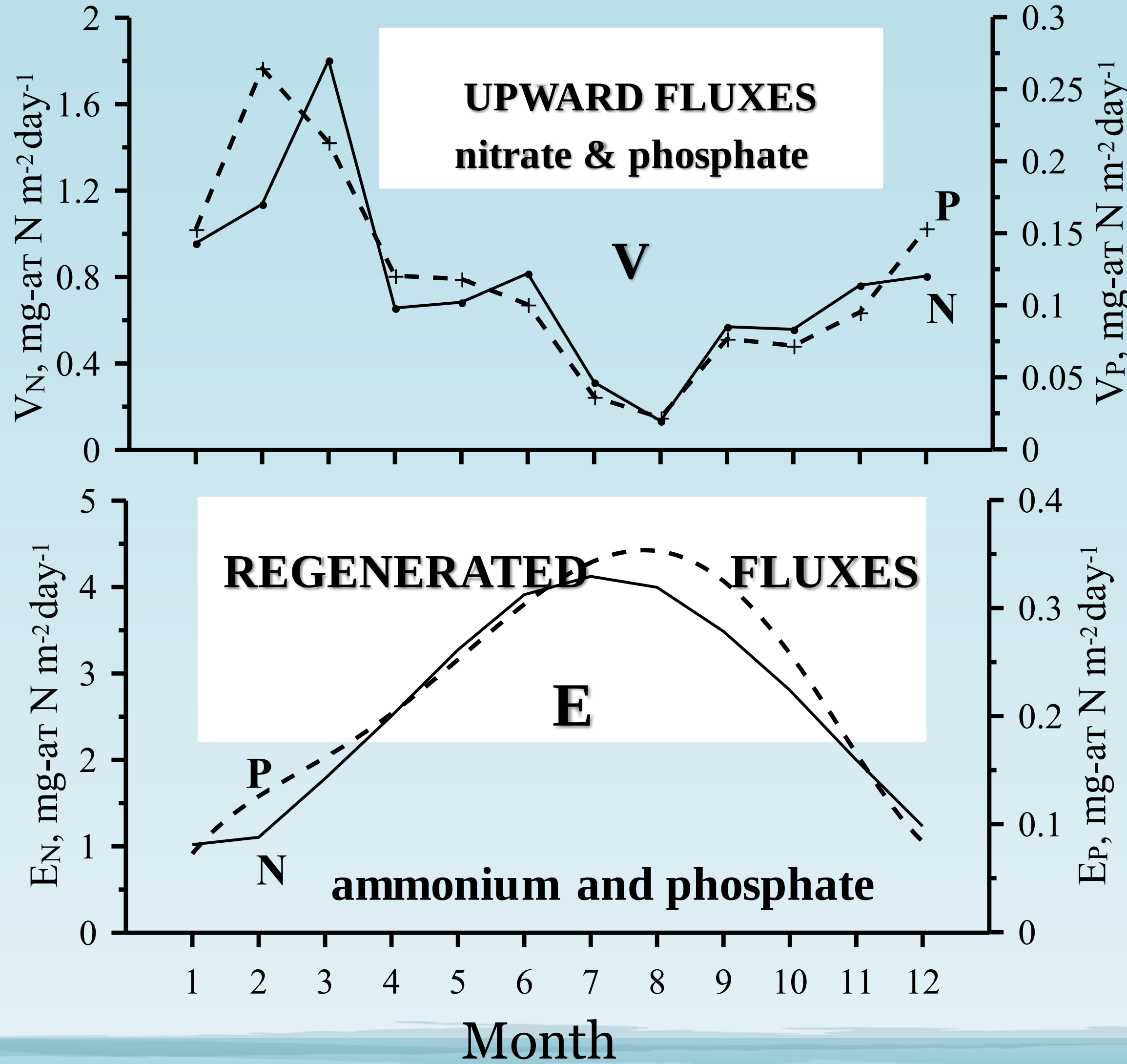
The mean monthly dP/dz and dN/dz in the upper part of the nitra-/phosphacline (40 - 60 m layer) change within two times over a year with coefficient of variation is mainly at 50 - 75 %. The main factor, which determines the annual dynamic of the upward nutrient fluxes is the turbulent intensty.

Regenerated fluxes

Regenerated fluxes were calculated as an ammonium and phosphate excretion rate by zooplankton based on methodology that has been described in (Parkhomenko 2005, 2007). Published data about zooplankton physiology, their temporal dynamics and size-specific structure of the community in the deep-water region.

Details you could find in the (Parkhomenko 2005, 2007)

Seasonal dynamics of upward and regenerated fluxes



Upward fluxes gradually increase over the autumn-winter period;

reaching its maximum in the February – March;

decline by about half from Apr to Jun when thermal stratification in the serface water are formed;

reach minimum in July – August.

