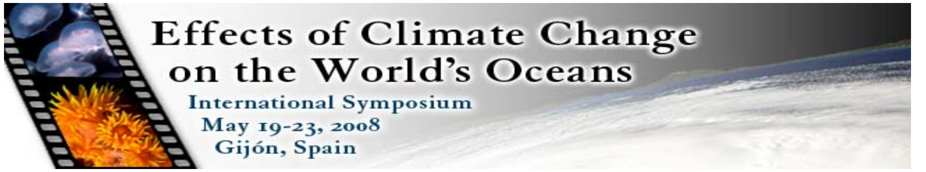


# Functional indicators monitoring ecological status and vulnerability of marine macroalgae to climate change

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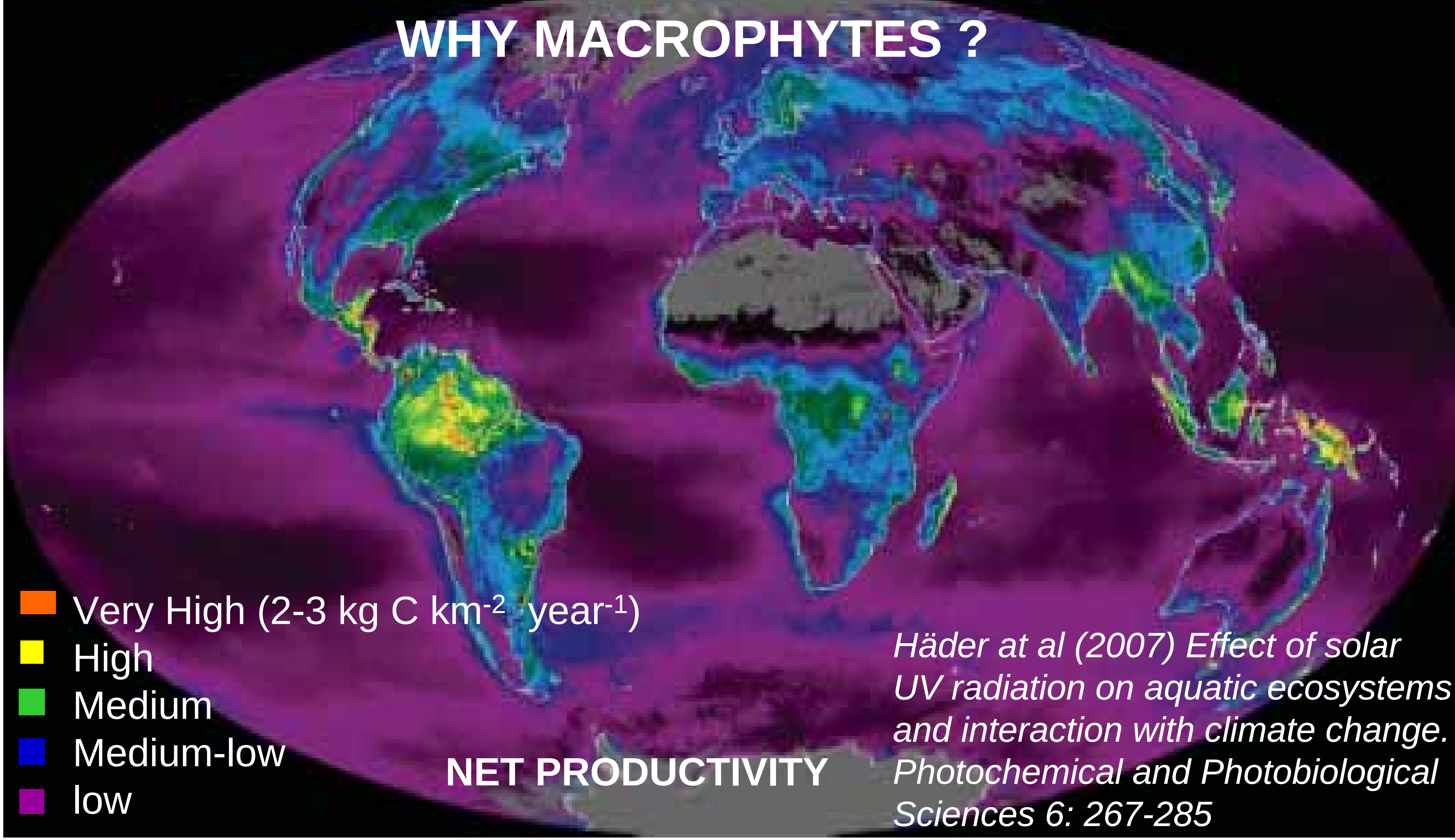
# WHY MACROPHYTES ?




*Häder at al (2007) Effect of solar UV radiation on aquatic ecosystems and interaction with climate change. Photochemical and Photobiological Sciences 6: 267-285*

Fig. 1 This false-color map represents the Earth's carbon "metabolism"—the rate at which plants absorbed carbon out of the atmosphere during the years 2001 and 2002. The map shows the global, annual average of the net productivity of vegetation on land and in the ocean. The yellow and red areas show the highest rates, ranging from 2 to 3 kg of carbon taken in per km² per year. The green areas are intermediate rates, while blue and purple shades show progressively lower productivity. In any given year, tropical rainforests are generally the most productive places on Earth. Still, the ongoing productivity near the sea's surface, over such a widespread area of the globe, makes the ocean more productive than the land. (Image courtesy of NASA, 2003).

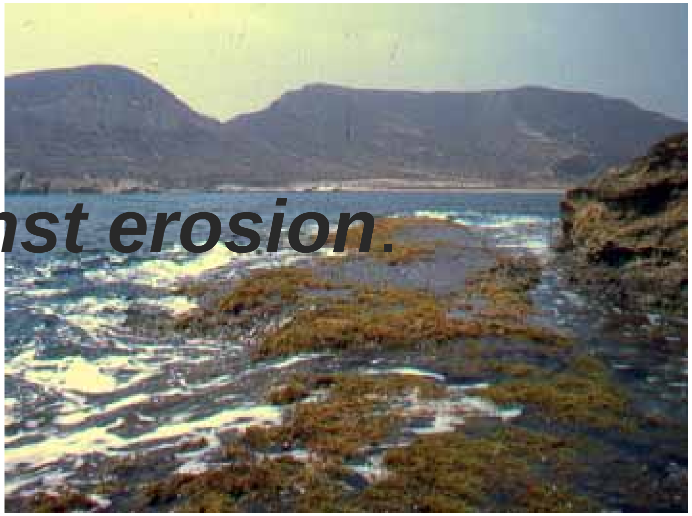
# 1. CLIMATE CHANGE

-High contribution in the ***aquatic global carbon upake*** in coastal area is due to macrophytes (10%) : high diversity of carbon metabolism and physiological strategies of nutrient assimilation and store.

-***Indicators of climate variations***: temperature dependence of the growth and reproduction (Biogeographical distribution).

-***Protection*** of coastal area ***against erosion***.

-***Habitat*** *and* ***feed*** for animals.



# 2. OZONE DEPLETION

-***Photoinhibition and damage by UV-B radiation***: negative effects on DNA, proteins and lipids; reduction of carbon and nutrient assimilation, inhibition of growth and reproduction.

-***Photoprotection*** mechanisms (UV-photoprotectors, antioxidants) as indicators of acclimation to stress conditions.

# 3. INDICATORS OF ECOLOGICAL STATUS OF THE COSTAL WATERS

Abundance

Species richness

Diversity

P/B ratio

Rhodophyta/Chlorophyta ratio

Perennal/Annual species

## **Water Framework Directive** (2000/60/CE)

Evaluation of the *Ecological Status* of Coastal Waters by using *Biological indicators:* ***Macrophytes***

## **Ecophysiology Structure-Function**

***Ecological indicators***

Biodiversity, species richness

***Functional Indicators***

-Bio-optical and Chla fluorescence: Maximal quantum yield and ETR

-Stoichiometry (C:N:P)

-Stress indicators (HSP, ROS Antioxidants and proteases)

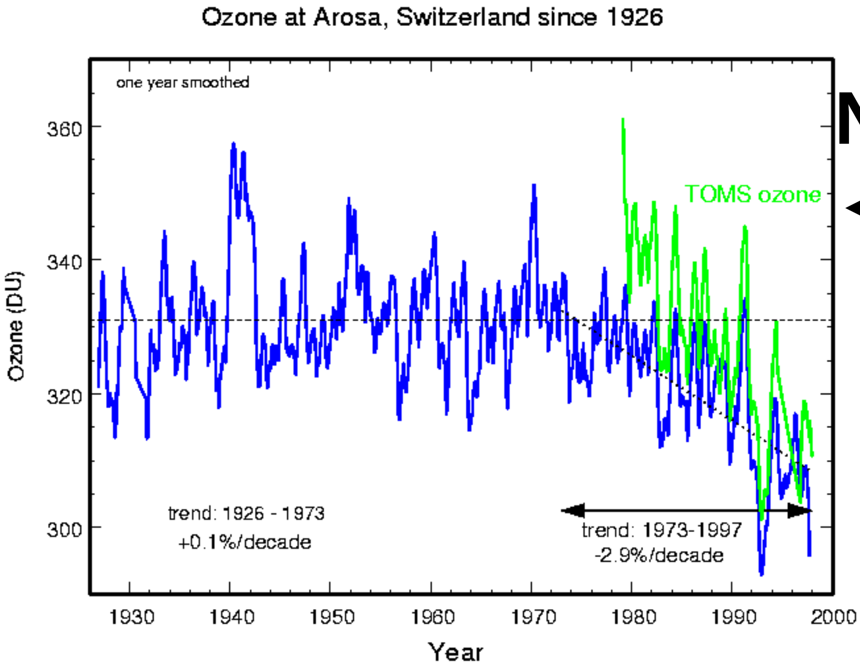
## **Climate Change** (IPCC, 2007)

-Vulnerability analysis

-$CO_2$ sinks, Primary production.

