Eukaryotic picophytoplankton and eutrophication

André VAQUER
UMR 5119 - CNRS/ UMII
Ecologie du Plancton

Biological characteristics of picophytoplankton

Essentially related to small size

High Surface-to-Volume ratio (S/V)
Non scalable components fraction
Reduced machinery
Storage capacity
Thickness wall

Picophytoplankton size

Tab. 1. Classification of plankton of microscopic and submicroscopic size (From Sicko-Goad & Stoermer 1984, modified).

Terminology	Size	References
Net plankton	>45 µm	Throndsen 1978
	>64 µm	Vollenweider *et al.* 1974, Ross & Duthie 1981
Microplankton	20 - 200 µm	Dussart 1965, Sieburth *et al.* 1978
	50 – 500 µm	Margalef 1955
	60 - 500 µm	Hutchinson 1967
Nanoplankton	2 - 20 µm	Dussart 1965, Sieburth *et al.* 1978
	5 – 50 µm	Margalef 1955
	5 - 60 µm	Hutchinson 1967
	<45 µm	Throndsen 1978
	<100 µm	Rodhe 1958
	<64 µm	Vollenweider *et al.* 1974
	15 - 64 µm	Ross & Duthie 1981
Ultrananoplankton	<2 µm	Dussart 1966
Ultraplankton	<5 µm	Margalef 1955
	0.5 – 5 µm	Hutchinson 1967
	1 - 10 µm	Throndsen 1978
	1 – 15 µm	Reynolds 1973
	<15 µm	Ross & Duthie 1981
Picoplankton	0.2 – 2 µm	Sieburth *et al.* 1978
Femtoplankton	0.02 0.2	Sieburth *et al.* 1978

Since 1990's

Picoplankton <3µm

Iriarte & Purdie, 1994
Ochs & Rhew, 1997
Hung et al., 1999
Jacquet et al., 1998

Sizes of picoeukaryotes in mediterranean coastal lagoons

<3 µm

Eukaryotes : 84% picophytoplankton

<1µm : 16%

1 - 2µm : 25%

2 - 3µm : 59%

<2 µm

Eukaryotes : 43% picophytoplankton

<1µm : 37%

1 - 2µm : 63%

Picoprokaryotes size < 1µm

Effects of small size

Process		Smaller vs larger cells
Influx/efflux	Resource acquisition	better
	Loss diffusion	higher
Package effect		lower
	Absorption coefficient	better
	UV-damaging	higher
Resource use	µmax	better
Sinking rate		lower
Parasistism		lower
Viral lysis		=
Grazing		=

Non scalable components

Genome

Membranes (plasmalemma, plastid envelop)

Increasing fraction with deceasing size

Decreasing µmax related to decreasing scalable components (e.g. scalable catalysts)

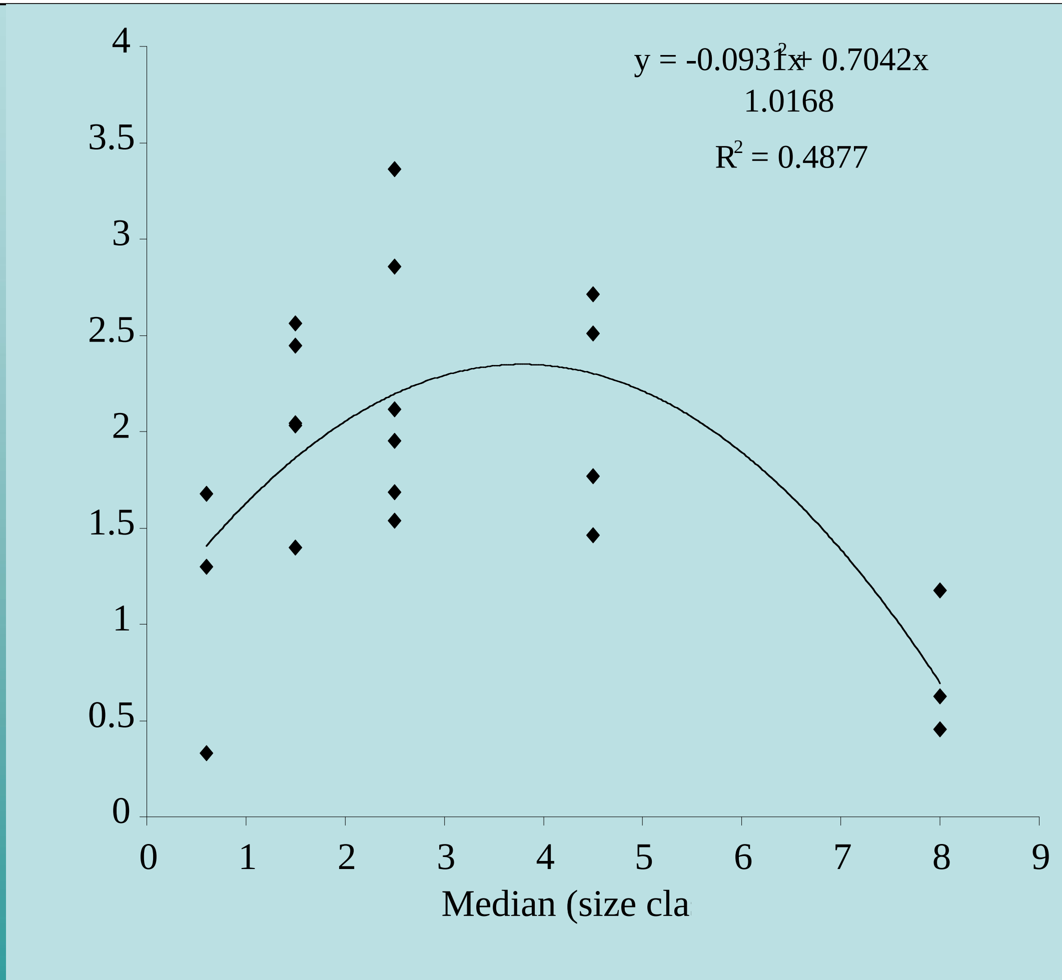
Lower catalyst activity lower material or energy conversion per biomass unit