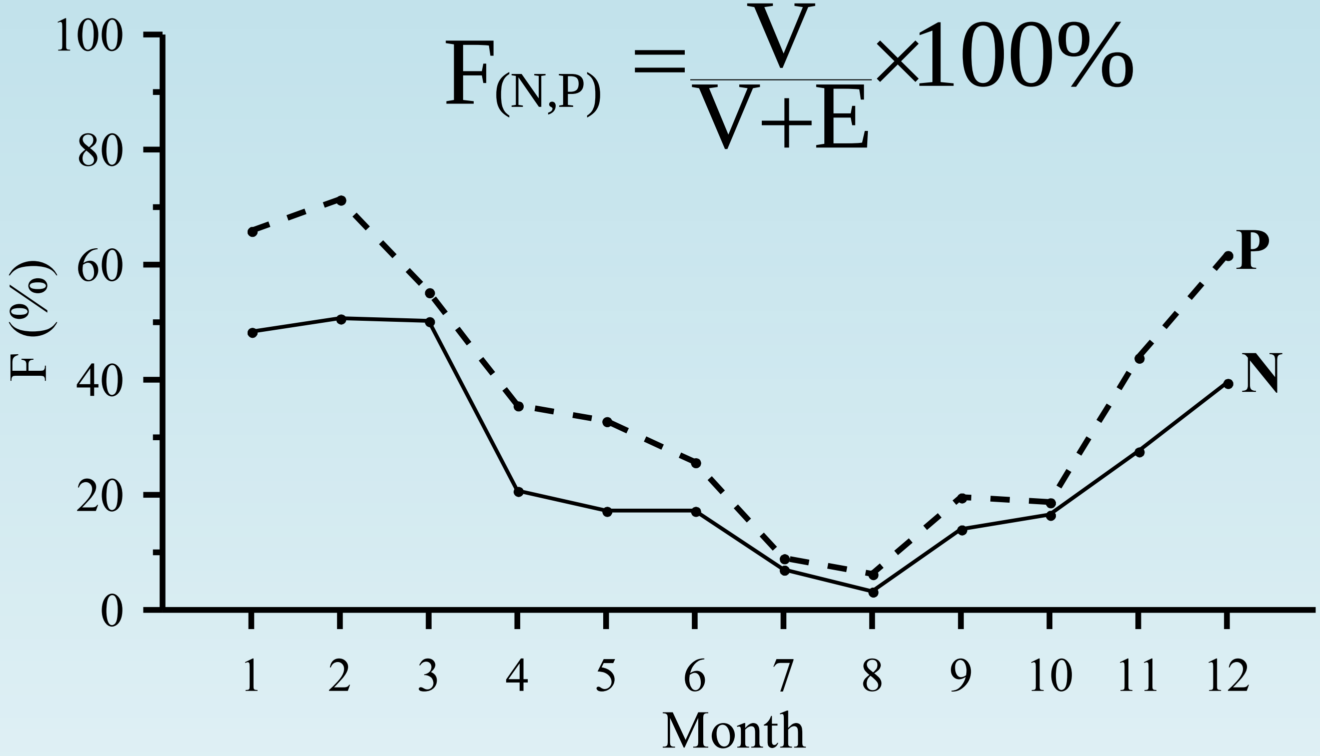
Regenerated fluxes varies opposite to the upward flux over the year;

In a summer regeneration increase four-fold in compare to a winter

Upward to total flux ratio

The contribution of the upward flux to the total nutrient supply in the euphotic zone has been calculated and named as F_N-(F_P)-ratio

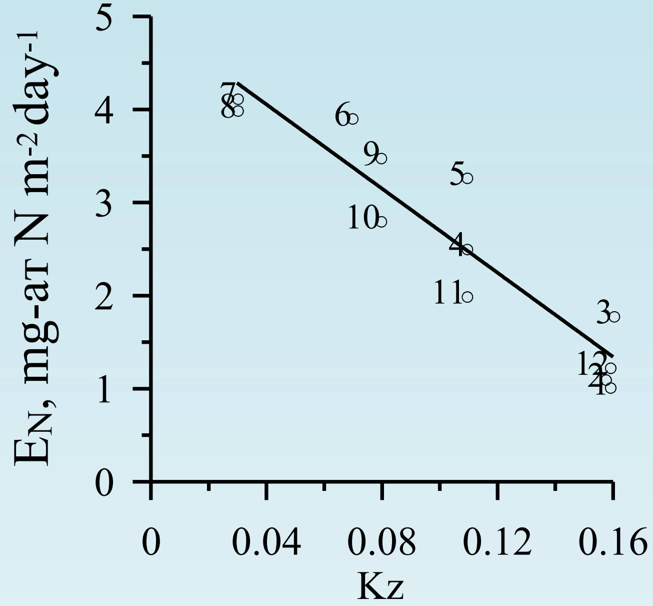
$$F_{(N,P)} = \frac{V}{V+E} \times 100\%$$



On average, the upward flow of nitrates and phosphate provides respectively 26% and 37% of the total inorganic nitrogen and phosphorus supply in the euphotic zone

