The PERSEUS Summer School 2013

” The contribution of environmental indices in meeting the objectives and principles of the Marine Strategy Framework Directive”

TRIX index

MAZZIOTTI CRISTINA

ARPAER V.le Vespucci 2 – 47024 Cesenatico, Italy

th

Constanta,

Romania

9.00 – 12.00

- Environmental indices in MSFD
- Coastal eutrophication
- Northern Adriaic sea system: Emilia-Romagna coastal waters
- N/P ratio
- DPSIR model
- Trix index: hystory

13.30 – 15.30

- Trix index: computation
- Trix index: application
- Trix index: exercises

CESENATICO


US Dept of State Geographer
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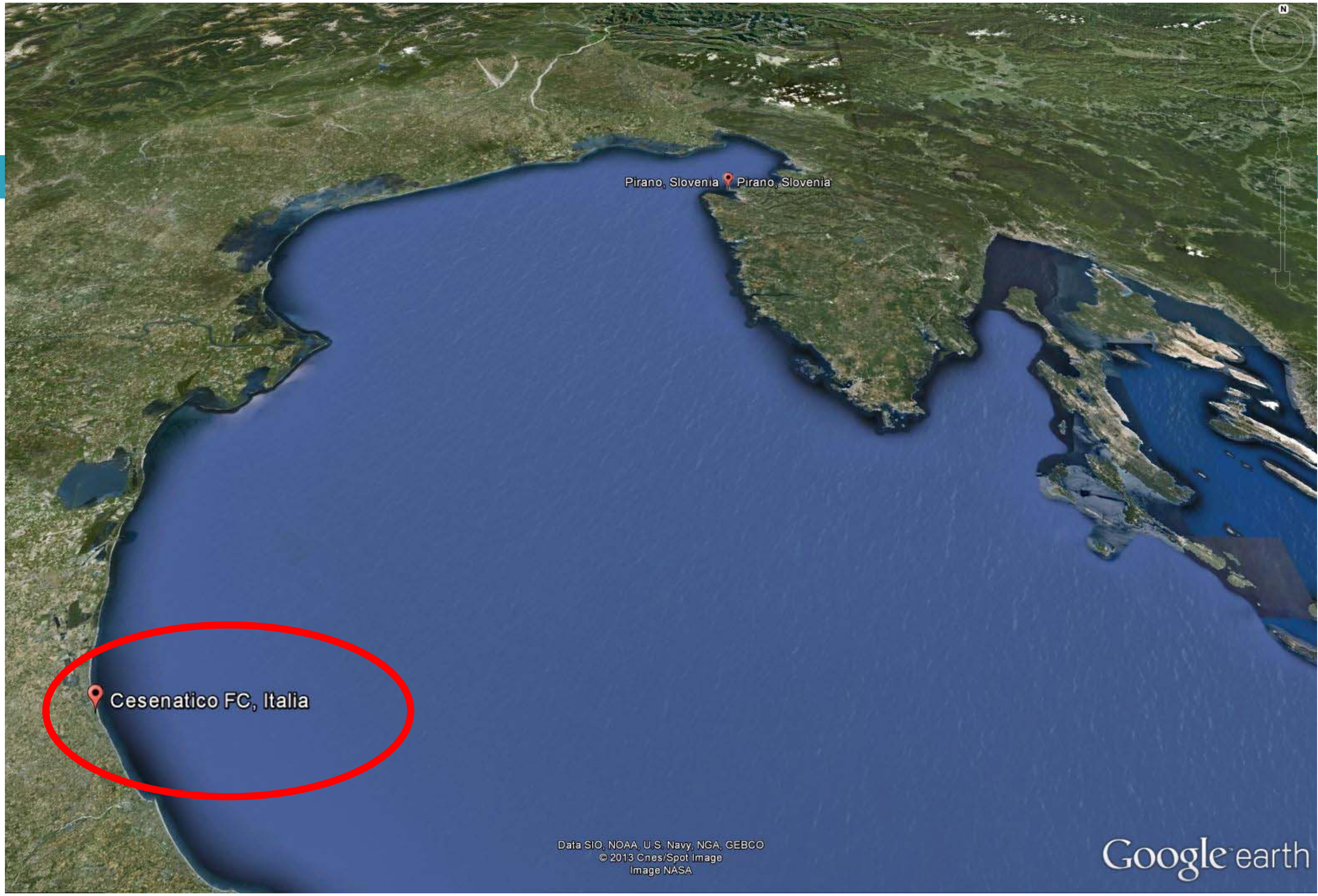

Pirano, Slovenia
Pirano, Slovenia
Cesenatico FC, Italia
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Cnes/Spot Image
Image NASA
Google earth

ARPA
Regional Agency for Environmental Protection in the Emilia-Romagna Region
Bologna Italy

ARPA is a support to the Region's environmentally sustainable policies

The branch office

ARPA
The Oceanographic Structure Daphne
Cesenatico Italy

Legal Status Public Body

daphne arpa

th

Constanta, Romania

The **Daphne Oceanographic Structure**
is a thematic unit in the field of coastal marine monitoring

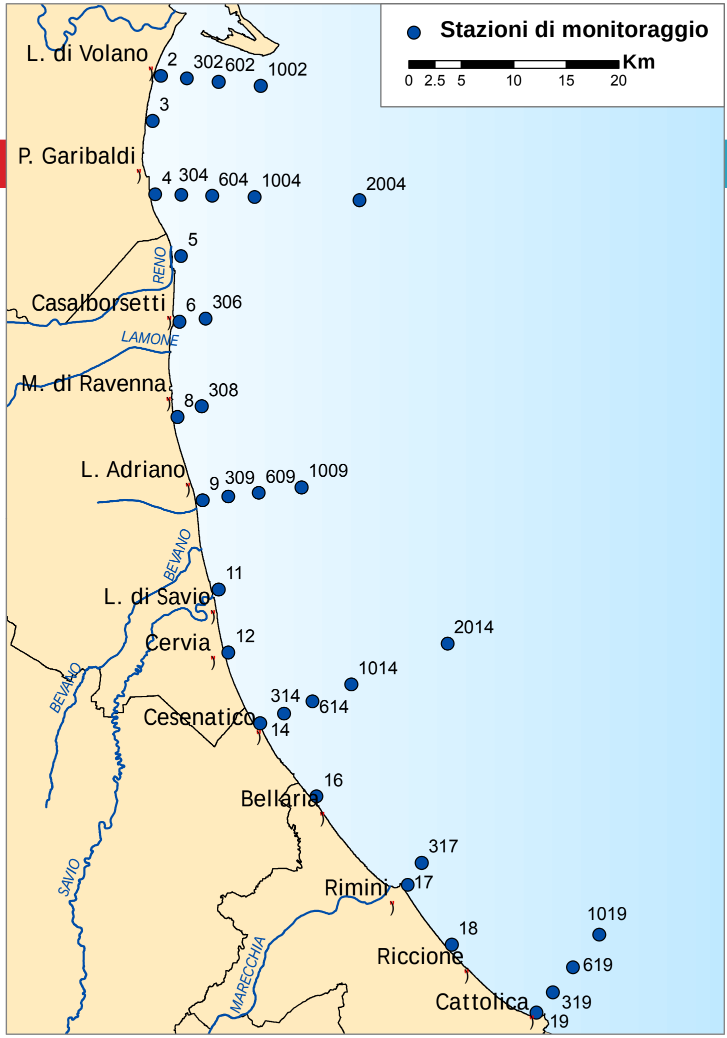
Daphne was founded by the regional authorities of Emilia-Romagna

in **1977** and then it was transferred to

arpa
agenzia regionale prevenzione e ambiente dell'emilia-romagna

Since 1978 the **Daphne Structure**
has actuated a plan of survey with weekly frequency
on a network of 34 stations

Monitoring network ARPA (D.Lgs. 152/06)

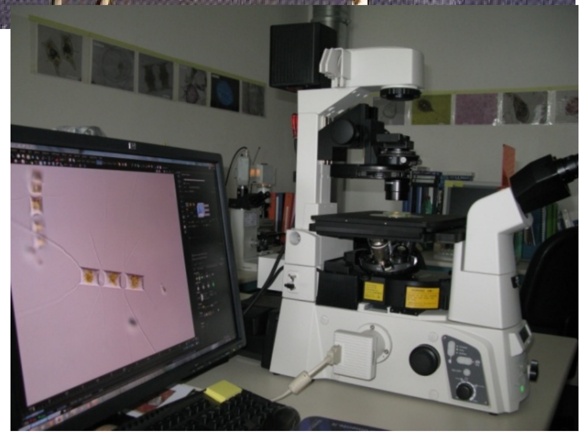


has developed a wide spread database on

th

Constanta, Romania

- Hydrological parameters
- Nutrient concentrations
- Phytoplankton
- Zooplankton
- Ecotoxicological tests
- Benthos
- Heavy metals
- IPA
- Pesticides
- PCB



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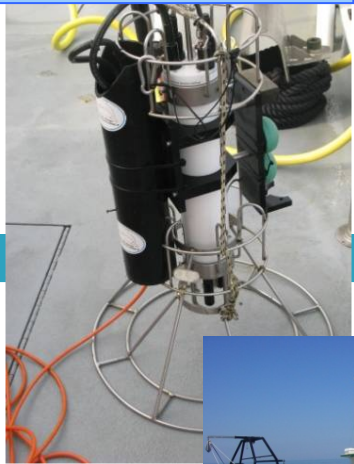
ARPA Emilia Romagna

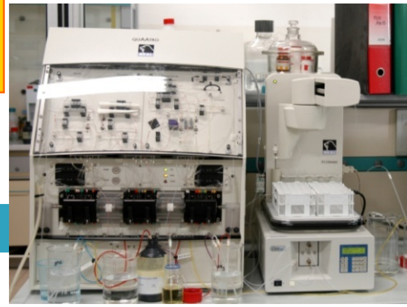
Physical analysis



- Trasparence
- Temperature
- Salinity
- Oxygen dissolved
- Chlorophyill a
- pH
- PAR
- granulometry

Chemical oceanography

- Nitrogen Forms
  - Nitrite N-NO_2
  - Nitrate N-NO_3
  - Ammonia N-NH_3
- Phosphorus Forms
  - Orthophosphate P-PO_4
- Silicates Si-SiO_2



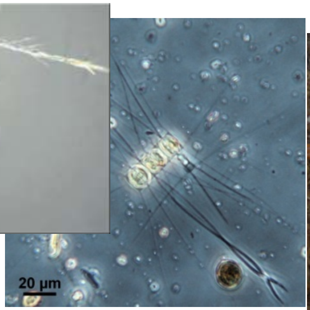
Toxicity bioessays

Bioessay with *Vibrio fischeri*

- Bioessay with *Brachionus plicatilis*
- Bioessay with *Ampelisca diadema*
- Bioessay with *Paracentrotus lividus*

Biological analysis

- Plankton
- Phyitoplankton
  - Zooplankton
- Benthos



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ARPA Emilia Romagna

AGENZIA REGIONALE PREVENZIONE E AMBIENTE DELL'EMILIA-ROMAGNA

il mare oggi in Emilia-Romagna

bollettino mare in-forma

Bollettino N°9 del 02-06 Maggio 2011

La fascia costiera monitorata (Goro - Cattolica) risulta ancora caratterizzata da bassi valori di salinità come conseguenza dei continui apporti di acqua dolce provenienti sia dal bacino padano che dai fiumi costieri. Gli indicatori di stato trofico sono diminuiti in particolare nella zona centro meridionale; pur mostrando una forte diminuzione permane nella zona settentrionale una condizione di eutrofia sostenuta ancora da Diatomee che, insieme al sedimento di natura inorganica presente in sospensione, contribuisce alla torbidità delle acque.
I controlli dell'ossigeno disciolto rilevano una generalizzata buona condizione di ossigenazione lungo la colonna d'acqua con limitati e localizzati casi di ipossia (sottosaturazione di ossigeno disciolto) sotto costa nella zona più settentrionale (Bagni di Volano e Lido delle Nazioni) e più meridionale (3 km al largo di Cattolica). Le temperature delle acque superficiali rilevate risultano di 1 o 2 gradi superiori rispetto al monitoraggio precedente.

Scarica bollettino

VARIABILI	ZONE		
	MEDIA ZONE A	MEDIA ZONE B	MEDIA ZONE C
Temperatura °C	18,93	16,44	17,79
Salinità psu	22,2	32,44	30,17
Ossigeno di superficie mg/L	10,23	8,48	7,14
Ossigeno fondo mg/L	4,84	7,39	6,3
pH	8,62	8,54	8,66
Trasparenza m.	1,04	1	3,02
Clorofilla "a" µg/L	18,48	7,8	5,77

Distribuzione delle stazioni costiere (0.5 km) divise per subarea

Temperatura | Salinità | Clorofilla A | Ossigeno Disciolto | Porto Garibaldi | Cesenatico | Cattolica

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www.arpa.emr.it/daphne/

The aim of the European Union's ambitious **Marine Strategy Framework Directive** (adopted in June 2008) is to protect more effectively the marine environment across Europe. It aims to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend

The goal of the **Marine Strategy Framework Directive** is in line with the objectives of the Water Framework Directive 2000/60 which requires surface freshwater and ground water bodies (such as lakes, streams, rivers, estuaries and coastal waters) to be ecologically Sound by 2015 and that the first review of the River Basin Management Plans should take place in 2020.

Directive 2008/56 of June 2008

Article 9

Determination of good environmental status

Member States shall also take into account the pressures or impacts of human activities in each marine region or subregions, having regard to the indicative lists set out in Table 2 of Annex III.

Directive 2008/56 of June 2008

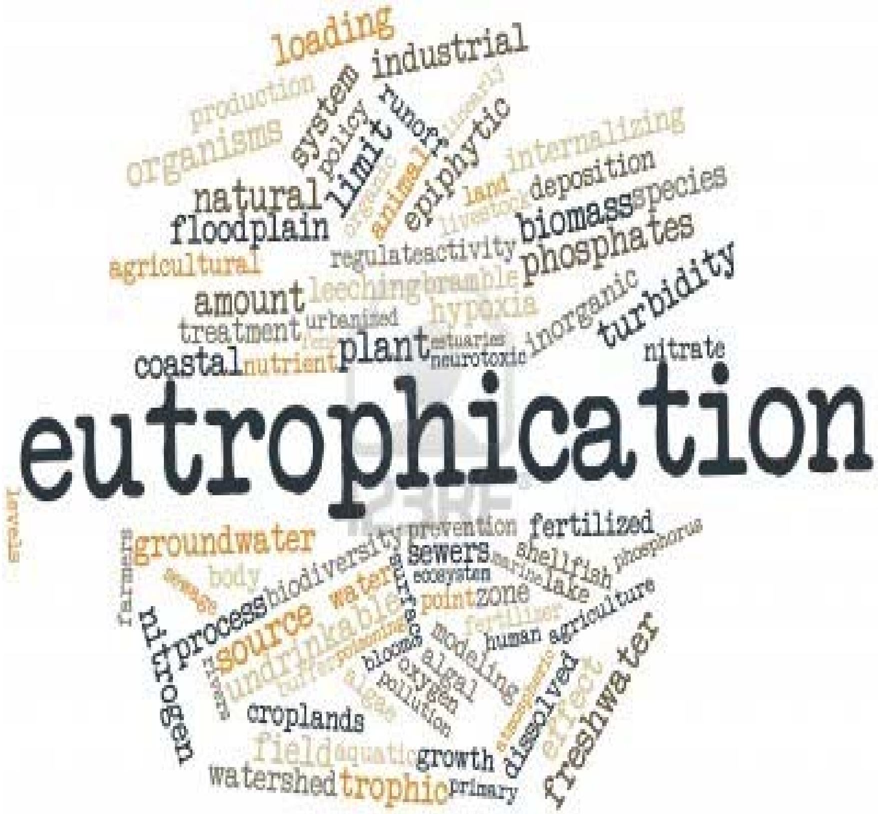
Table 2

Pressures and impacts

•Nutrient and organic matter enrichment

Inputs of fertilisers and other nitrogen and phosphorus rich Substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition).

Input of organic matter (e.g. sewers, mariculture, riverine inputs)


eutrophication
loading
industrial
production
organisms
system
policy
limit
runoff
epiphytic
internalizing
natural
floodplain
deposition
biomass
species
phosphates
agricultural
regulate
activity
leeching
hypoxia
turbidity
amount
treatment
inorganic
coastal
nutrient
plant
nitrate
groundwater
prevention
fertilized
sewers
shellfish
biodiversity
process
source
water
point
zone
lake
agriculture
nitrogen
modeling
algal
human
dissolved
effect
freshwater
croplands
oxygen
pollution
field
growth
watershed
trophic
primary

Etymology from Greek word ευτροφός = well fed

High nutrients concentration and algal biomass

Definitions of EUTROPHICATION: variation of the

Early definition (Steel, 1974)

"Eutrophication is the increase of the growth rate of algae following a faster rate of nutrients in the marine environment as well as the consequences"

(Vollenweider,1992)

"Eutrophication – in its more generic definition applies to both fresh and marine waters is the process of enrichment of waters with plant nutrients, primarily nitrogen and phosphorus that stimulates aquatic primary production and in its more serious manifestations leads to visible algal blooms, algal scums, enhanced benthic algal growth of submerged and floating macrophytes"

Definitions of EUTROPHICATION: variation of the

(Gray,1992)

"Eutrophication occurs when the nutrients are added to the body of water they load, provided that they are not toxic compounds and provided that there is sufficient light to increased autotroph growth and also to increased heterotroph growth"

(Ospar, 2003)

"Eutrophication means the **enrichment** of water by nutrients causing an accelerated **growth** of algae and higher forms of plant life to produce an undesiderable **disturbance** to the balance of organisms present in the water and the quality of the water concerned….."

Definitions of EUTROPHICATION: variation of the

UNEP

“Eutrophication is defined as an environmental disturbance caused by excessive supply of organic matter ”

(Nixon,1995)

“Eutrophication is an increase in the rate of supply of organic matter to an ecosystem”

Definitions of EUTROPHICATION: variation of the

All the definitions agree at one point:

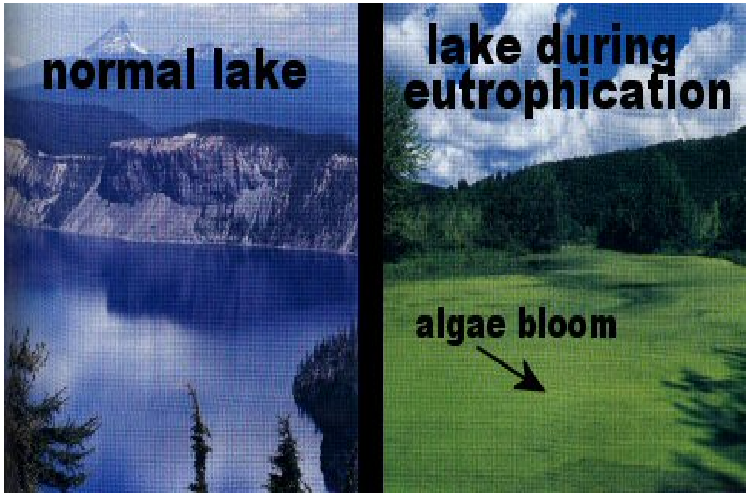
They consider eutrophication as a "disturbance" and not as a form of pollution

(Vollenweider,1992)

"Eutrophication – in its more generic definition applies to both fresh and marine waters is the process of enrichment of waters with plant nutrients, primarily nitrogen and phosphorus that stimulates aquatic primary production and in its more serious manifestations leads to visible algal blooms, algal scums, enhanced benthic algal growth of submerged and floating macrophytes"

Ecosystem DISTURBANCE: phases of

Once a WB has been characterized as eutrophic…….deviation from “healthy conditions”



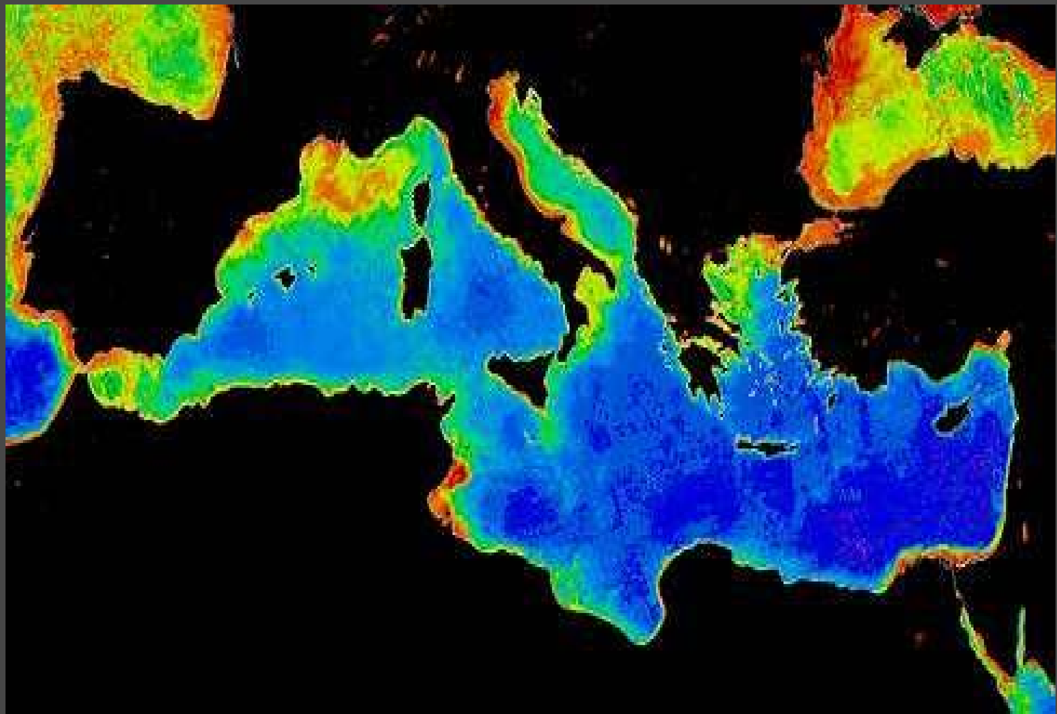
A “Healthy” Ecosystem is the ecosystem that functions well and is able to resist or recover from disturbance (Costanza, 1992)