Lower light harvesting material

Trend for increasing in µmax with decreasing size is reversed below ~2µm for eukaryotes and ~0.9µm for prokaryotes

Raven, 1994

Reversal of the relationship between cell size and growth rate in small size classes of marine picoeukaryotes



B.Bec[1], Y.Collos[1*], A.Vaquer[1], D.Mouillot[1], P.Souchu[2] (in prep.)
[1]UMR CNRS 5119 -UMII, [2]Lab. Ecologie DEL IFREMER-Sète

Abundance, biomass and production of picophytoplankton (PPP)

Picophytoplankton present in marine and freshwater ecosystems

Generally maximum development in summer

Picoprokaryotes dominant in marine and freshwater ecosystems

Because of their larger size Picoeukaryotes biomass > picoprokaryotes biomass

Abundance, biomass and production of PPP increase with increasing total phytoplankton biomass and production

Abundance and biomass of freshwater and marine picophytoplankton (PPP) in systems of increasing trophic status

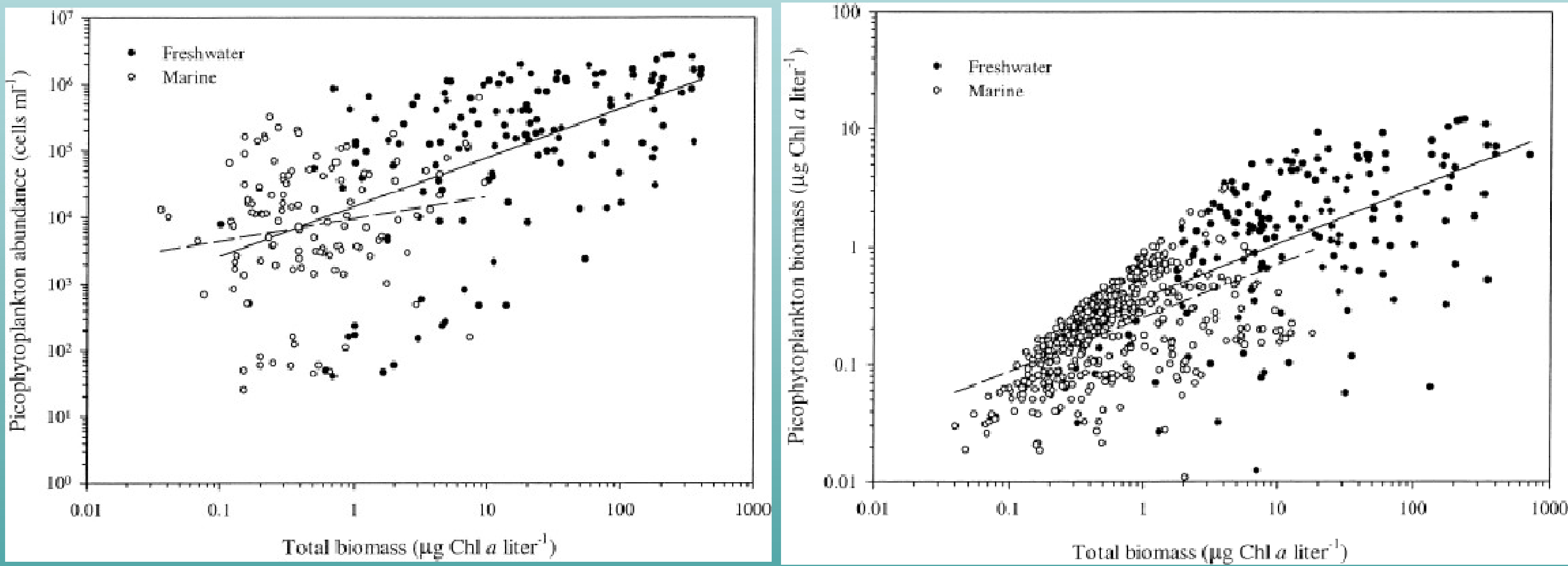
Abundance, Biomass and production of PPP increase with increasing trophic status, nutrient charge (N,P)
Relative contribution decrease with increasing trophic status

Eukaryote abundance 2-3 order of magnitude lower than prokaryote abundance
Along a gradient of increasing nutrients Picoeukaryotes replace progressively prokaryotes

In oligotrophic lakes and central part of oceans, PPP is the dominant fraction of phytoplankton community.

