



Long time series in high mountain lakes:

Global change laboratories

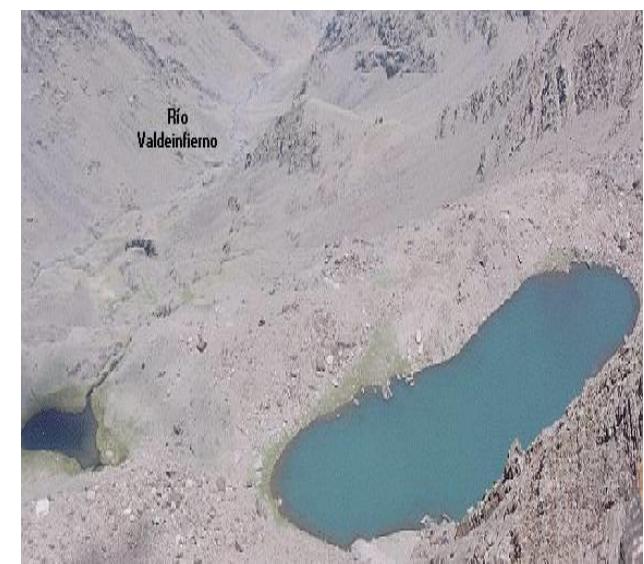
Manuel Villar-Argaiz

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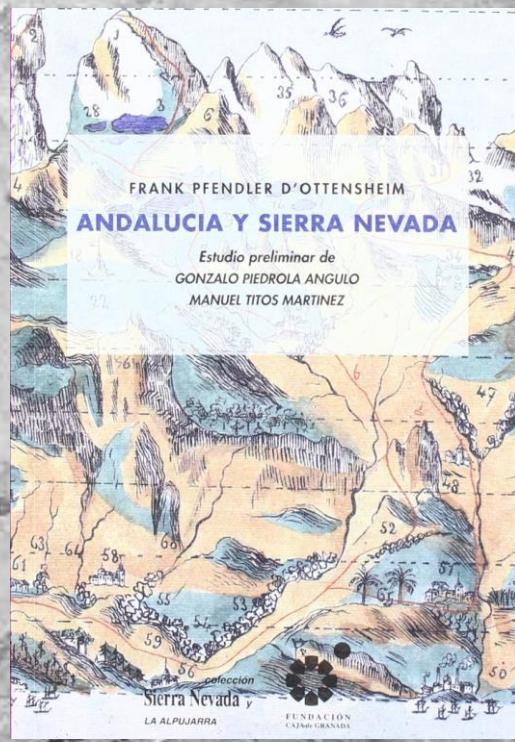
mvillar@ugr.es



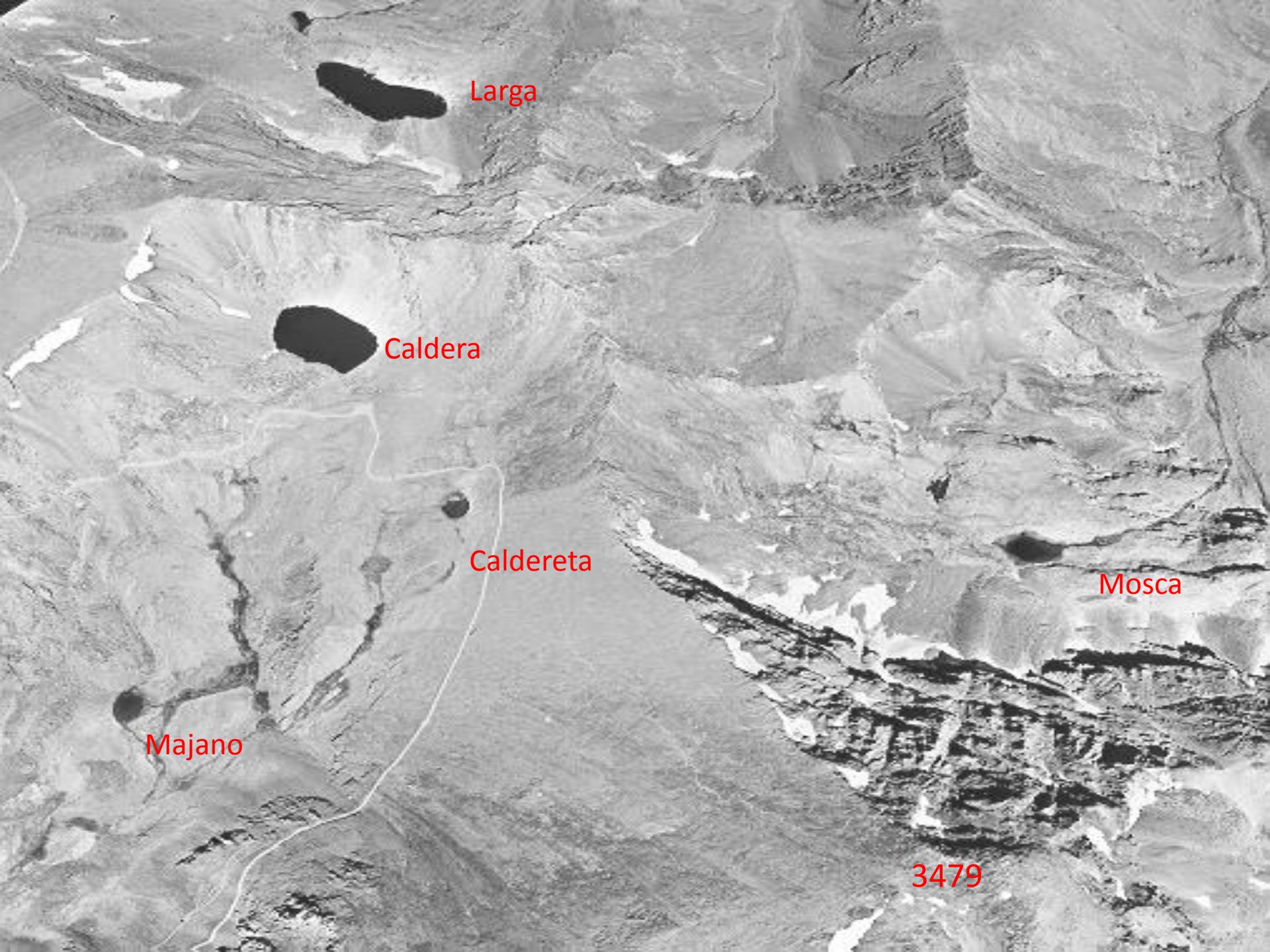
.....between 50 and 74 lagoons !!!



The most interesting curiosity in the Sierra
..... true suspended ponds in the
mountains, at heights that are found
nowhere else in Europe



(Frank Pfendler, 1846)



Larga

Caldera

Caldereta

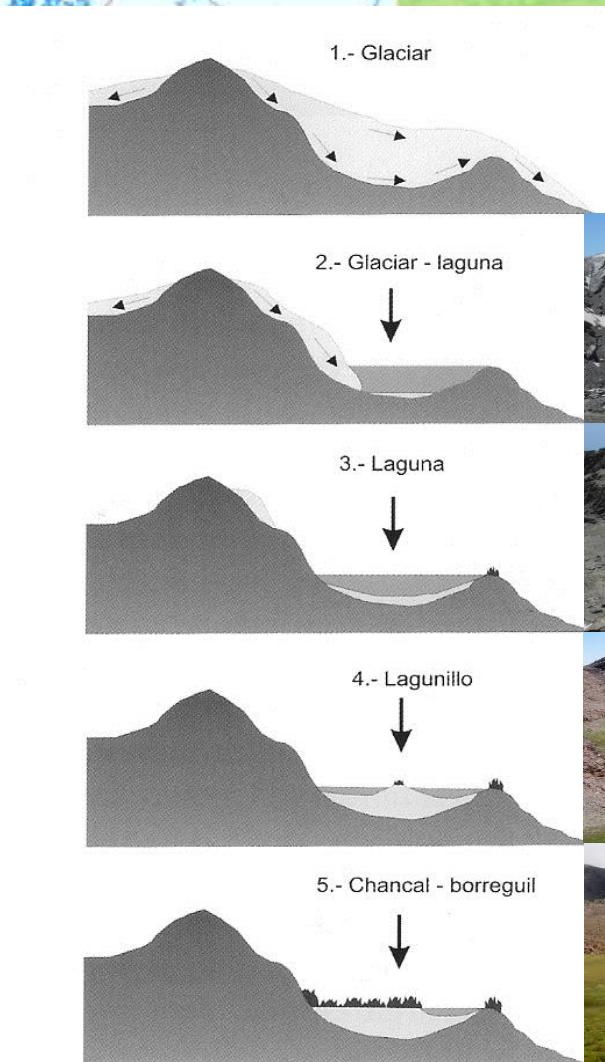
Majano

Mosca

3479

Glacial origin of the lakes

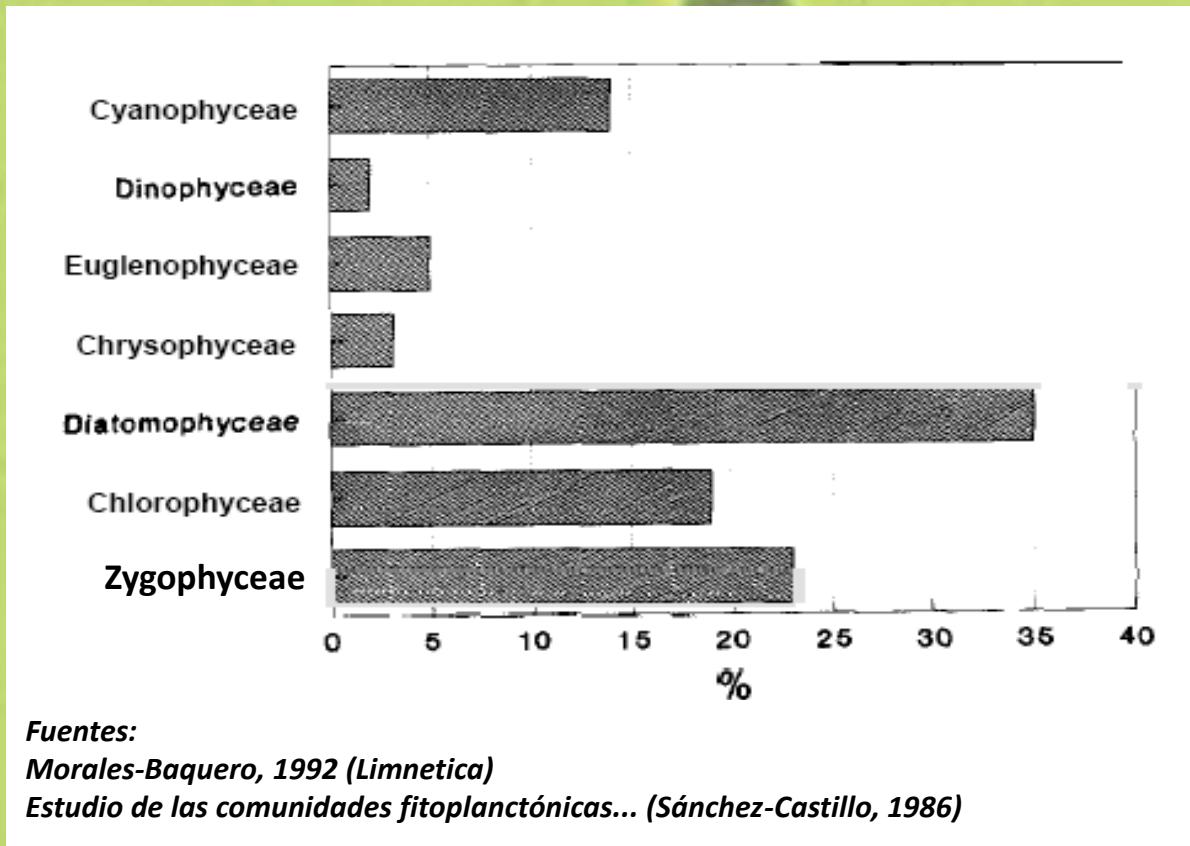
Würm glacial age (*ca* 24,000-10,000 years)



Fuente: *Lagunas de Sierra Nevada* (Castillo, 2009).