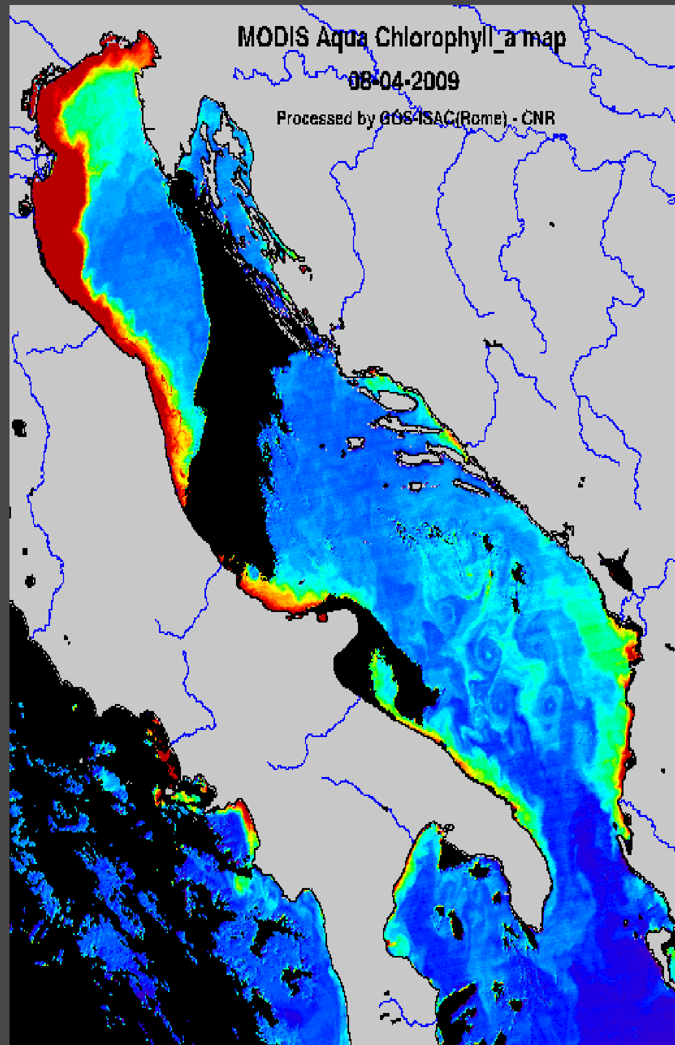
VIGOUR	ability of the biotic components to “recover” from impacts
ORGANIZATION	food web and the biodiversity
RESISTANCE	non-response of impacts such as nutrient enrichments
RESILIENCE	ecosystem ability to survive through the applied pressures

Healthy Ecosystem

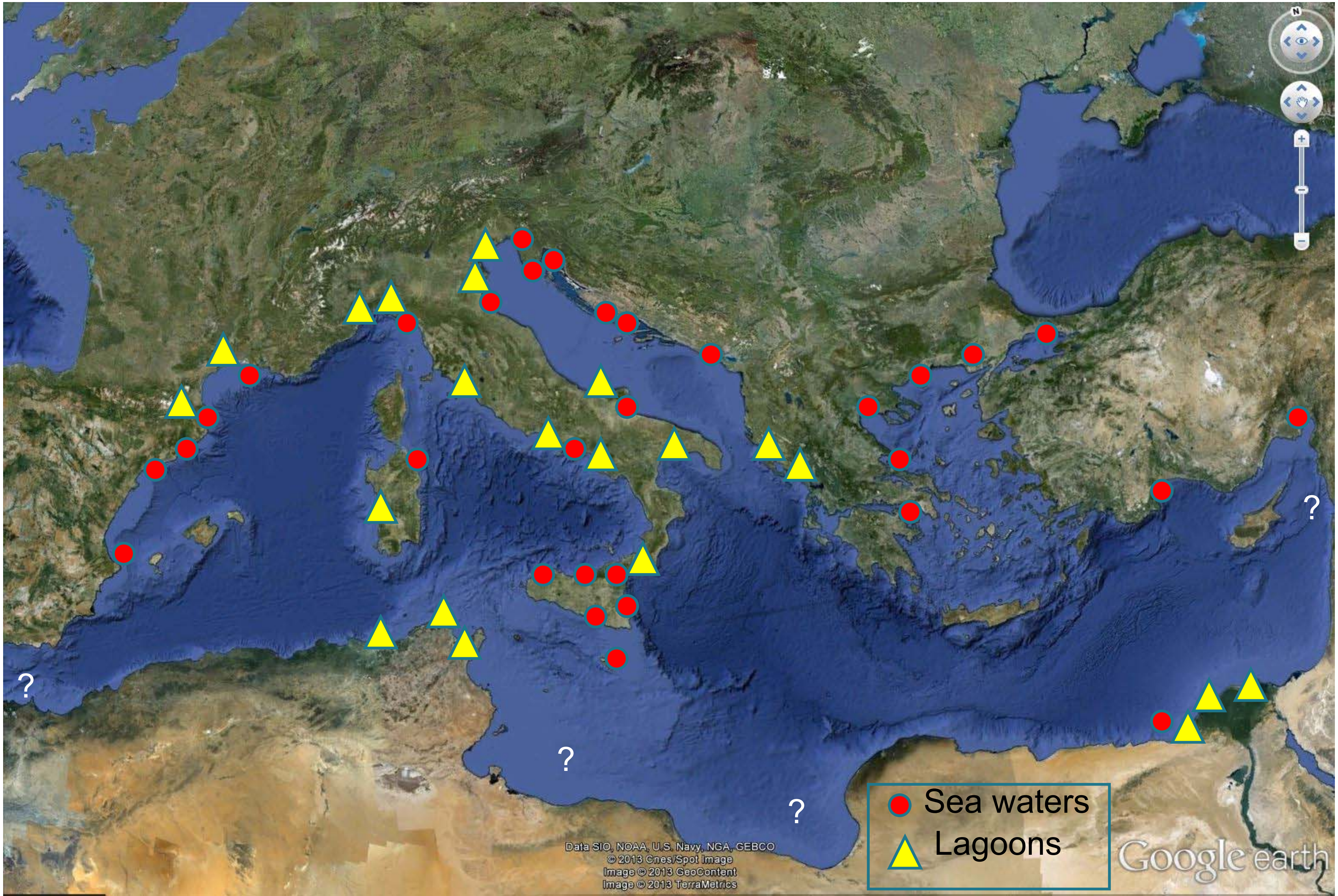
What are the threshold values characterizing water body that gets into eutrophic phases ?

Nutrient, chlorophyll and phytoplankton biomass variables are ecosys variables showing significant spatial and seasonal fluctuation





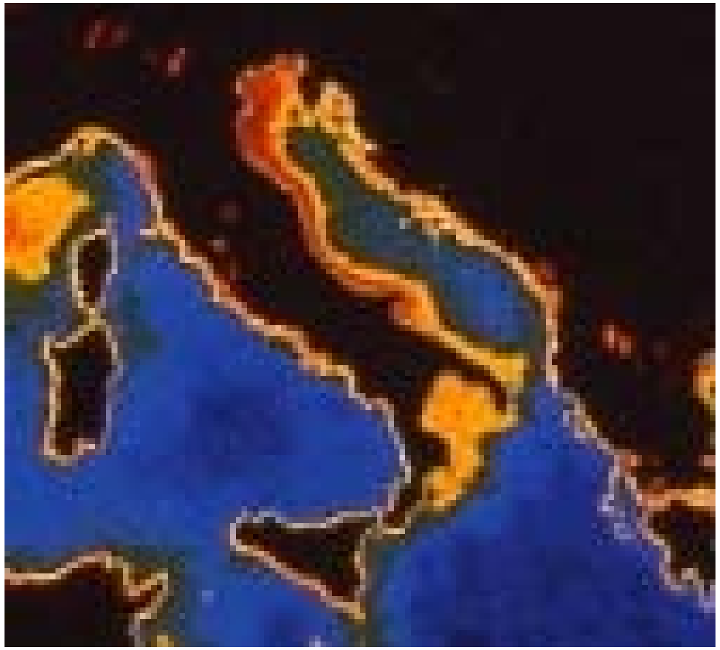
CHLOROPHYLL MAP



Unep, 1996

Mediterranean areas where eutrophication phenomena were reported

Taking into account the frequency and the extension of microalgal blooms, we can declare that the trophic levels of the Nortwestern Adriatic sea represent one of the italian principal problem and probably one of the most serious of the Mediterranean



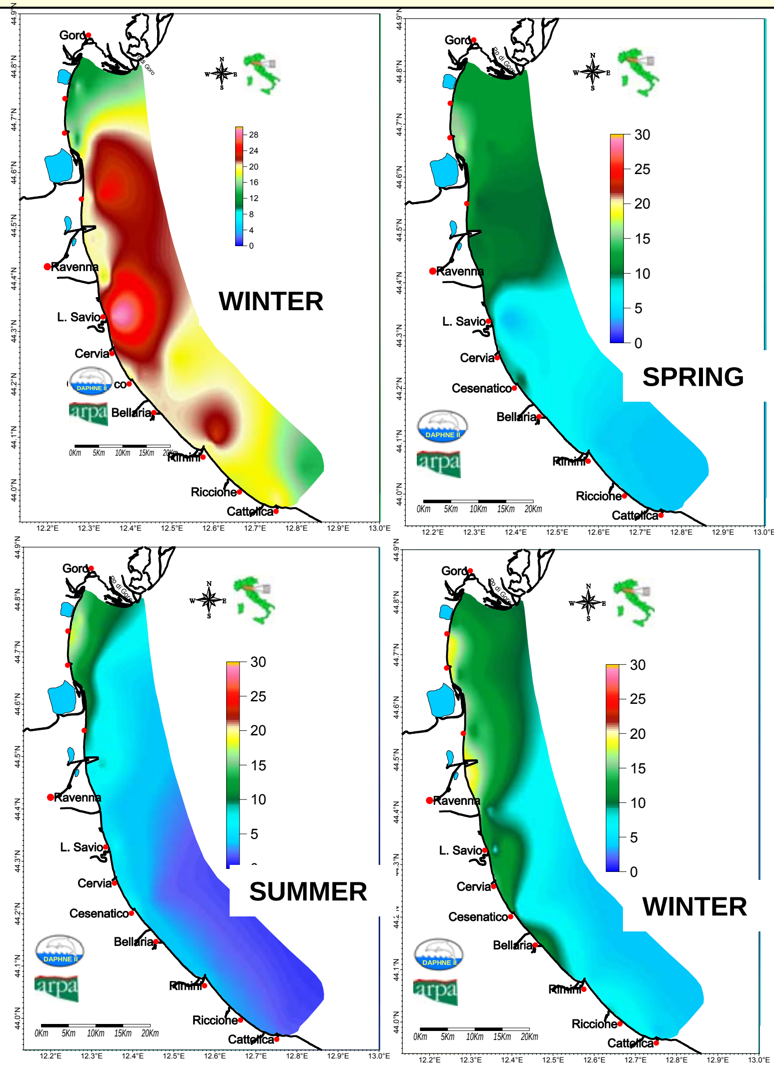
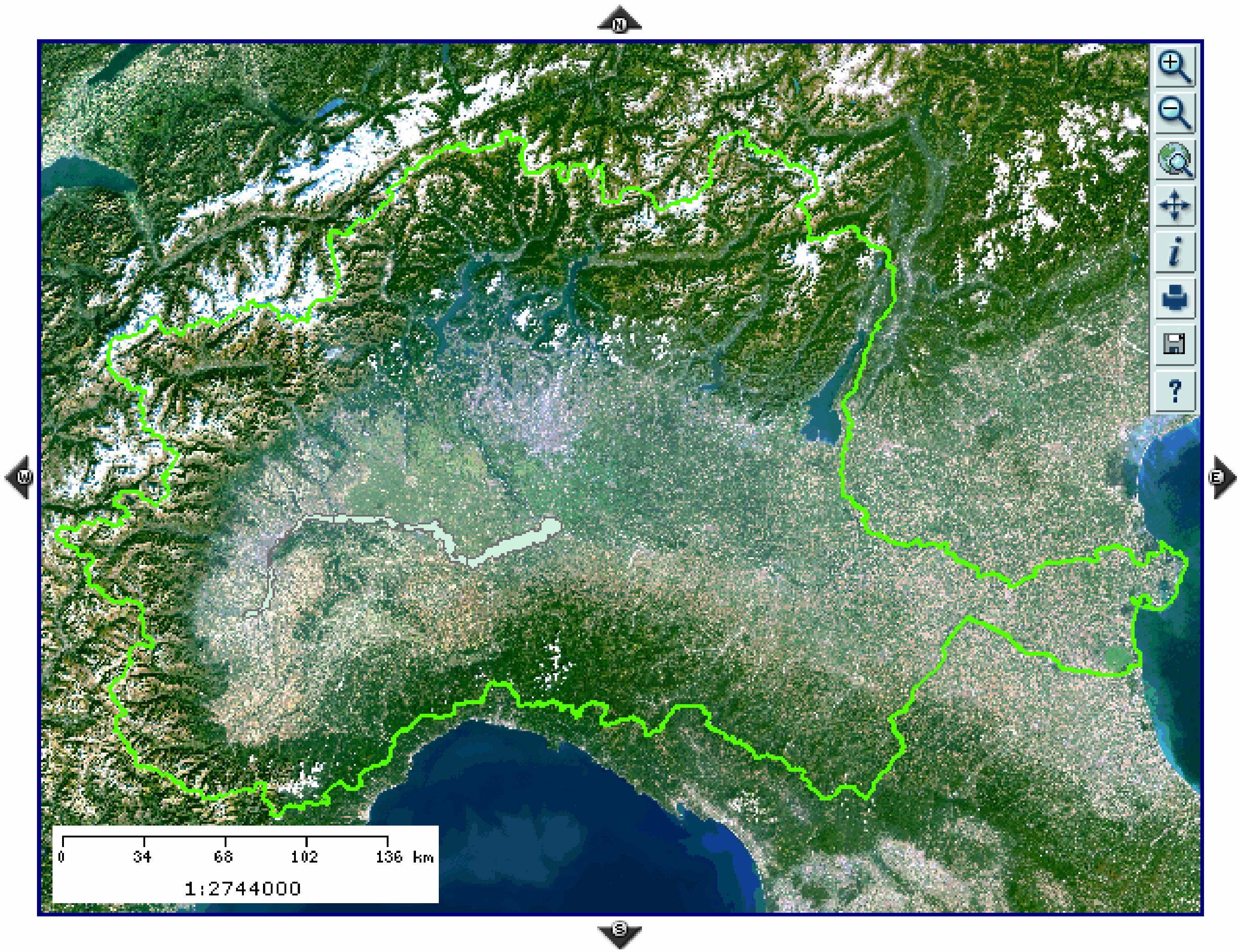


Fig. Mappe di distribuzione della Clorofilla "a" (µg/l) in superficie lungo la costa emiliano-romagnola fino 10 Km al largo nel periodo 1982-2003: medie stagionali

More serious impacts of eutrophication decrease the water trasparency and accumulation of organic matter is observed due to the uncoupling between nutrient supply and use

Hydrographic basin Po river



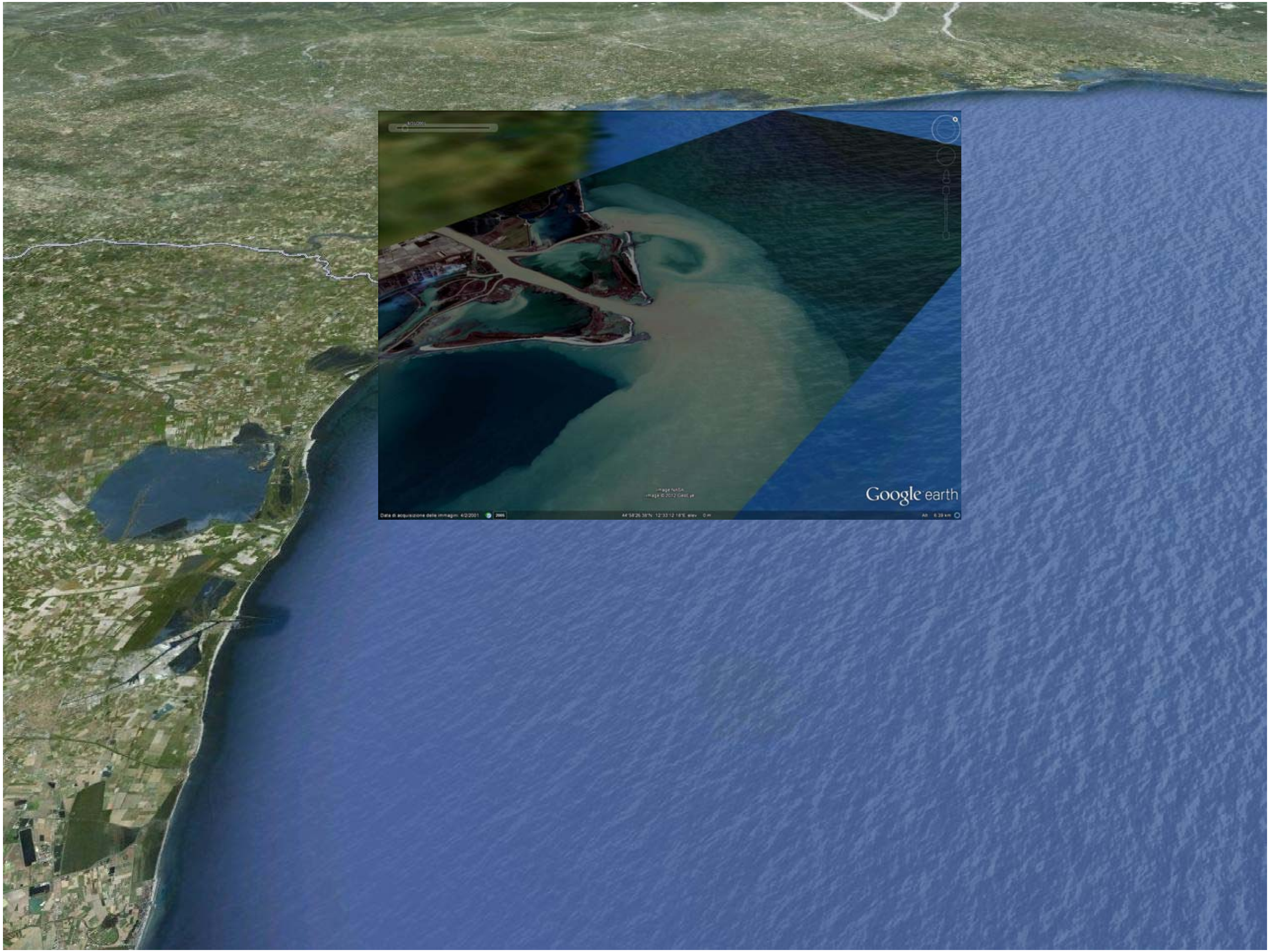
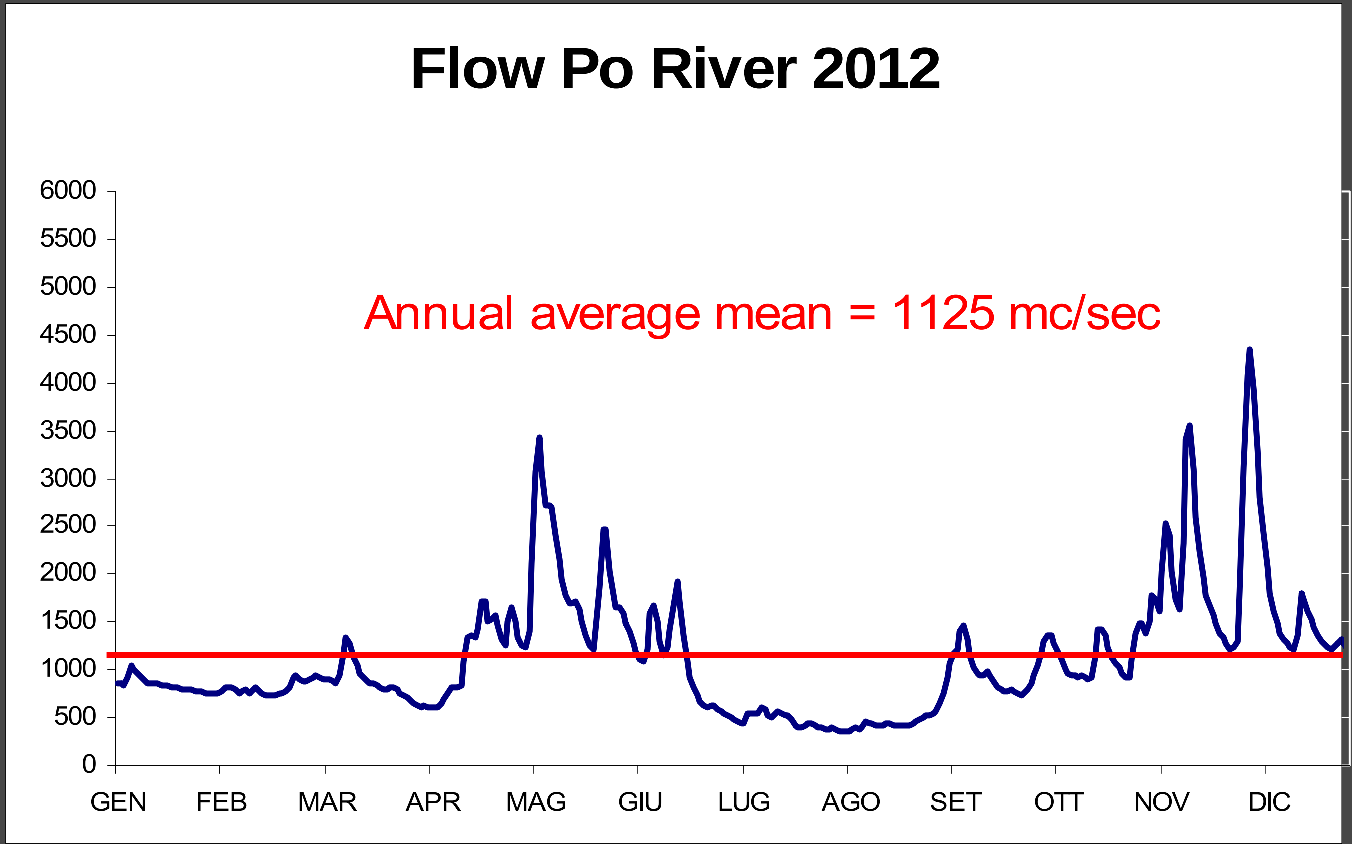
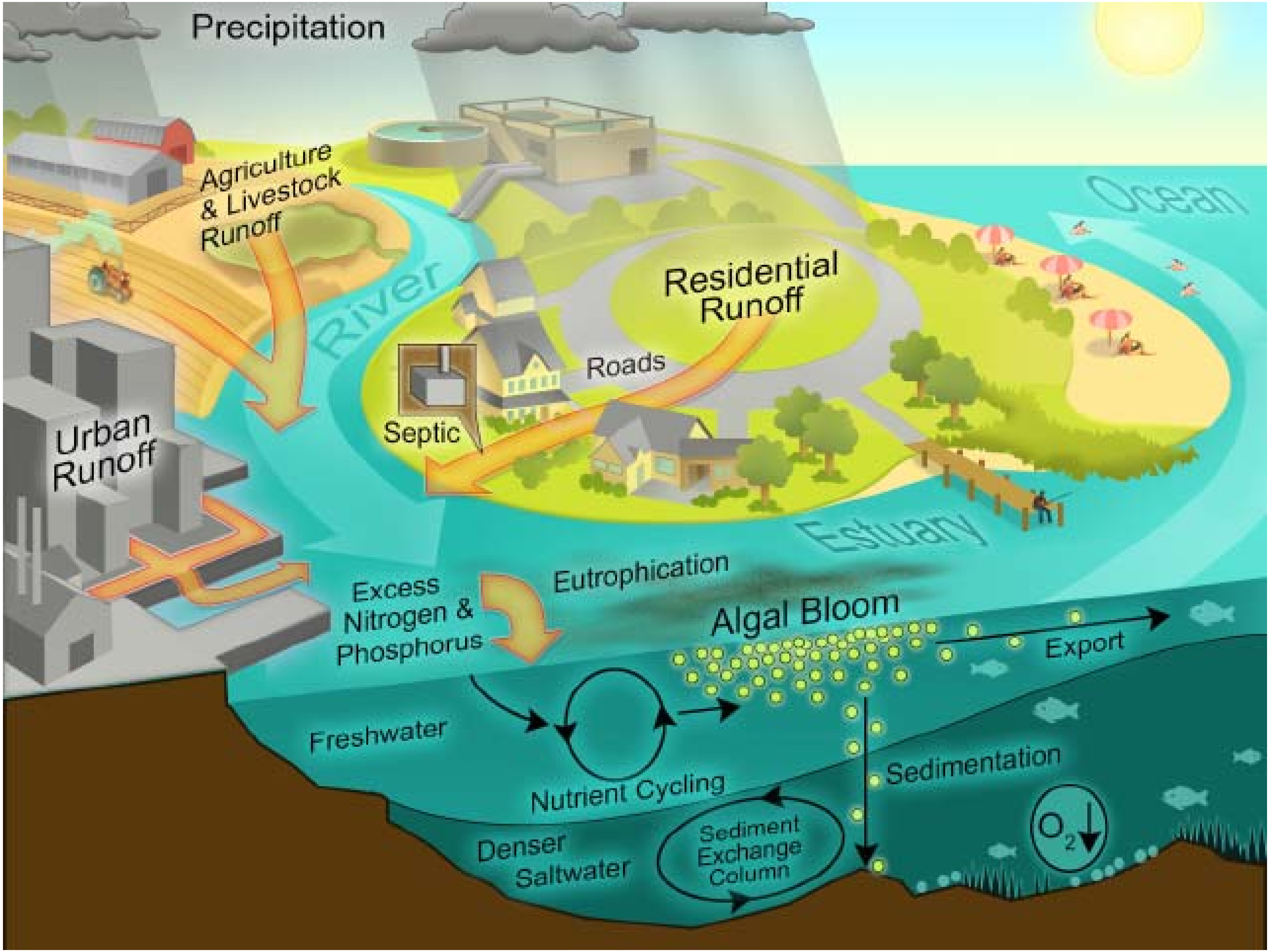