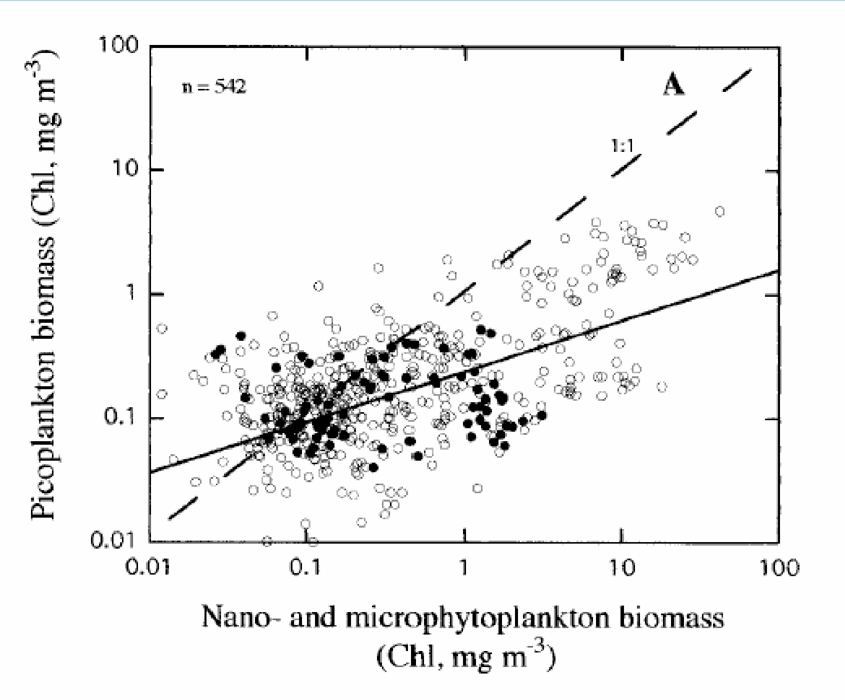
Reviews by Weisse, 1993 - Bell et al, 2001 - Agawin et al, 2000 - Callieri et al, 2002

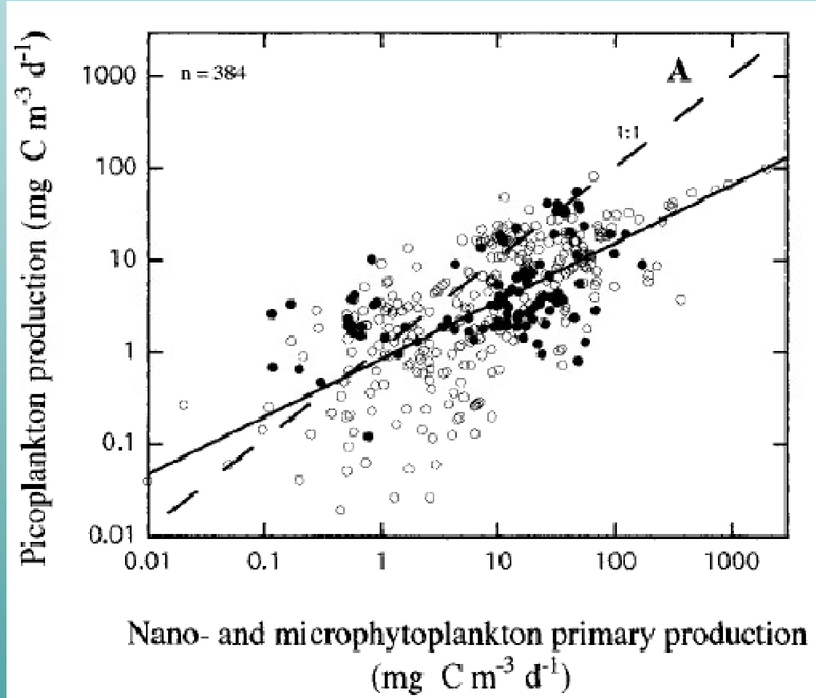
Abundance and biomass of freshwater and marine picophytoplankton in systems of increasing trophic status