Phytoplankton

→ **EXTREMELY LOW DIVERSITY (number sp.)**



Zooplankton

8 sps de cladóceros

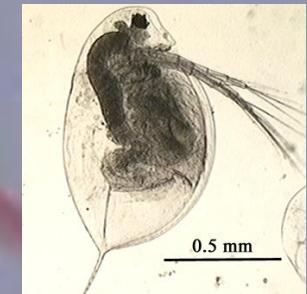
→ **Low number of species**

Zooplankton communities....(Cruz-Pizarro et al., 1981)

Rotifers... (Morales-Baquero, 1985)

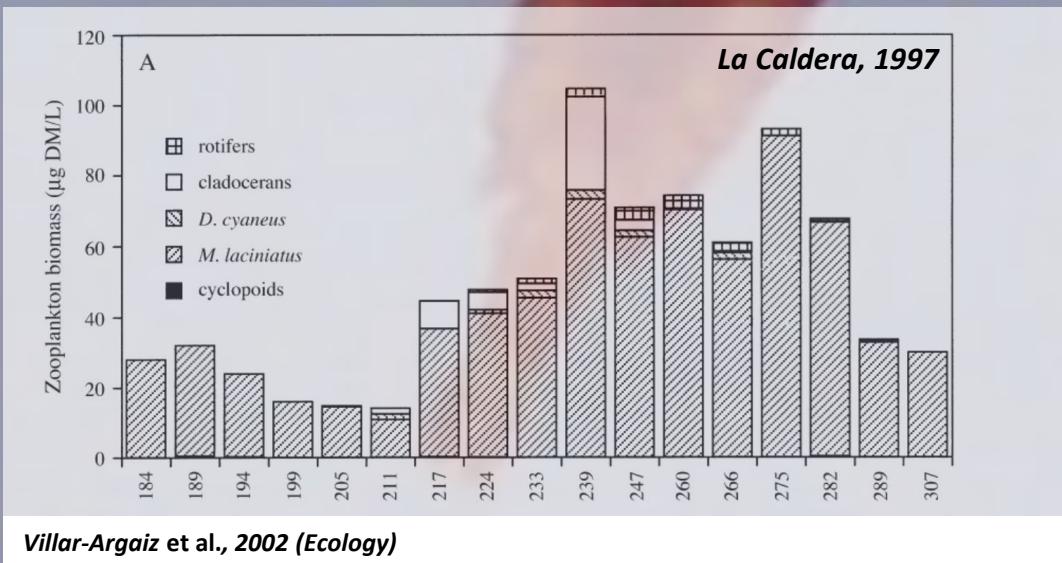


5 sps de copépodos



20 sps de rotíferos

→ **One species comprises >95% biomass in lake La Caldera**



Then.....Why study High Mountain lakes?





Photo: Agencia EFE

Why study High Mountain lakes?

Minor human disturbance

Remote sites

Above tree line, small catchments

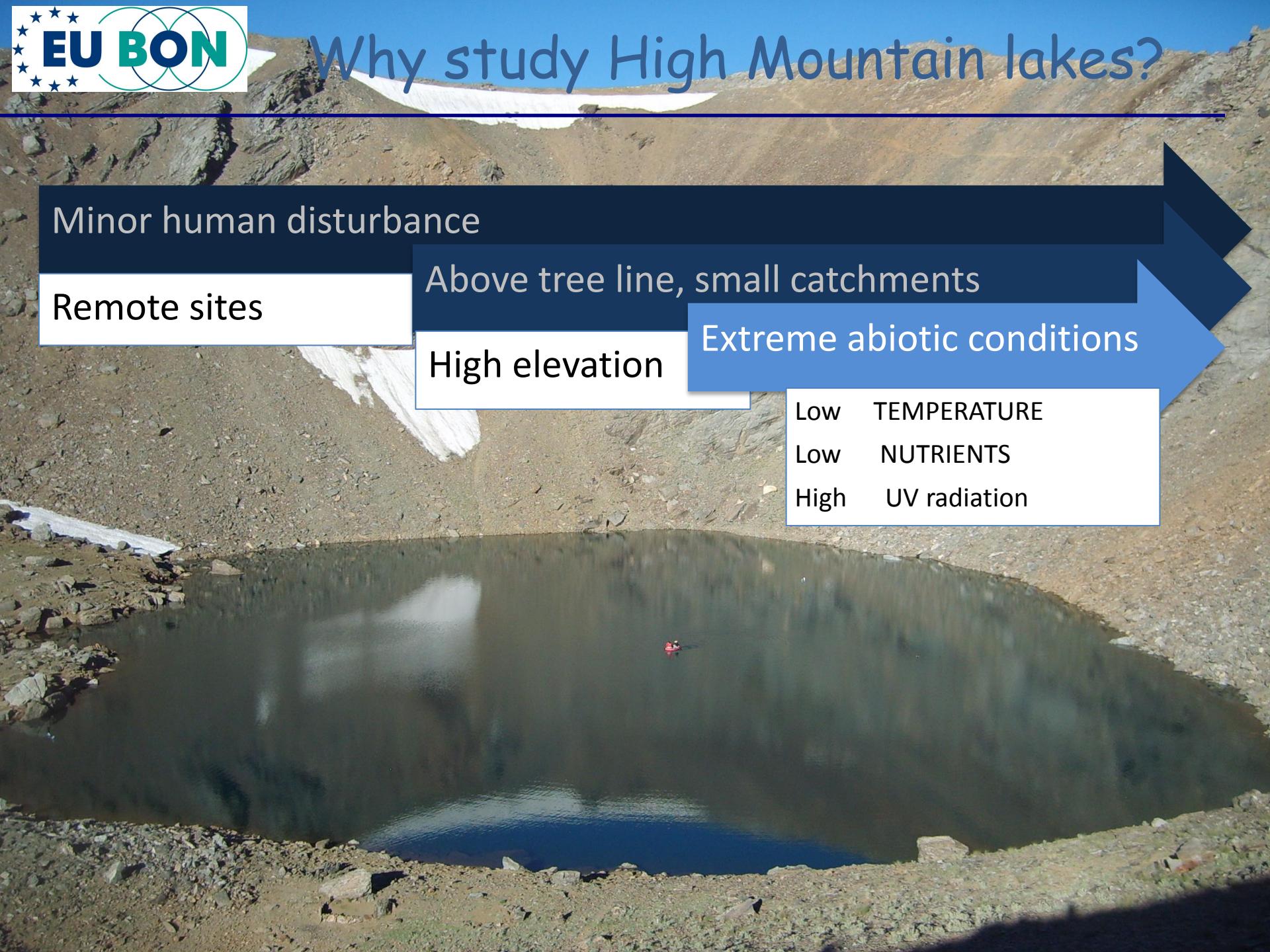
High elevation

Extreme abiotic conditions

Low TEMPERATURE

Low NUTRIENTS

High UV radiation



Why study High Mountain lakes?

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Remote sites

Above tree line

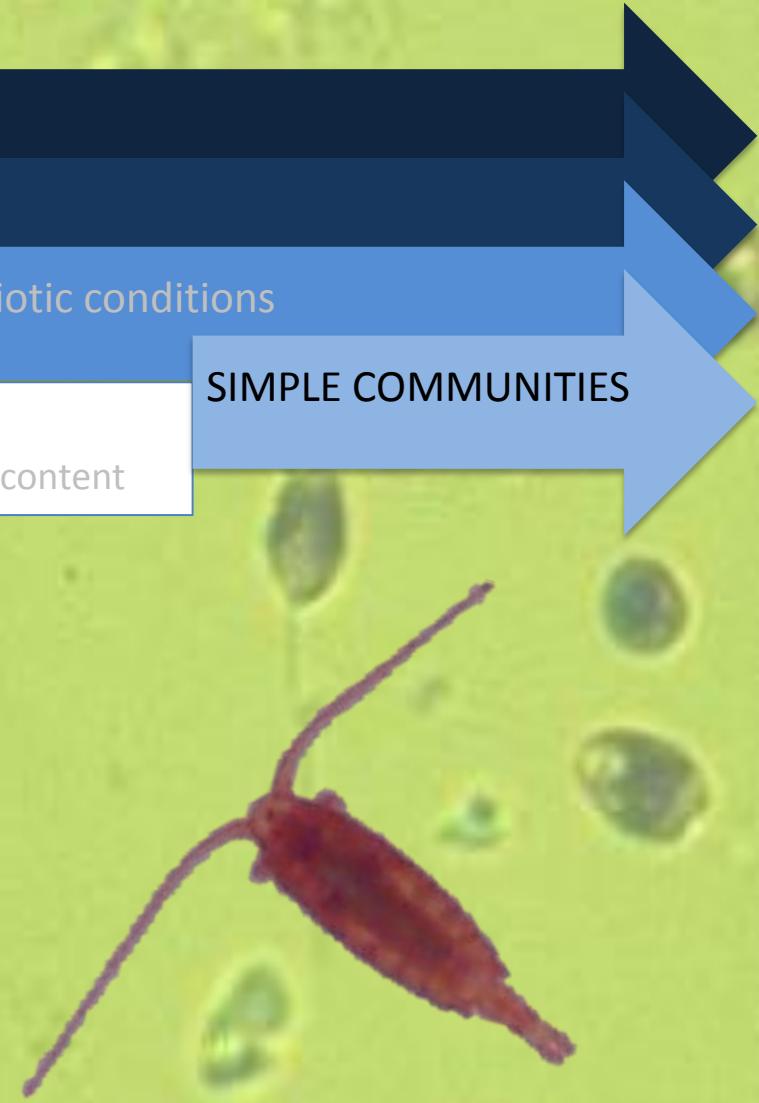
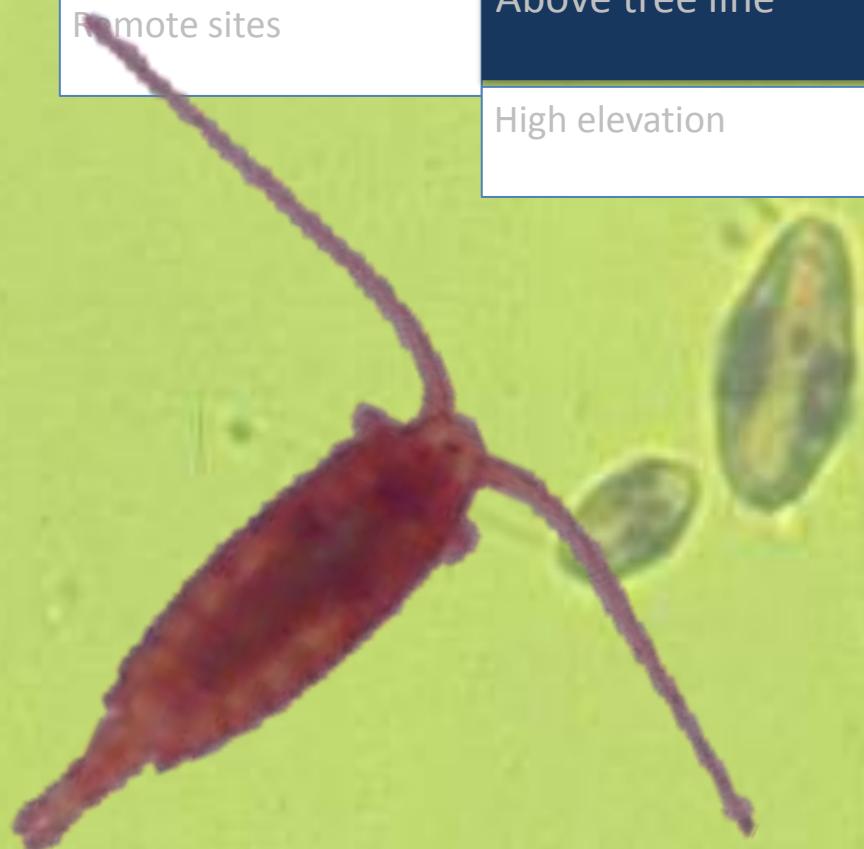
High elevation