Image NASA
Image © 2012 GeoEye
Google earth
Data di acquisizione delle immagini: 4/2/2001
2005
44°58'26.38"N 12°33'12.18"E elev 0 m



Annual mean

Flow Po River


Precipitation
Agriculture & Livestock Runoff
River
Residential Runoff
Ocean
Roads
Septic
Urban Runoff
Estuary
Eutrophication
Excess Nitrogen & Phosphorus
Algal Bloom
Export
Freshwater
Nutrient Cycling
Sedimentation
Denser Saltwater
Sediment Exchange Column
O_2

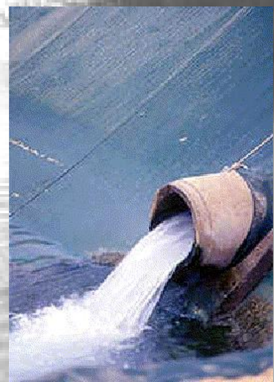
NITROGEN

…in the rivers

fertilizers in agriculture

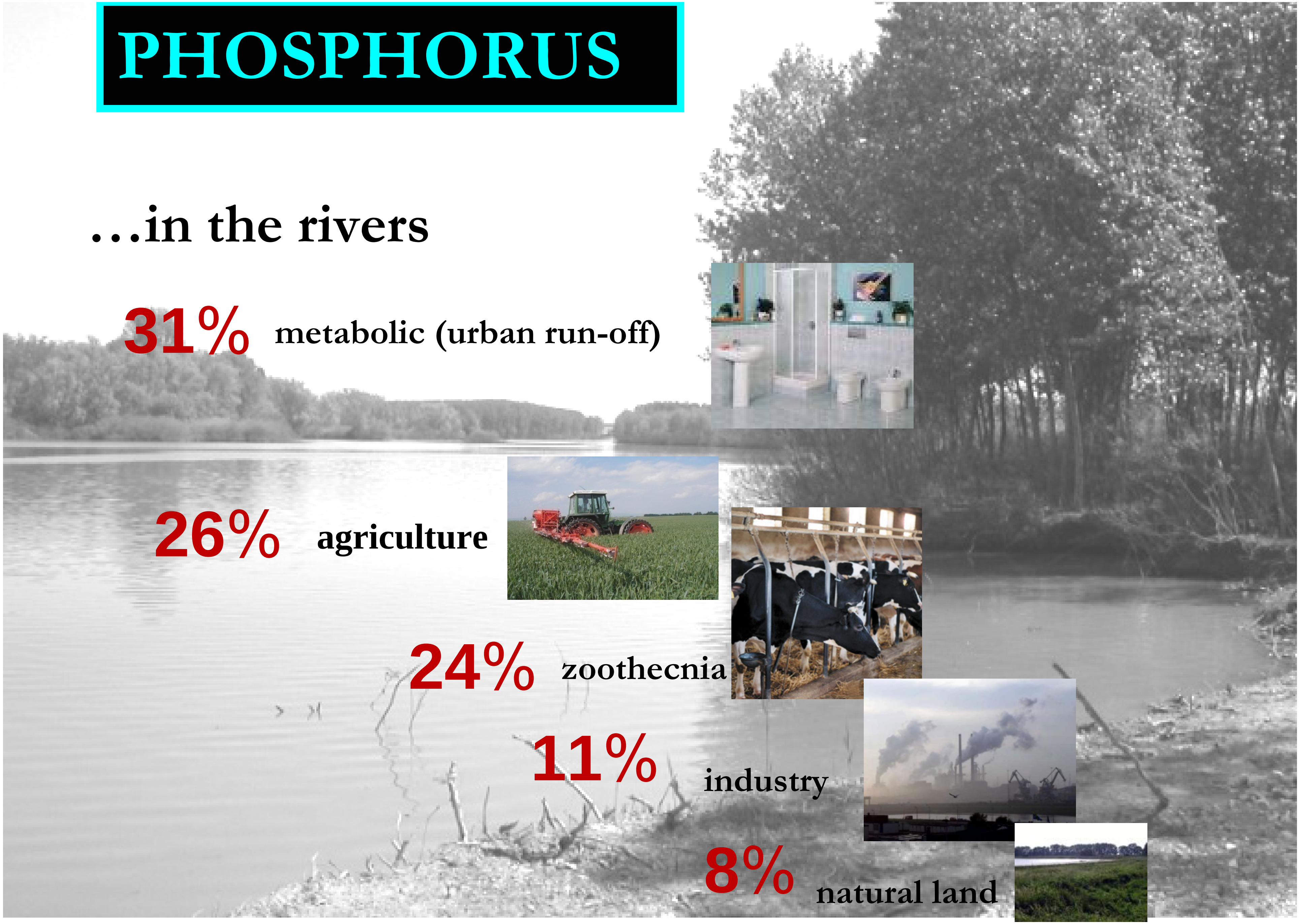
60%

breedings



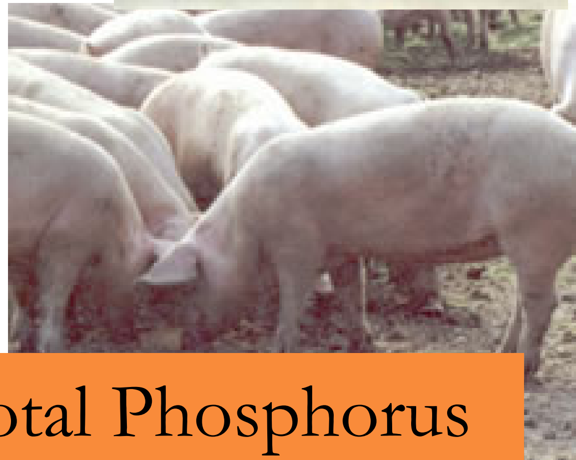
urban and industrial sewage

40%

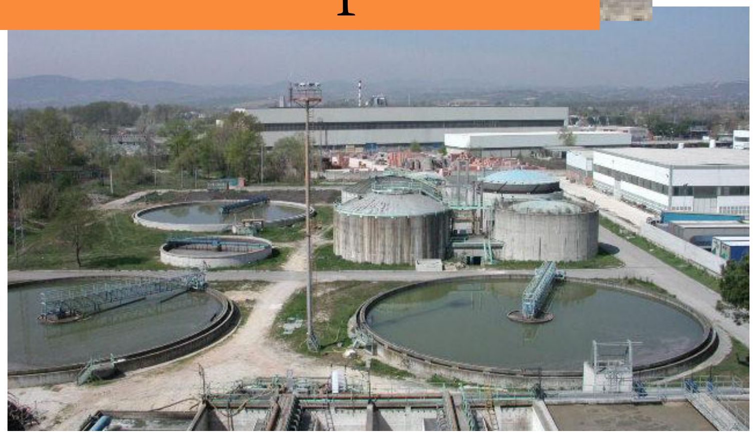

PHOSPHORUS
…in the rivers
31% metabolic (urban run-off)
26% agriculture
24% zoothecnia
11% industry
8% natural land

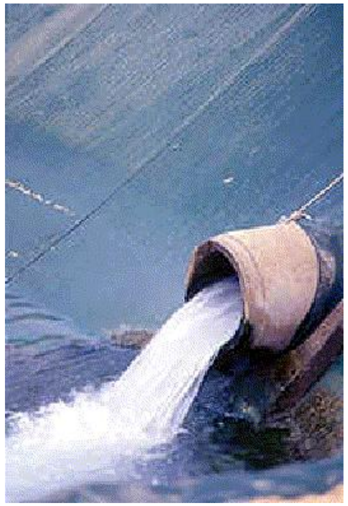
Loads of Nitrogen and Phosphorus (Po river)

100000 t/y total Nitrogen



7100 t/y total Phosphorus





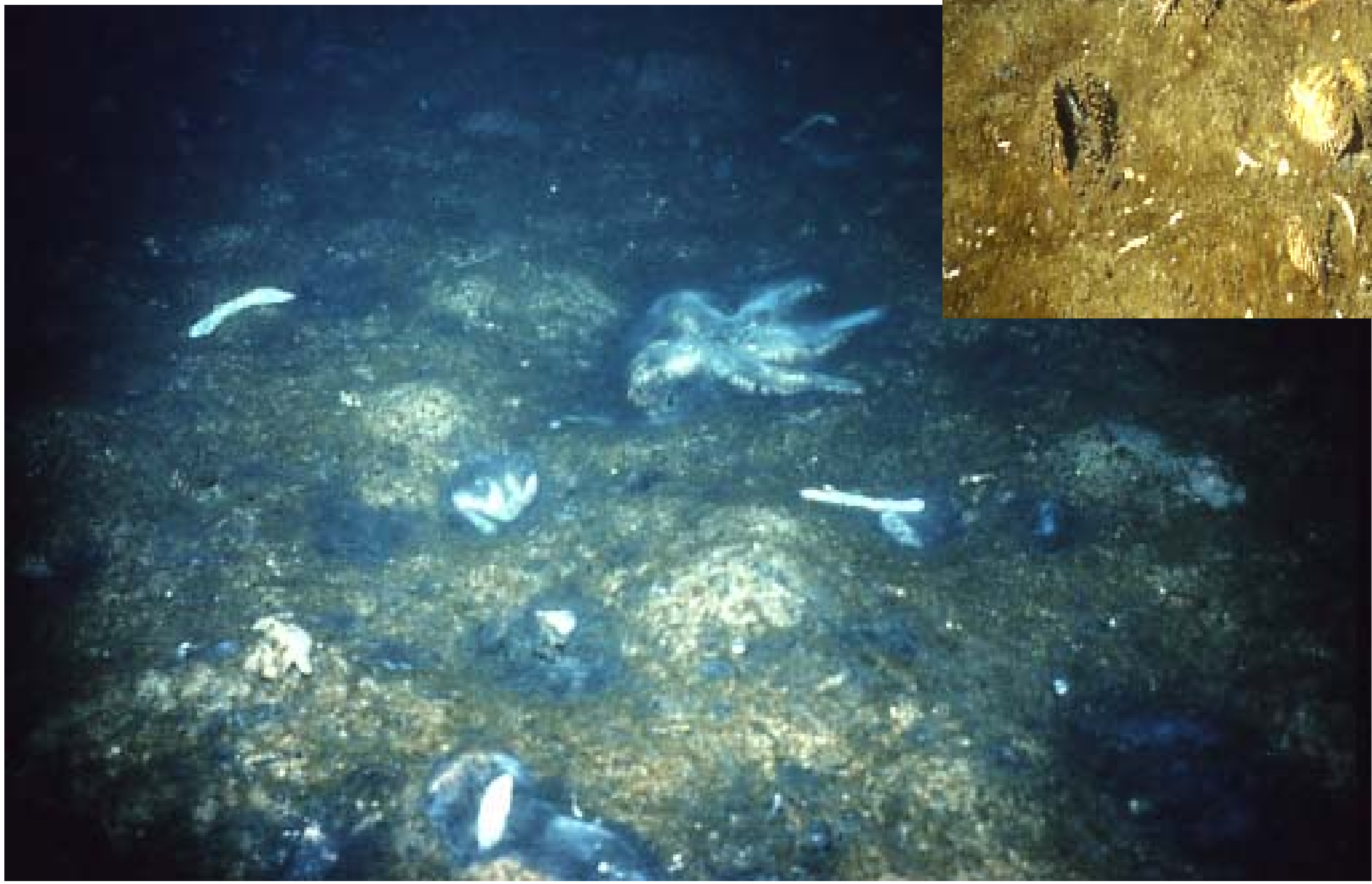
Adriatic/Mediterranean

1/20 surface
1/125 volume
1/3 freshwater che in esso si versano

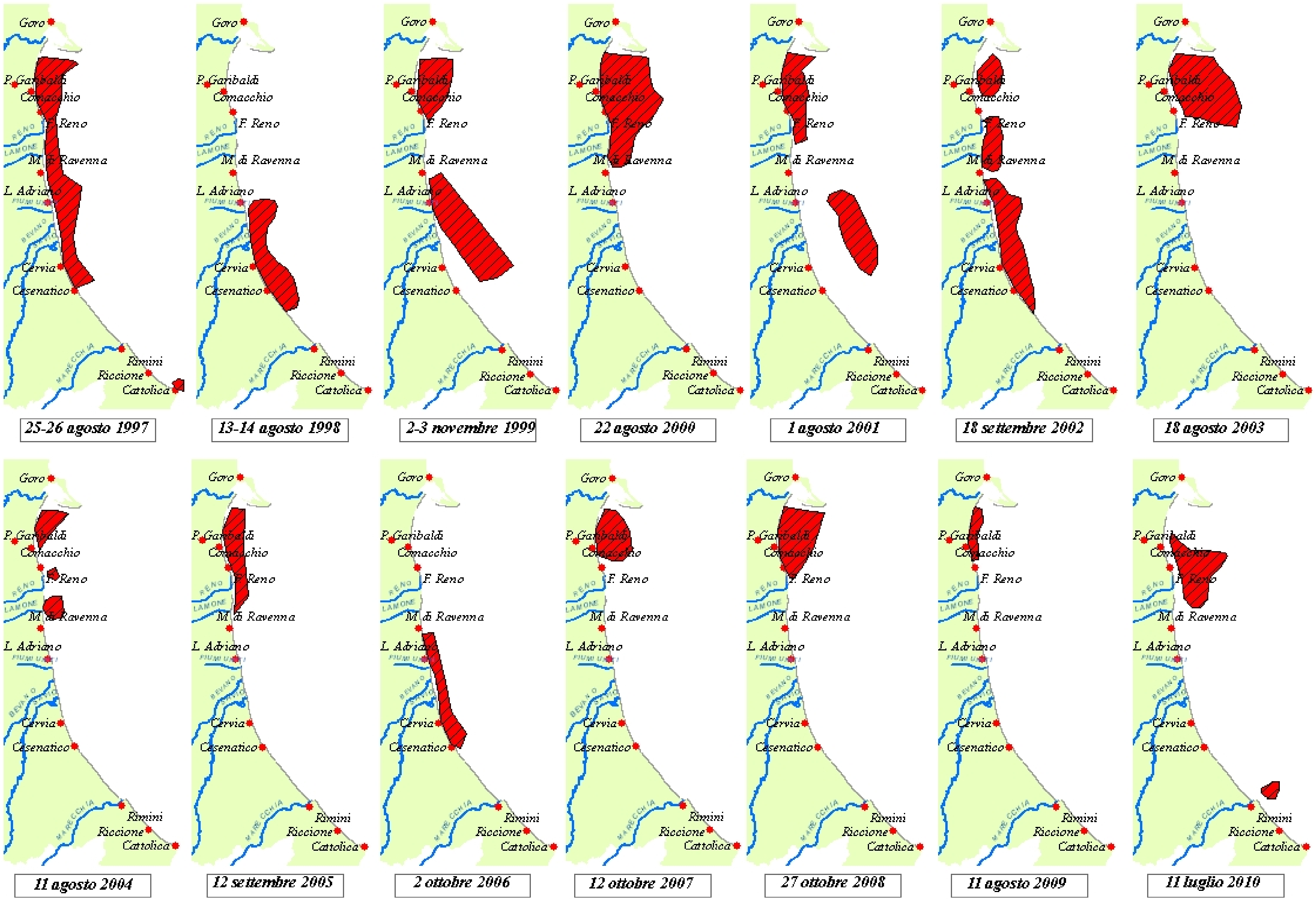
- Hydrographic Basin 70.090 km^2
- Po Average flow 1510 m^3/sec
- Population 17.000.000
- Inhabitants equivalents 115.000.000
- Cultivate Surface 31.000 km^2

Emilia-Romagna

Factors of Pressures



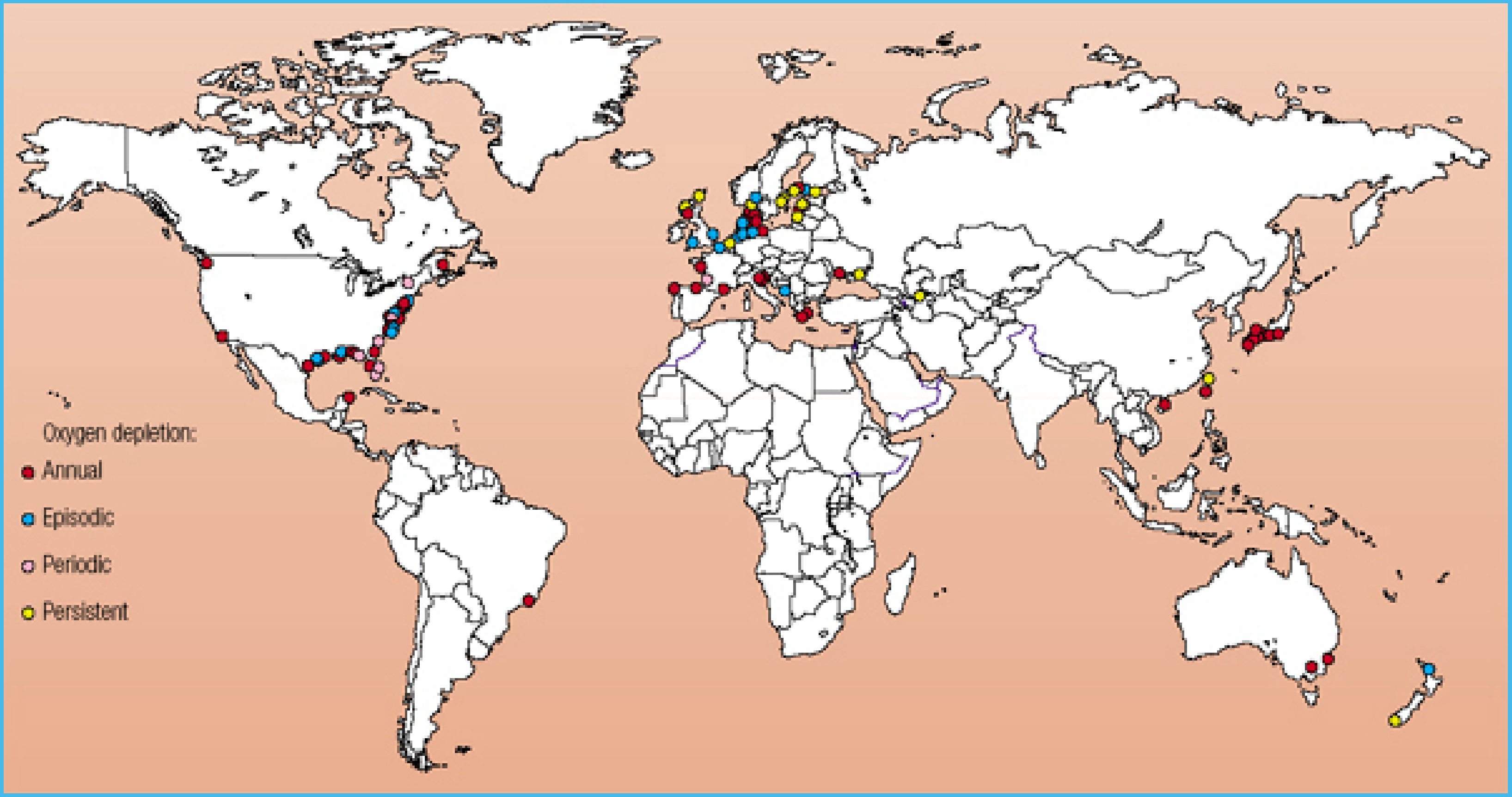
Maps of anoxic areas from 1997 to 2010



The areas with anoxic conditions are 146 in the world (on the whole 70.000 km^2)