Bell & Kalff, 2001

Picoplankton versus nano- and microphytoplankton biomass and production



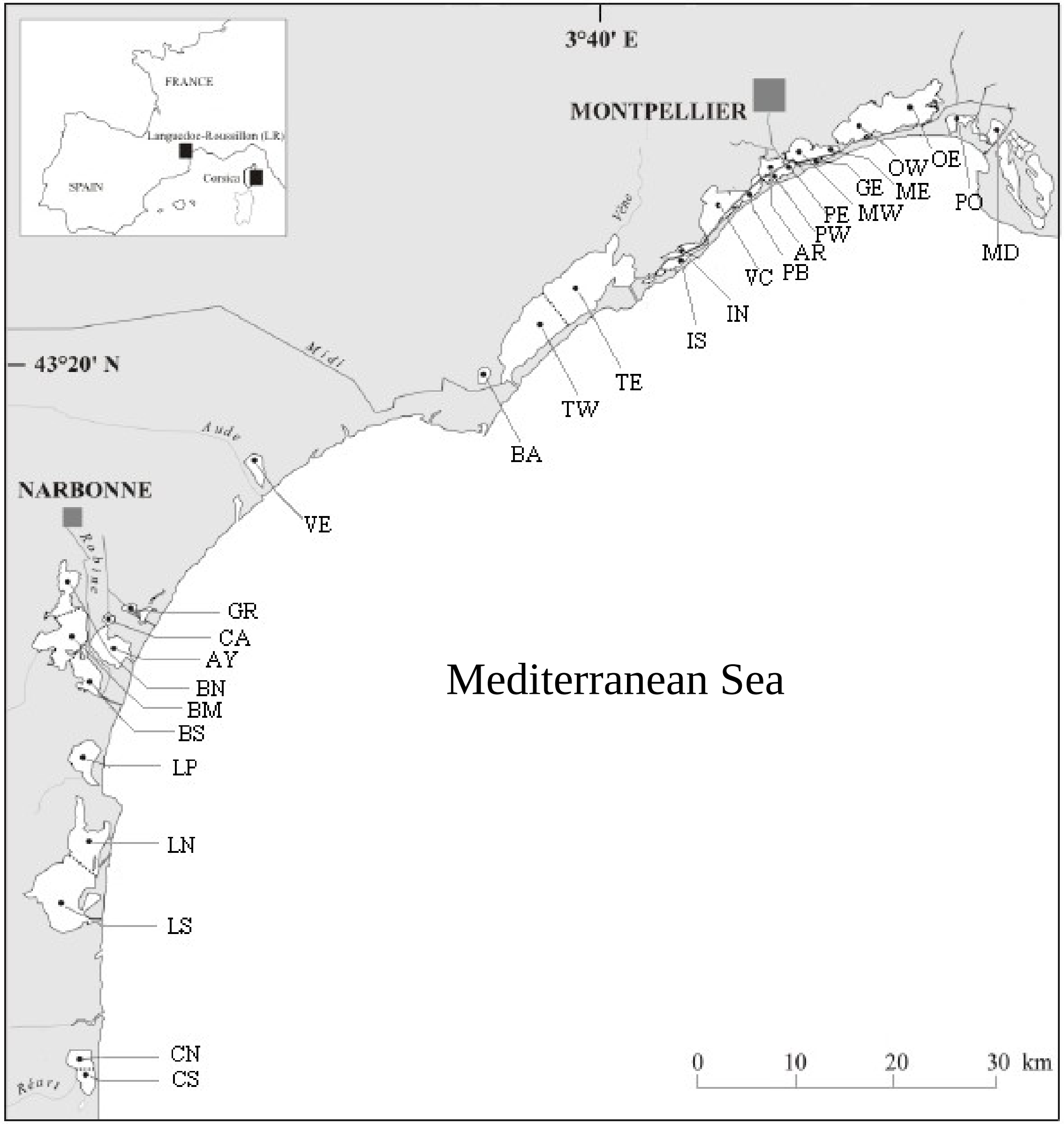


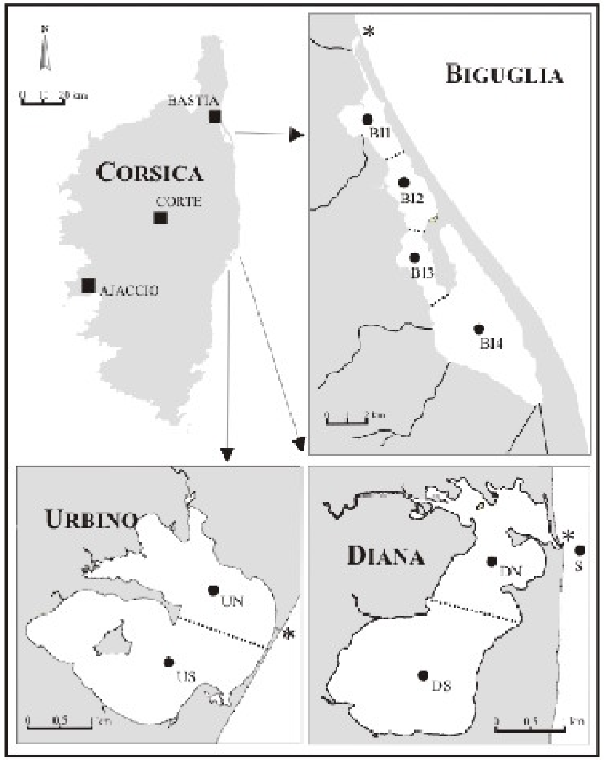
Agawin et al., 2000

Range of abundance of picoeukaryotes in marine (M) and freshwater (FW) ecosystems

Oligotrophic waters 10^6 - 10^7 cells l^{-1}	Fahnenstiel et al 1991 Vanucci et al 1998 Jacquet et al 1998 Gregori et al 2001	FW M M M
Mesotrophic waters 10^7 - 10^8 cells l^{-1}	Sondergaard 1991 Courties et al 1994 Vaquer et al 1996 Worden et al 2004 Larsen et al 2004 Not et al 2004	FW L L M M M
Eutrophic waters 10^8 - 10^9 cells l^{-1}	Sorokin et al 1996 Szelaz-Wesielewska 1997 Hepperle et al 2001 Gobler et al 2002 Kelly et al 2003	L FW FW M M

Coastal lagoons in South of France and Corsica





Mean depth (m)

0,35 (Canet) - 6 (Diana)