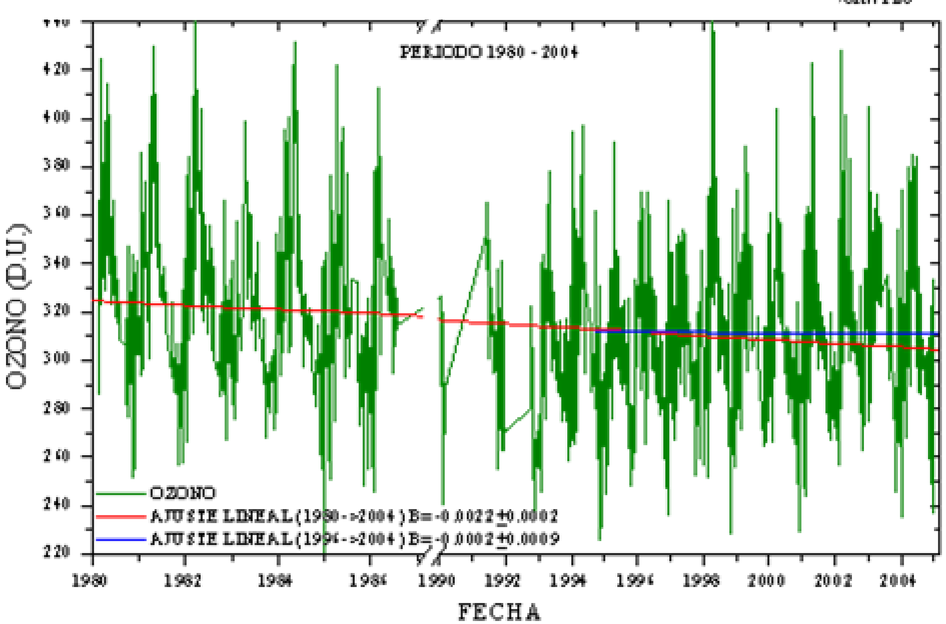
**-Interaction between CC and ozone depletion**

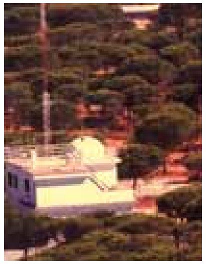
# OZONE DEPLETION IN NORTHERN MID-LATITUDES



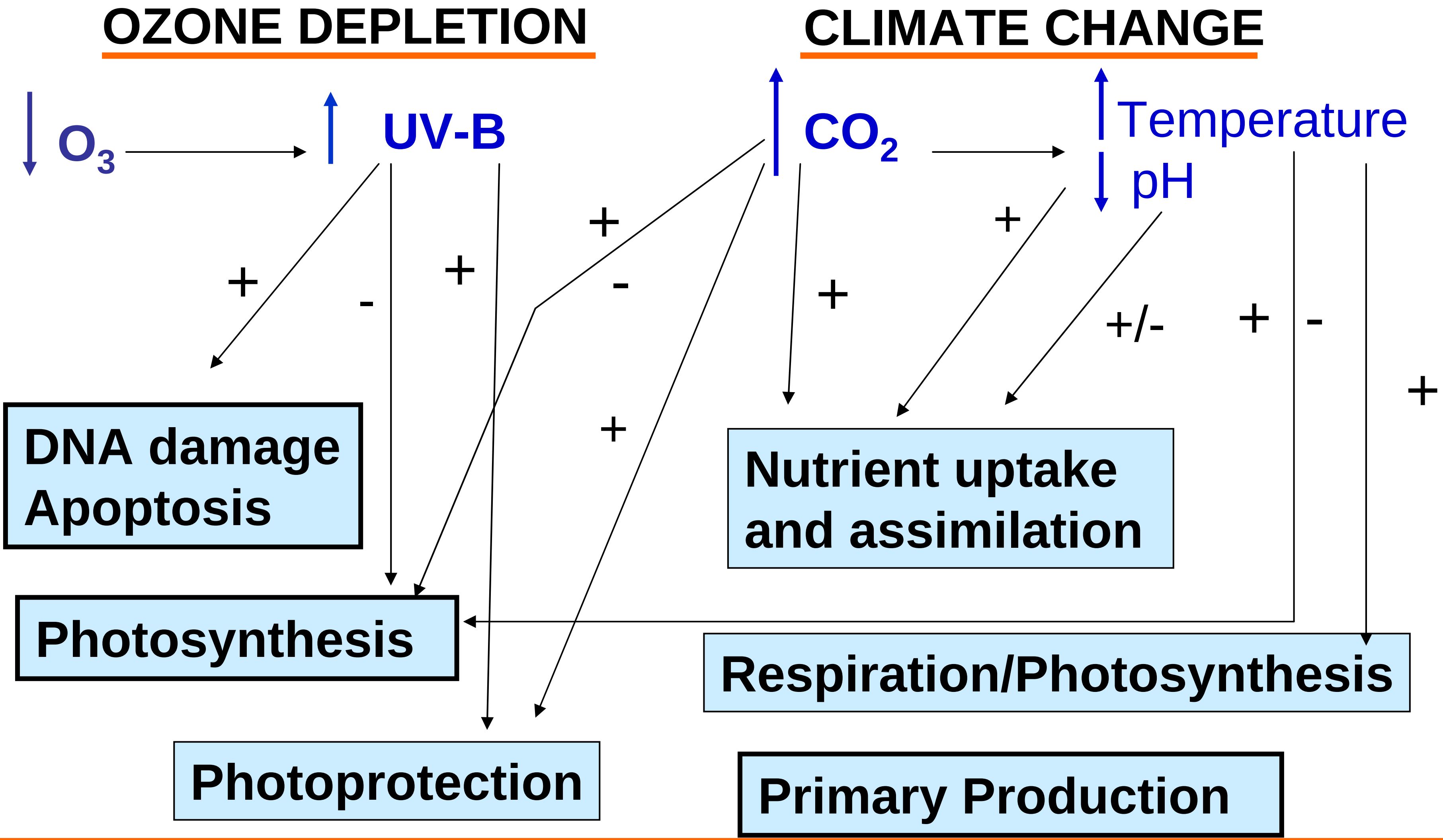

Arosa (Switzerland): 2.9% per decade

Arenosillo (Southern Spain): 2.6% per decade



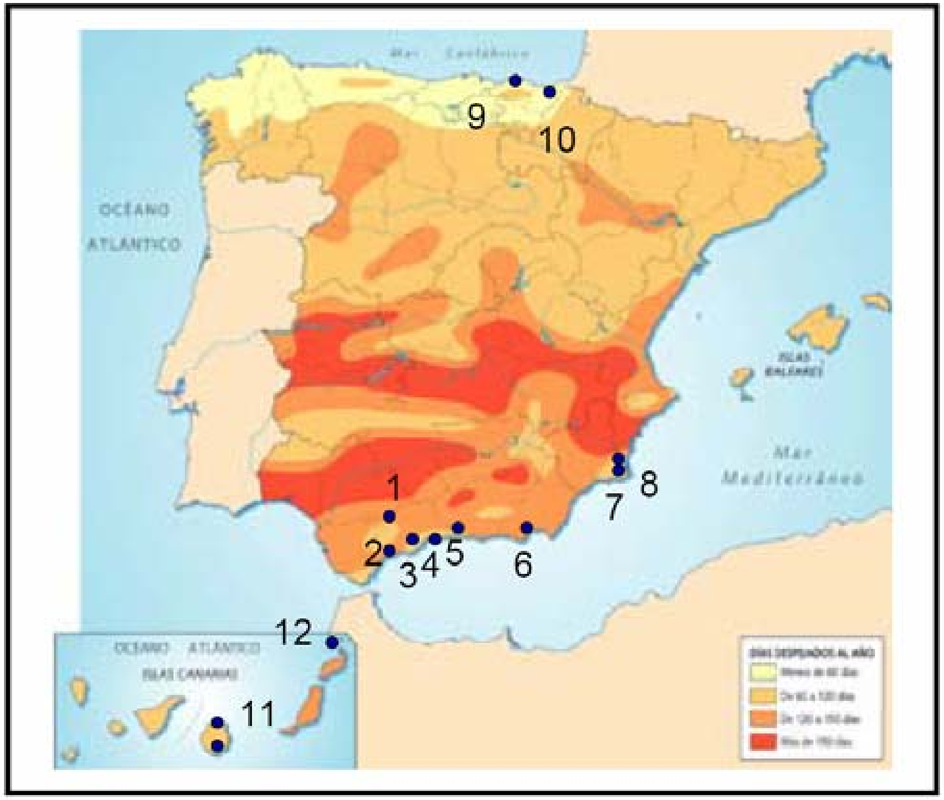



***The ozone layer will be recovered to the level of 1980 on 2070 (a delay because the cooling of stratrophere due to Climate change)***




Effect of ozone depletion and climate change on algae: Antagonistic or synergistic, depending on the species

# AREA OF STUDY: PROJECT ECOLIFE




**Subproject 1: Mediterranean**

1: Fuente de Piedra (L), 2: Punta de Calaburra (C), 3: Desembocadura del Guadalhorce (L), 4:Peñón del Cuervo (C), 5: Maro-Cerro Gordo and Torrox coast (C), 6: Cabo de Gata-Níjar (C), 7: Mar Menor (L), 8: Cabo de Palos (C)