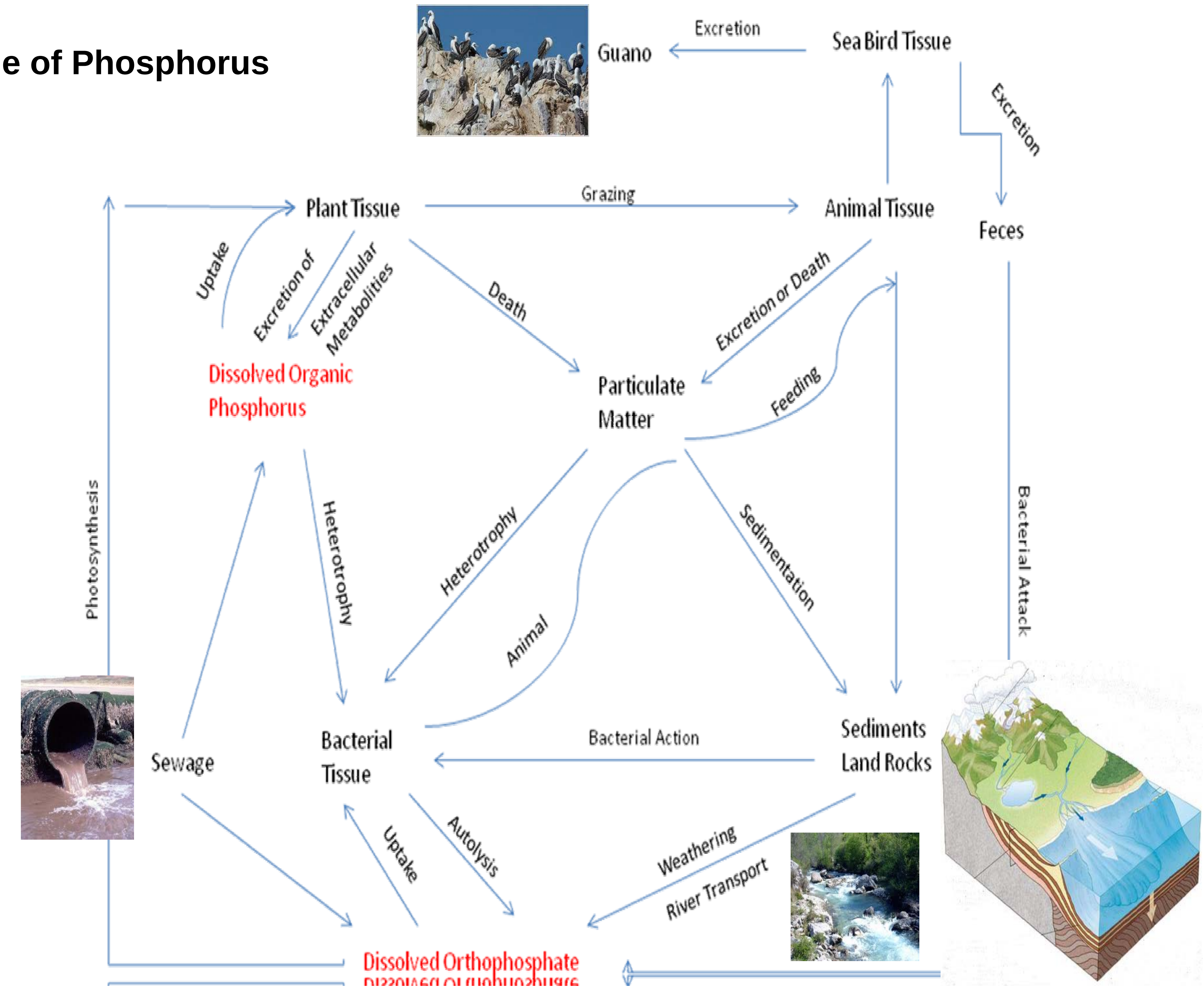
Since 1960 Sixty the number of anoxic zones is doubled every decade

Many phenomena are seasonal

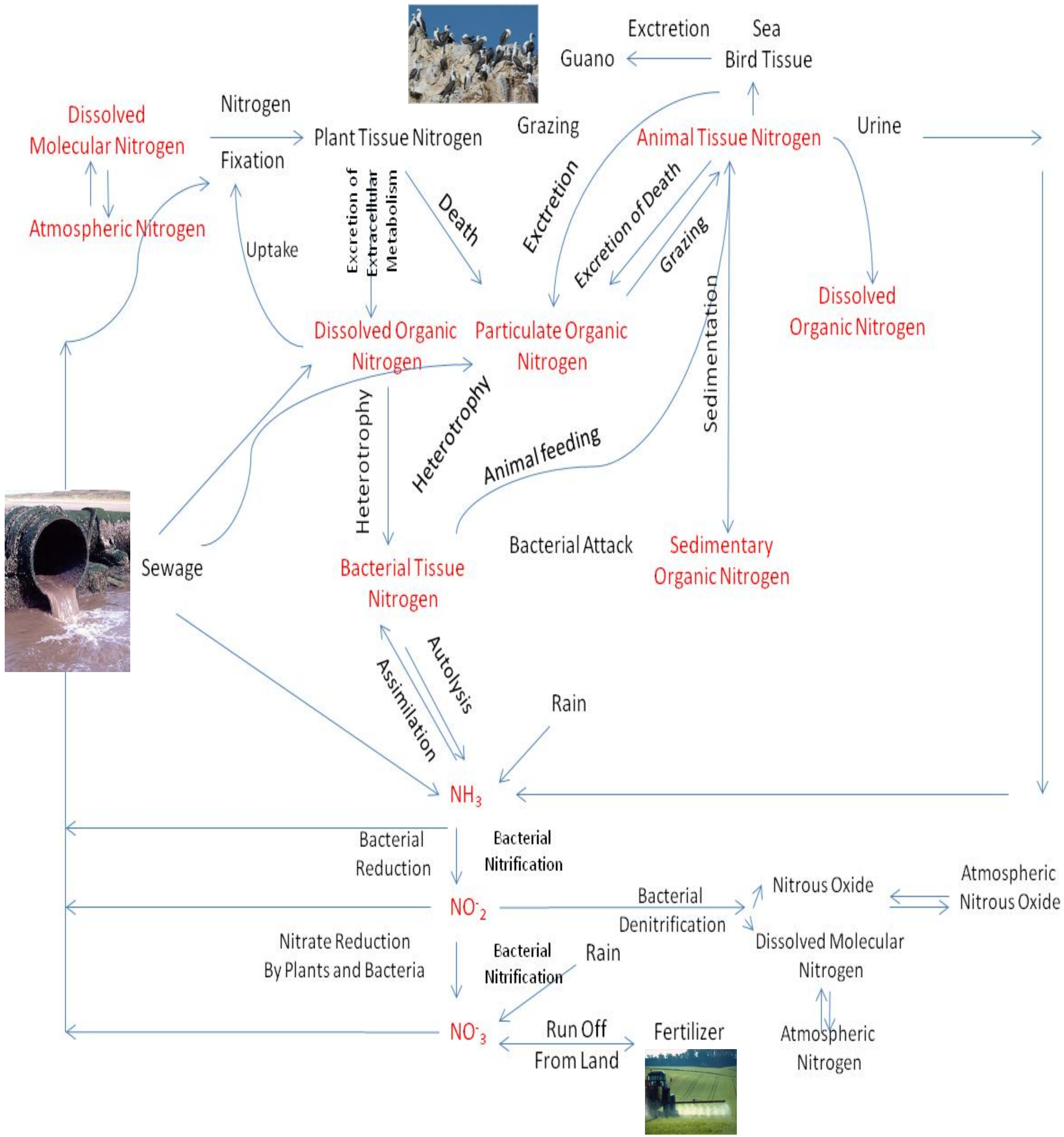


Anoxic areas

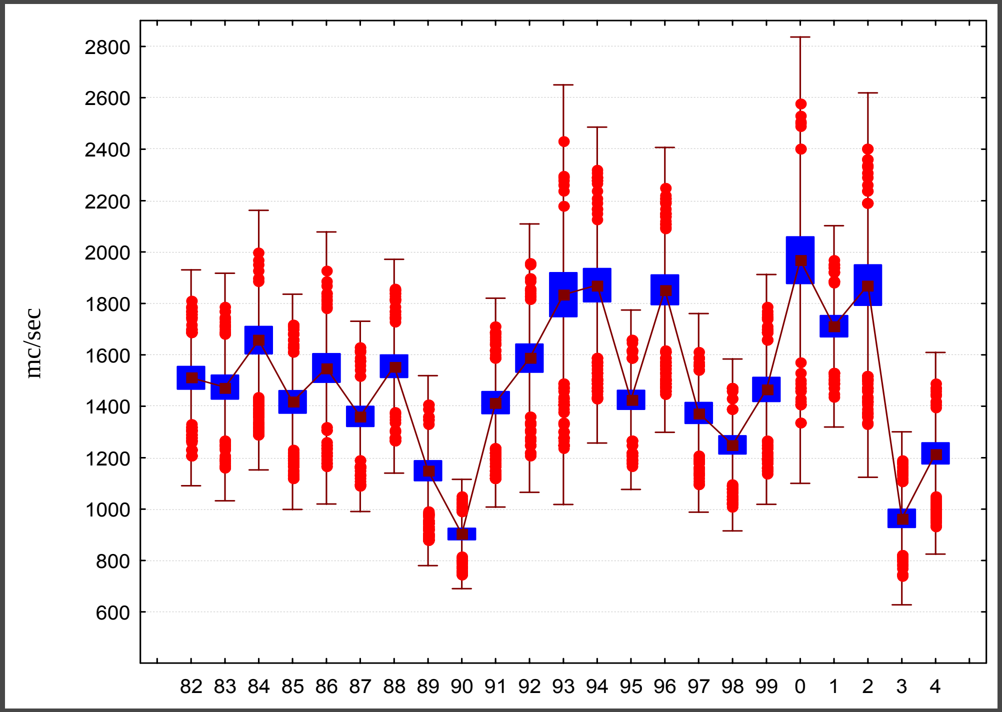
Cycle of Phosphorus



Cycle of Nitrogen

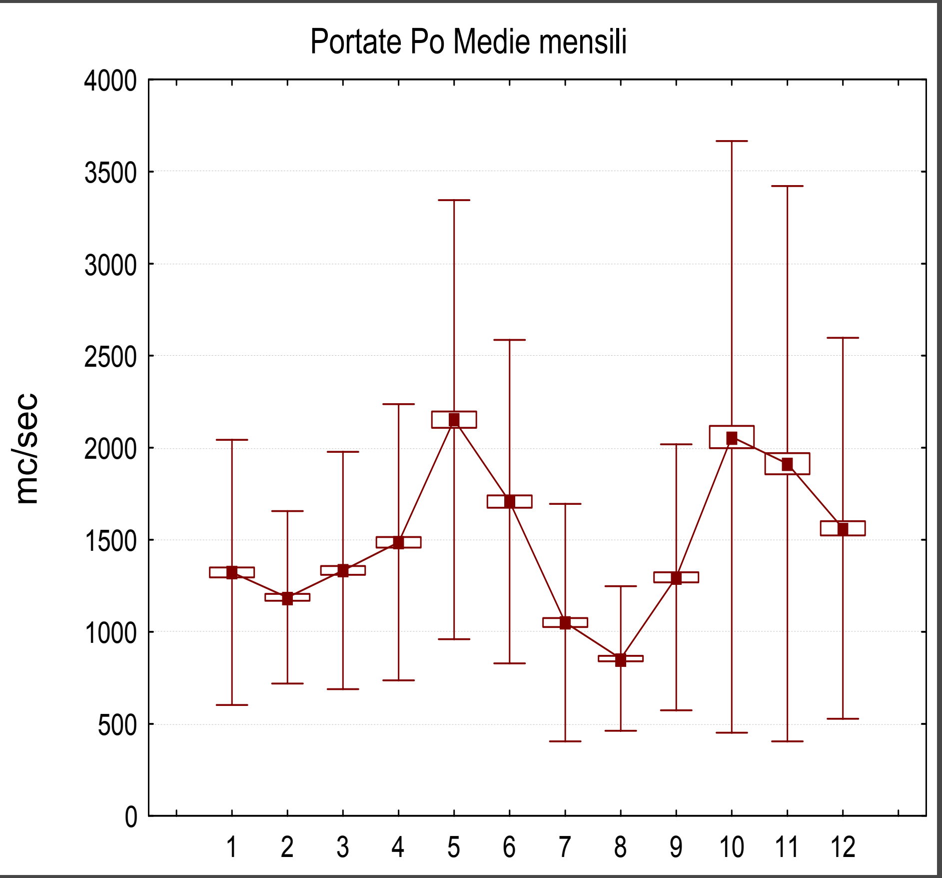


Stat.	Locality	Distan. from coast	Depth (m)	LAT xx°xx, xx' WGS84	LAT yy°yy, yy' WGS84	Period	N° of data
4	P.Garibaldi	0.5	3.7	44°39,69'	12°15,42'	82-04	739
14	Cesenatico	0.5	3.1	44°12,72'	12°24,15'	82-04	1006