In the deepwater area of the Black Sea

- •Mean monthly Кz and upward nitrate and phosphate fluxes increase fivefold in the winter in comparing to July – August;
- •Inverse relationship between the average monthly values of regenerated fluxes and Kz values adopted in the calculations is observed

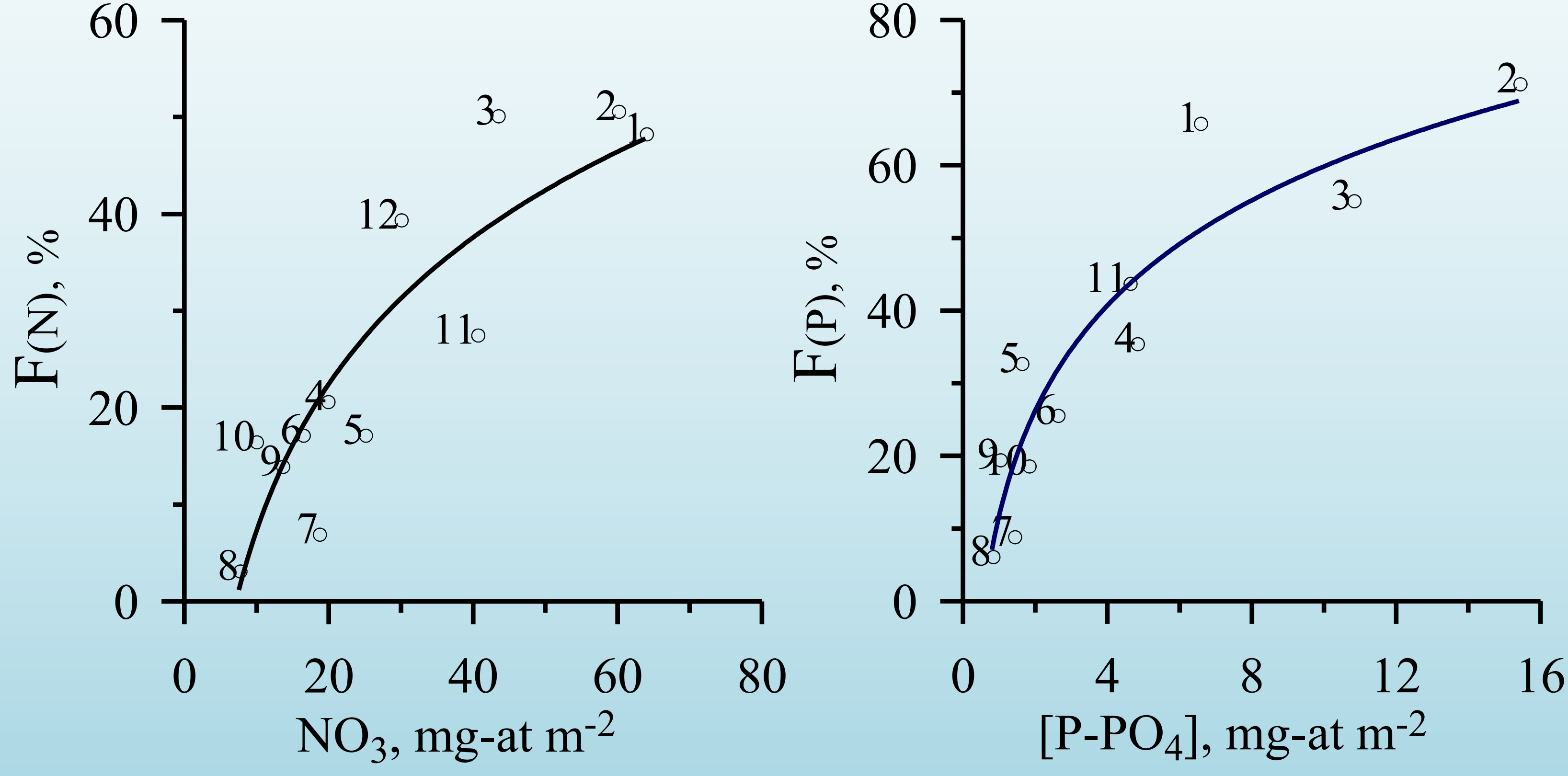


Global relationships
between f-/*e*-ratio and environment characteristics

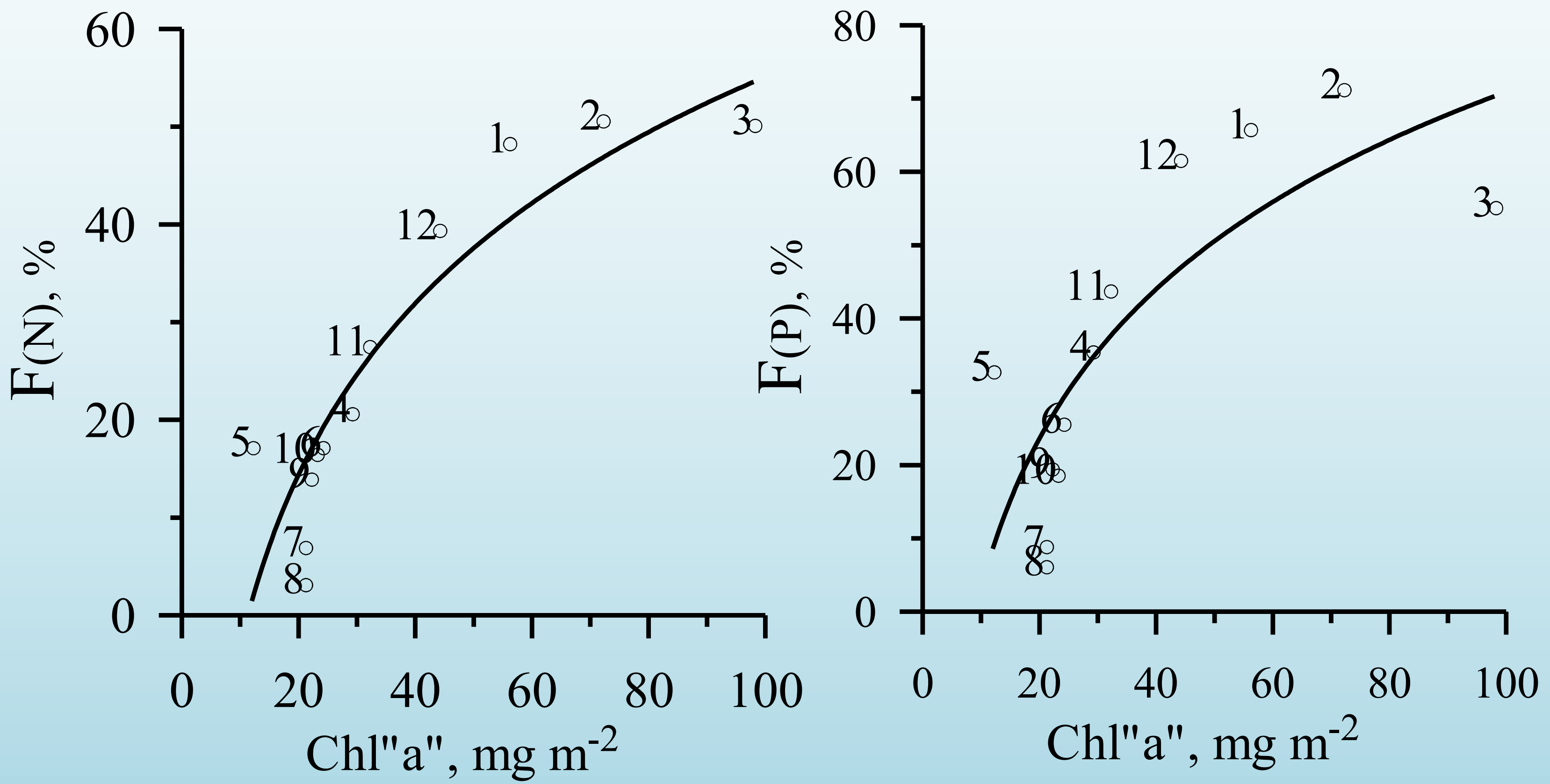
- f-ratio via primary production (Eppley, Peterson , 1979)
- new production and sinking particle coupling over long time scales (Eppley et al. , 1983)
- f-ratio via NO3 concentration (Harrison et al. , 1987)
- f-/*e*-ratio via temperature and primary production considering size structure of phytoplankton (Laws et al., 2000)

Similar relationships were obtained for the Black Sea, while comparing the monthly averaged values of $F_{(N,P)}$ and the corresponding integral estimates of hydrochemical and some production indicators in the euphotic layer,

RELATIONSHIPS BETWEEN MEAN MONTHLY $F_{(N,P)}$ AND NITRATE AND PHOSPHATE INTEGRAL CONCENTRATION IN THE EUPHOTIC ZONE OF THE DEEP BLACK SEA