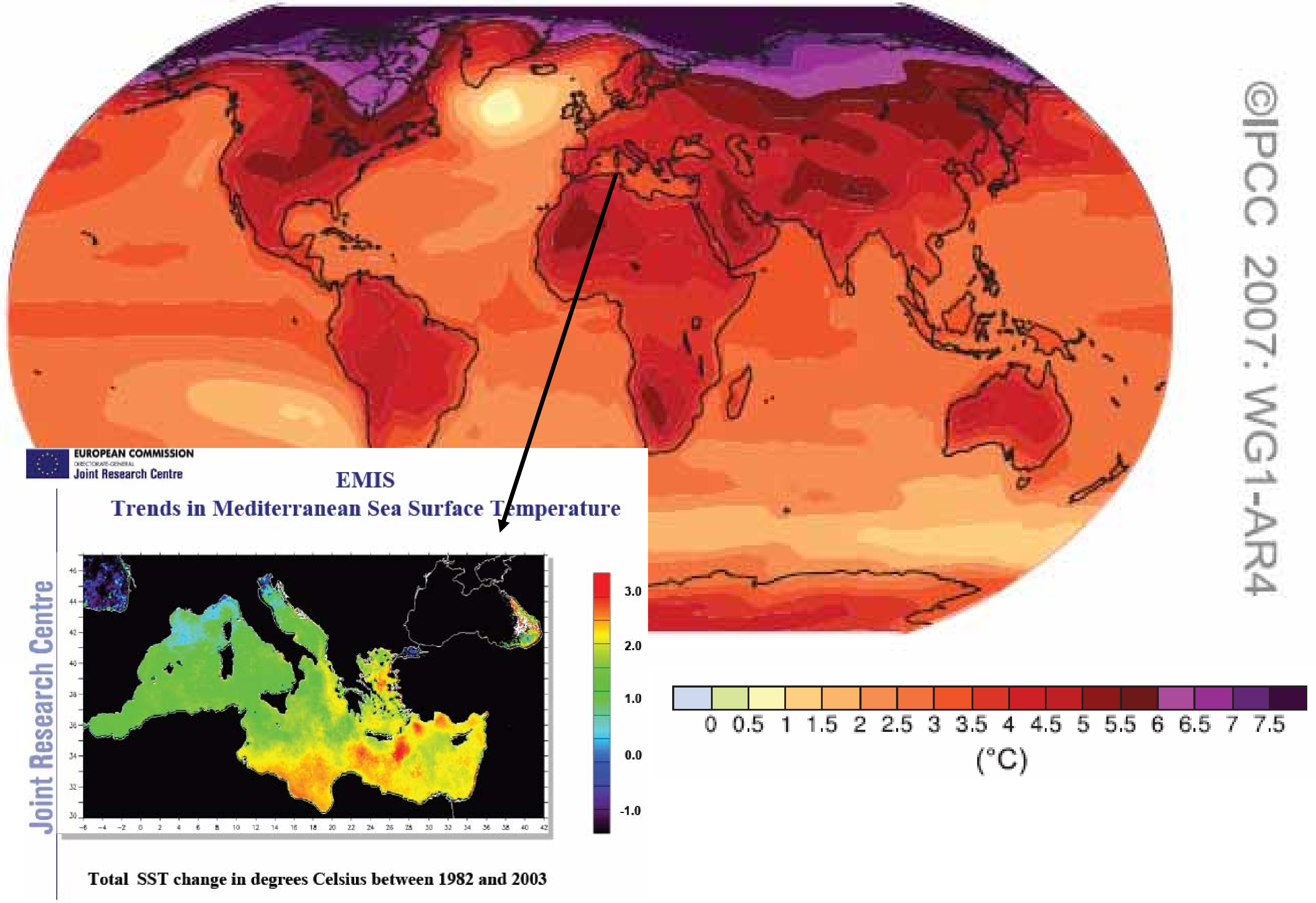
**Subproject 2: Cantabrian Sea**

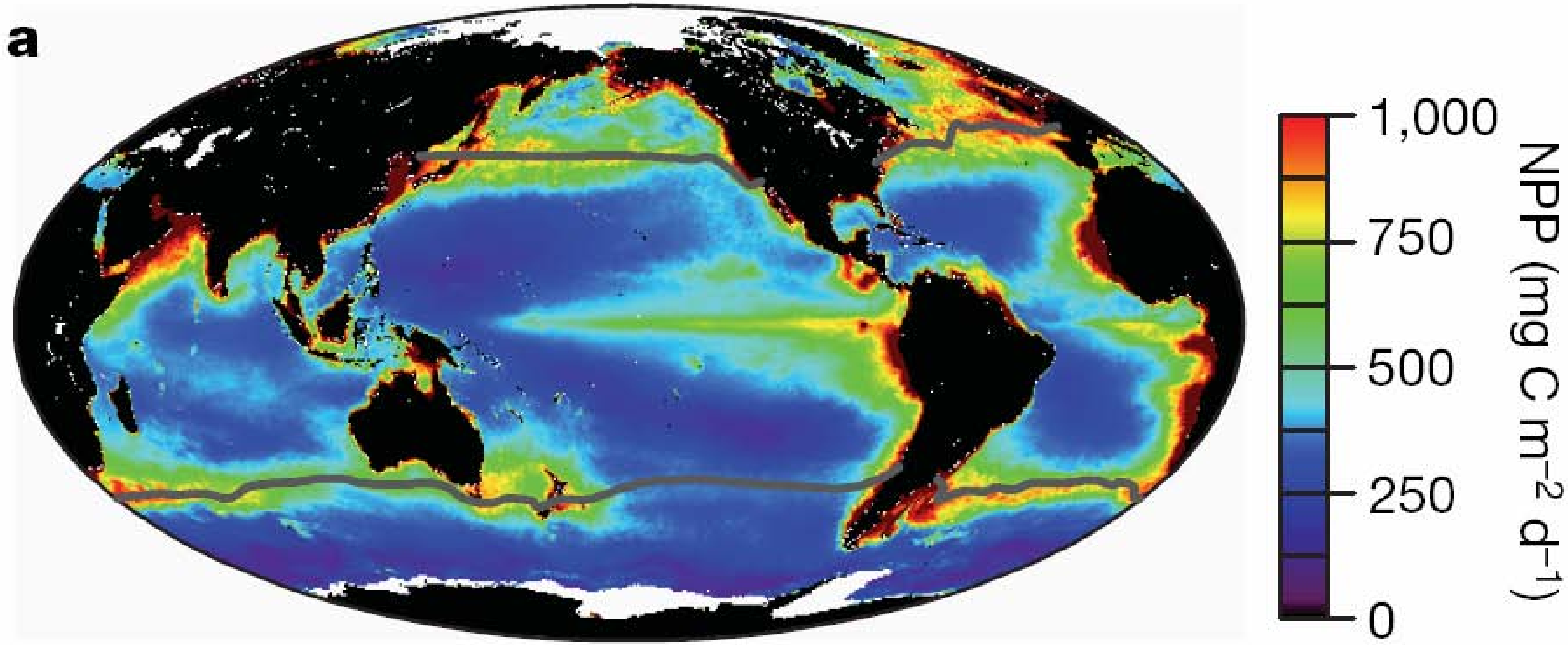
9: Guipuzcoa, 10: Vizcaya,

**Subproject 3: Atlantic (Canary Islands)**

11: Gran Canaria: Bañaderos y Taliarte

12. La Graciosa (P.N. Archipiélago Chinito); Orzola (Lanzarote)


©IPCC 2007: WG1-AR4
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)
EUROPEAN COMMISSION
Joint Research Centre
EMIS
Trends in Mediterranean Sea Surface Temperature
Joint Research Centre
3.0
2.0
1.0
0.0
-1.0
Total SST change in degrees Celsius between 1982 and 2003




By using the upper ocean chlorophyll concentration (from SeaWiFS data) , phytoplankton standing stocks and productivity are estimated

Behrenfeld et al. (2006). Nature 444

# PHYSIOLOGICAL STATUS OF MACROALGAE: PHOTOSYNTHESIS AS CHLOROPHYLL FLUORESCENCE

**PAM-2000**

**DIVING-PAM**

**WATER-PAM**

**1. MAXIMAL QUANTUM YIELD**:

Fv/Fm

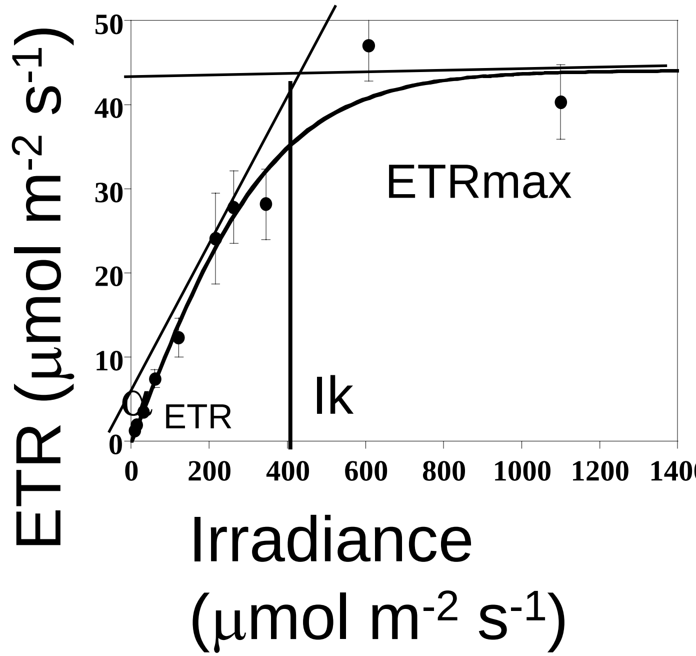
**2.ELECTRON TRANSPORT RATE**

**ETR= Δ F/F´m x E x A x FII**

ΔF/F´m= Effective quantum Yield
E= Irradiancia
A= Absortance
FII: fraction of chlorophyll associated to PSII

FII Chlorophyta (0.5) Rhodophyta (0.15), Phaeophyta (0.8)