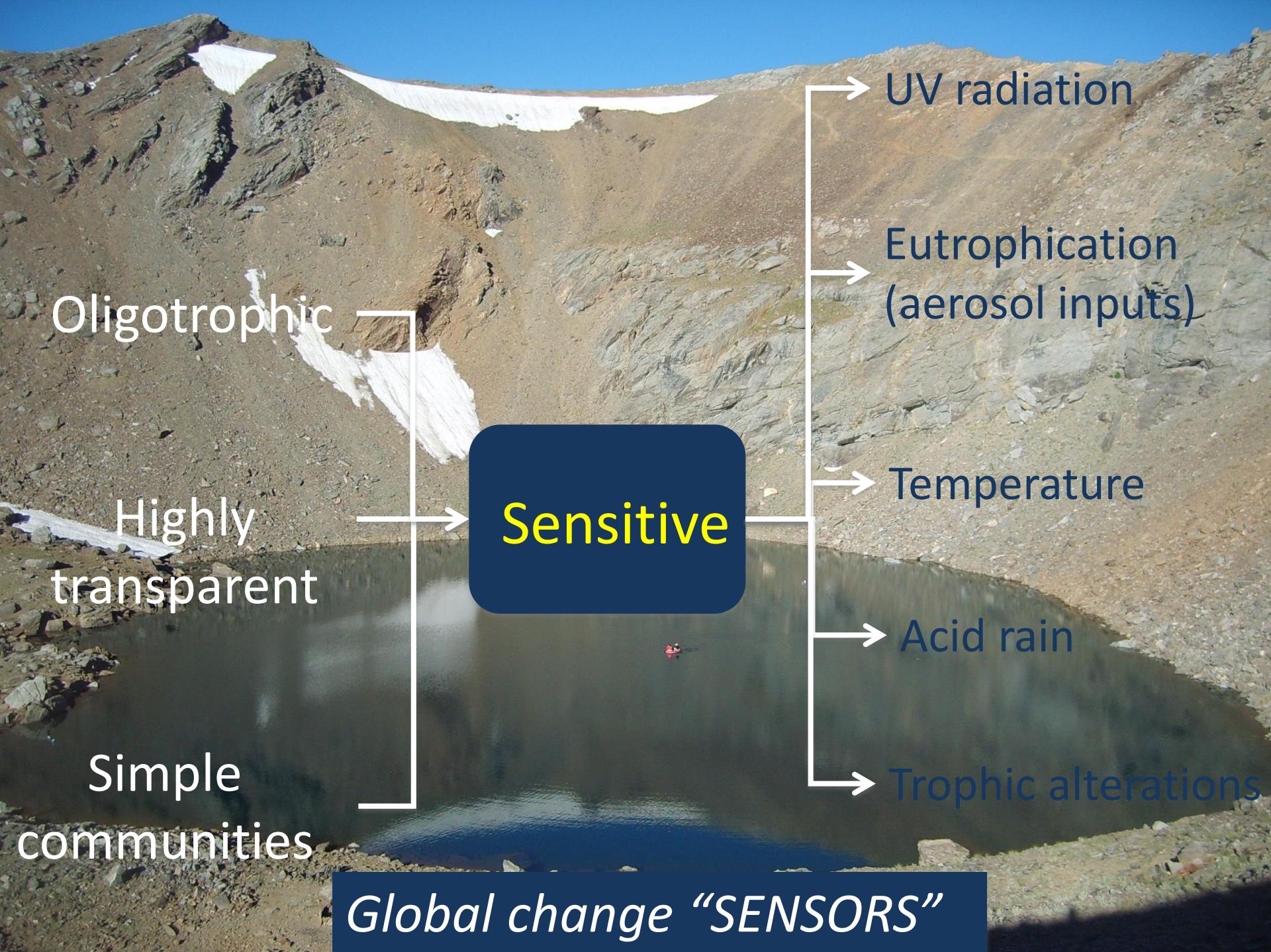
Extreme abiotic conditions

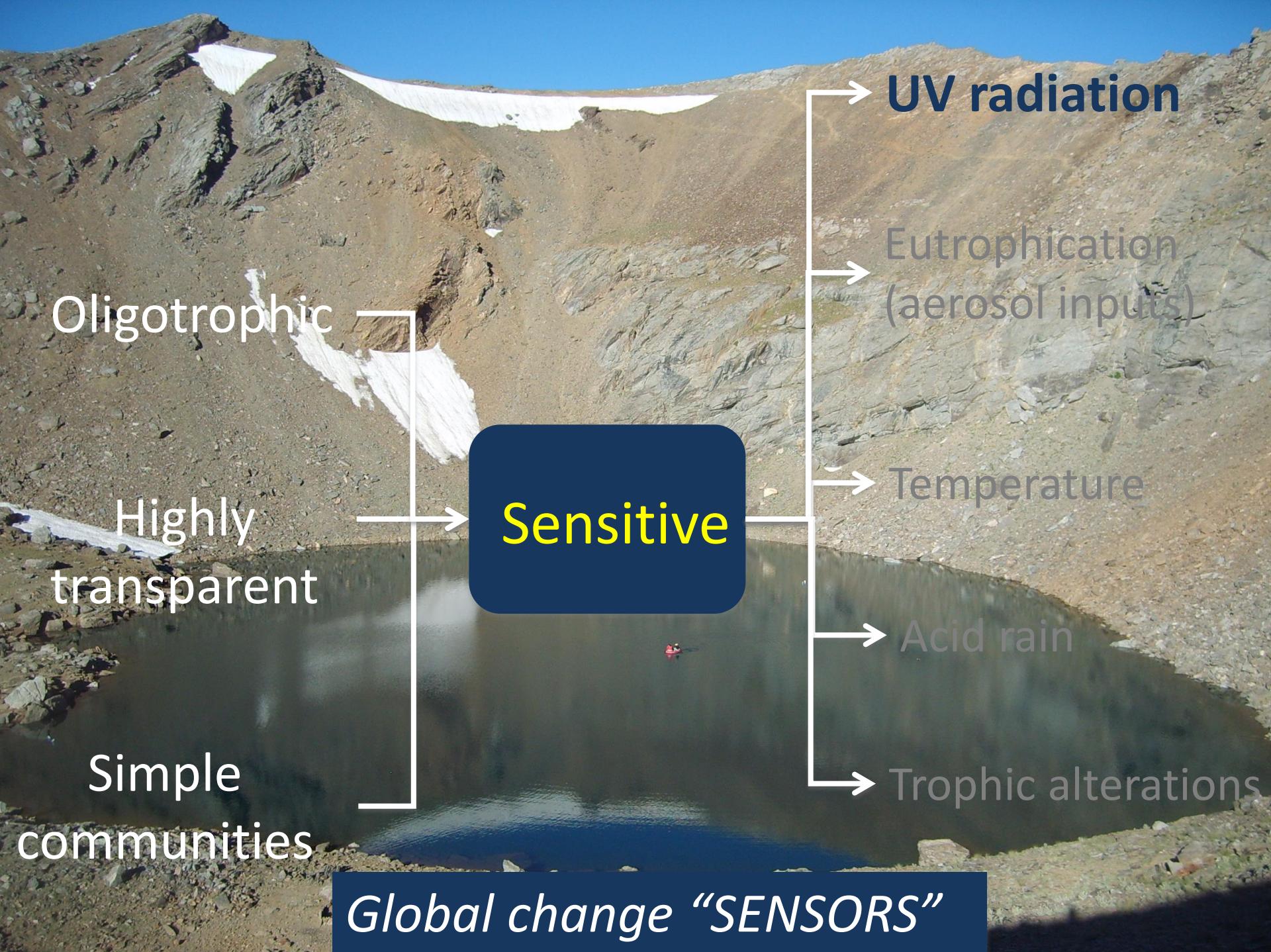
Temperature

Low nutrient content

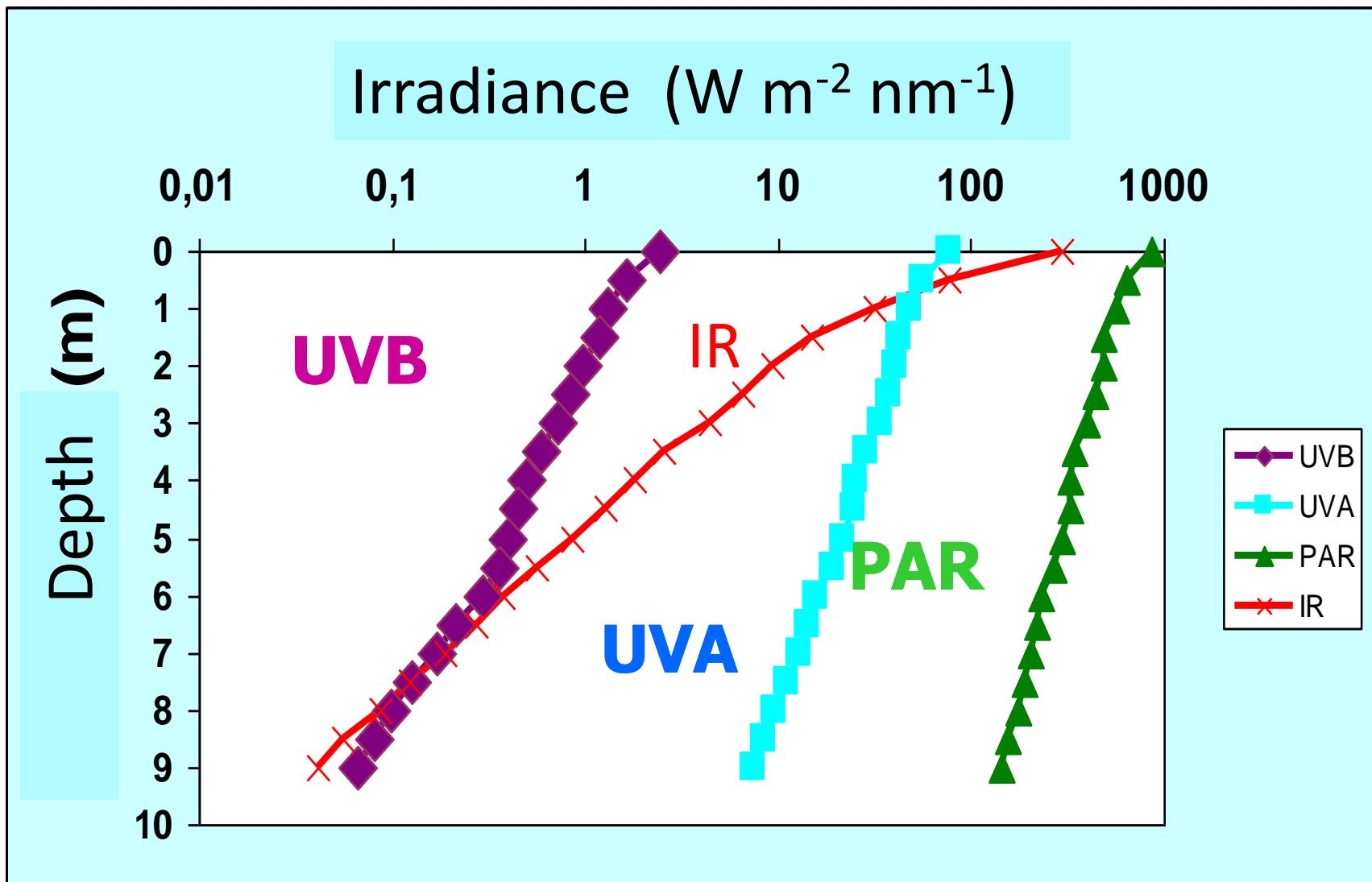
SIMPLE COMMUNITIES

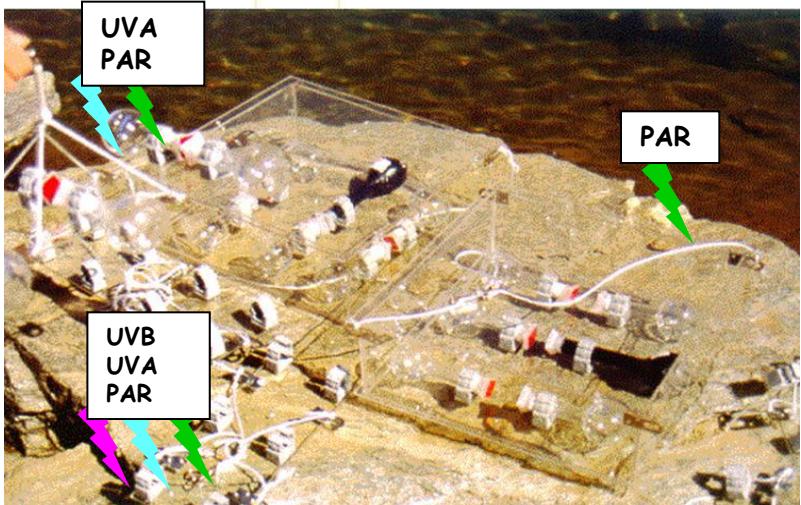