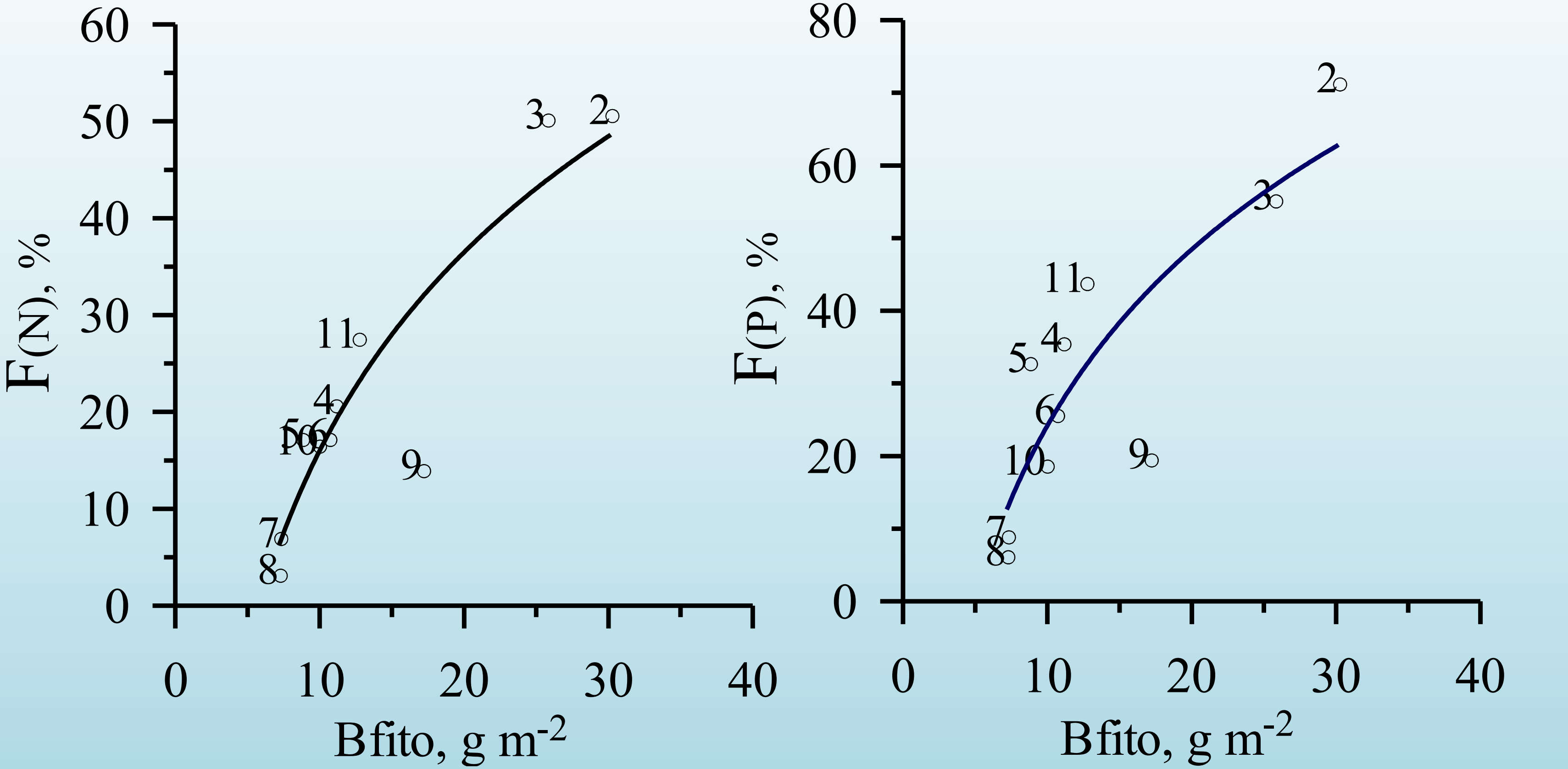


RELATIONSHIPS BETWEEN MEAN MONTHLY F(N,P) AND INTEGRAL CHLOROPHYLL *a* CONCENTRATION IN THE EUPHOTIC ZONE OF THE DEEP BLACK SEA



Mean monthly chlorophyll
from (Vedernikov, Demidov, 1997)