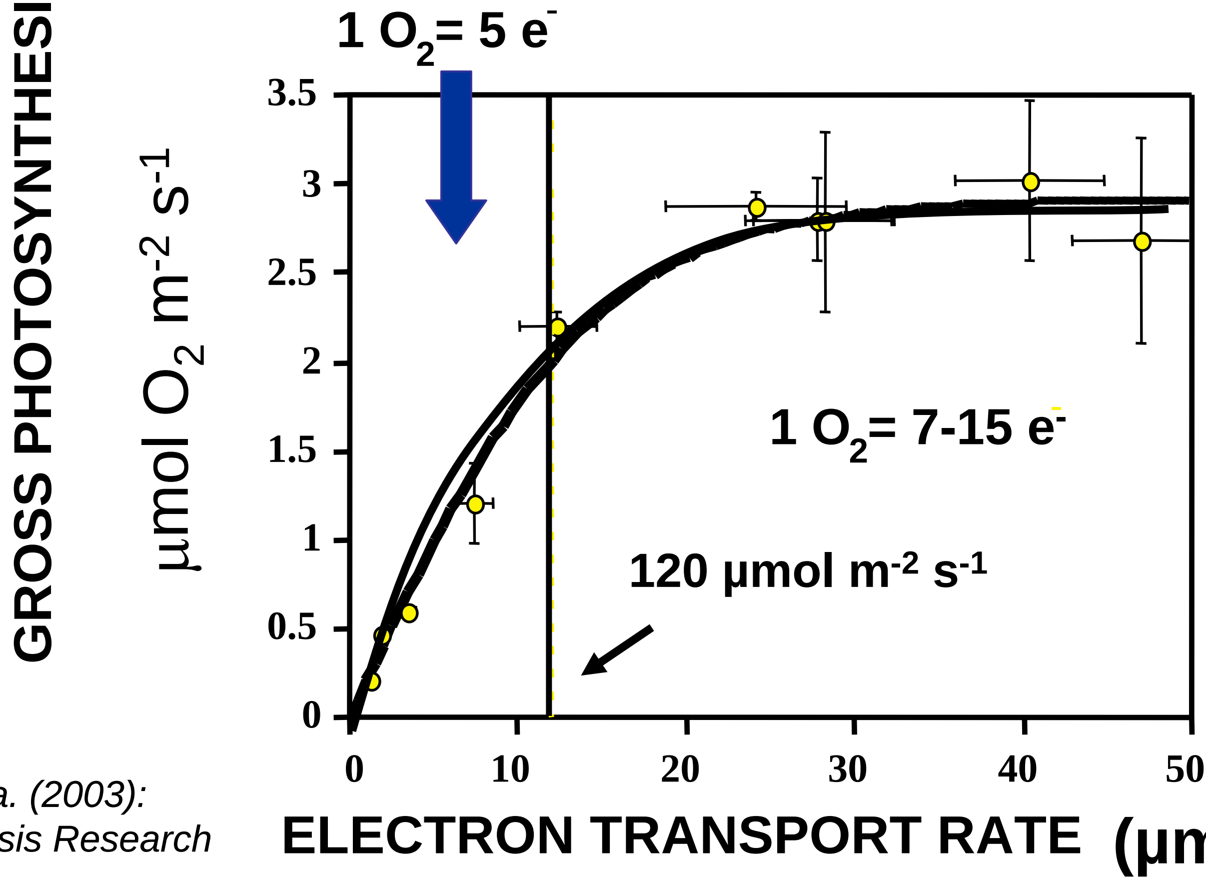
**ETR as Gross Photosynthesis** is a function of: Irradiance (quantity and quality), Temperature, Nutrients and water motion.




# CORRELATION ETR-$GP_{OXYGEN}$

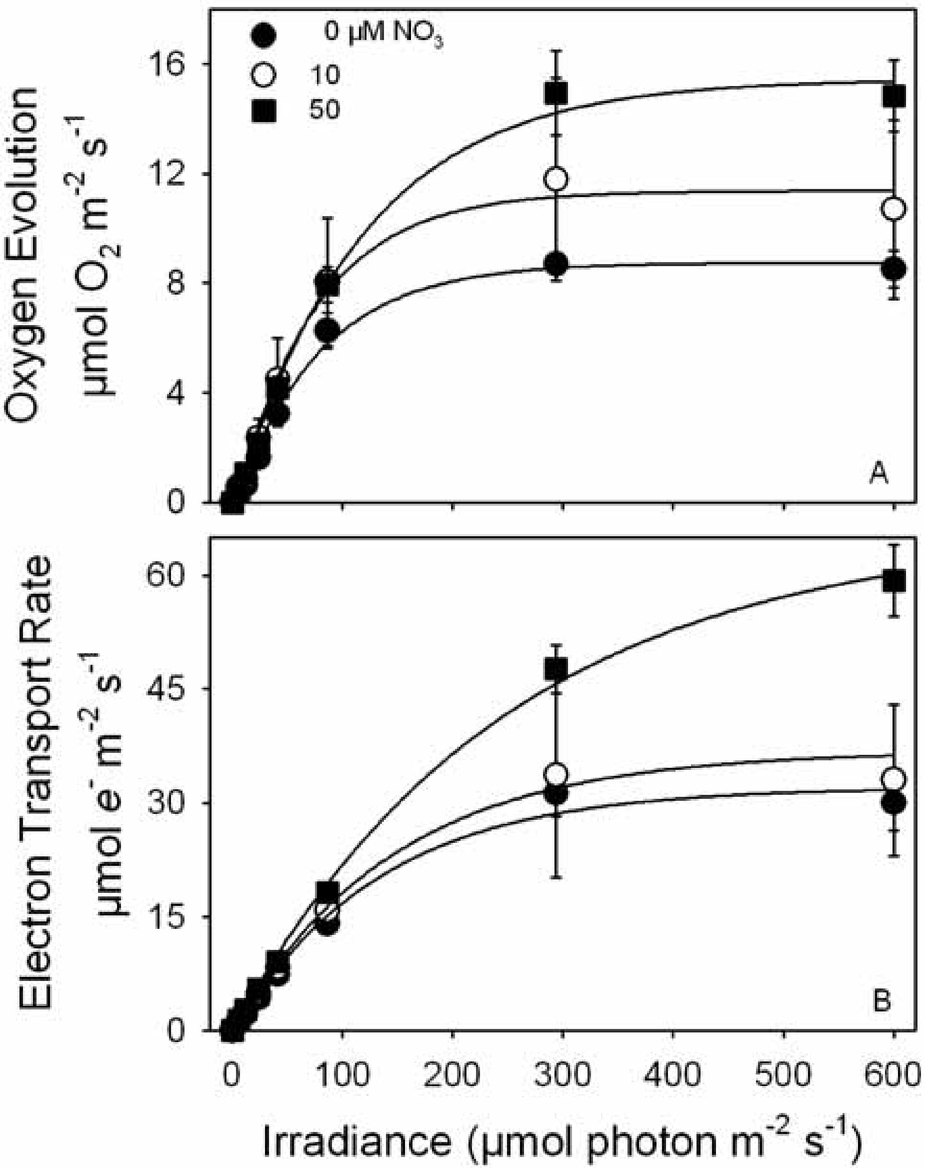
Linear relation between ETR and GP
only below EK

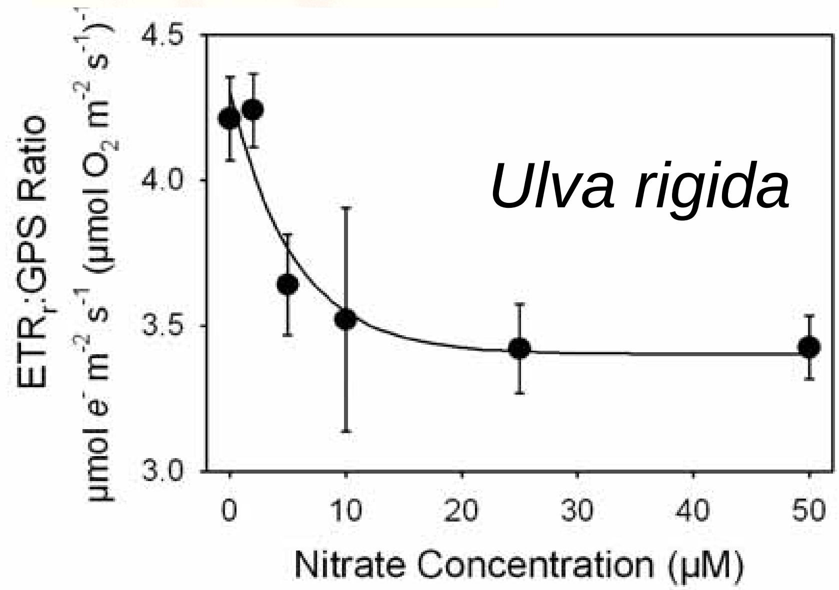
$$FB = FB_{max} * (\tanh(\alpha * ETR / FB_{max}))$$