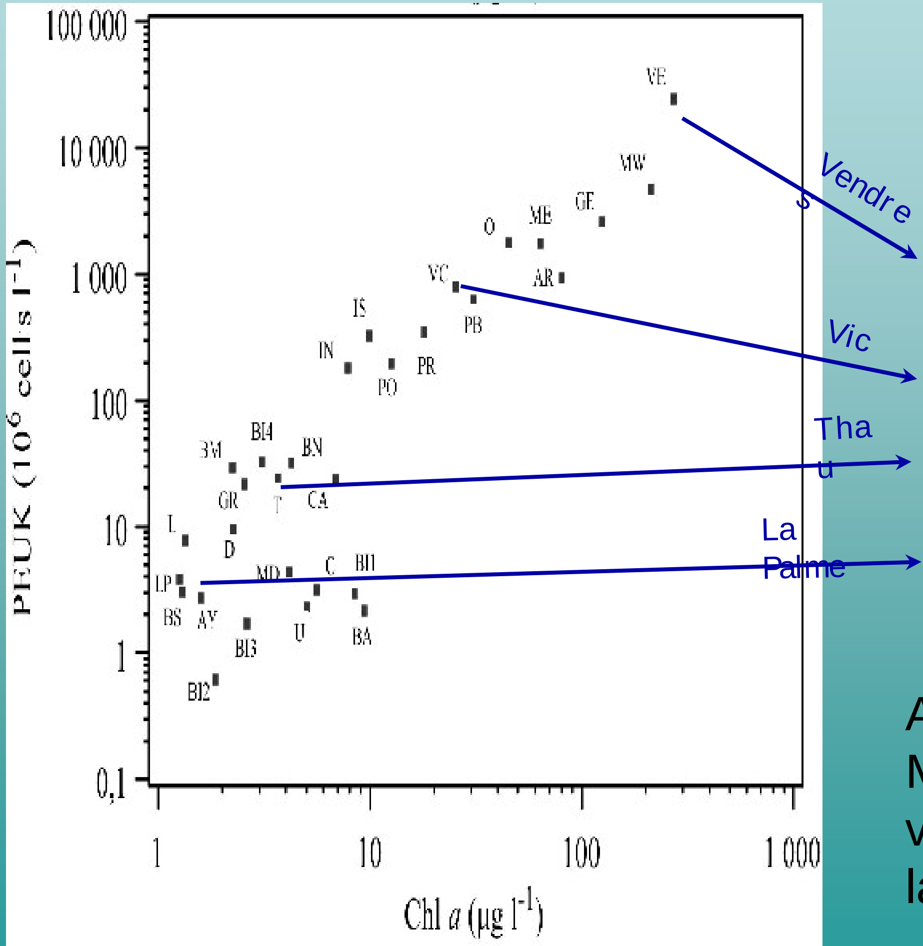
Surface (km²)

1,1 (Campignol) - 75 (Thau)

Volume (x 10^6 m³)

0,5 (Campignol) à 260 (Thau)

Picophytoplankton and gradient of eutrophication in coastal lagoon ecosystems



Range of abundance of picoeukaryotes in summer:

$7,8 \times 10^{9}$ - $6,4 \times 10^{10}$ cellules L^{-1}

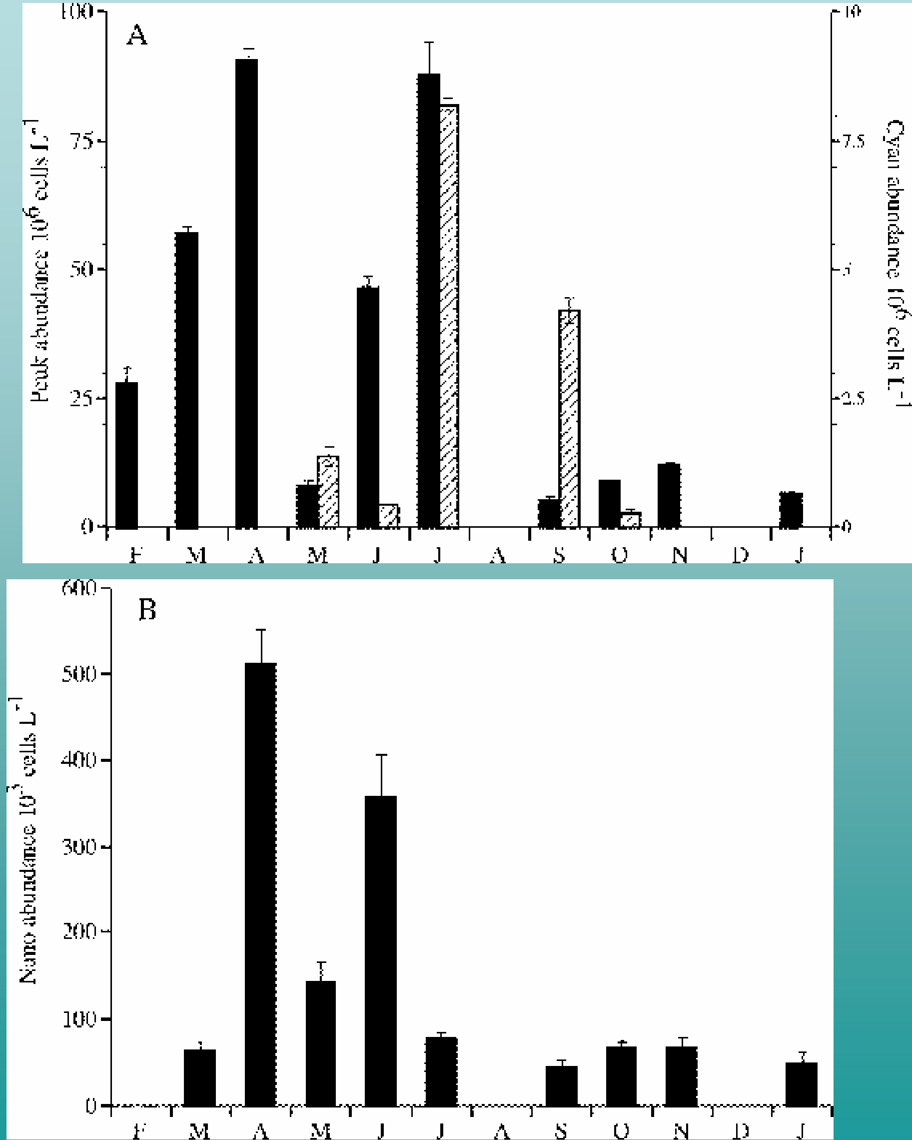
$5,5 \times 10^{7}$ - $3,2 \times 10^{9}$ cellules L^{-1}