RELATIONSHIPS BETWEEN MEAN MONTHLY F(N,P) AND INTEGRAL PHYTOPLANKTON BIOMASS IN THE EUPHOTIC ZONE OF THE DEEP BLACK SEA

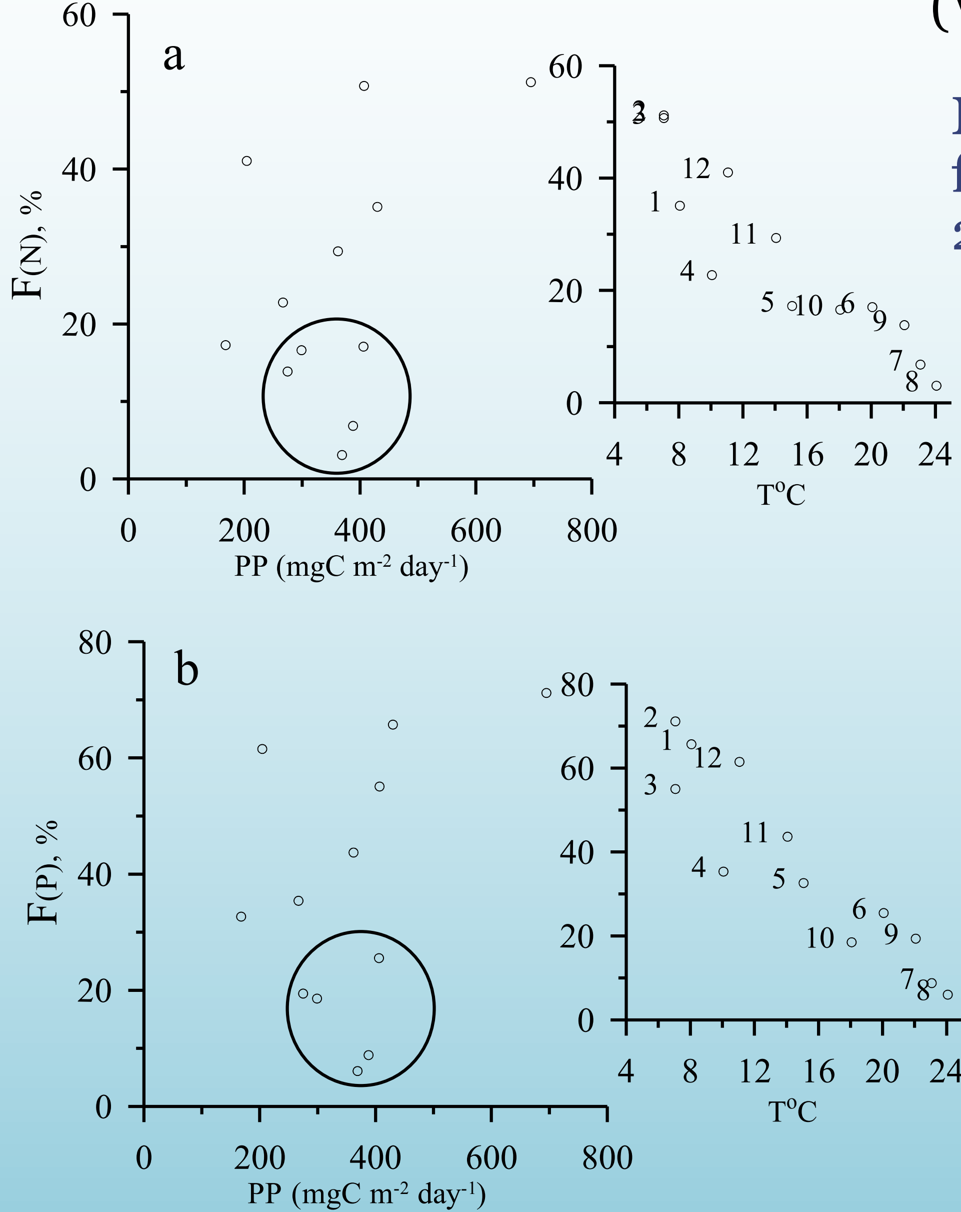


Mean monthly phytoplankton biomass from (Kryvenko, Parkhomenko, 2010)

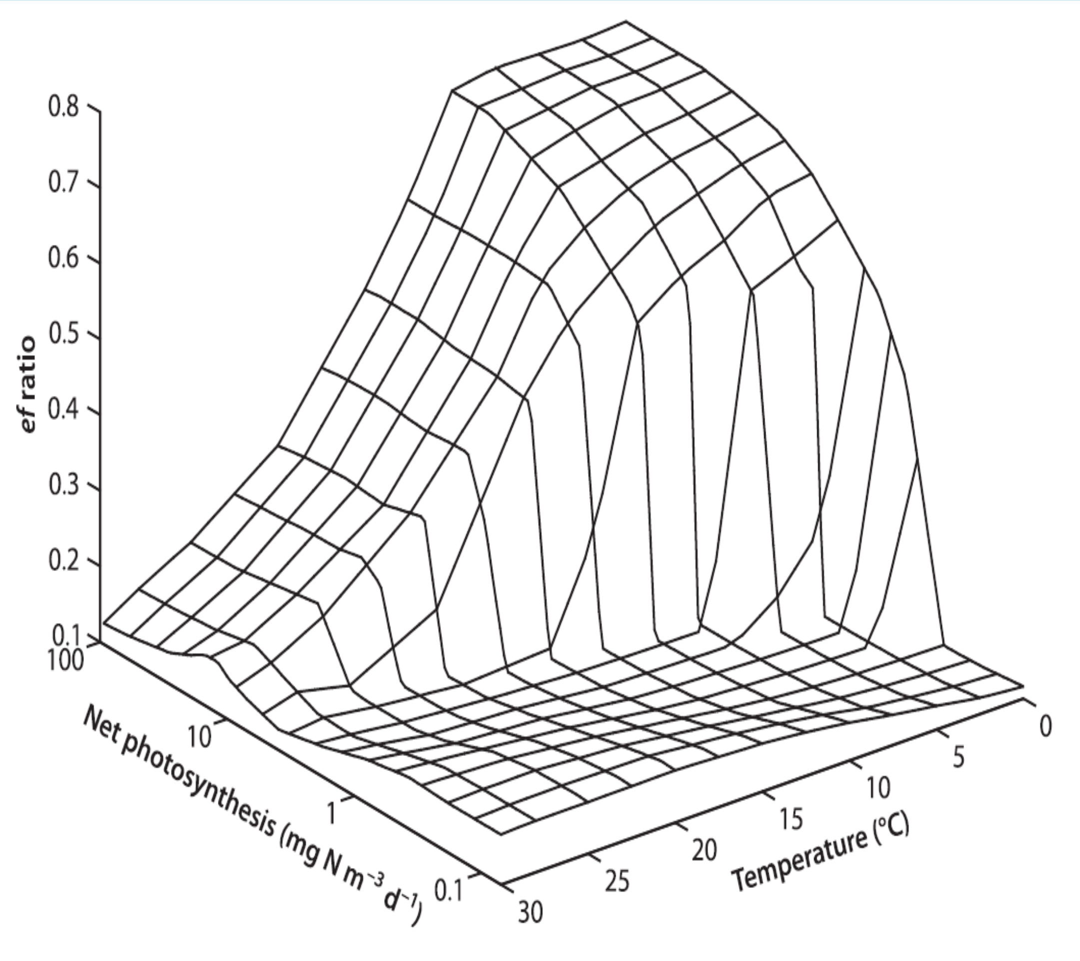
RELATIONSHIPS BETWEEN MEAN MONTHLY $F_{(N,P)}$ AND INTEGRATED PRIMARY PRODUCTION