*Figueroa et a. (2003):*
*Photosynthesis Research*

# THE RELATION ETR/GP IS AFFECTED BY THE NITROGEN AVAILABILITY

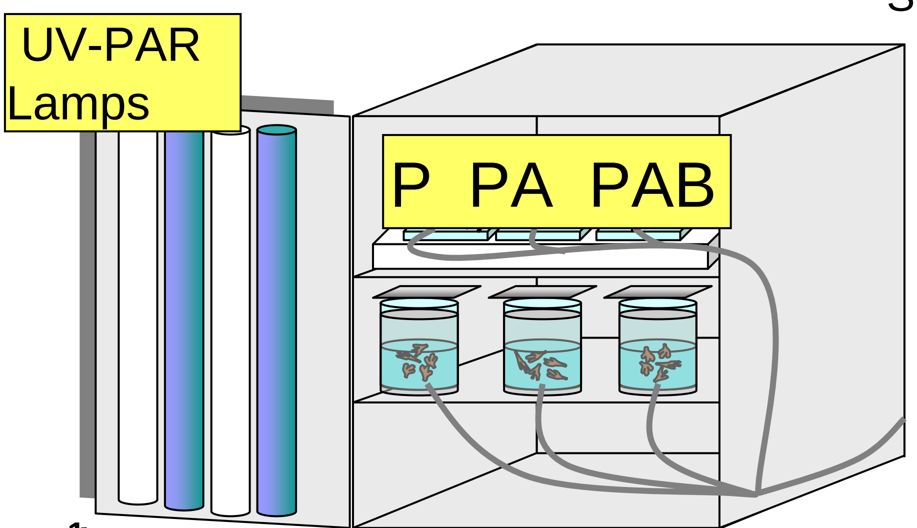



*Cabello et al. (2005). J. Phycol.*

# EXPERIMENTAL DESIGN: UV RADIATION (ARTIFICIAL AND SOLAR) UNDER CONTROLLED CONDITIONS

## ARTIFICIAL RADIATION




**LIGHT TREATMENTS:**

Simulating ozone depletion or different depths

P (PAR)= 400-700 nm

PA (PAR+UV-A)= 315-700 nm

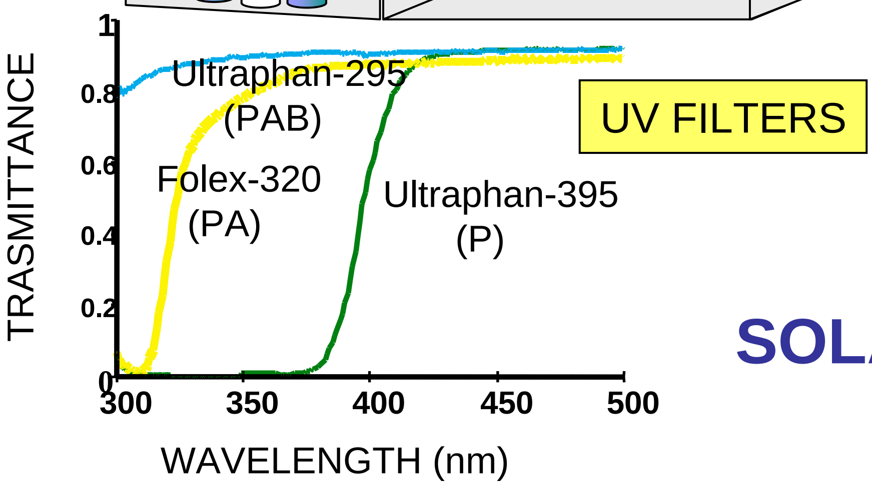
PAB (PAR+UV-A+UV-B)= 280-700 nm

**NUTRIENT TREATMENTS**

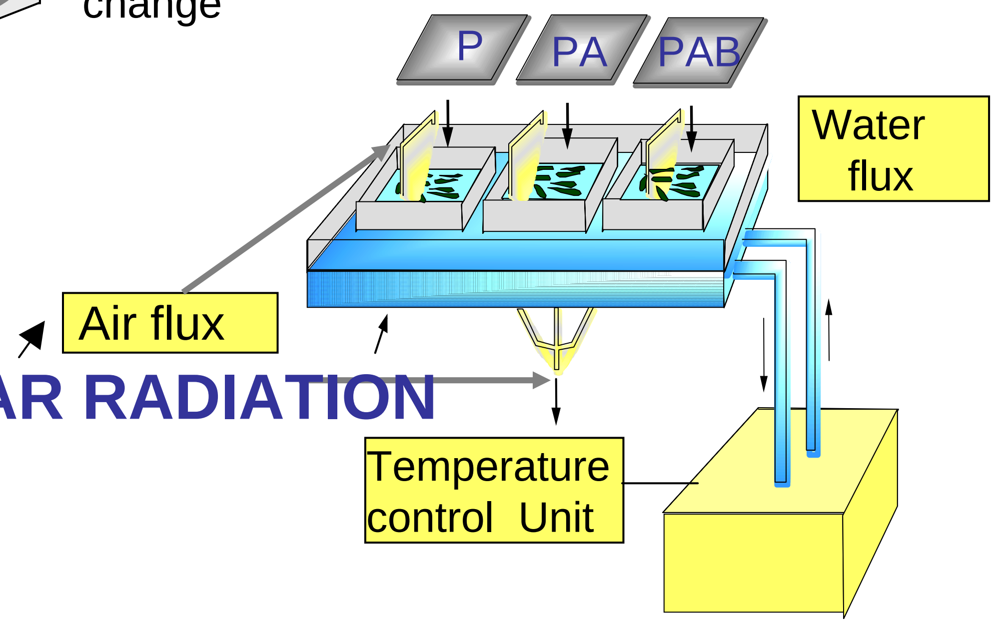
Different levels of Nitrate, Ammonium, Phosphate

**TEMPERATURE TREATMENTS**

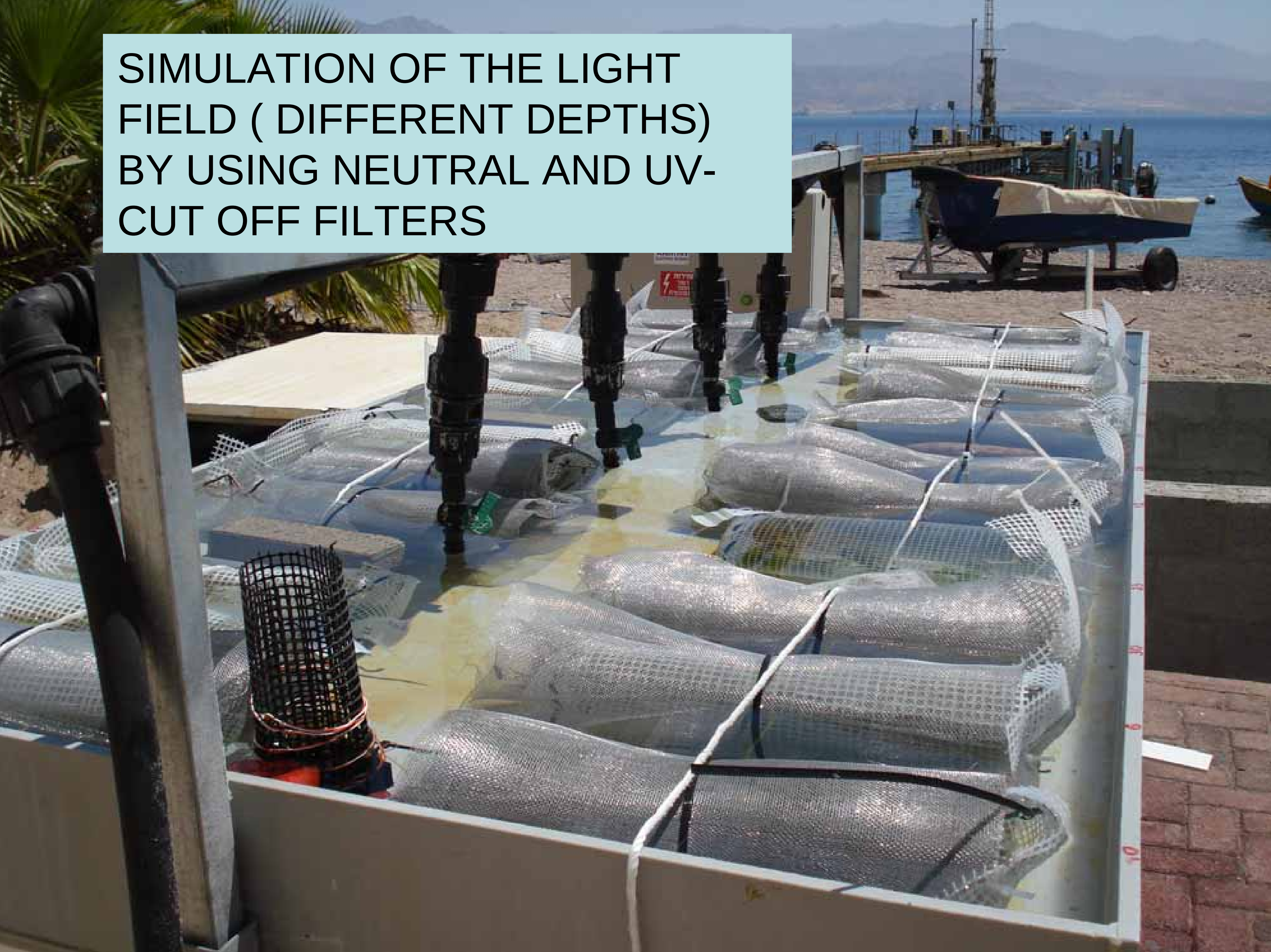
Simulating seasonal variations and climate change