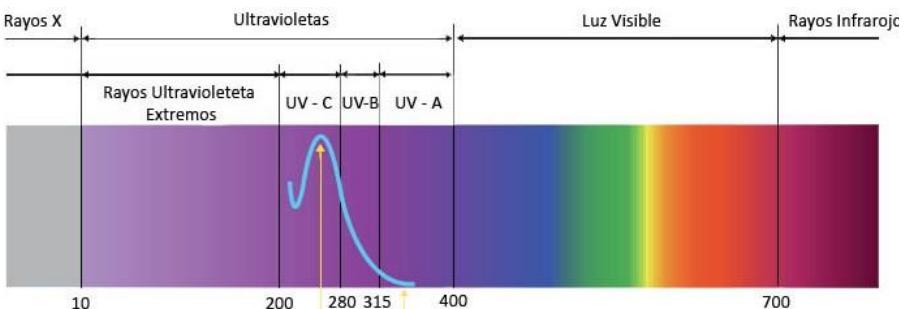






Ultraviolet radiation





Up to 75% inhibition in PP by UV radiation !!!!

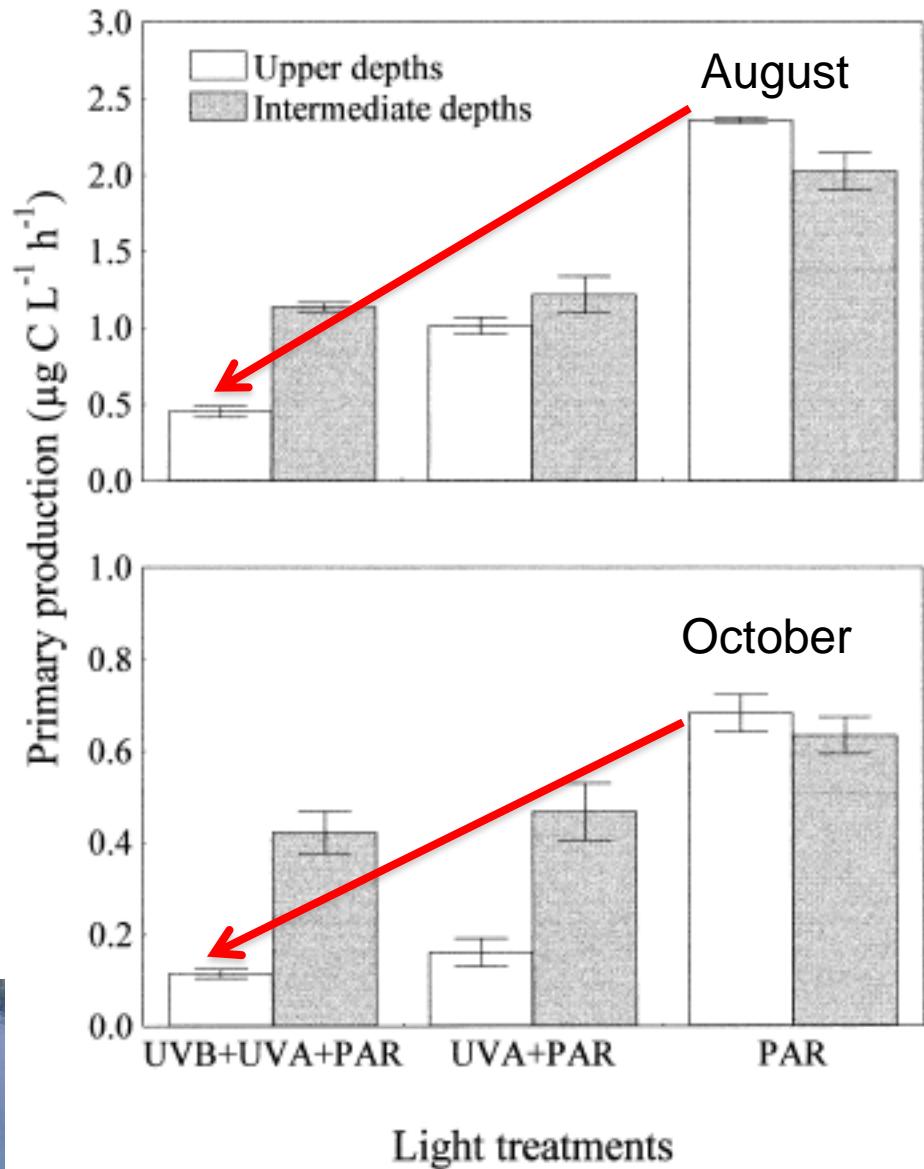
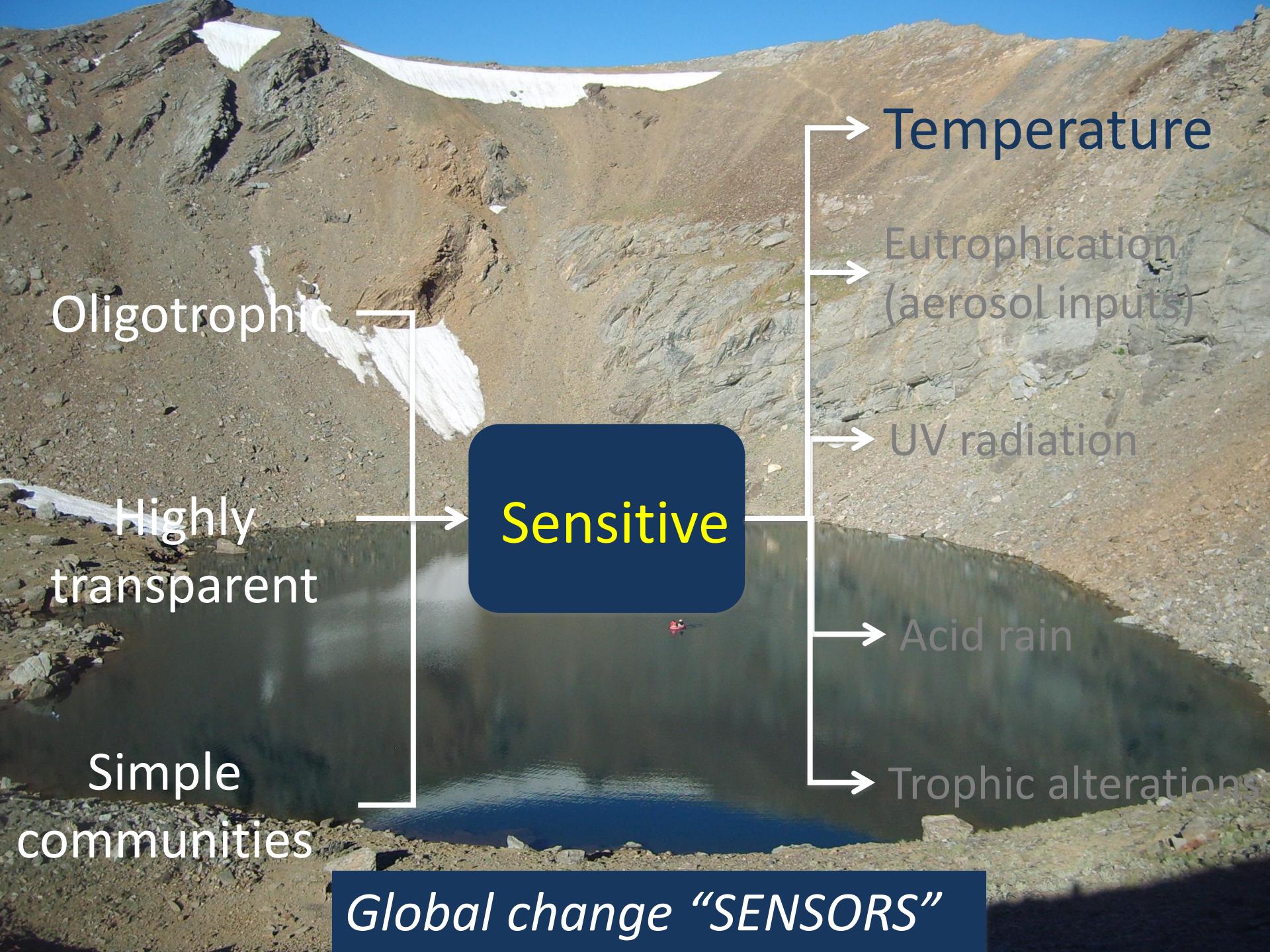
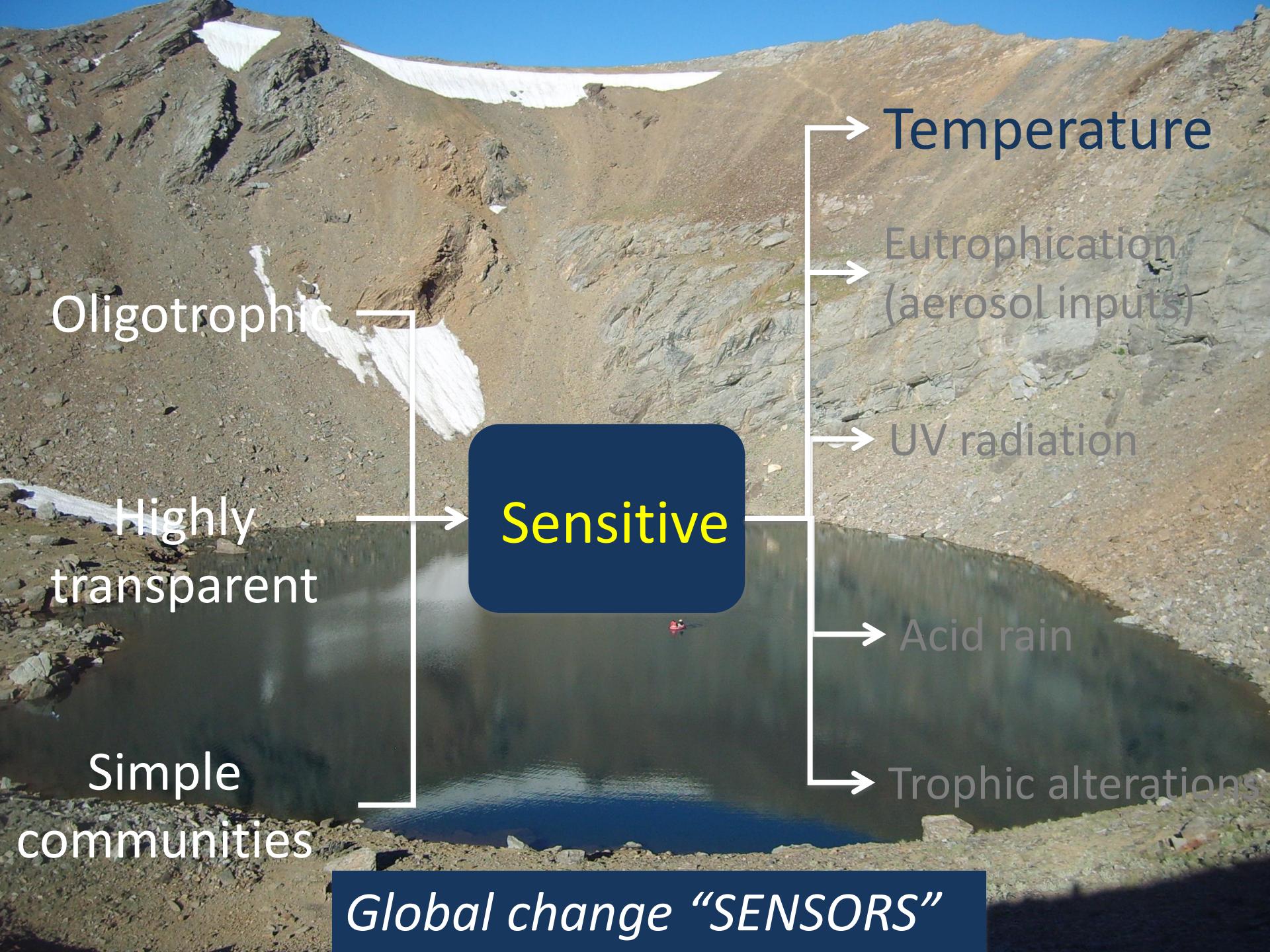
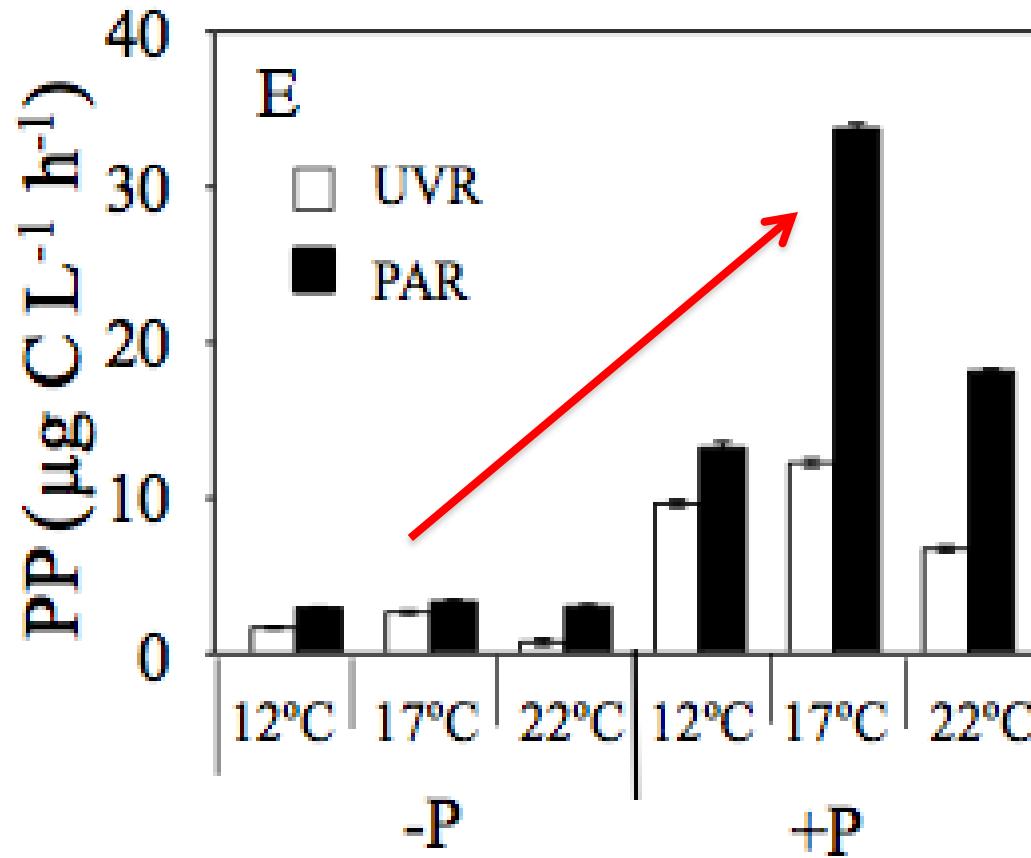