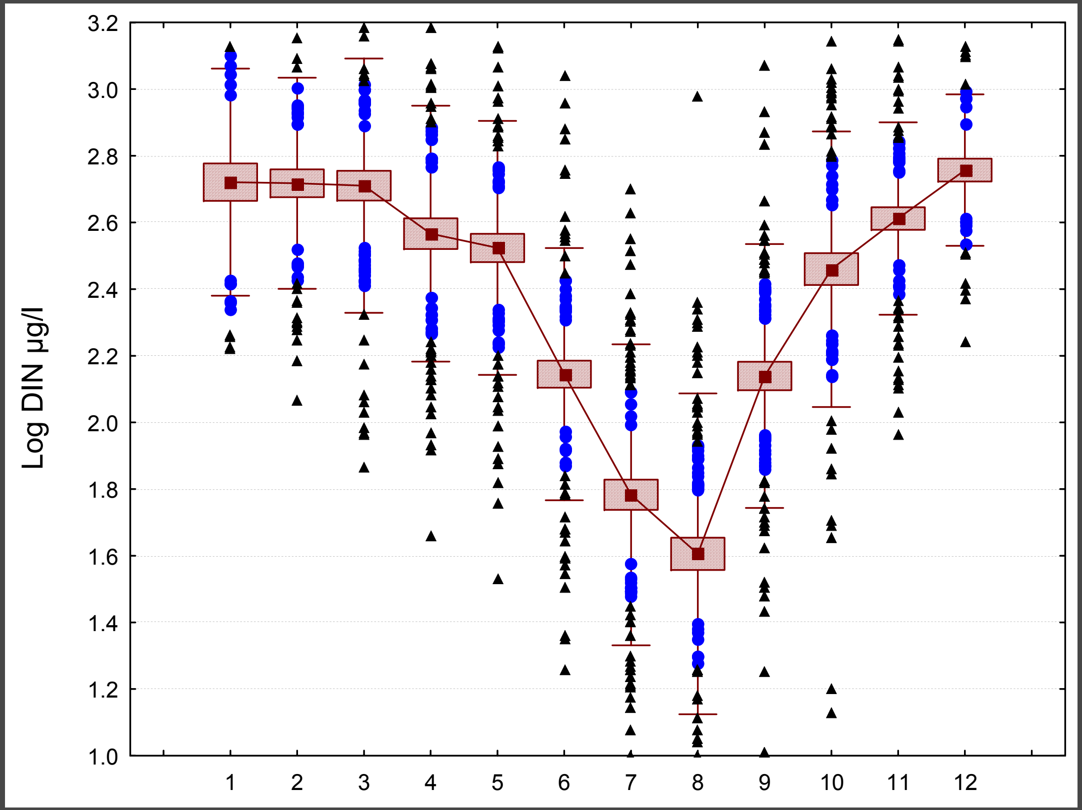
Annual mean

Boxplots Po river discharges



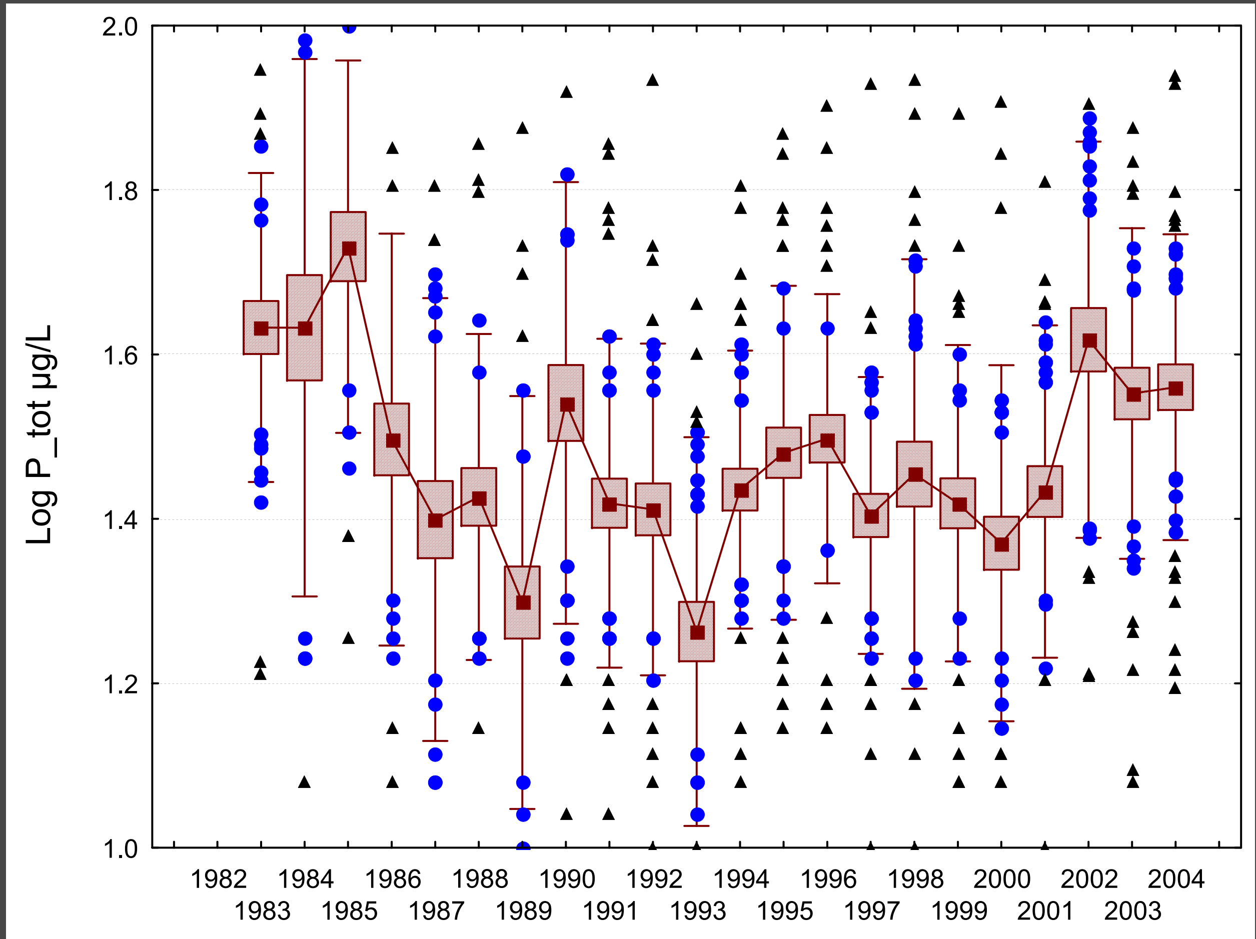
Monthly mean

Boxplots Po river discharges



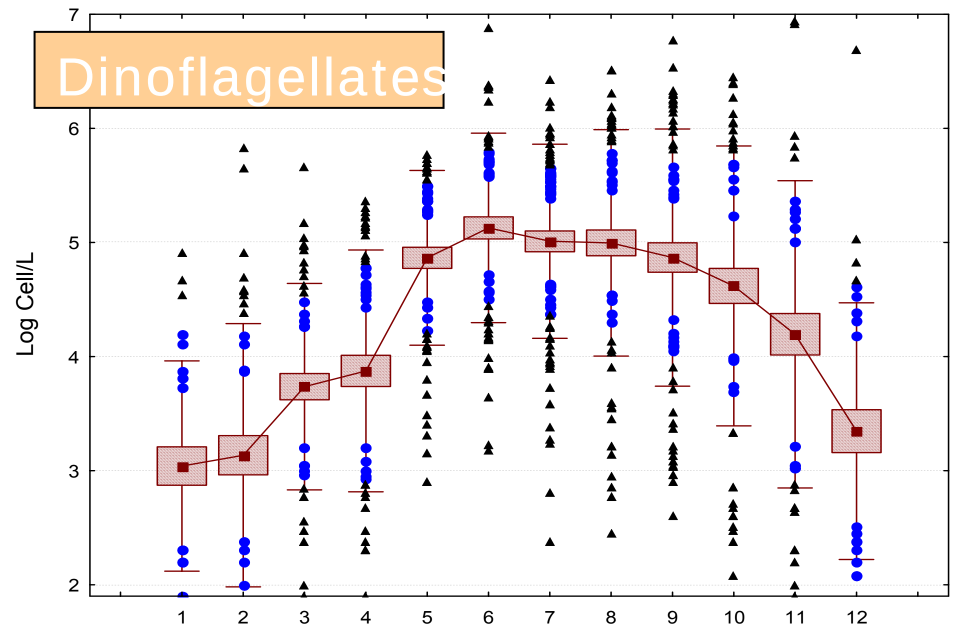
Monthly mean

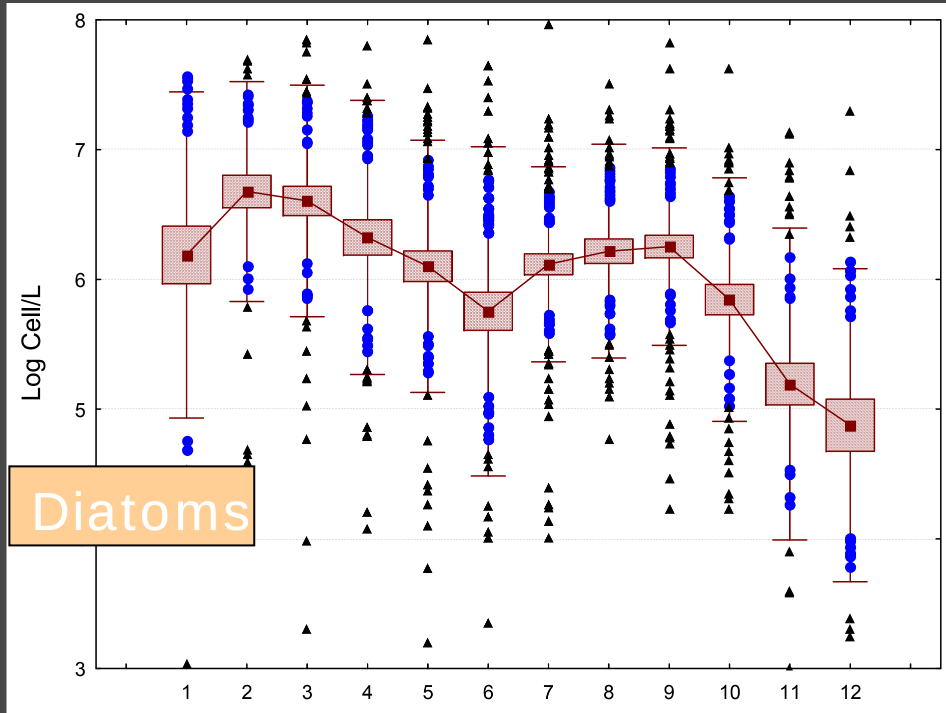
Boxplots DIN



Annual mean

Boxplots Ptot

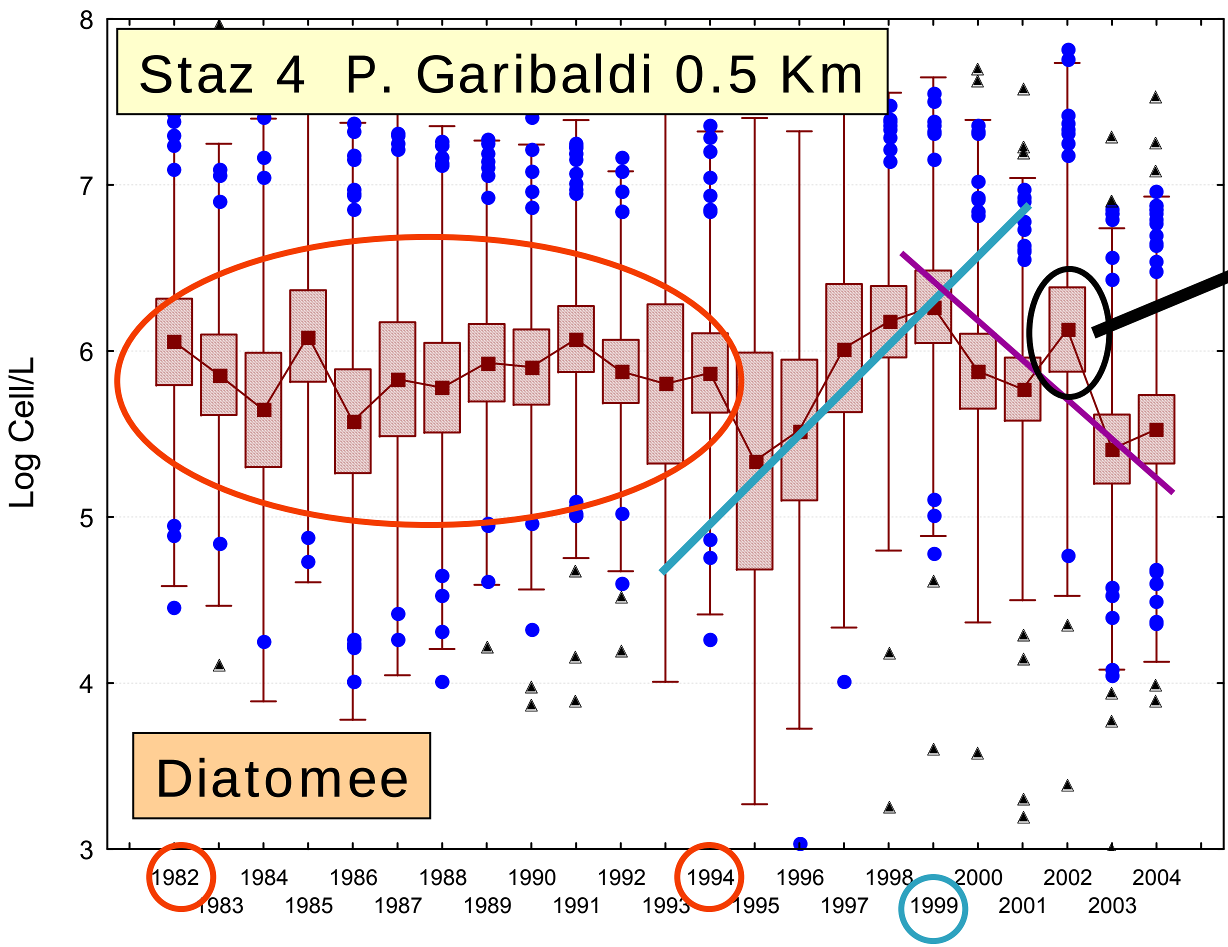




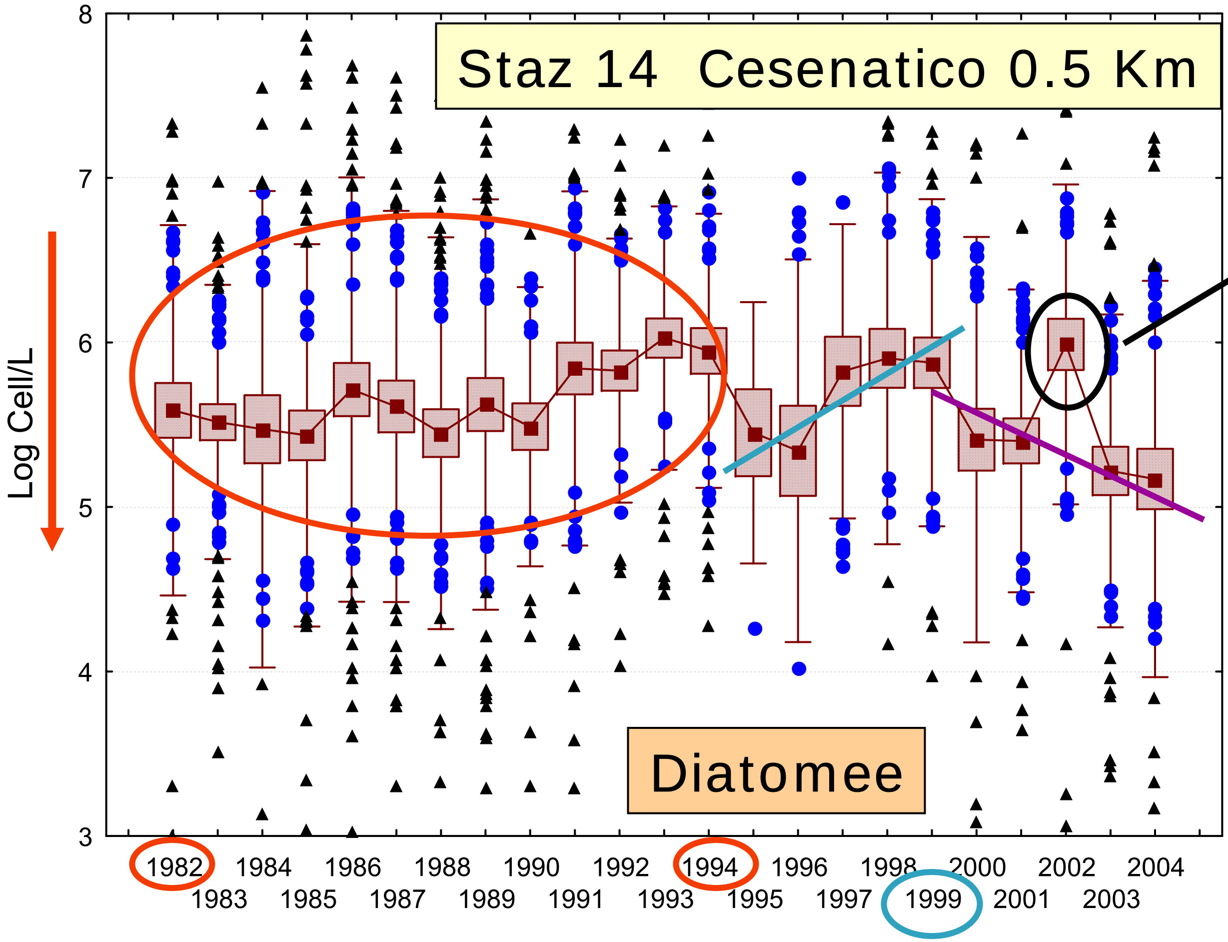
Monthly mean

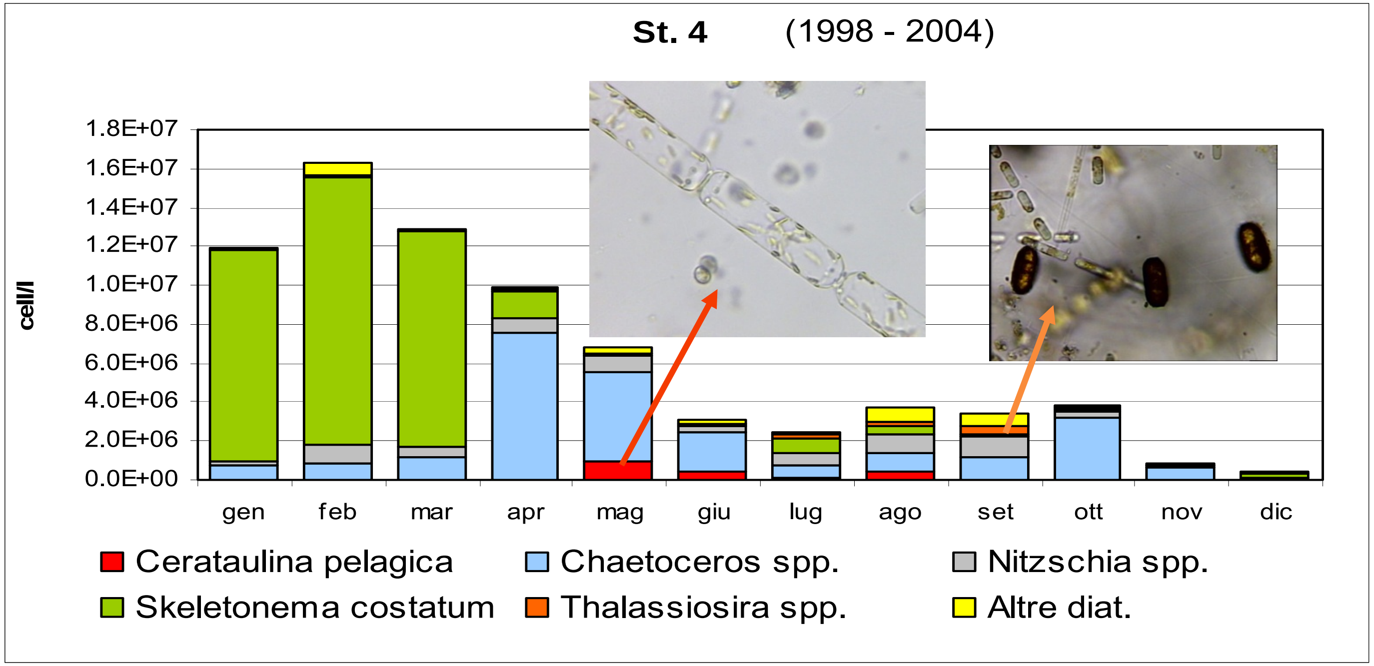
Boxplots Phytoplankton

Valori medi annuali e campi di variazione



Valori medi annuali e campi di variazione





St. 4 (1998 - 2004)
cell/l
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
0.0E+00
gen
feb
mar
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mag
giu
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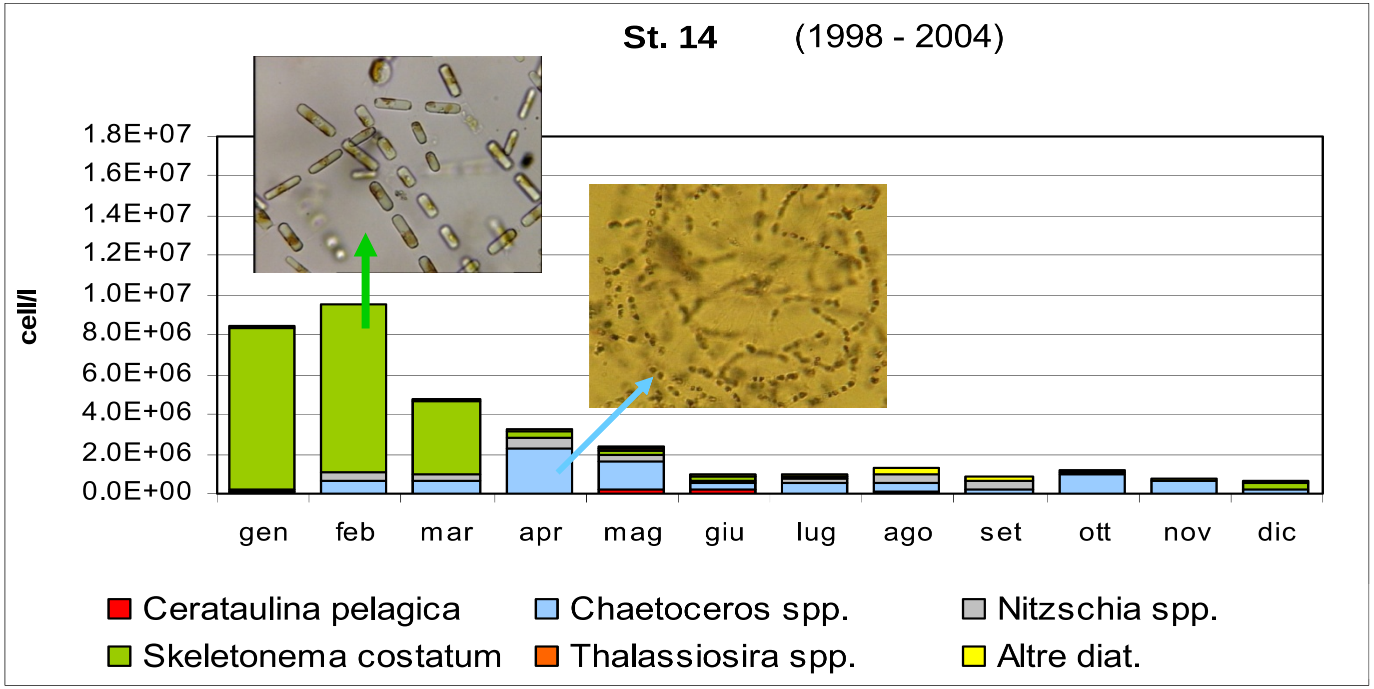
ott
nov
dic
Cerataulina pelagica
Chaetoceros spp.
Nitzschia spp.
Skeletonema costatum
Thalassiosira spp.
Altre diat.



St. 14 (1998 - 2004)
cell/l
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
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Cerataulina pelagica
Chaetoceros spp.
Nitzschia spp.
Skeletonema costatum
Thalassiosira spp.
Altre diat.

The term bloom means the suddenly increase of microalgal population which has found favourable conditions for the grow up.

Among about 4000 species of known planktonic microalgae, there are about 200-300 that causes negative impacts.

- The growth of some species may be favored not only by an increase in nutrients but also by an imbalance of their relationship

daphne arpa

Bloom

Classification of organisms based on the effects produced

There are different tipology of organisms that cause bloom:

- organisms producing toxines
- organisms producing high biomass
- organisms producing both

Tipology of effects: Damages to the human health

The species that produce toxins cause problems such as:

- biointoxications related to the ingestion of shellfish which accumulated toxins though filtration of seawater containing toxic phytoplankton

- biointoxications related to consumption of tropical fish which accumulated algal toxins through the foodweb

- breathing difficulties after inhalation of aerosol containing toxic species/compounds

Tipology of effects:
Damage to the ecosystem and recreational activities

The species that produce high biomass can lead to:
damage to the marine ecosystem (mortality by anoxia, community and foodweb change) impact on tourism and recreational use of the coast (discoloration, odors, accumulation of foam or mucous substance)

Tipology of effects: impact on the living marine resources

The effects characterized by high biomass and production of toxins are usually associated with death of fish due to various causes:

- direct toxicity
- haemolysis
- mechanical damages
- low oxygen levels

Tipology of effects: impact on the living marine resources

The algal blooms are natural phenomena that take place in various parts of the world since ancient times, however, there are triggers that make more frequent blooms

It is believed that these actions consist in natural and human factors and their interaction. Biological, physical and chemical elements are therefore implicated.

Biological factors influencing the microalgal growth

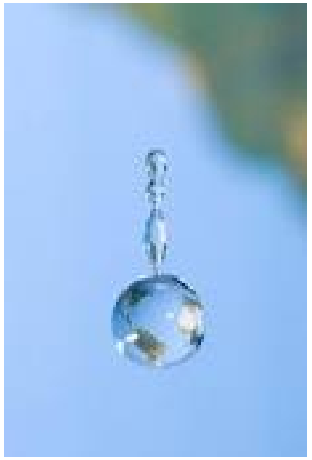
- adaptation to environmental conditions varying among and within species
- movement ability in the water column
- presence of complex life cycles, characterized by different resting stages to adverse conditions
- ability to utilize organic sources of nutrients (mixotrophy)
- negative and positive interactions with other organisms (e.g. **negative**: predators, viral infections, competition; **positive**: utilization of released and regenerated nutrients)

Human factors affecting the growth of microalgae

- intense urbanization
- high nutrient discharges
- creation of artificial structures in coastal areas
- overfishing and the consequent decrease of filter feeding organisms
- aquaculture practice
- transfer of species due to the transfer of shellfish stocks, the release of ballast water and plastic waste floating

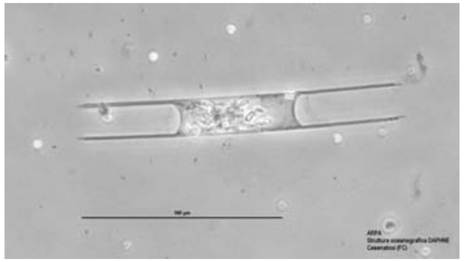
The protagonists of our study

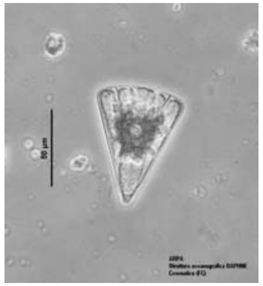
- The great majority of the plants in the sea are various types of planktonic, unicellular algae, collectively called Phytoplankton



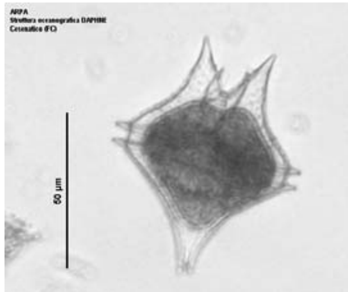
- They are the dominant primary producers converting inorg. materials into new organic compounds by the process of photosynthesis

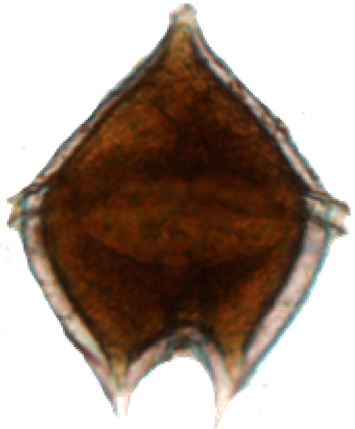
Diatoms

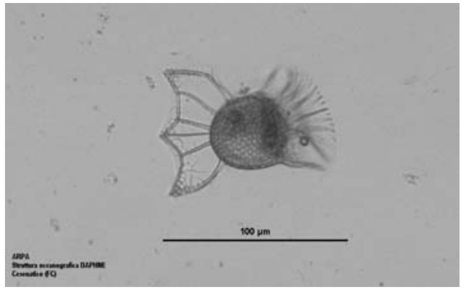




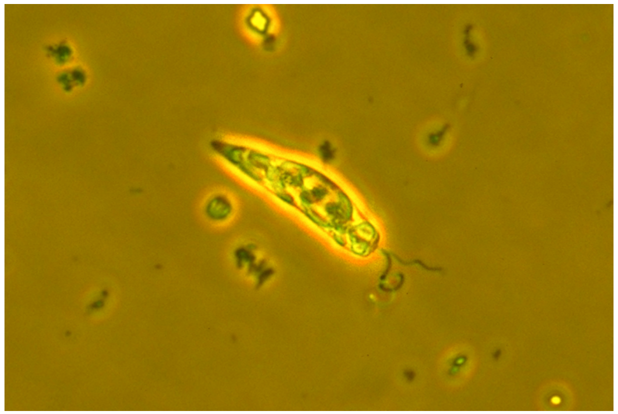
Dinoflagellates



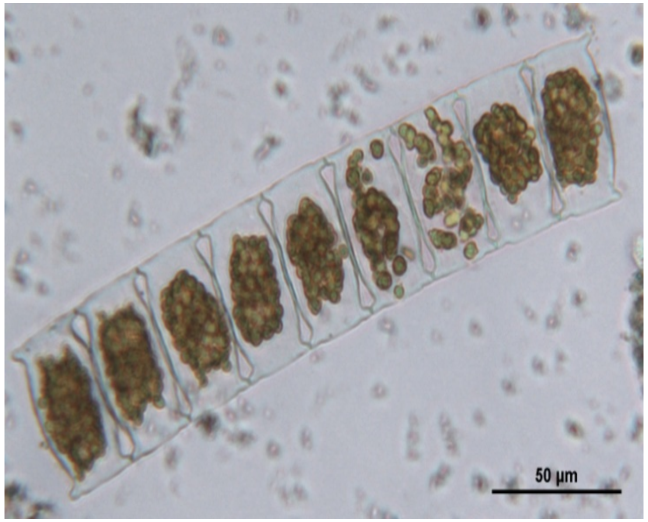


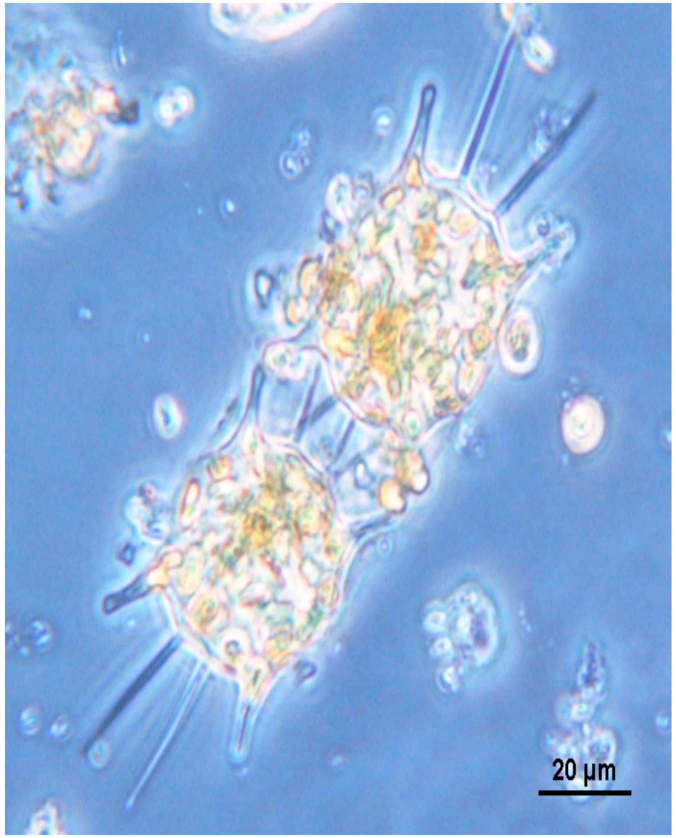


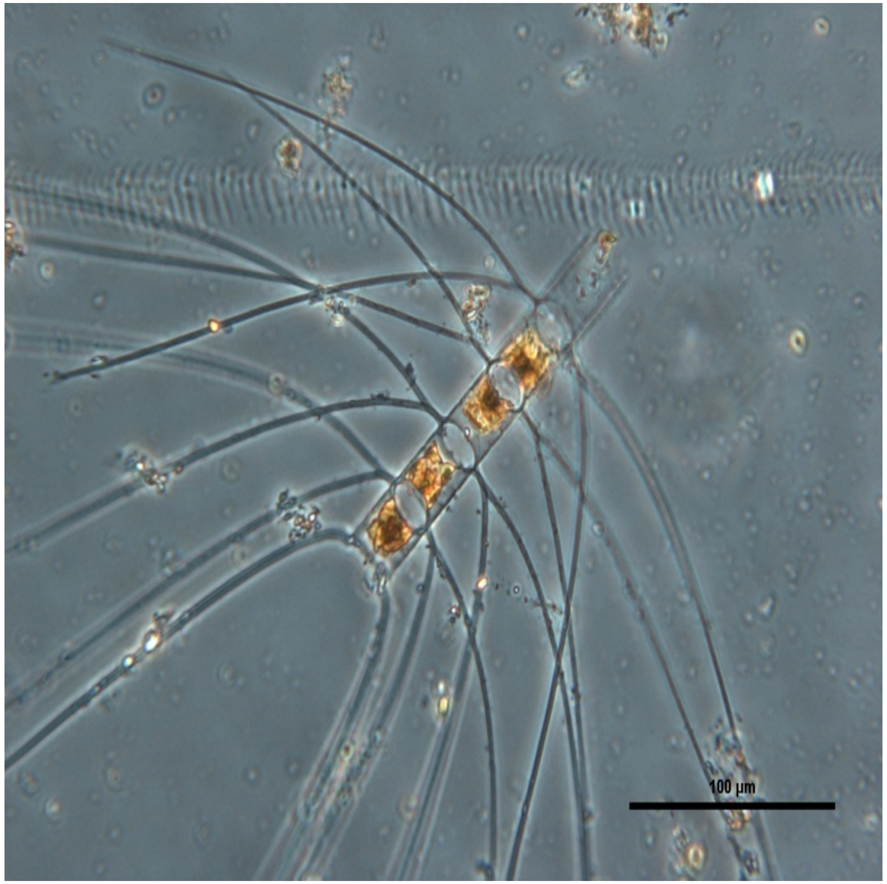
Others



Phytoplankton blooms develop when a species suddendly increases in number under favourable conditions