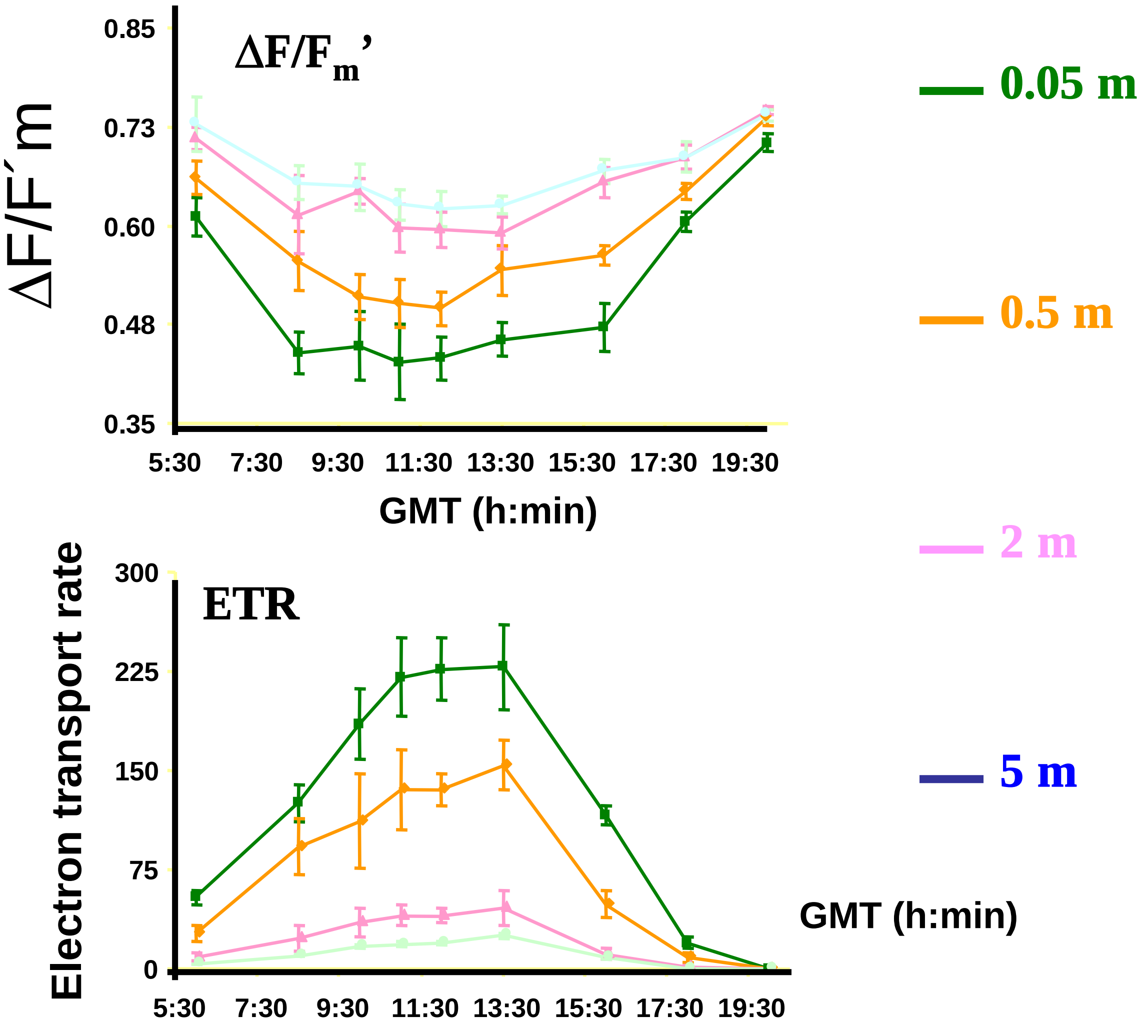

## SOLAR RADIATION

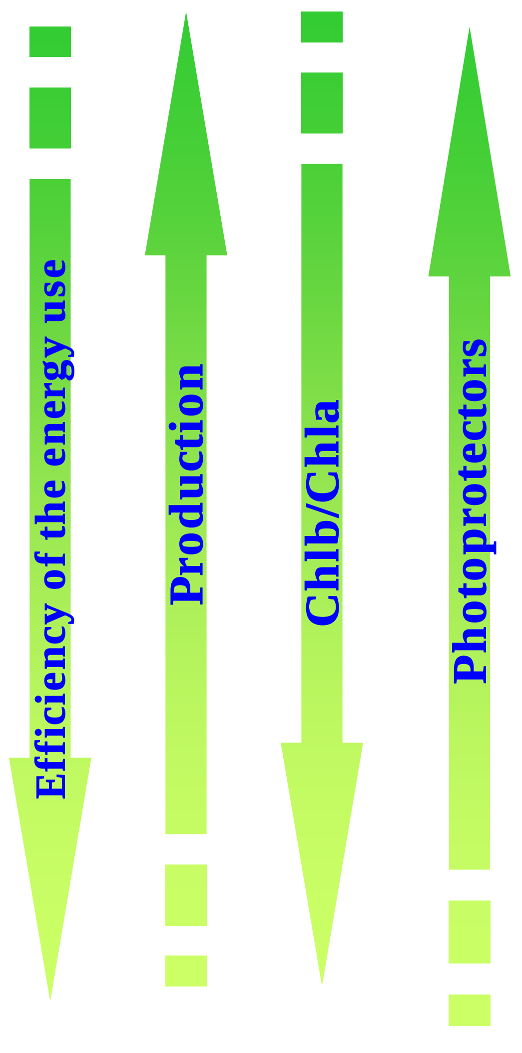


# SIMULATION OF THE LIGHT FIELD ( DIFFERENT DEPTHS) BY USING NEUTRAL AND UV-CUT OFF FILTERS

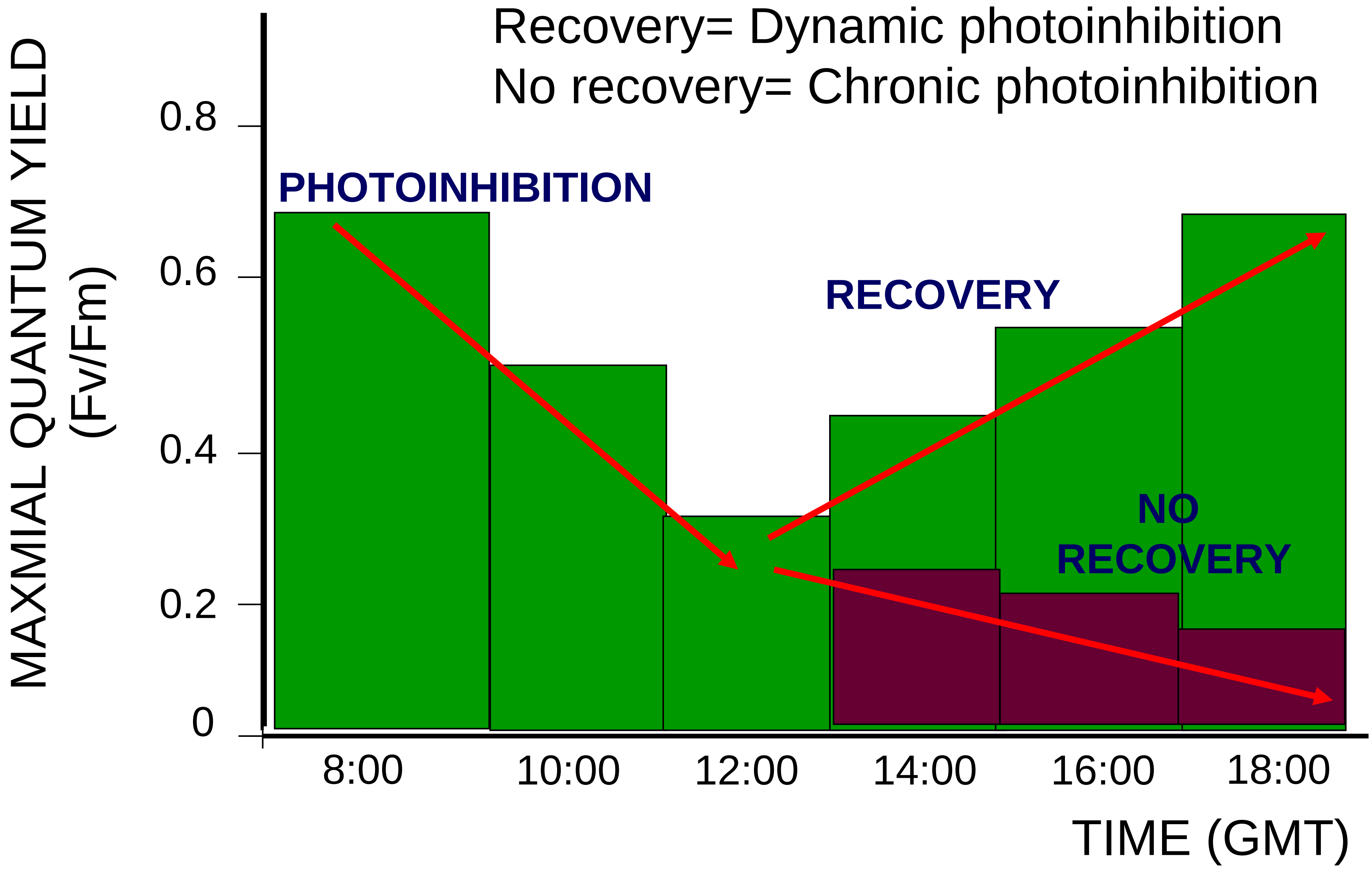


# IN SITU DAILY CICLES OF YIELD (EFFICIENCY) AND ETR (PRODUCTION)

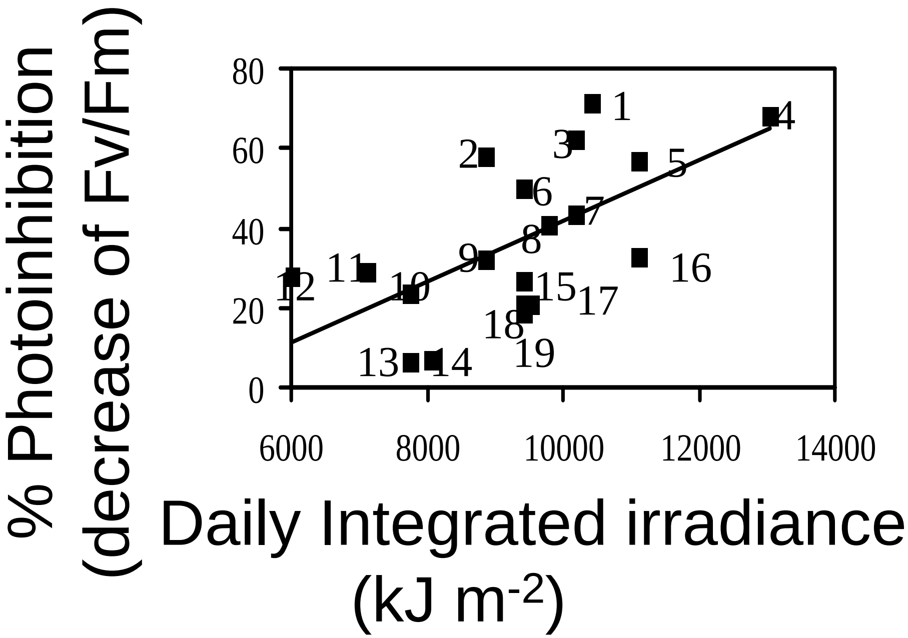


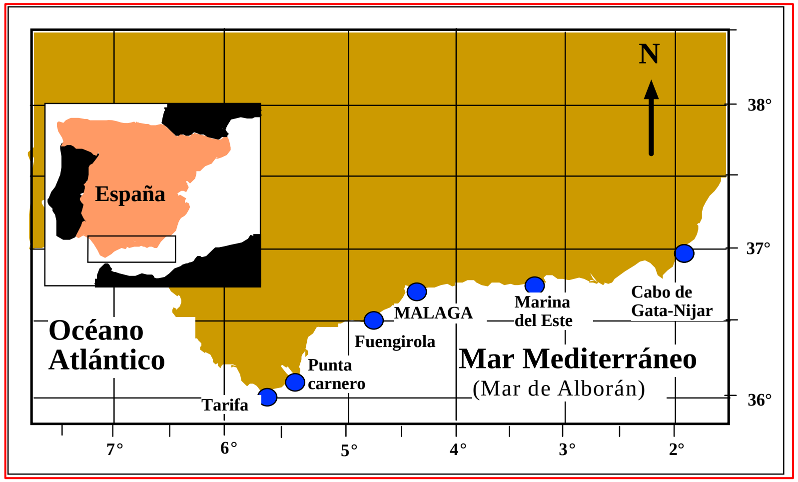



# MAXIMAL QUANTUM YIED AS INDICATOR OF THE PHYSIOLOGICAL STATUS OF THE ALGAE

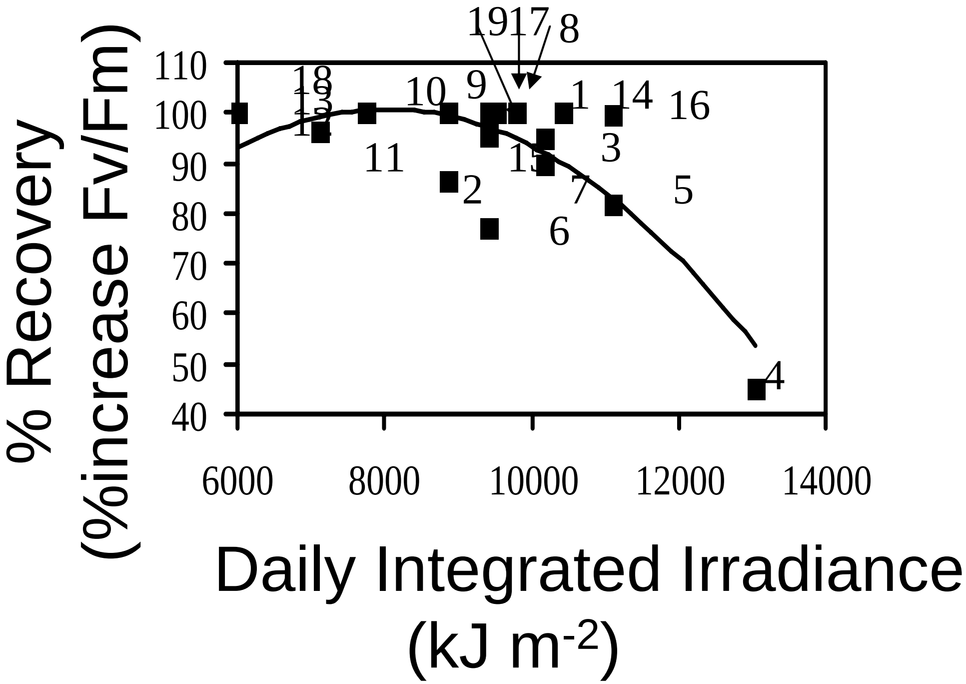