(Vedernikov, Demidov, 2002)

Mean monthly TSS from (Ivanov, Belokopytov, 2011)

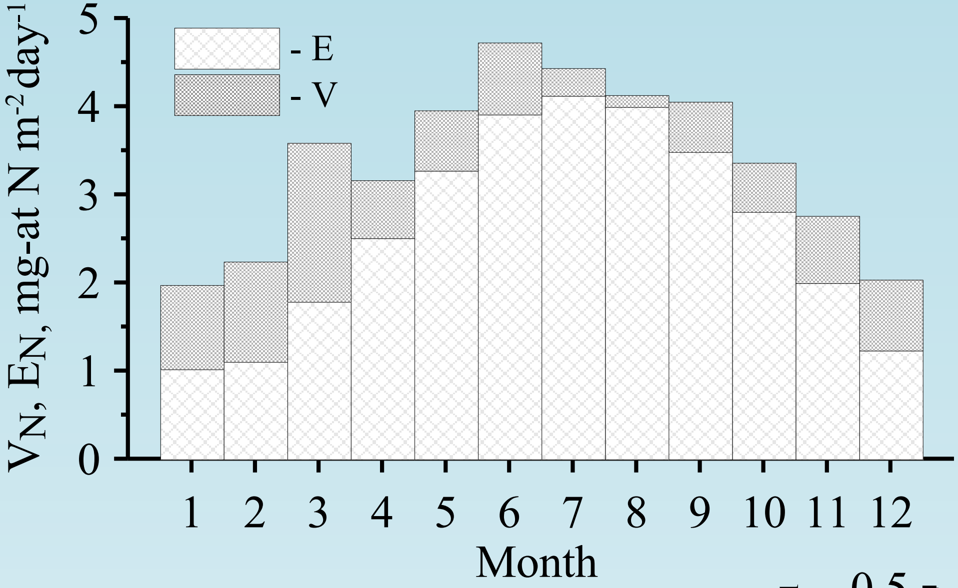


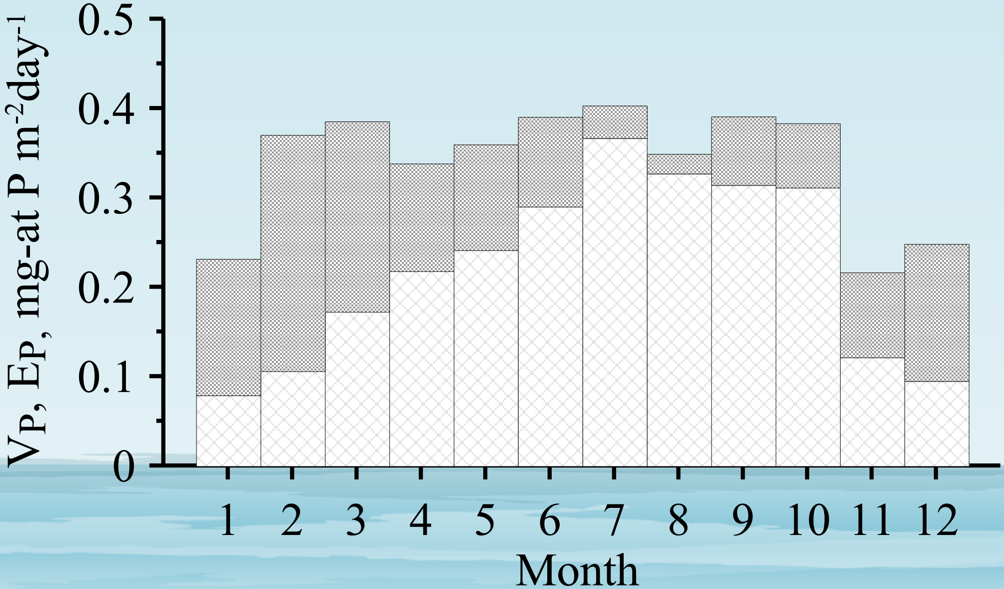
Calculated export ratios as a function of temperature and net photosynthetic rate (from Laws et al. (2000))



A similar change in the relationship between the values of f/e-ratio and primary production at different temperatures was shown in the comparison of data from different climatic zones of the ocean [Falkowski et al., 2003; Dunne et al., 2005] and is described by the mathematical model (Laws et al,. 2000).