$2,5 \times 10^{6}$ - $1,3 \times 10^{8}$ cellules L^{-1}

$1,3 \times 10^{6}$ - $4,2 \times 10^{7}$ cellules L^{-1}

Abundance range from values observed in Mediterranean coastal waters (min) to values observed in eutrophic/dystrophic lakes (max)

Abundance of picophytoplankton in Thau Lagoon



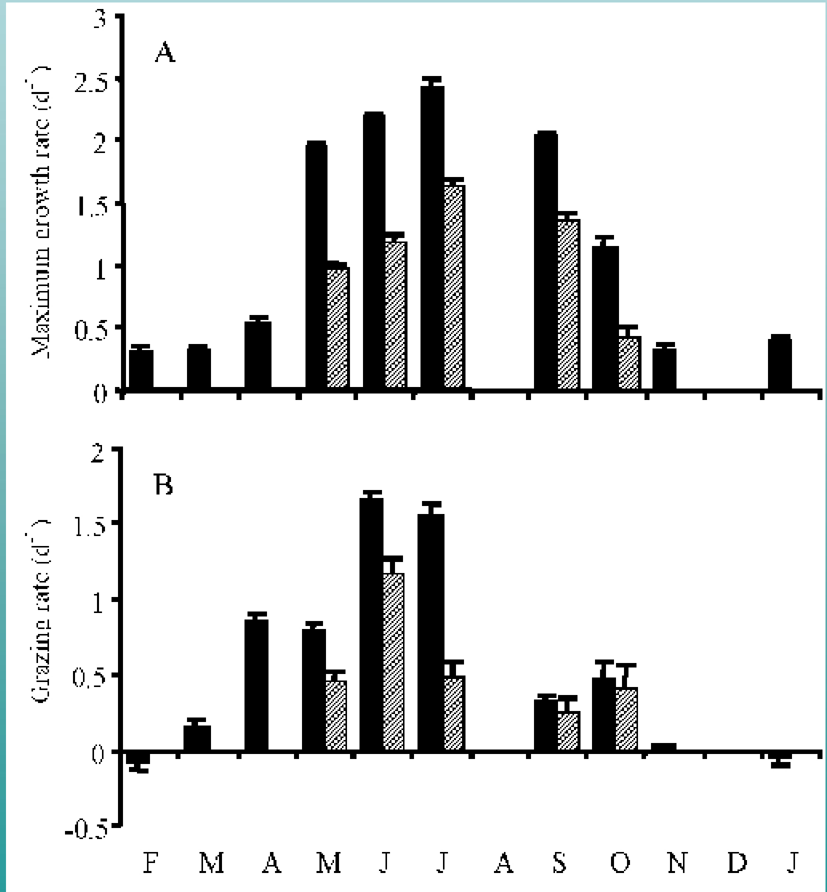
Annual cycle : 02/99 - 01/00

Picoeukaryotes : 5,2 x 10^6 to 90,8 x 10^6 cells L^{-1}

Picoeukaryotes : 55% to 100% of total picophytoplankton

Bec et al., J. Plankton Res.