# RELATION BETWEEN PHOTINHIBITION-RECOVERY AND DAILY INTEGRATED IRRADIANCE IN MACROALGAE

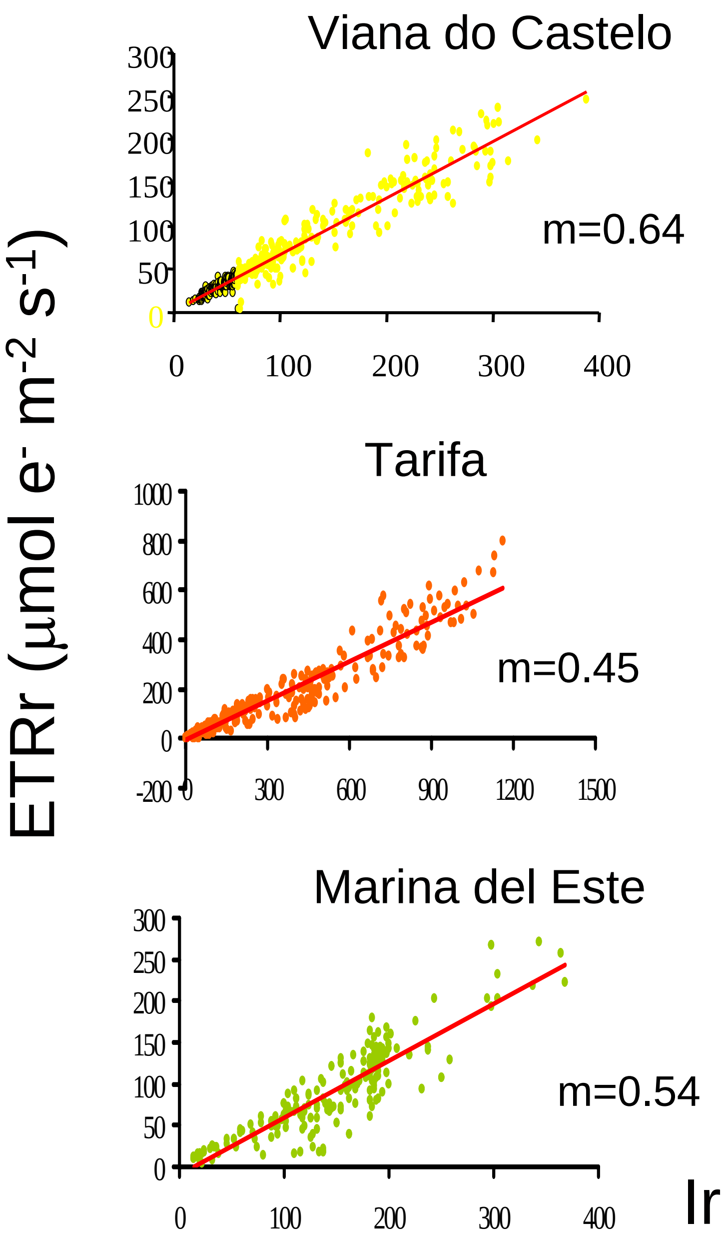


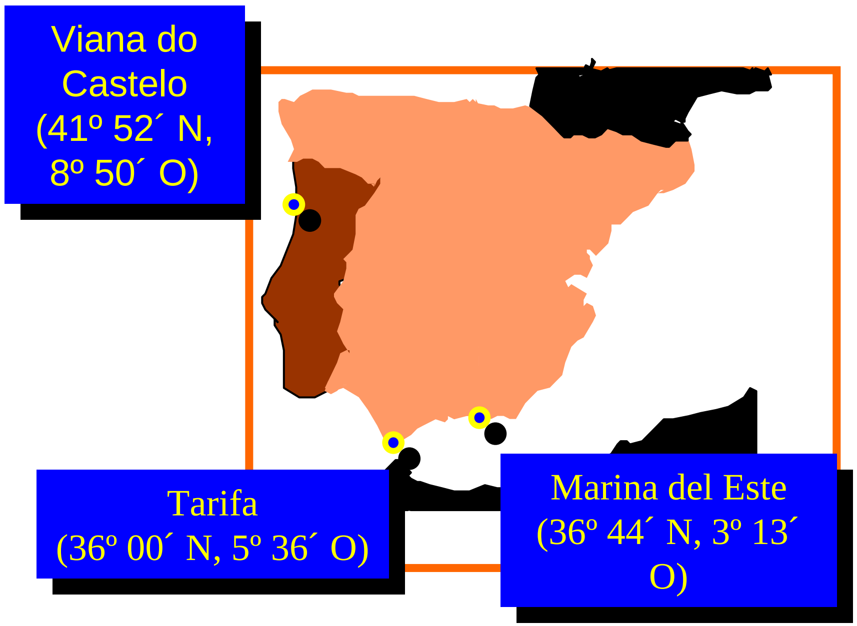




Cabo de Gata-Níjar

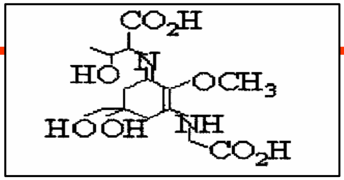


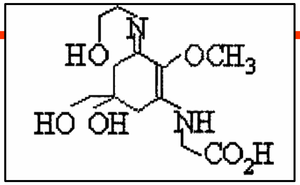
# *IN SITU* MEASUREMENTS OF ELECTRON TRANSPORT RATE (ECOSYSTEMS)



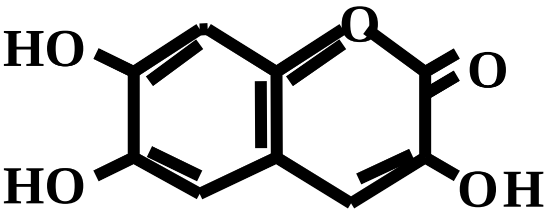
# PHOTOPROTECTION SYSTEMS AS RESPONSE TO STRESS





## 1. PHOTOPROTECTORS

Rhodophyta: Mycosporine-like amino acids (MAAs)
Phaeophyta: Phenolic compouds
Chlorophta: Trihidroxicoumarins