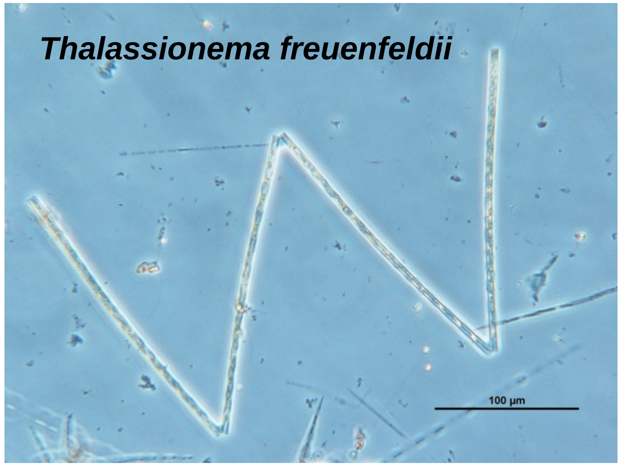




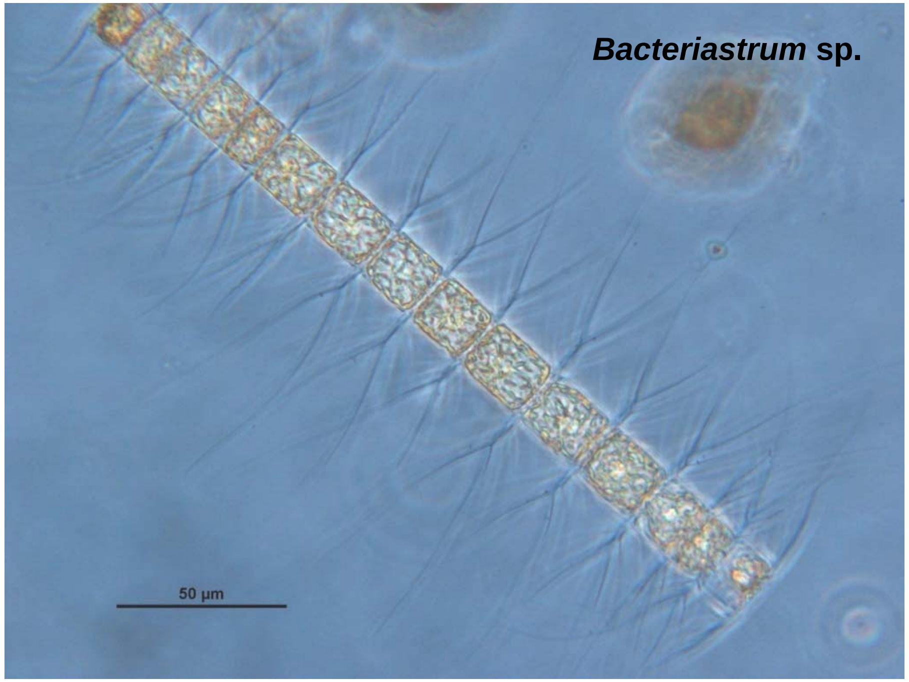

100 µm


50 µm

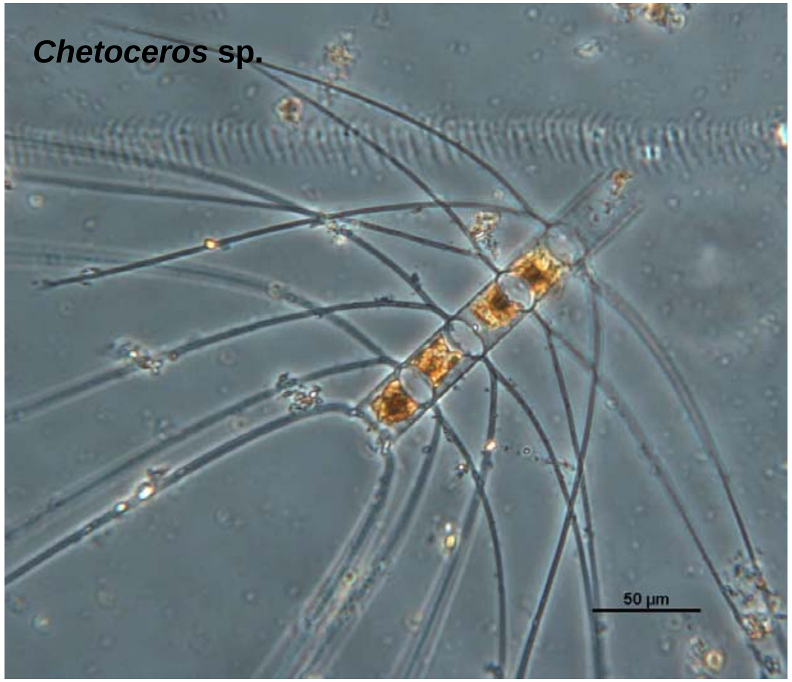
DIATOMEE



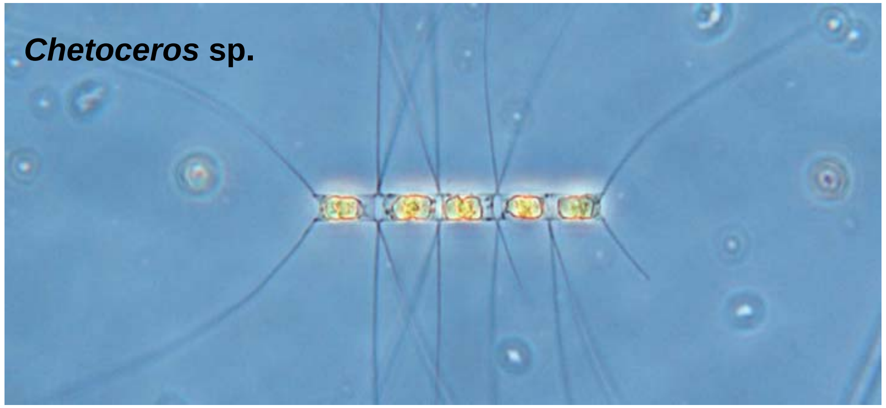
Thalassionema freuenfeldii



***Bacteriastrum* sp.**



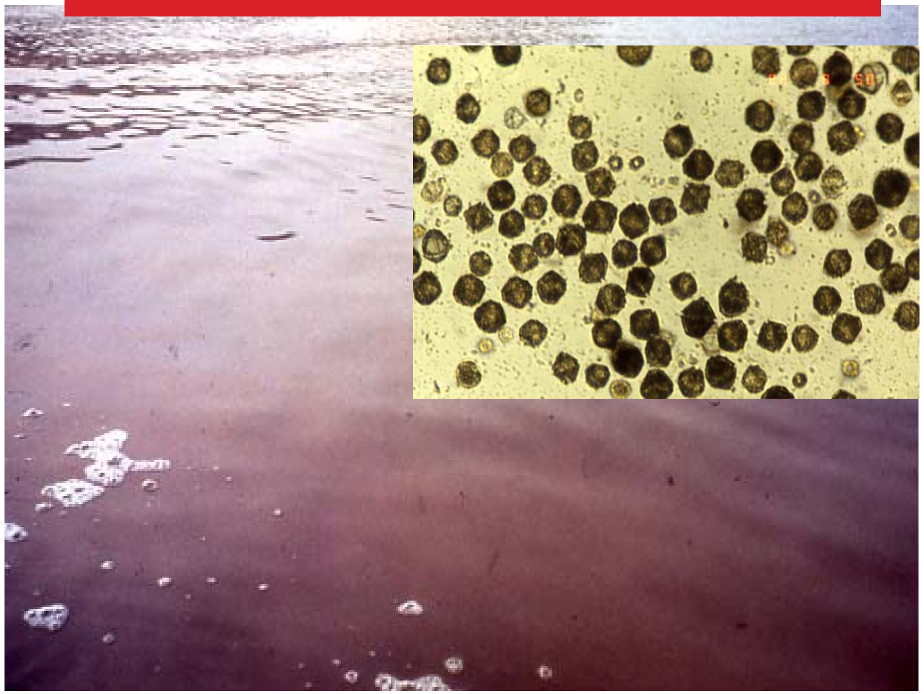
***Chetoceros* sp.**



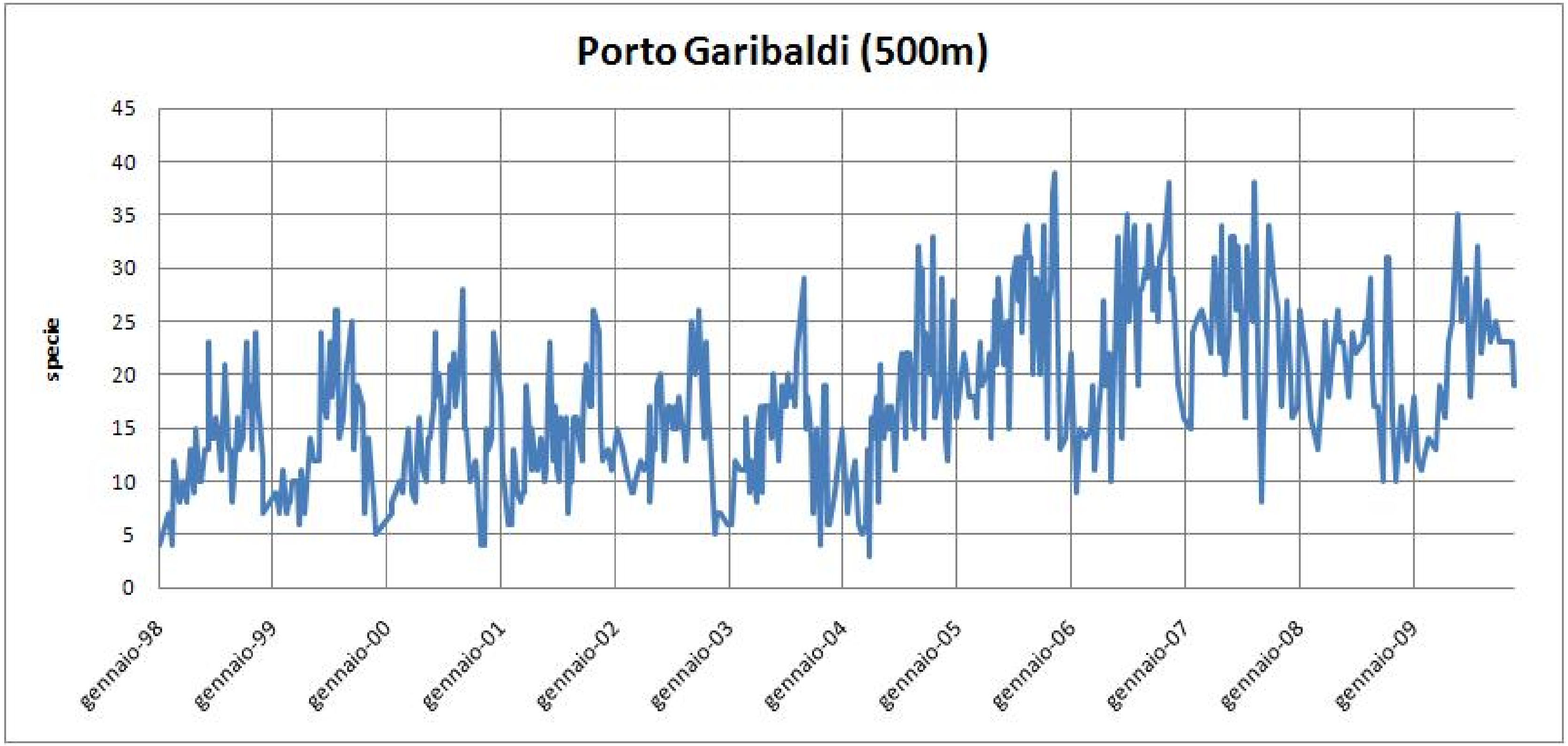
***Chetoceros* sp.**

Red tides

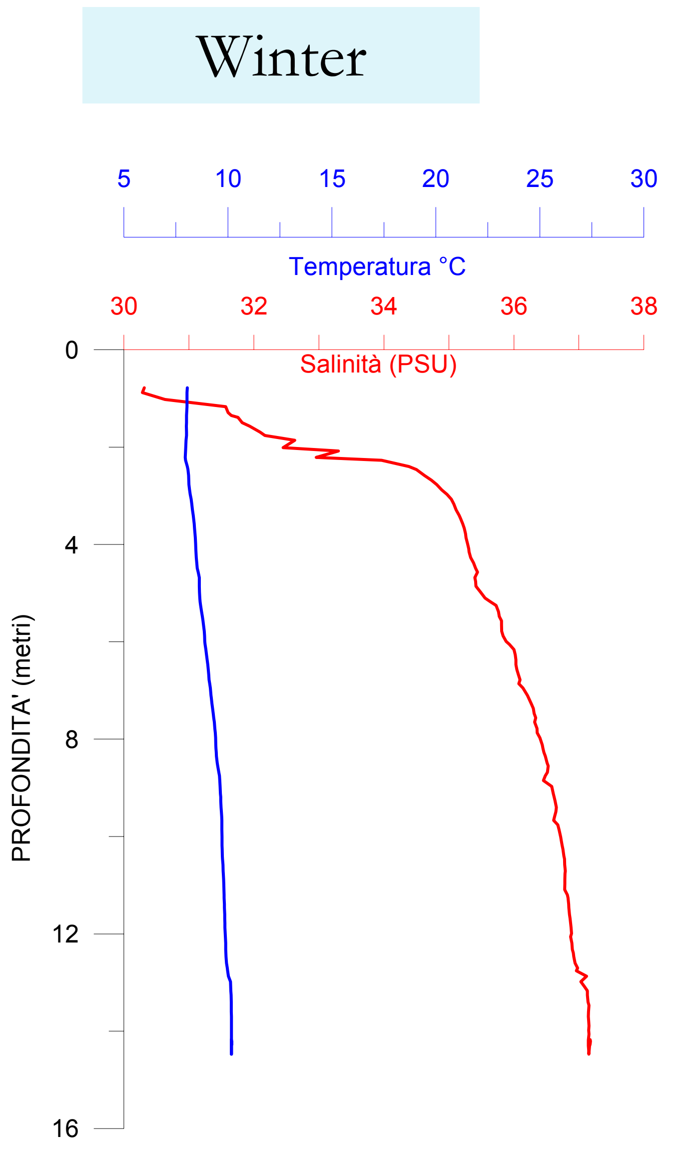
Lingulodinium polyedrum

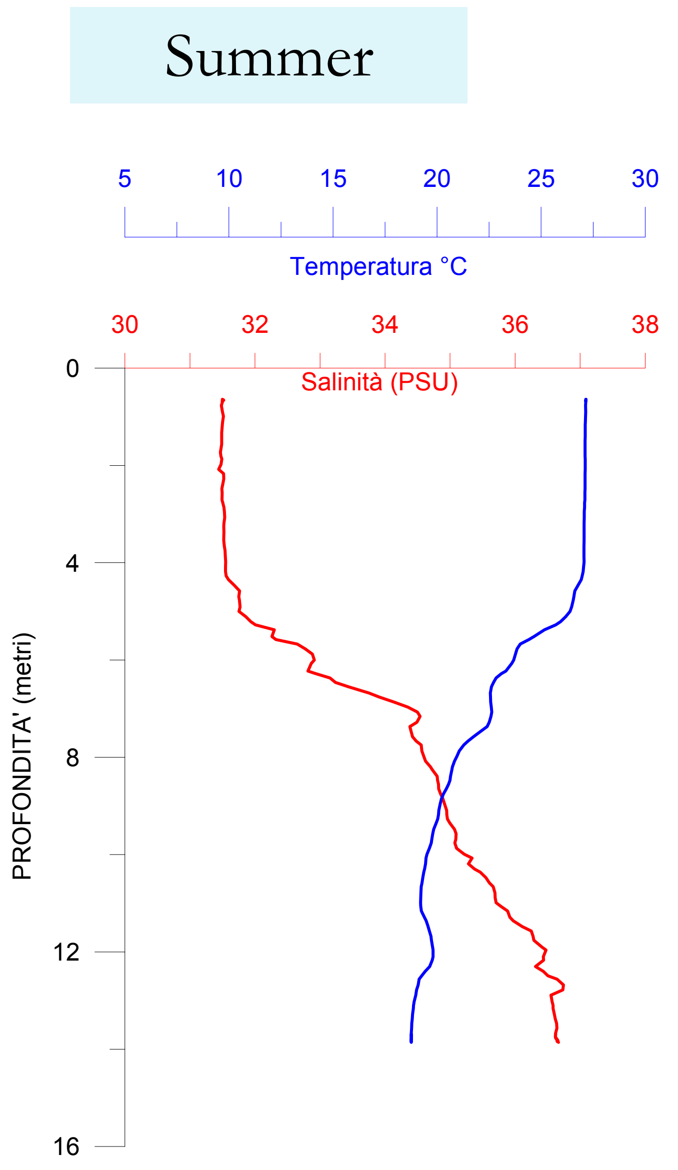


Gymnodinium rotundatum



St. 4 Total Species Richness





Column water stratification

Redfield ratio (1934)

is the atomic ratio of C N P found in phytoplankton

C:N:P = 106:16:1

2 mutually non-exclusive mechanisms:

The N:P in plankton tends to the N:P composition of seawater

The N:P in seawater "must tend to approach that characteristic of protoplasm in general"

daphne arpa

N/P

The interpretation of simple N/P ratio statistics is not always easy because the organisms have sometimes vast reservoir of N and P stored

If one accepts the conceptual reference of the mineral fraction N/P ratio being indicative of nutrient limitation , then the limiting factor would have been N in less than10 cases, but P in 250 of the 301 cases

It is interesting to remark that Phosphorus not only represents the main pressure indicator that affects Chlorophyll variation, but it assumes also the role of limiting factor for the algal growth, as well highlighted in the following diagram (Fig. 5), where the N/P ratios (i.e. the ratio between the available nitrogen –DIN- and the soluble orthophosphate) are plotted vs Chl g-means, for each sampling station belonging to Type 1.