Growth and grazing rates of picophytoplankton in Thau Lagoon



- Picoeukaryotes

μ_{max} = 0,31 à 2,44 j^{-1}

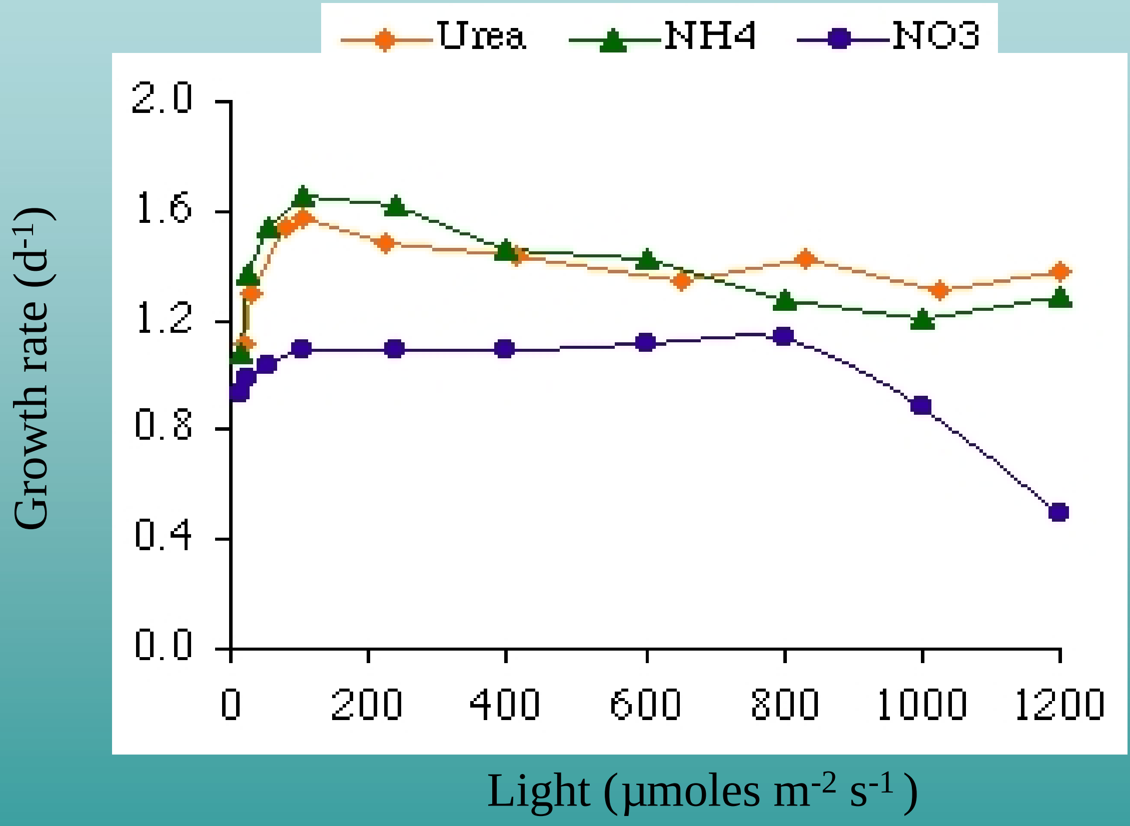
T° $r^2 = 0,88$, $p<0,0001$

Irr. $r^2 = 0,55$, $p<0,05$

Grazing rate lower than growth rate

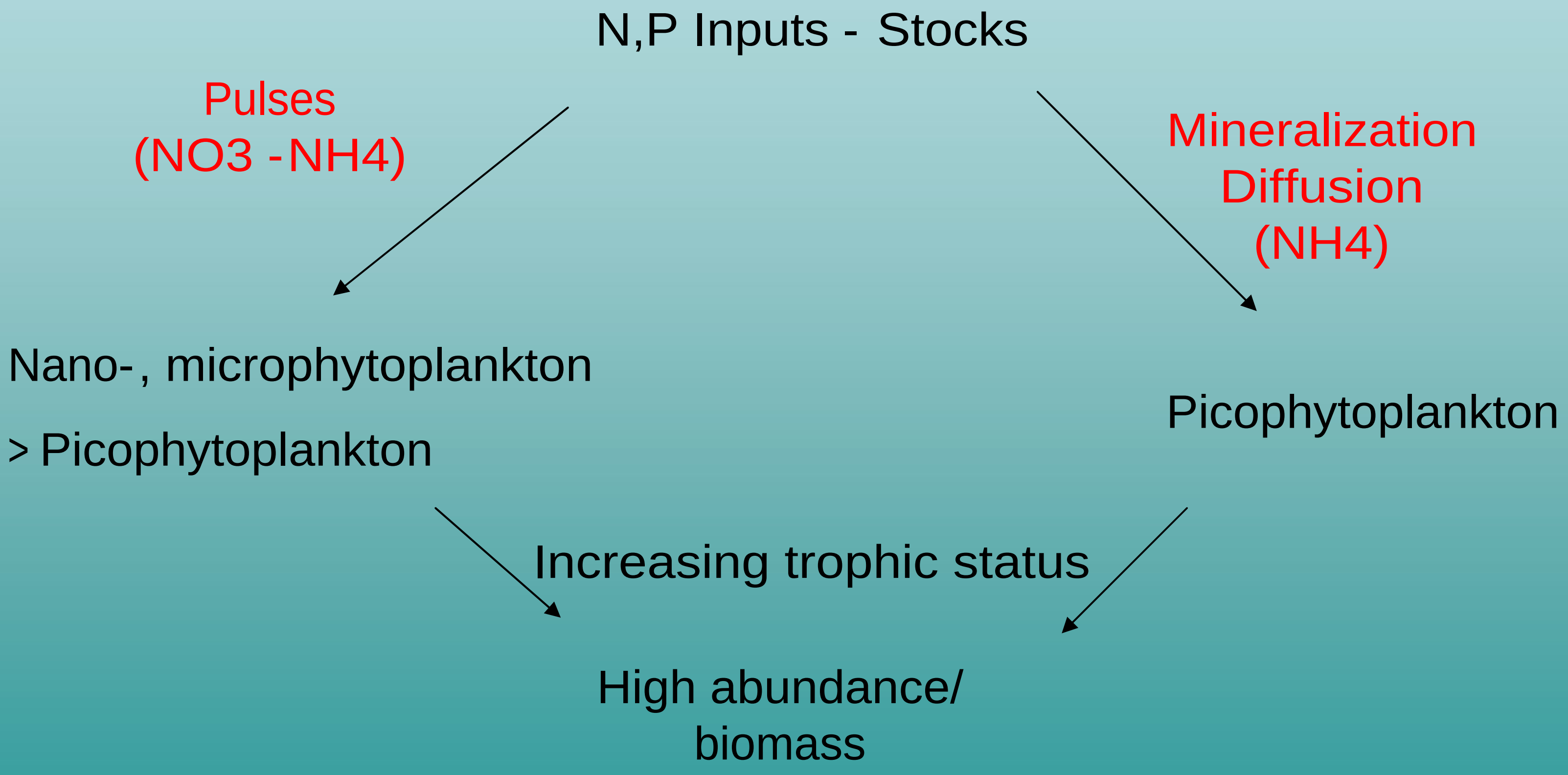
Bec et al., J. Plankton Res.