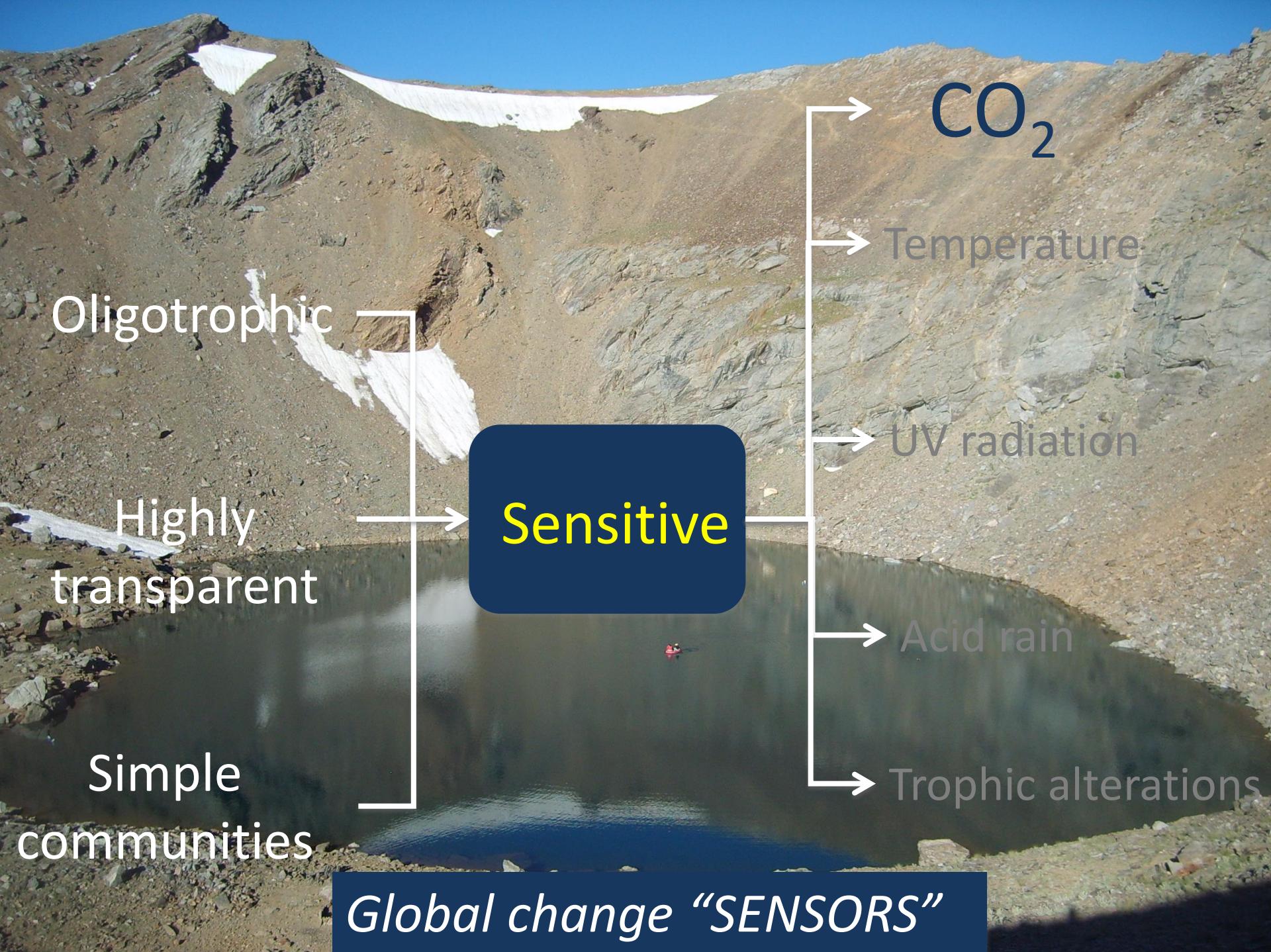
Fig. 5. Primary production measured under light treatments (UVB + UVA + PAR, UVA + PAR, PAR) at upper and intermediate depths in (A) August and (B) October experiments. Bars indicate means \pm SD, $n = 3$.