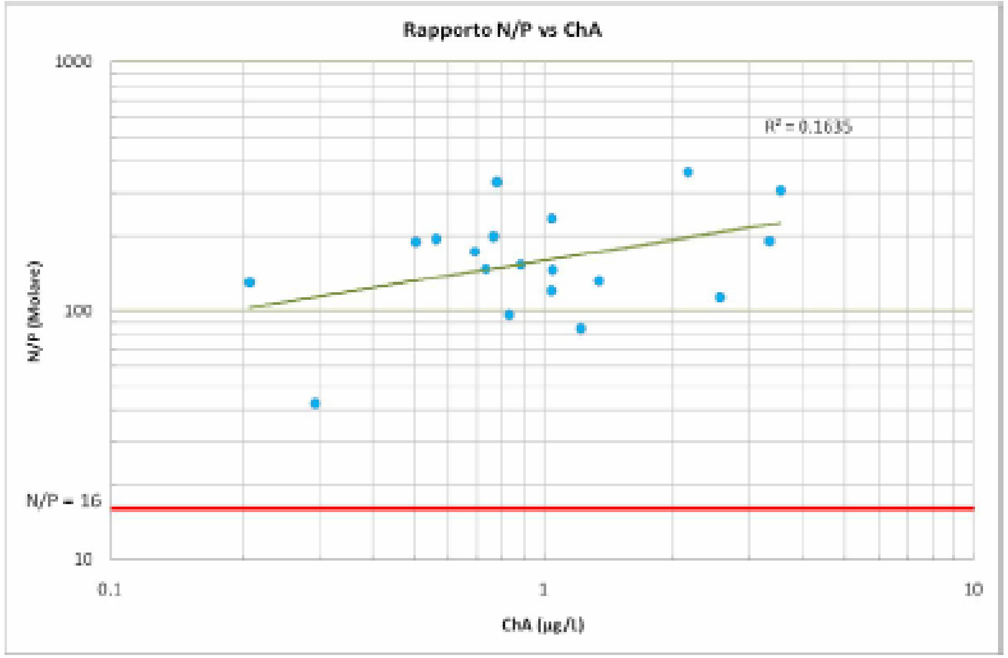
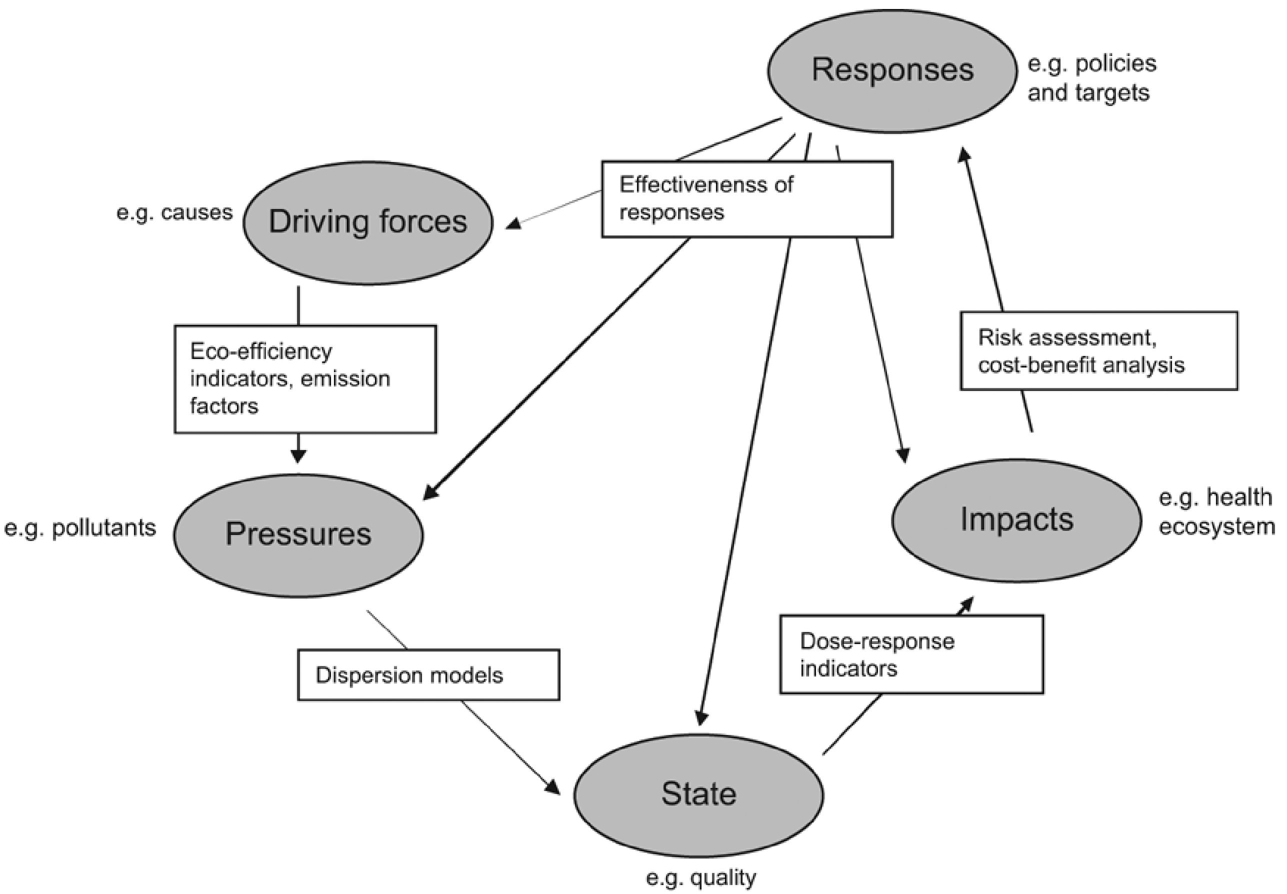


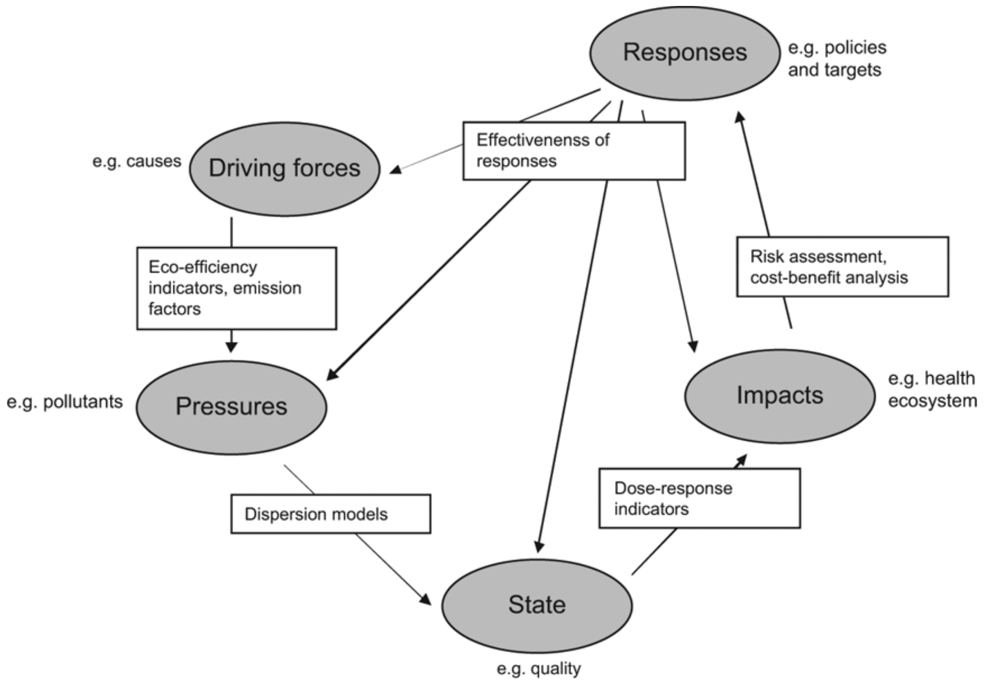
Figure 5: Type 1 - N/P ratios against Chl g-mean concentration, per sampling station. (Source: MED GIG technical document - F.Giovanardi, R.Precali and C.Mazziotti: Elaborations on the common Data Base)



Source: Elaboration from EEA (2003)

Driving Force-Pressure-State-Impact-Responses (DPSIR) model

DPSIR is a casual framework for describing the interactions between society and the environment.
There is a chain of causal links starting with
Driving forces……through **Pressures**…to **States**…and **Impacts**…..leading to Political **Responses**



Source: Elaboration from EEA (2003)

AIR

Driving Force	Pressure	State	Impact	Responses
		CH_4,CO_2,N_2O,NH_3	Climate change	Global politics
Transport →	petrol →	CO,SO_2,NO_X,Benzene, PM_{10}	Urban city	Human health
Industry				
Energy				

daphne arpa

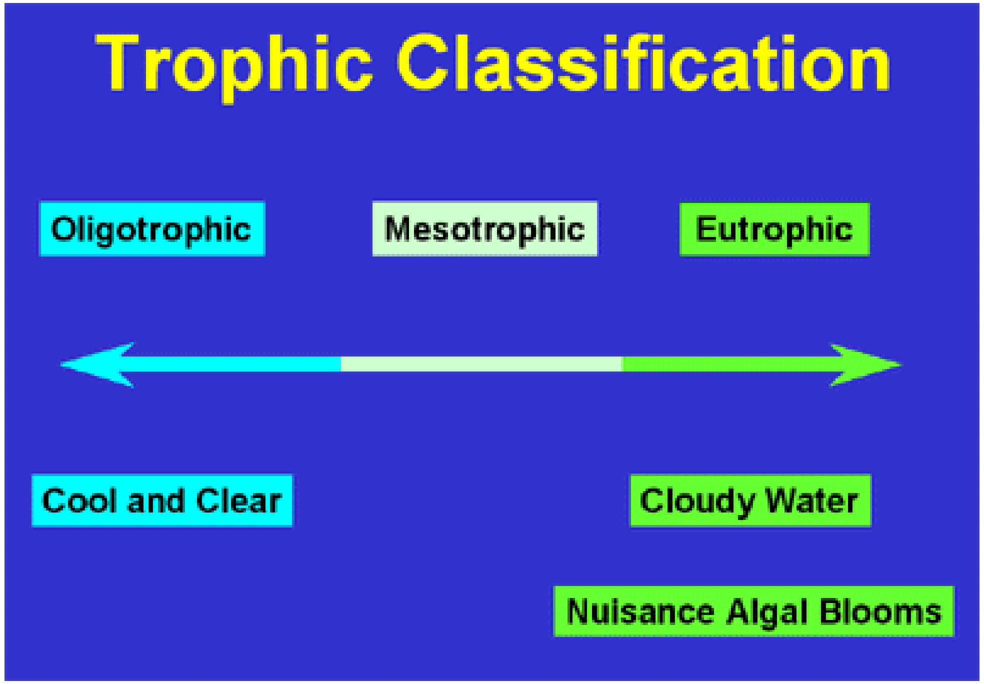
EUTROPHICATION

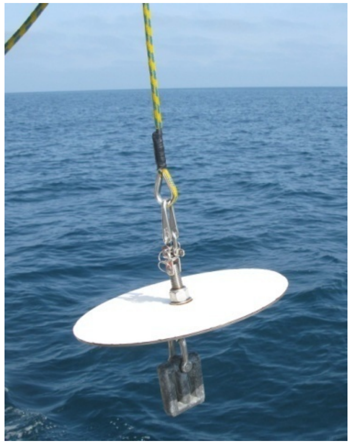
Driving Force	Pressure	State	Impact	Responses
Agriculture	Nitrogen	Chl"a", Ptot, PO_4,	O_2 in bottom sea	Local/National law
Industry	Phosphorus	NO_3,NO_2, NH_3 Trix	Phytoplankton	Monitoring grid
Breeding				
Tourism				

Driving Force-Pressure-State-Impact-Responses (DPSIR) model

Methodological Approach for a practical trophic index

There is general agreement that oligotrophy means nutrient poor (=low productivity) and eutrophy means nutrient rich (=high productivity) waters. However, little is said regarding "how productive", and where the boundaries between categories are to be set

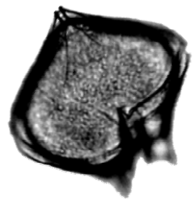




Phosphorus

Nitrogen

Silicates



Uhlmann/Verduin index (1968) using carbon, nitrogen and phosphorus

$$Y = Y_m (1-2^{-c})(1-2^{-n})(1-2^{-p})$$

$0>Y<1$ $c = C/42$ $n = N/7*2$ $p = P/1$

Rank waters according to their trophic potential while accounting for the most production limiting nutritional factor

It's not clear which forms of P or N should be used for calculation

- inorganic
- soluble
- total

?

Carlson/Walker/Porcella index (1977) using chlorophyll, total phosphorus, Secchi trasparency

The raw data are transformed by appropriate equations to meet the condition That the transformed lowest and highest range values for the three factors equal 0 to 100.

Equations:

Ch”a”= 9.81*ln Ch”a”+30.6

Pt = 14.42*ln PT 4 4.15

ST = 60-14.42 ST

Schröder’s correlation model (1991) that considers a variety of nutritional and environmental factors in a correlative way

Anabolic processes:

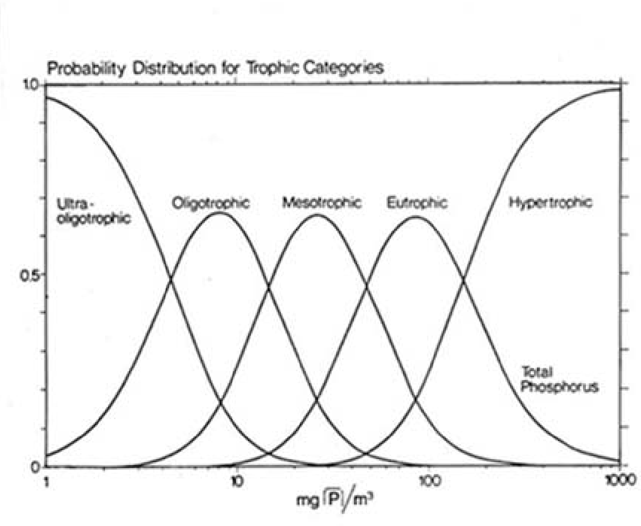
- Chlorophyll
- P-PO4
- PT
- Fe
- N-NH4
- Chemical oxygen demand
- …..

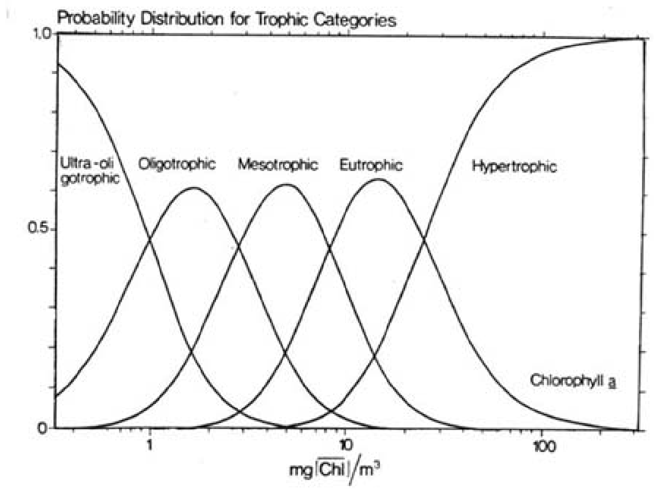
Ambient parameters:

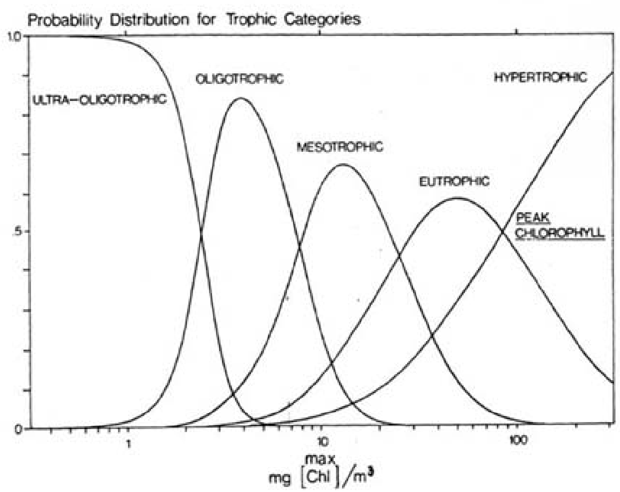
- Mean and maximum depth
- Altitude above sea level
- Epilimnetic temperature
- Lake surface
- …….
- …….

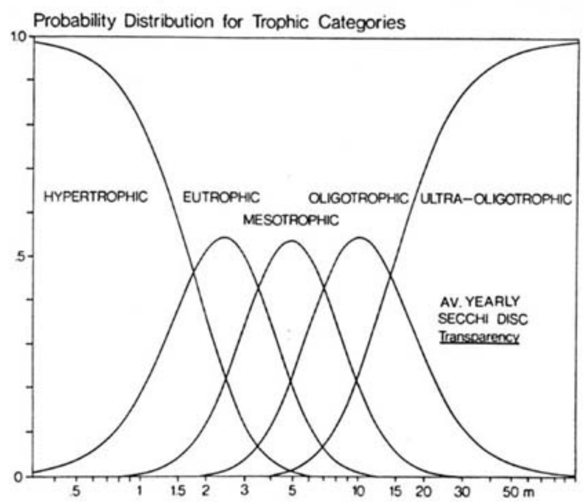
The OECD classification (Vollenweider and Kerekis, 1982) that defines trophic categories probabilistically using total phosphorus, average chlorophyll, peak chlorophyll, Secchi trasparency

This approach relates a subjective qualitative class judgement with a parametric objective quantity

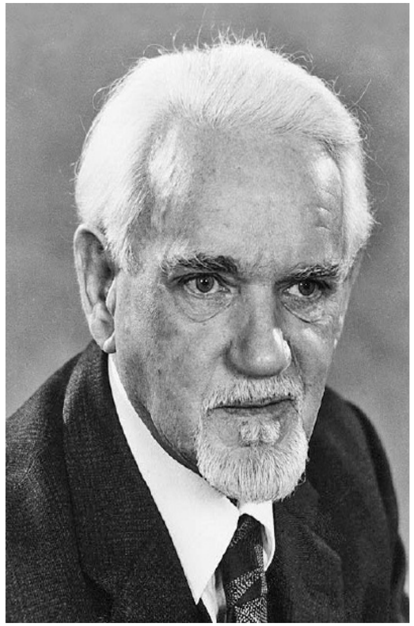






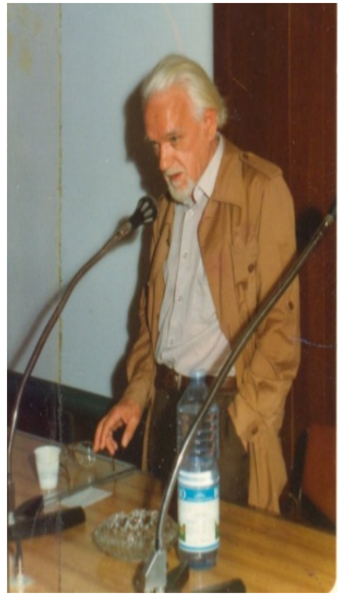


Born on 27 June 1922, in Zurich, Switzerland,
completed a graduate degree at the University of Zurich.
He studied the dynamics of life in inland waters in Sweden,
Egypt and Italy before undertaking his monumental analysis
of nutrients and plant growth in lakes (eutrophication) for the
Organization for **E**conomic **C**o-operation and **D**evelopment (OECD).



Richard Arthur Vollenweider 1922-2007

He was lured by Wally Johnson of the Fisheries Research Board of Canada to head the Great Lakes biological detachment at the Canada Centre for Inland Waters in Burlington, Ontario



Later became Senior Scientist at the CCIW in the Federal Department of the Environment

It latter also paved the way for a major OECD study of the causes and control of eutrophication in 18 countries, at 50 institutes, and of 200 water bodies over a period of 15 years.

ENVIRONMETRICS
Environmetrics, **9**, 329–357 (1998)

CHARACTERIZATION OF THE TROPHIC CONDITIONS OF MARINE COASTAL WATERS WITH SPECIAL REFERENCE TO THE NW ADRIATIC SEA: PROPOSAL FOR A TROPHIC SCALE, TURBIDITY AND GENERALIZED WATER QUALITY INDEX

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SUMMARY

In pursuing earlier attempts to characterize the trophic state of inland waters, a new trophic index (TRIX) based on chlorophyll, oxygen saturation, mineral and total nitrogen and phosphorus, and applicable to coastal marine waters, is proposed. Numerically, the index is scaled from 0 to 10, covering a wide range of trophic conditions from oligotrophy to eutrophy. Secchi disk transparency combined with chlorophyll, instead, defines a turbidity index (TRBIX) that serves as complementary water quality index. The two indices are combined in a general water quality index (GWQI). Statistical properties and application of these indices to specific situations are discussed on examples pertaining to the NW Adriatic Sea. It is believed that these indices will simplify and make comparison between different spatial and temporal trophic situations of marine coastal waters more consistent. © 1998 John Wiley & Sons, Ltd.

KEY WORDS eutrophication; trophic indices; Adriatic Sea

1. INTRODUCTION

The harmful effects of eutrophication on the coastal marine environment worldwide are well documented (Vollenweider *et al.*, 1992; REDTIDE Newsletters, various). Since marine coastal eutrophication has become more frequent over recent years, words like 'oligotrophy', 'mesotrophy' and 'eutrophy' (a terminology largely developed by limnologists to characterize the trophic conditions of inland waters) have also become more frequent in the marine literature. There is general agreement that oligotrophy means nutrient poor (=low productivity) and eutrophy means nutrient rich (= high productivity) waters. However, little is said regarding 'how productive', and where the boundaries between categories are to be set.

Trophic condition of vast marine areas, like the Mediterranean, vary considerably from region to region and within regions (UNESCO, 1988; Vollenweider *et al.*, 1996). In coastal areas

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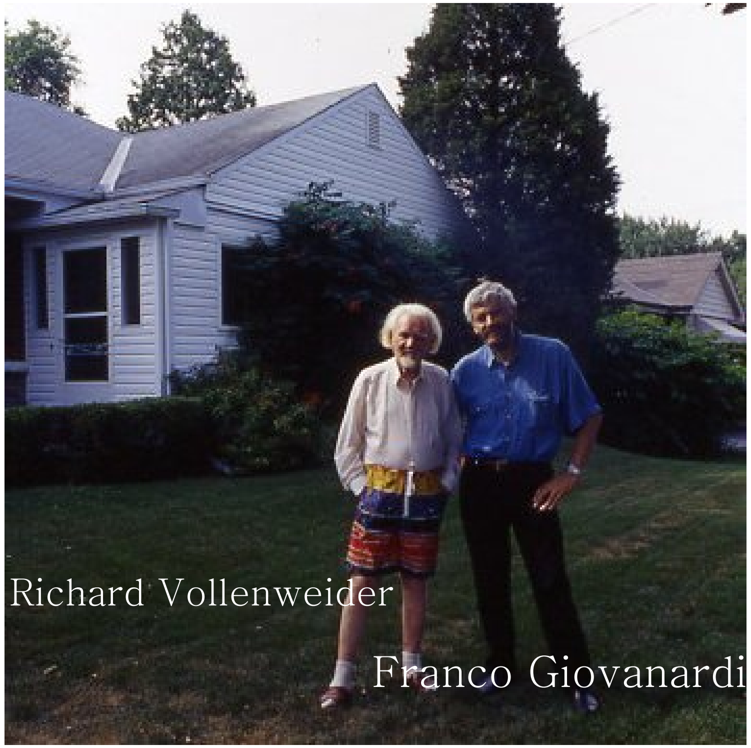


The Authors of TRIX

Now is clear what's mean the eutrophication problem, but how we can quantify the consequences ?

How we can transfer the knowledges of the process to the stakeholders in a easy way?

The Trophic index introduction (and the correlate scale) permits to leave the traditional categories and make possible the measure of trophic levels rigorously

The fundamental parameters that lead to trophic index definition had to:

- To be representative in terms of both phytoplanktonic biomass and production's dynamic;
- To identify the phenomena in a significative and unequivocal way;
- Take into account the principal causal factors and express the maximum total variability of the system;
- To base on measures and parameters routinary measured during the marine analysis;

The data analysis show that none of the selected parameters for the TRIX is distributed in the normal way. Experience shows that for the parameters of interest, the simple transformation Log decimal is more than suitable to approximate the distributions to the normal distribution for the raw data.

The TRIX use answers to three basic requirements:

- the value comes out from the integration of more factors indicating the trophic level; it eliminates the subjective estimations based on the singular parameters;

- it reduces the complexity of coastal system;

- it distinguishes among different spatio-temporal situations, thus allowing a quantitative comparison;

The authors have developed a numerical scale in order to characterize the phenomenon quantitatively and qualitatively.

From the numerically point of view the Trix is diversify in classes from da 0 to 10 that cover all the trophic conditions from oligotrophy to eutrophy.

Very often the TRIX values in the different areas are, in general, included between 2 and 8.

Trophic Index TRIX.