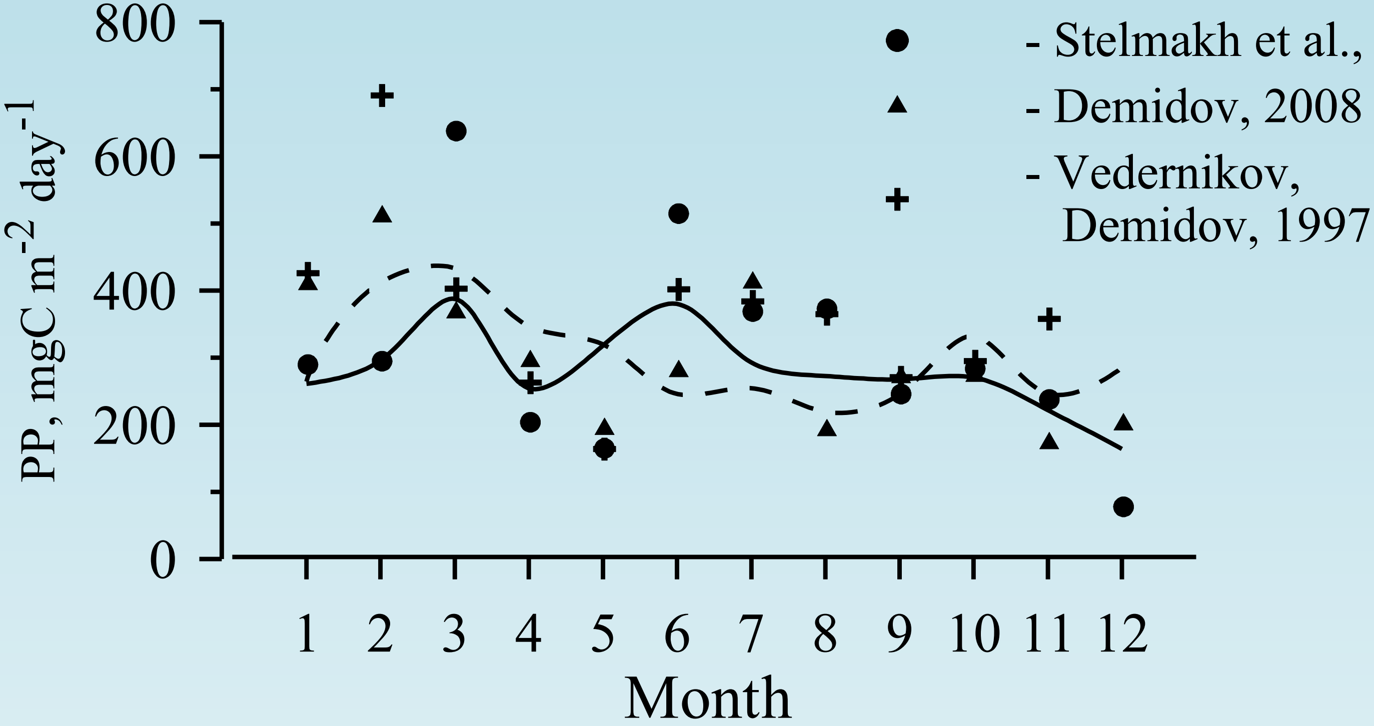
Total inorganic nitrogen and phosphorus supply





Potential Primary Production

Annual primary production



130 $gC \cdot m^{-2} \cdot year^{-1}$

137 $gC \cdot m^{-2} \cdot year^{-1}$

110 $gC \cdot m^{-2} \cdot year^{-1}$

Annual primary production
106 – 115 $gC \cdot m^{-2} \cdot year^{-1}$

Conclusions

- Mean monthly values of upward and regenerated fluxes of inorganic nitrogen and phosphorus in the Black Sea deep-waters have been estimated
- The upward fluxes were calculated using mean monthly values of nitrate and phosphate concentration and their gradients beneath the euphotic layer, assuming that the vertical nutrient flux are dependent on water density gradient at the upper pycnocline over the year
- Seasonal dynamics of the total nutrient flux has been estimated. using two independent methods. Physical forcing of nutrient supply in the euphotic zone is mainly appeared from December to March. Biological processes (regeneration) are the most important drivers in the summer. In the transitional seasons, regeneration provides the main part of nutrient supply, but the contribution of the upward flux is higher than in the summer.
- The relationships between the mean monthly values of F and the trophic water indicators (integral content of nitrate and phosphate, chlorophyll "a", biomass of phytoplankton, primary production in the euphotic zone) are consistent with global relationships for ocean waters .
- Assessment of the annual dynamics of the key parameters of biotic cycles of nitrogen and phosphorus in the pelagic zone of the Black Sea has been performed, which provide new knowledge on the Black Sea ecosystem function

Thank you for your attention