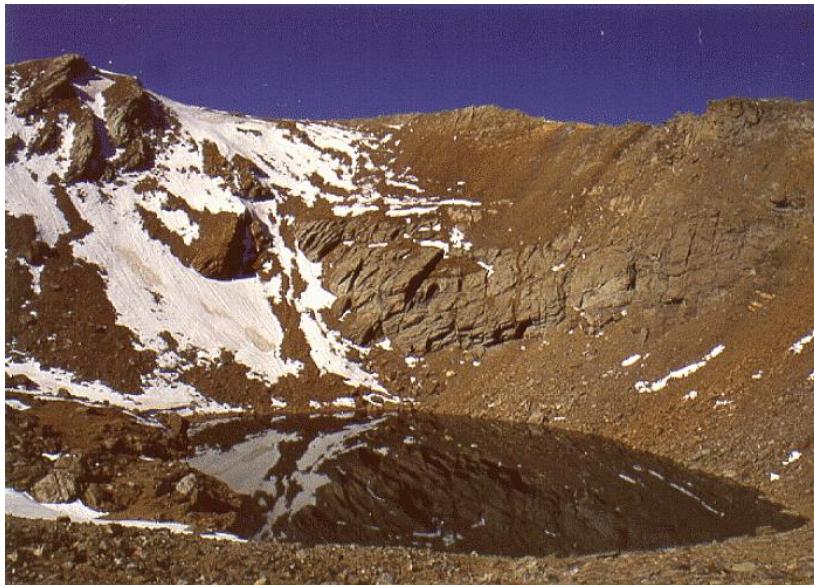
Temperature



Interactive effects: Temperature stimulates PRIMARY PRODUCTION (PP) when nutrients (Phosphorus) is available

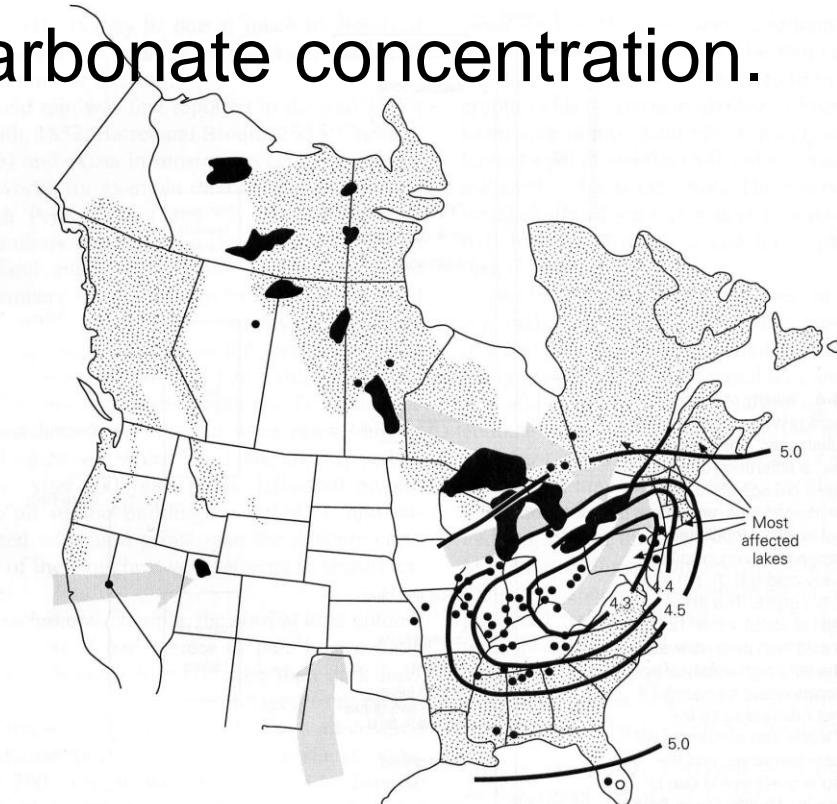


CO_2 : direct acidification effect

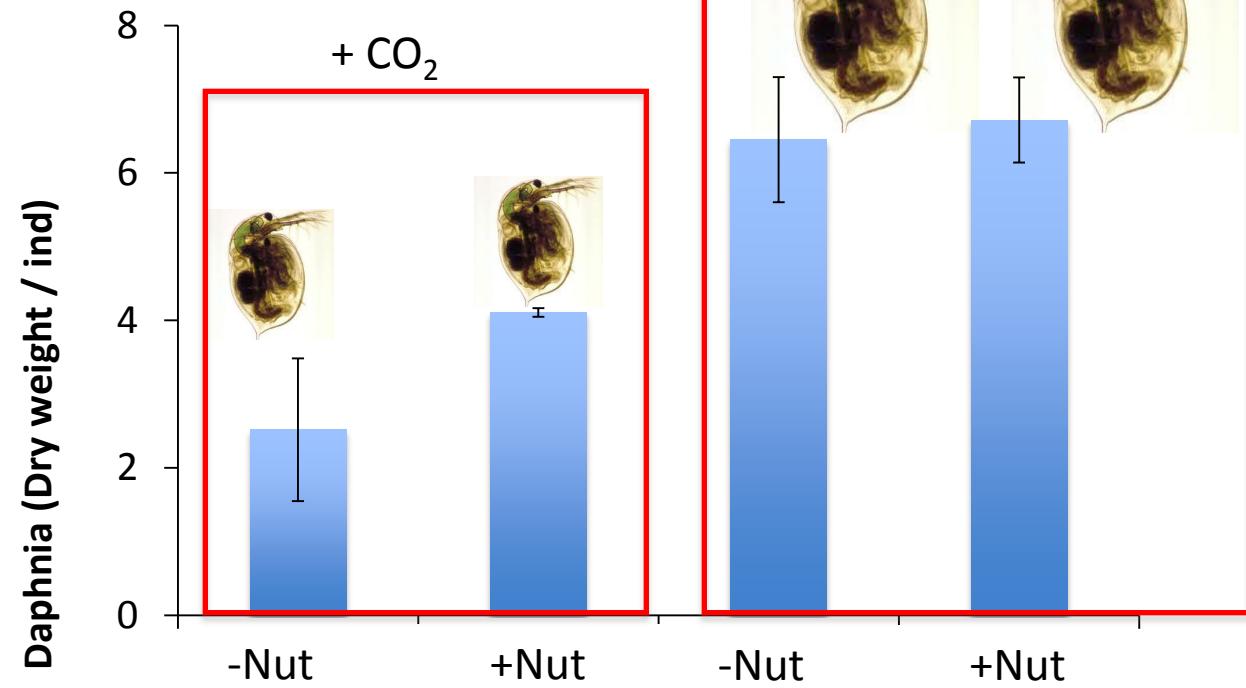
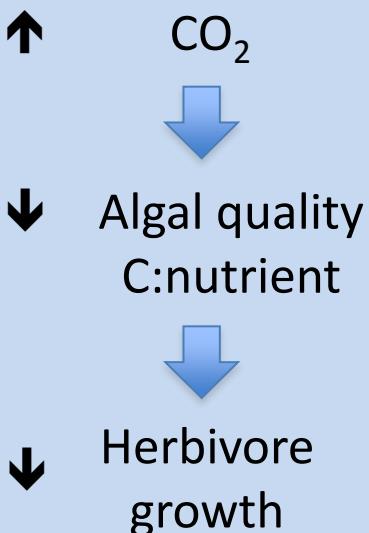


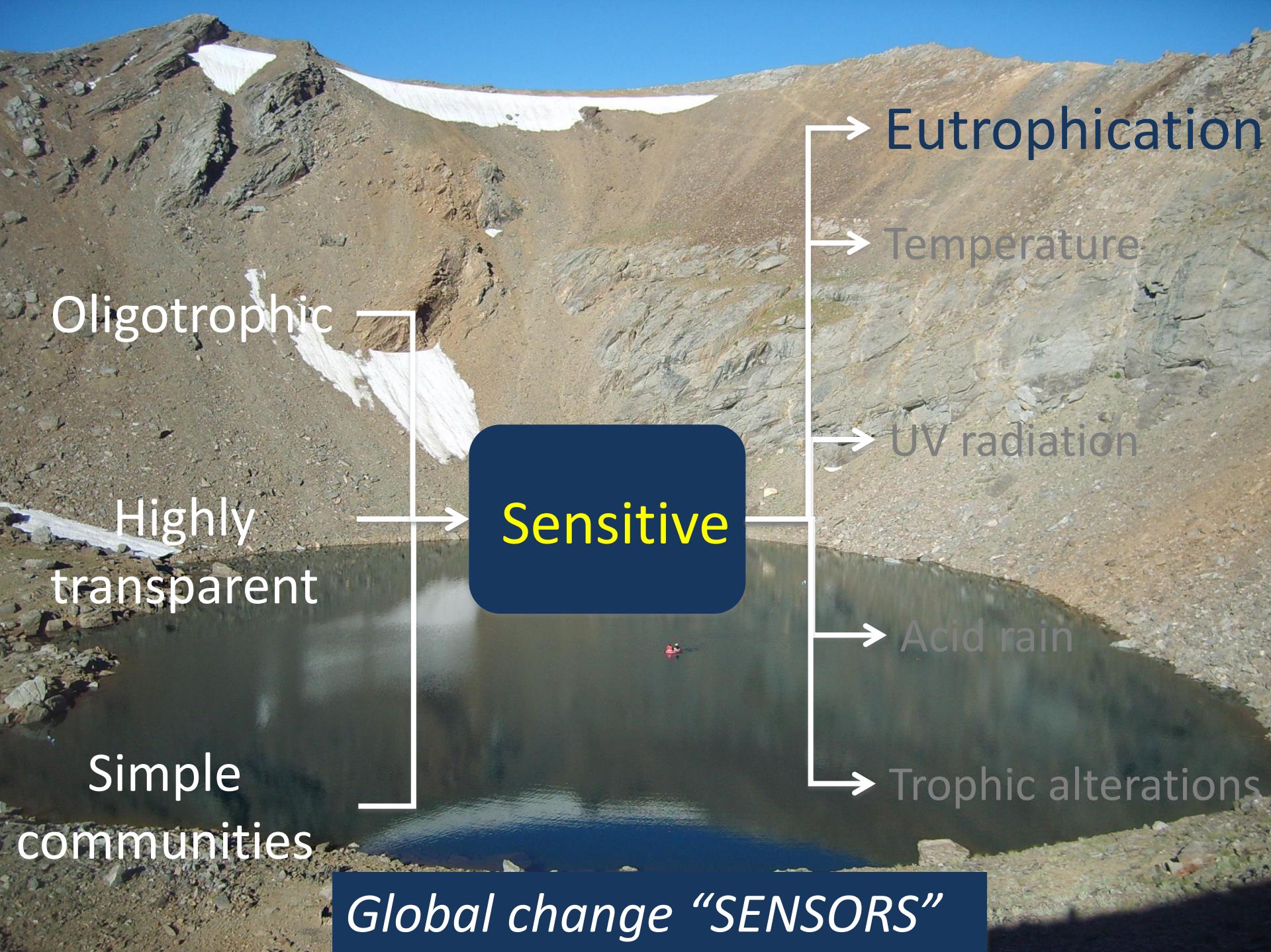
Low alkalinity systems are highly vulnerable to **ACIDIFICATION** because of their low carbonate and bicarbonate concentration.