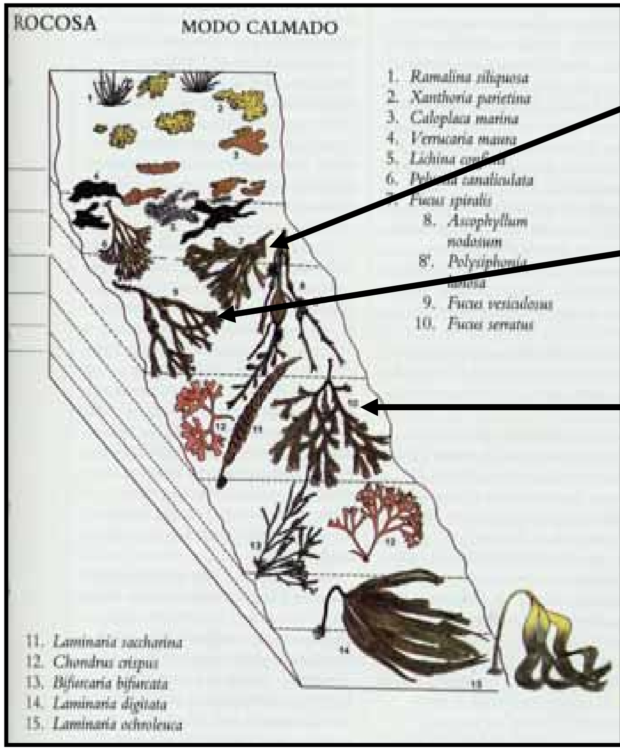


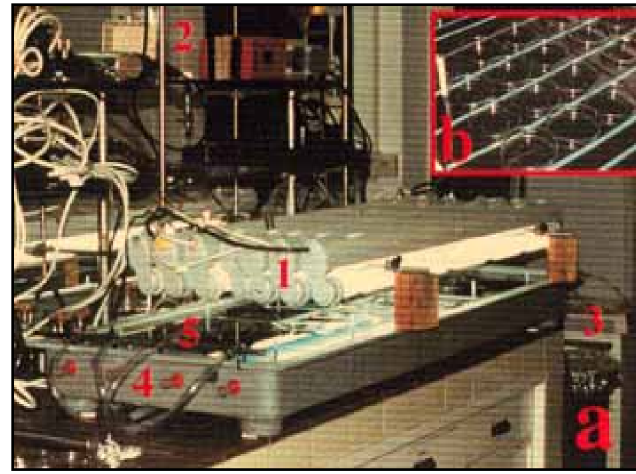
## 2. CAROTENOIDS AND XANTOPHYLL CYCLE

## 3. ANTIOXIDANT SYSTEMS

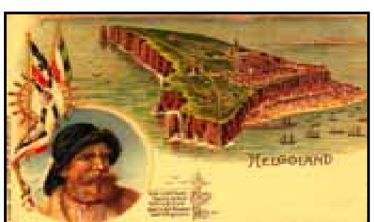
- No enzymatic: Vitamins C-E, Gluthation
- Enzimatic

# COMBINED EFFECT OF UV AND TEMPERATURE ON GROWTH OF EMBRYONS AND ZYGOTE GERMINATION IN *FUCUS* SP.-BROWN ALGAE




**ALGAL ZONATION OF *FUCUS* SPECIES IN HELGOLAND (NORTH SEA )**




## EXPERIMENTAL DESIGN:

**PAR**

**PAR+UV-A**

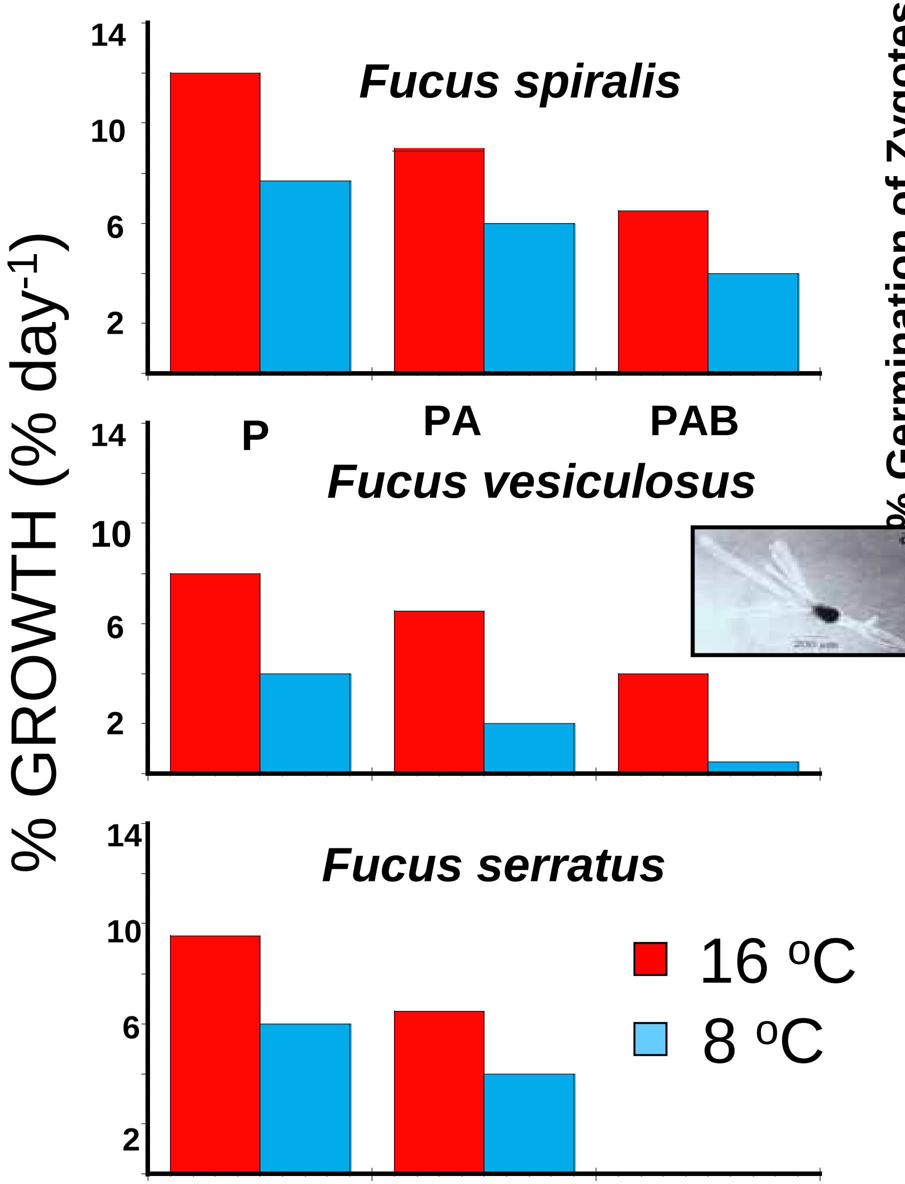
**PAR+UV-A+UV-B**

**Temperatures: 8 y 16 ºC**

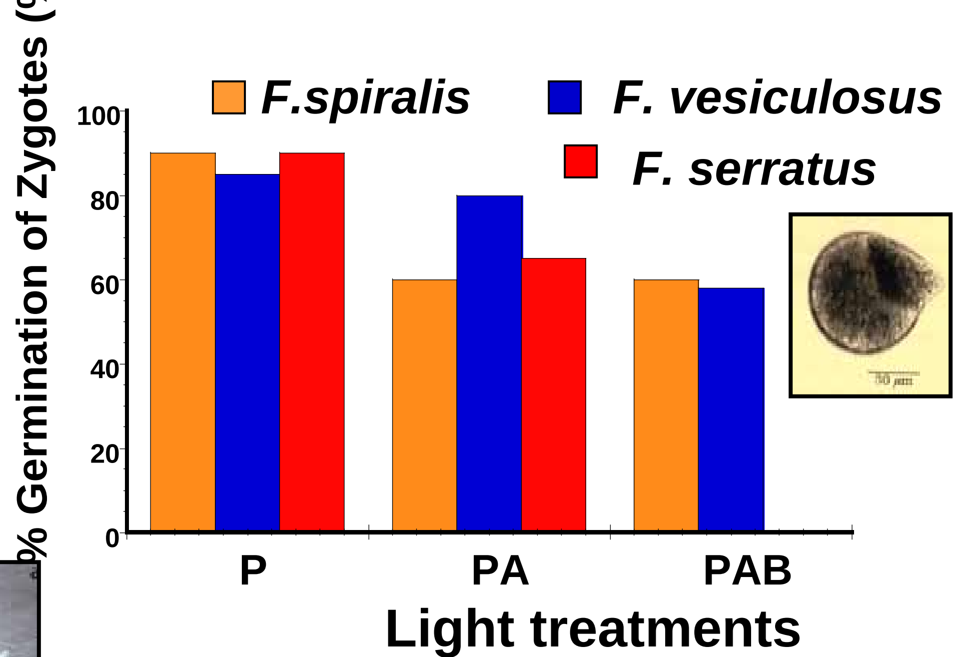
**Germination of Zigotes: 25 h**

**Growth of embryons: 14 d**

# GROWTH OF EMBRYONS




# GERMINATION OF ZYGOTES




The sensitivity to UV radiation in *Fucus* species is related to the zonation (growth site) and it is dependent on the temperature (photoprotection and repair mechanisms).

*Altamirano et al. (2003). Aquatic Botany*

## CLIMATE CHANGE

↑ $CO_2$

↑ Temperature

↓ pH

## IMPACTS ON MACROALGAE

► Negative effects on the present C-saturated algae (with carbon concentration mechanism)

► +/- effect on stoichiometry (C:N:P)

► + effect on respiration/photosynthesis ratio

► Antagonistic/Synergistic effects with UVB

**MONITORING : Production (adaptation and vulnerability)**

**PHYSIOLOGICAL INDICATORS**: Maximal quantum yield and ETR through *in vivo* Chlorophyll fluorescence determination.

**BIOCHEMICAL STRESS INDICATORS**: UV-screen substances, HSP, Proteases, ROS-antioxidant systems

**PRIMARY PRODUCTION: OBSERVATION VERSUS MODELS**

# THANK FOR YOUR ATTENTION !