TROPHIC INDEX=TRIX

TROPHIC INDEX=TRIX=(Log[Cha*D%O*N*P]+1.5])/1.2

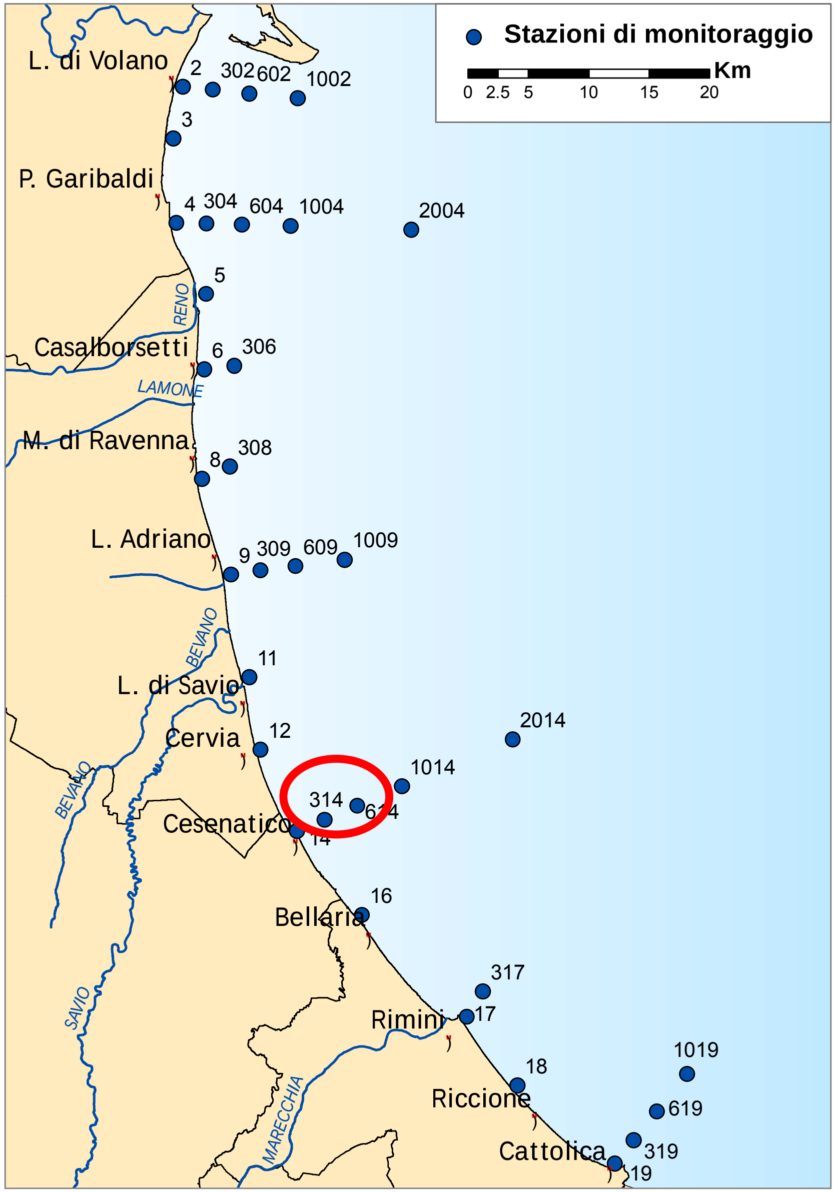
These parameters were selected as usable component of trophic index

a) **factors that are direct expression of productivity :**
   - ***ChA*** = chlorophyll *a* concentration, as *μg/L;*
   - ***aD%O*** = Oxygen as *absolute % deviation from saturation;*

b) **nutritional factors:**
   - ***DIN*** =mineral nitrogen: *dissolved inorganic nitrogen = N-*$(NO_3+NO_2+NH_4)$, as *μg/L;*
   - ***PT*** = total phosphorus, as *μg/L.*

The parameters ***k=1.5*** and ***m=1.2***, are scale coefficients, introduced to fix the lower limit value of the Index and the extension of the related Trophic Scale, from 0 to 10 TRIX units.

For the development of the proposed trophic index, data collected between 1982 and 1993 along Emilia-Romagna coast have been used as Reference; in particular data which refers to a special study at a fixed Station 3 km offshore of Cesenatico, where from June 1986 to October 1987 almost daily samples were taken.



Station 3 km offshore of Cesenatico
from June 1986 to October 1987

Parameter	Unit of measure	mean	STD	Max	Min	Geom. mean
pH		8.4	0.1	8.8	8	8.4
Temperatur	°C	18.0	6.9	27.1	3.8	16.2
Salinity	psu	32.5	2.9	37.4	16.2	32.4
% O_2		105.1	18.1	176.9	20.6	103.5
D%O	Abs.	13.1	13.5	79.4	0.0	
Chl.	µg/l	11.3	21.9	194.1	0.4	5.4
N-NO_3	µg/l	267.2	480.	4600.	0.1	138.5
N-NO_2	µg/l	11.2	17	215.0	0.1	5.7
N-NH_3	µg/l	22.1	25.1	220.0	0.1	12.4
DIN	µg/l	300.5	497.	4776.	6.1	174.1
P-tot	µg/l	20.8	10.5	60.0	2.0	18.1
P-PO_4	µg/l	5.6	4.8	34.0	0.1	2.9
Trasparenc	m	3.5	1.7	8.3	0.4	-
Po river	m^3/sec	1280	680	4750	530	1150

DESIGN OF A TROPHIC SCALE FOR MARINE WATERS

There are various modalities of contriving indices to characterize a phenomenon either qualitatively or quantitatively.

The conditions that pertain to all valid indices are:

1. relevance of the index components for identifying the phenomenon in a meaningful way

2. Limitation of validity within a specified numerical range definited by boundaries values

DESIGN OF A TROPHIC SCALE FOR MARINE WATERS

One of the simplest way to devise a numerical index is to express its component values X_i as a fraction of the specified validity range, i.e.:

$$X_i = (M_i - L_i)/(U_i - L_i)$$

M_i = measured value
L_i = Lower limit
U_i = Upper limit

M_i = 5
L_i = 2
U_i = 8

$$\frac{5-2}{8-2} = \frac{3}{6} = 0.5$$

M_i = 50
L_i = 20
U_i = 80

$$\frac{50-20}{80-20} = \frac{30}{60} = 0.5$$

DESIGN OF A TROPHIC SCALE FOR MARINE WATERS

One of the simplest way to devise a numerical index is to express its component values X_i as a fraction of the specified validity range, i.e.:

$$X_i = (M_i - L_i)/(U_i - L_i)$$

M_i = measured value
L_i = Lower limit
U_i = Upper limit

if $M_i = L_i$ $\quad X_i = 0$

$M_i = 5$
$L_i = 5$
$U_i = 8$

$$\frac{5-5}{8-5} = \frac{0}{3} = 0$$

DESIGN OF A TROPHIC SCALE FOR MARINE WATERS

One of the simplest way to devise a numerical index is to express its component values X_i as a fraction of the specified validity range, i.e.:

$$X_i = (M_i - L_i)/(U_i - L_i)$$

→ **0 - 1**

M_i = measured value
L_i = Lower limit
U_i = Upper limit

if $M_i = U_i \quad X_i = 1$

$M_i = 5$
$L_i = 2$
$U_i = 5$

$$\frac{5-2}{5-2} = \frac{3}{3} = 1$$

A composite index derived from more than one component parameter say (*n*) can be expressed either as sum or as average of the partial X*i* each one with its own upper and lower limits U and L, that make up the total index, i.e.

Parameter	Unit of measure
% O_2	
Chl.	µg/l
DIN	µg/l
P-tot	µg/l

$$X_c = 1/n \sum_{1}^{i=n} [(M-L)/(U-L)]_i$$

$$X_c = 1/n \sum_{1}^{i=n} [(M - L)/(U - L)]_i$$

If one wishes to express an index differentiated by degrees (0,1,2,3**….k**) rather than as fraction between 0- 1, the value ***1/n*** in the above equation is replaced by ***k/n***

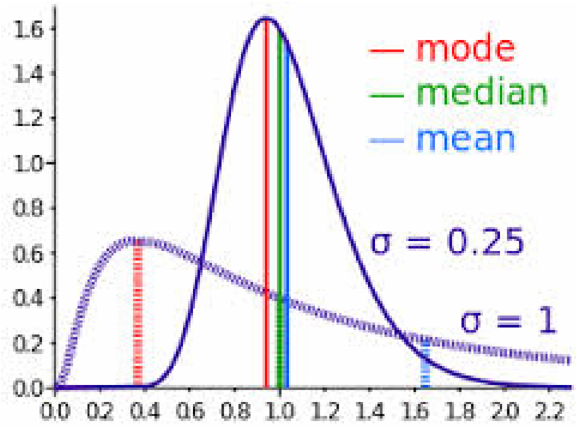
K = number of degrees

$$X_c = k/n \sum_{1}^{i=n} [(M - L)/(U - L)]_i$$

➢ For the definition of the upper limits one can use either MEAN +/- 2.5 STD or any other boundary.
In any case, it's desirable to exclude extreme values that occur rarely.

Standard Deviation:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

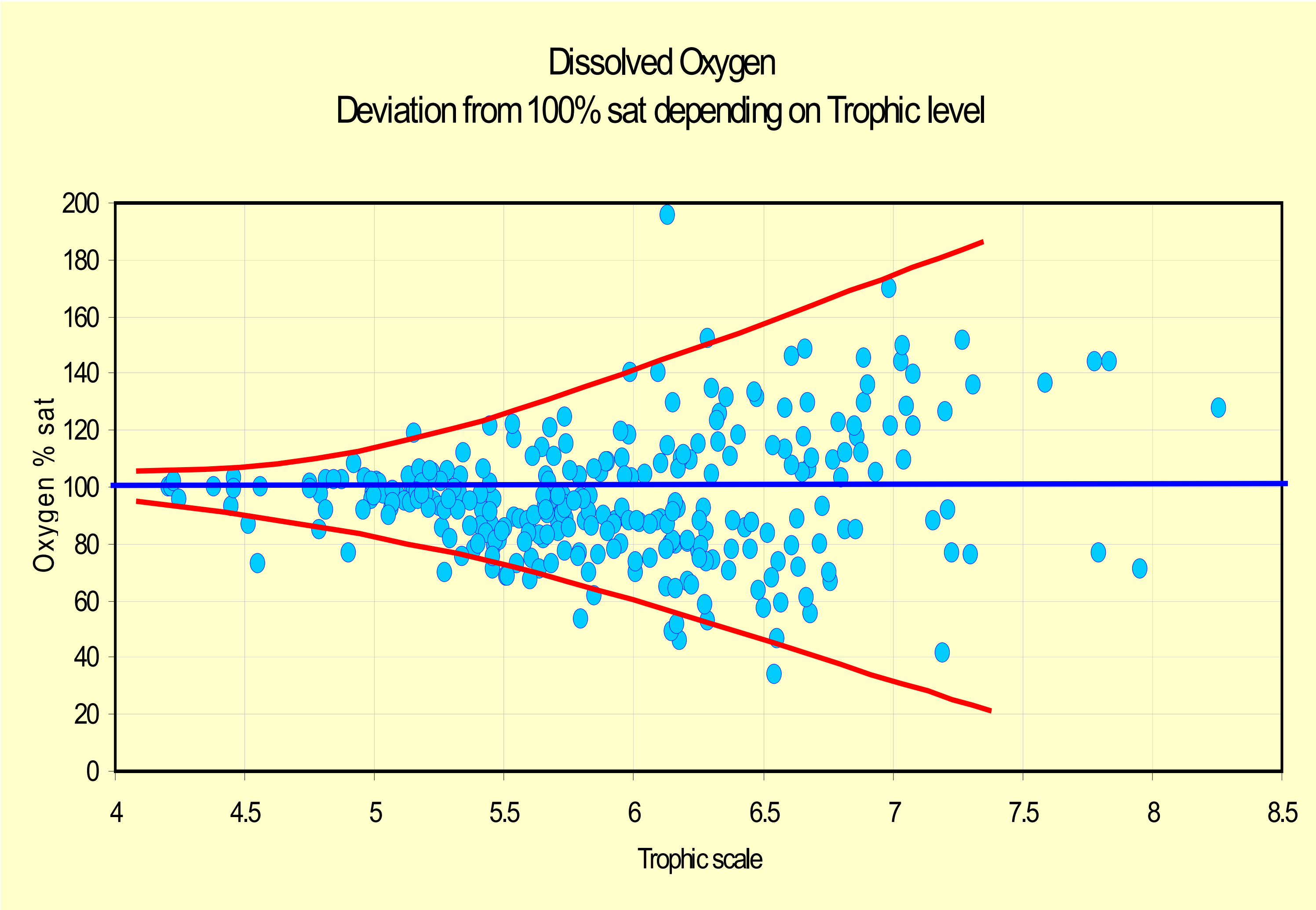


Simple log transformation approximates normal distribution for most parameters of interest.
Accordingly using logarithms ($\log_{10}$) rather than untransformed values, the basic structure of the TRIX reads:

$$Xc = k/n \boxed{\sum_{1}^{i=n}} [(\log M - \log L)/(\log U - \log L)]_i$$

	Sample size	N° of transe	Trix mean	STD	Pooled STD
Tuscany	1179	23	4.17	0.964	0.870
Emilia-Romagna	630	7	5.44	0.967	0.881

For management purposes, it is very important to identify critical areas, affected by heavy nutrient loadings coming from the continent (river discharges or local urban discharges) and compare these coastal areas with other reference areas, not affected by nutrients inputs.



Productive systems show noticeable variation in oxygen saturation low productive systems normally do not. Hence a D%O can be taken as an indicator for the production intensity of the system, encompassing both phases of active photosynthesis and phases of prevailing respiration

Limits and Ranges	Min log units	Max log units	Range log units U-L	Step Range/ 10
1 Chlorophyll "a"	- 0.5	2.5	3	
2 D%O-Saturation abs[100-%OD]	-1	2.0	3	0.3
3 DIN	0.5	3.5	3	0.3
4 PT	- 0.5	2.5	3	0.3
Sum of logs	- 1.5	10.5	12	1.2

Log U - Log L = 3

To simplify calculation, the ranges (log U-log L) have been standardized to 3 log units, anchoring the lower, and with this also the upper limits of validity for each parameters as listed in the table

k= scale, degrees from 0 to 10
n= num. of Parameters = 4

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$$Xc = k/n \sum_{1}^{i=n} [(\log M - \log L)/(\log U - \log L)]_i$$

Introducing these values into the equation and fixing the number of class to 10, one obtains by rearranging

$$\frac{10}{4}\left[\left(\frac{LogCha-(-0.5)}{3}\right)+\left(\frac{LogD\%O-(-1)}{3}\right)+\left(\frac{LogN-(0.5)}{3}\right)+\left(\frac{LogP-(-0.5)}{3}\right)\right]$$

$$\frac{10}{4}\left[\left(\frac{LogCha-(-0.5)}{3}\right)+\left(\frac{LogD\%O-(-1)}{3}\right)+\left(\frac{LogN-(0.5)}{3}\right)+\left(\frac{LogP-(-0.5)}{3}\right)\right]$$

$$\frac{10}{4}\left[\left(\frac{(Log(Cha*LogD\%O*LogN*LogP)-(-0.5-1+0.5-0.5))}{3}\right)\right]$$

$$\frac{10}{4}\left[\left(\frac{(Log(Cha*LogD\%O*LogN*LogP)-(-1.5))}{3}\right)\right]$$

$$\frac{10}{12}\left[\left(\frac{(Log(Cha*LogD\%O*LogN*LogP)-(-1.5))}{}\right)\right]$$

$$TRIX=*Log(Cha*D\%O*N*P)-(-1.5)/1.2$$

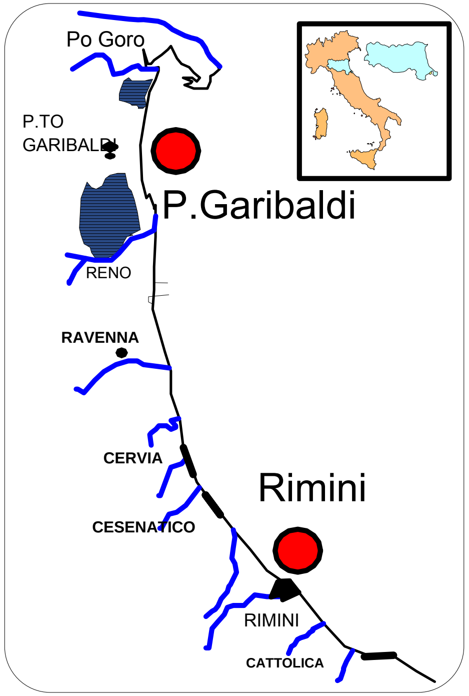
TROPHIC INDEX=TRIX=(Log[Cha*D%O*N*P]+1.5])/1.2

Reference values for TRIX means, corresponding trophic state and related coastal water quality conditions.

TRIX annual means	Trophic Status	Water quality Conditions
<4	**Elevated**	• Scarcely productive waters. • Good water transparency. • Absence of anomalous water colours. • Absence of Oxygen undersaturation in the bottom waters.
4-5	**Good**	• Moderately productive waters. • Occasionally water turbidity. • Occasionally anomalous water colors. • Occasionally bottom waters ipoxia episodes.
5-6	**Mediocre**	• Very productive waters. • Low water transparency. • Frequently anomalous waters colours. • Ipoxia and occasionally anoxia episodes in the bottom layers. • Suffering of the benthic communities.
>6	**Bad**	• Strongly productive waters. • High water turbidity. • Diffuse and persistent anomaly in the water colours. • Diffuse and persistent ipoxia/anoxia episodes in the bottom waters. • High mortality rate of benthic organisms. • Alteration of the benthic communities and strong decrease of the biodiversity

Trophic Classification 2002

Stations	Distance from coast	N. of data	TRIX	Trophic State
Porto Garibaldi	0.5 km	39	6.46	Bad
Rimini	0.5 km	39	5.30	Mediocre



Other derivated index

Efficient Coefficient

Assess the utilization level of dissolved nutrients in order to produce phytoplanktonic biomass

Efficient Coefficient

TRIX

- Log(Clax|OD%|) — indicators of **direct/real** productivity
- Log(DINxPt) — indicators of **potential** productivity

The Logarithm of the ratio Log([Clax|OD%|]/[DINxPt])
give a measure of nutrients utilization efficiency

In this coefficient is summarize the information related to capacity of production in function of available nutrients. In general presents negative values.

	Component real	Component Poten.	Coeff. di efficien.
P.Garibaldi	2.23	4.81	-1.80
Rimini	1.69	4.15	-1.48

Conclusion

The Trix represents a synthesis system of fundamentals trophic parameters with easy numerical values

The TRIX permit to synthesise key data into a simple numeric expression to make information comparable over a wide range of trophic situations, while avoiding the subjectivity in the usage of traditional trophic terminology

The management activity aimed at protecting water bodies, including coastal waters, requires appropriate tools such as TRIX index in order to classify and identify quality objectives

Conclusion

Permit the evaluation of trophic state taking into account the marine ecosystem variations on statistical base

The TRIX was originally developed for the Italian coastal waters to provide information useful for assessing eutrophic conditions and a scale of water quality has been established, compatible to the European Water Framework Directive

The TRIX has been implemented in the national legislation of Italy for the protection of water quality, D. Lgs. 152/99 and provides uniform criteria for the classification of the Italian coastal waters

The turbidity Index TRBIX

Re-elaborating data from limnological studies and using the same approach for marine-coastal environment, a simple relationships between transparency and chlorophyll under approximate conditions of optical saturation in terms of chlorophyll, has been derived as:

$$TRSP(p) = \text{from } 30\text{ m to } 35\text{ m}/(1 + ChA^{0.7})$$

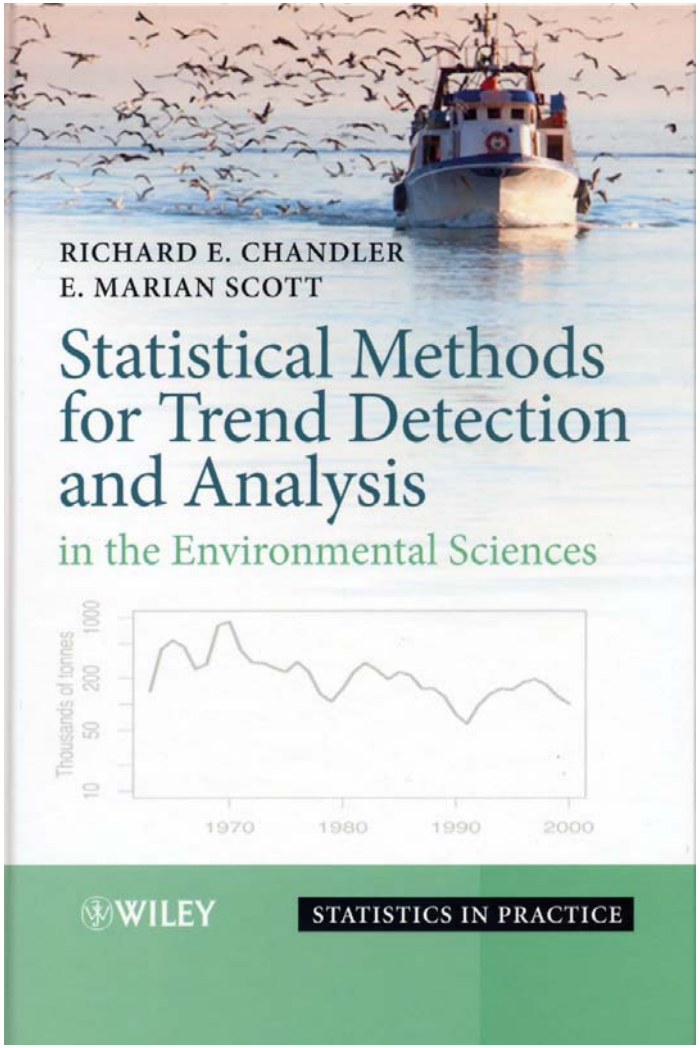
From the relationship a Turbidity/Chlorophyll ratio is defined, as the ratio between the potential (p) and the actual (a, i.e. the Secchi depth) transparency:

$$TRBR = TRSP(p)/TRSP(a)$$

and the turbidity index calculated as the log to the basis 2 of TRBR:

$$TRBIX = \log_2(TRBR).$$

The simple interpretation of this index is that waters are optically "biomass saturated" with regard chlorophyll, if TRBIX = 0 (i.e. the potential and actual transparencies are the same If TRBIX = 1, chlorophyll and other causes of turbidities would be about equal. If TRBIX = 2, chlorophyll would make out 1/4, and so on.



9

Estimation of common trends for trophic index series

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9.1 Introduction

Eutrophication – the presence of abnormally high levels of nutrients in water bodies, often caused by agricultural fertilisers leaching into lakes and coastal waters – often leads to an increase of phytoplankton in the water and to the development of nuisance phytoplanktonic blooms. This often results in discoloration and reduced transparency of the water column, and in severe cases may significantly impact the benthos. Eutrophication is a global problem and has increased considerably in the last few decades in coastal and shelf waters (Fletcher, 1996). In the most serious manifestations, microalgal blooms are accompanied by a massive growth of submersed and floating macrophytes (Vollenweider, 1968, 1981). Other undesirable effects may follow, such as reduced biodiversity and formation of toxic nutrients (H_2S, CH_4, CO_2 and NH_3). These phenomena have been observed and documented with increasing frequency, raising concerns over whether the monitoring of such events is adequate and whether current practice affords a sufficient sampling frequency to manage and protect coastal function effectively.

Statistical Methods for Trend Detection and Analysis in the Environmental Sciences, First Edition.
Richard E. Chandler and E. Marian Scott.

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

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5th June 2013 Wednesday **Constanta, Romania**