- CO_2
- Acid rain (reference site in European projects ALPE, MOLAR)



CO_2 : food web indirect effect





Sierra Nevada

Low latitude and High altitude

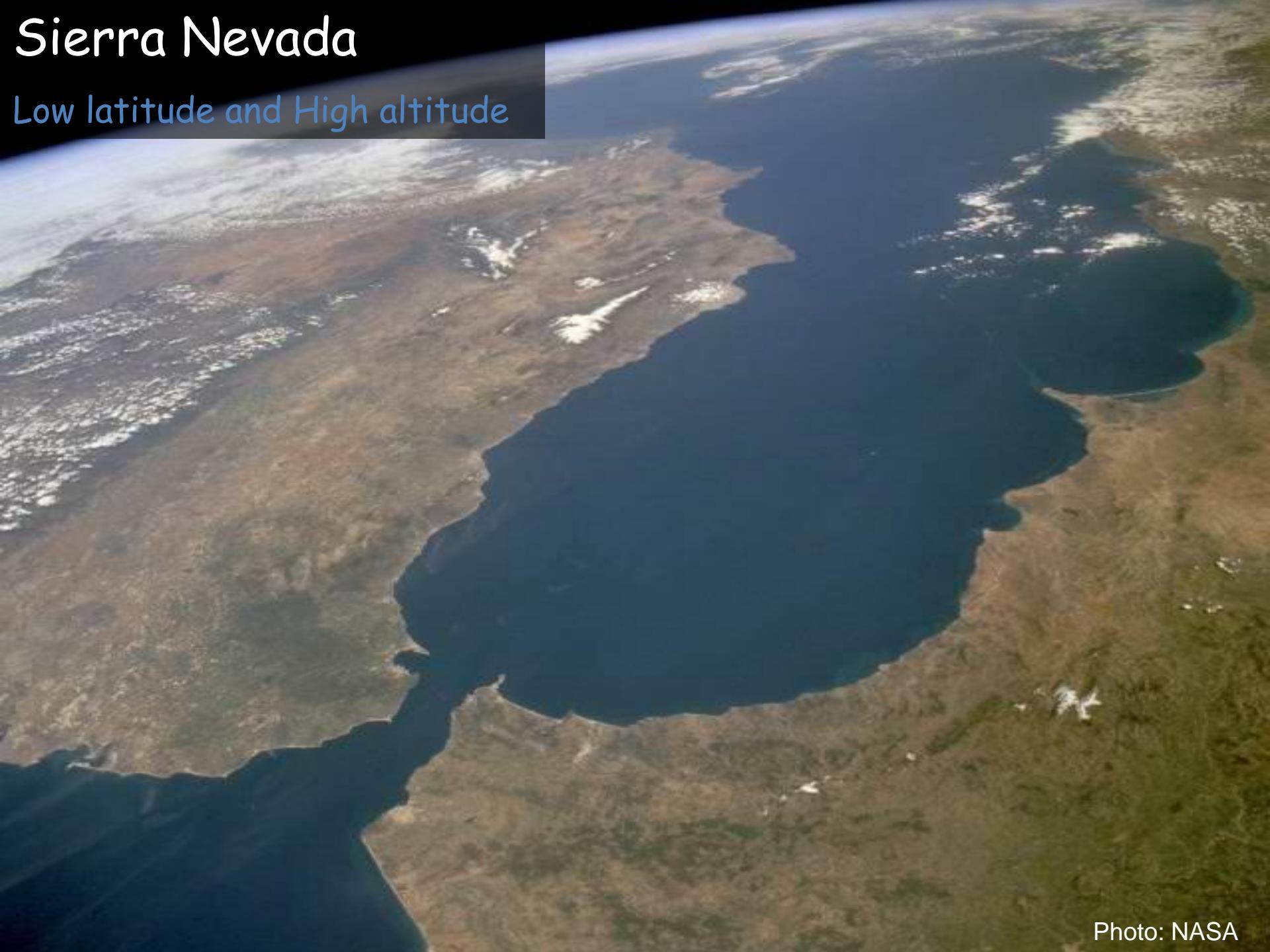
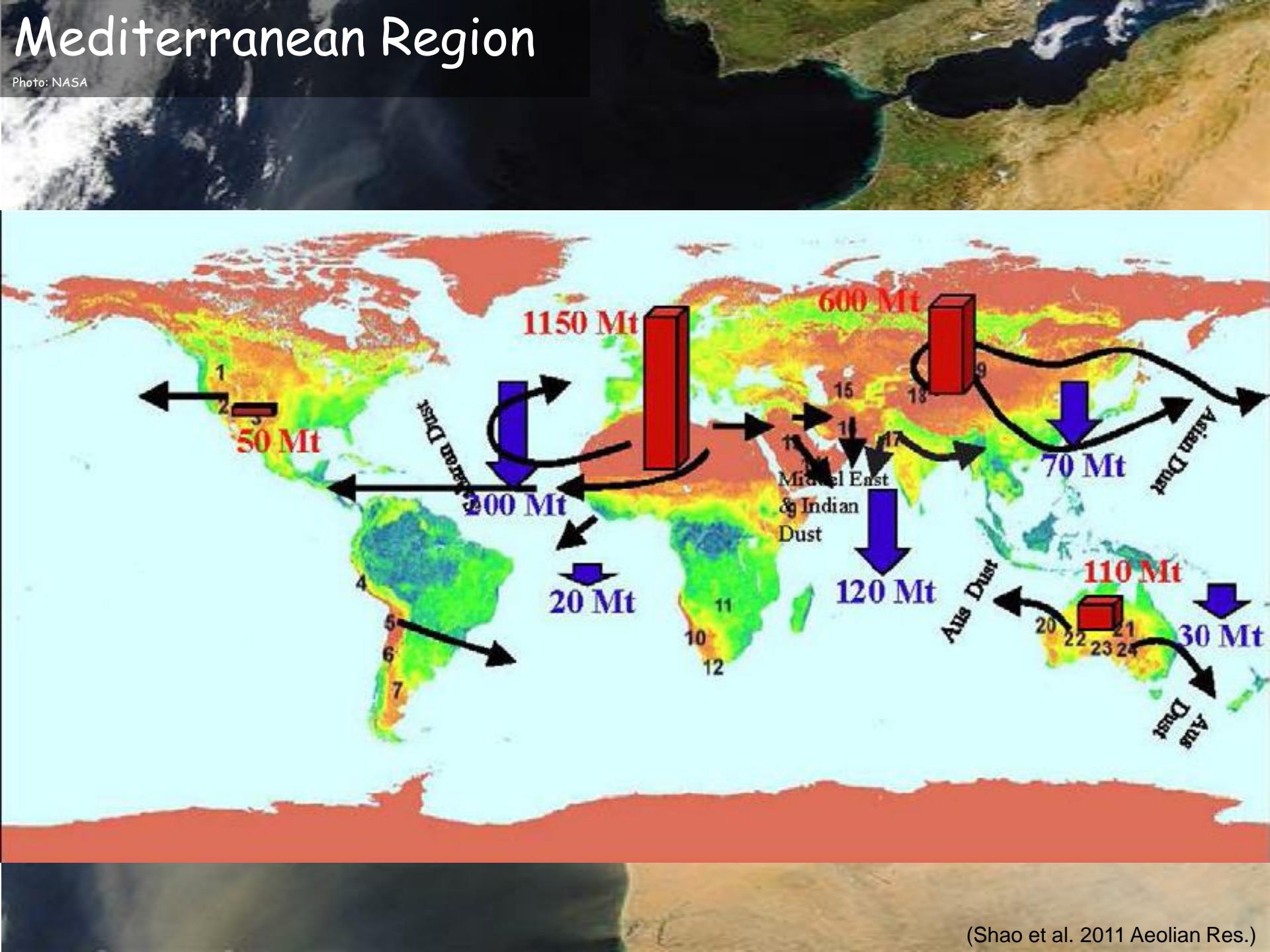


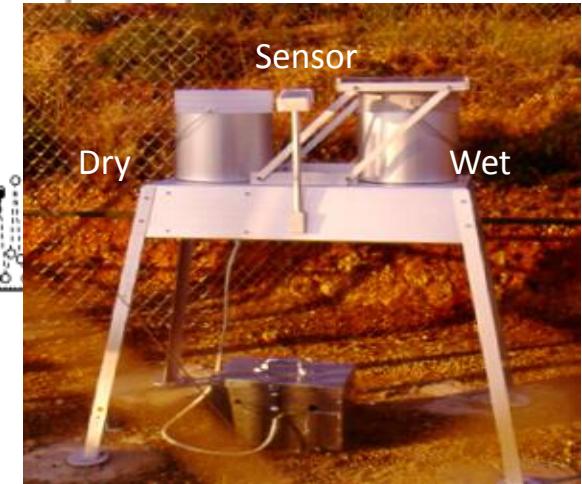
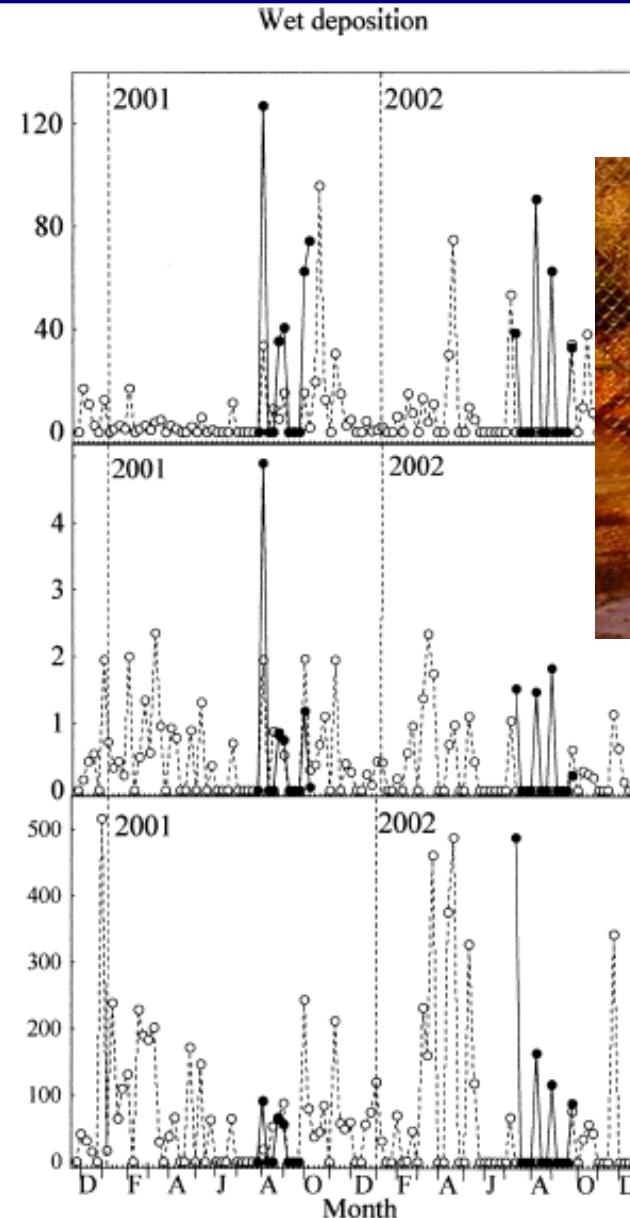
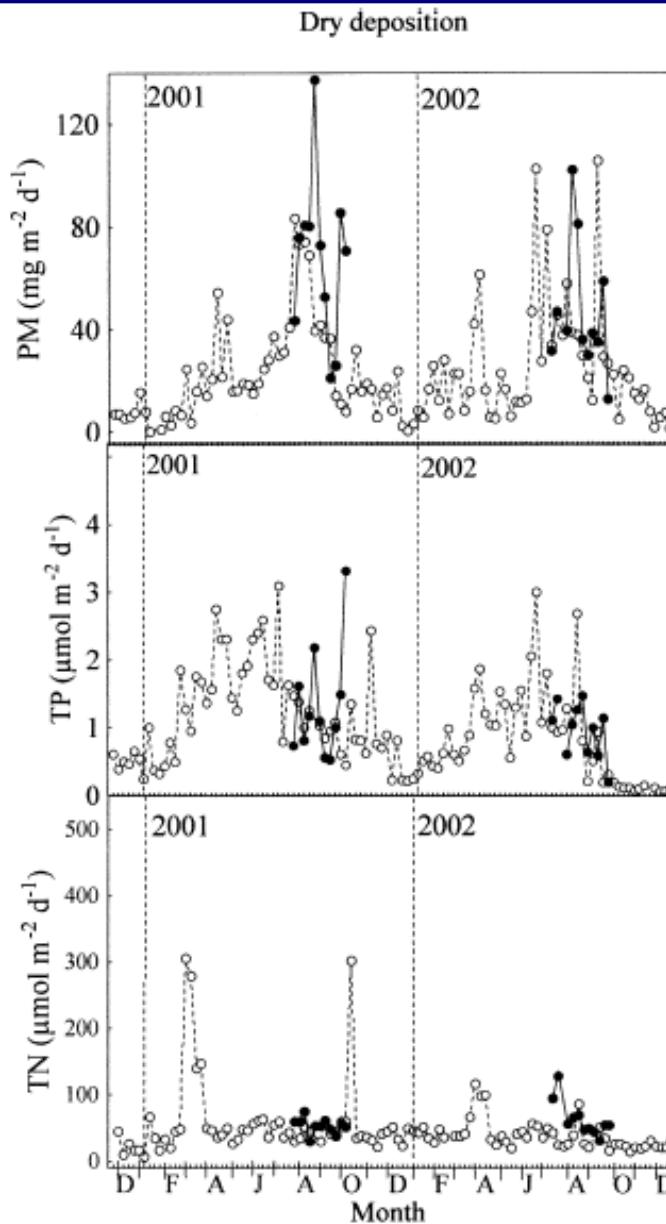
Photo: NASA