Growth of Ostreococcus tauri under different nitrogen supplies and light intensities



B. Bec et al, Gordon Conference, Roscoff 2004
Ecosystèmes Lagunaires (UMR CNRS 5119 -UMII),

Nutrients gradient and growth of phytoplankton



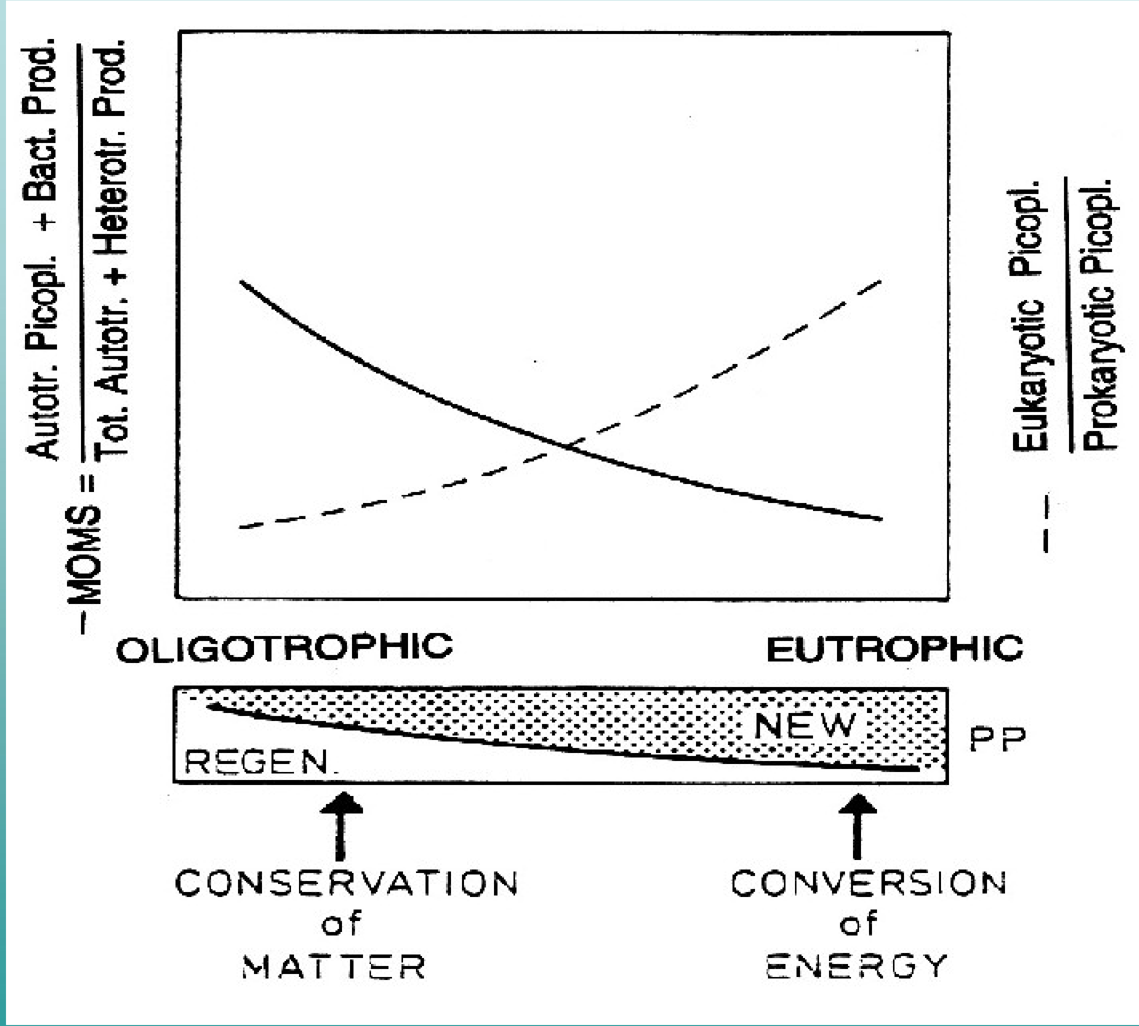
Abiotic factors

Morphometry (and depth) influences phytoplancton structure, sinking rates and suspension of microphytobenthos in related to turbulences

No limiting light : self-shading and turbulences inducing vertical displacement and turbidity (frequent winds) in shallow waters

Temperature supports development of PPP (maximum in summer) and grazing losses

Eukaryotic versus prokaryotic in gradient of eutrophication



Weisse, 1993

Conclusions

PPP : important component in aquatic ecosystems, specially in oligotrophic and mesotrophic waters

Abondant litterature relative to autotrophic picoplankton, frequent use of fractionated biomass indice (such as Chlorophyll) and no differentiation between picophytoplanktonic groups

Recent studies point to the same general trends in the responses of total autotrophic picoplankton related to eutrophication.

In most ecological studies less attention is focused on picoeukaryotes because of their lower abundances related to prokaryote abundances

Studies (in extension) of specific diversity of eukaryotes will ameliorate the understanding of aquatic ecosystem functioning under different trophic status.