Mediterranean Region

Photo: NASA



Aerosol allochthonous inputs

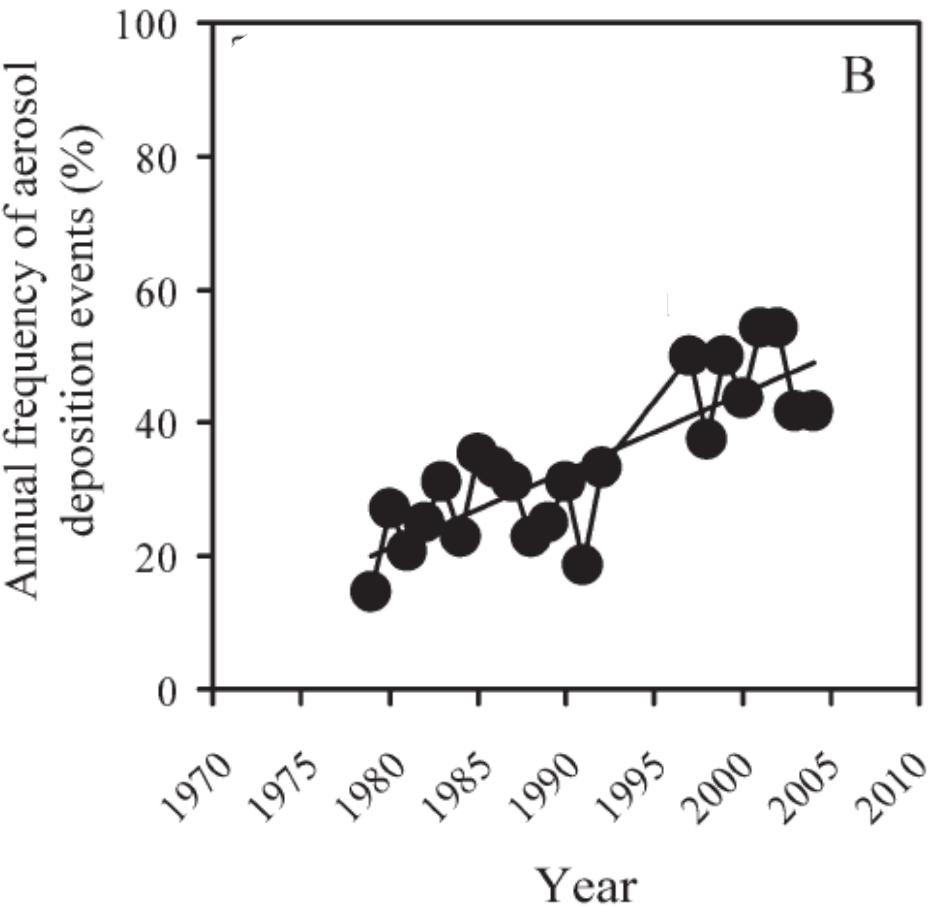
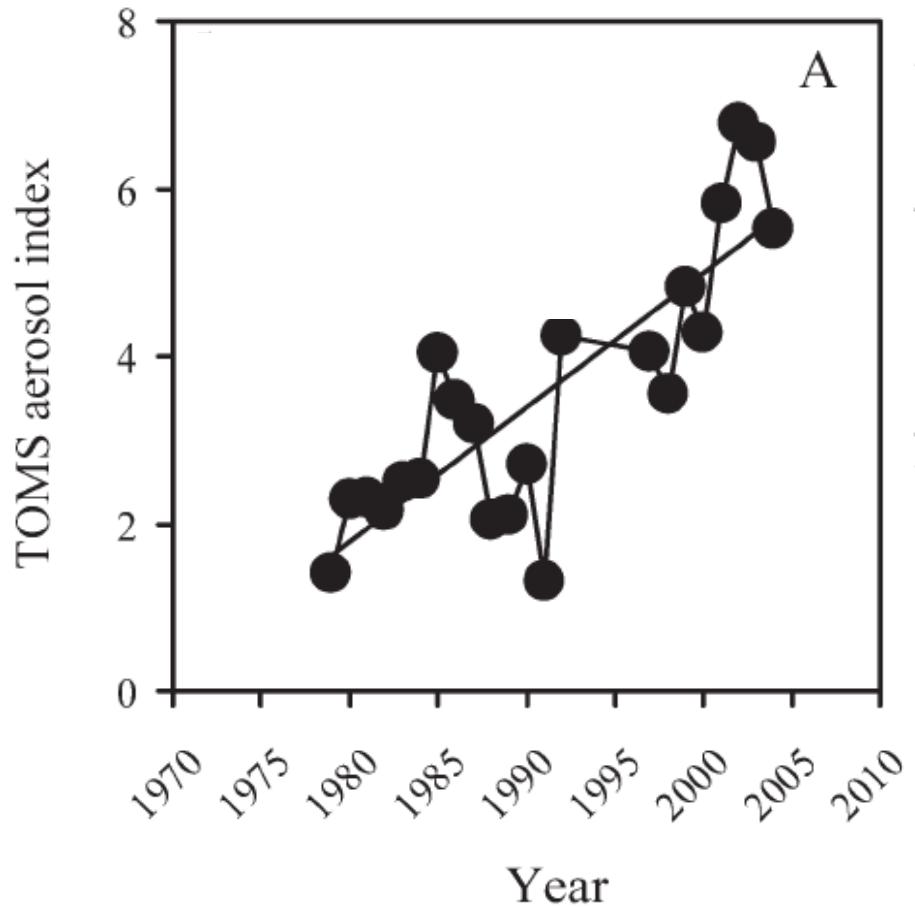
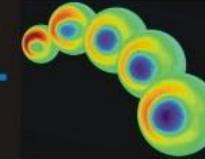


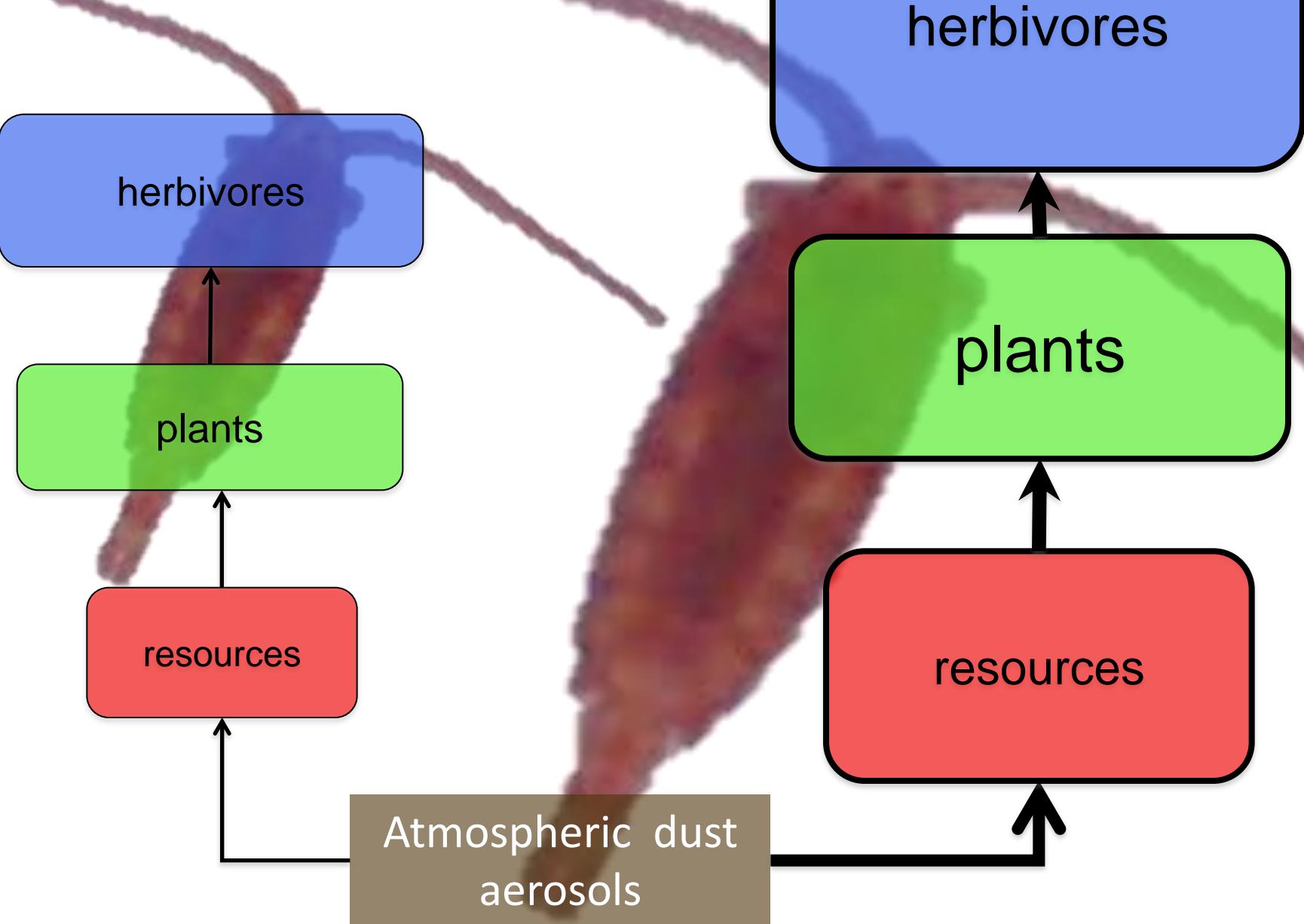
Satellite measurements

Total Ozone Mapping Spectrometer



Ozone Processing Team - NASA/GSFC Code 613.3





Long-term Aquatic Research in Sierra

Population / Community
Ecology



1975

Hidrogeology
Geomorphology

1980

1985

1990

1995

2000

2005

2010

2014

Biochemistry

Physical limnology

Castillo-Martín

Paleolimnology

Rodríguez-Rodríguez

Oliva

Cruz-Pizarro

Rueda

García-Jurado

Morales-Baquero

***Reche

Pulido-Villena

Linares-Cuesta

Mladenov

Conde-Porcuna

Bullejos

Souza

Giménez-Herrera

Durán-Romero

Dorado

Martínez-Silvestre

Cruz-Pizarro

Morales-Baquero

Sánchez-Castillo

Carrillo***

Rodríguez
Echevarría

Pérez-Martínez

Lango
Toth

Villar-Argaiz

Barea-Arco

Medina-Sánchez

Delgado-Molina

Linares-Cuesta

Anderson
Jiménez-Moreno
Pérez-Martínez
Conde-Porcuna
Liébanas



SIERRA
NEVADA

PARQUE NACIONAL

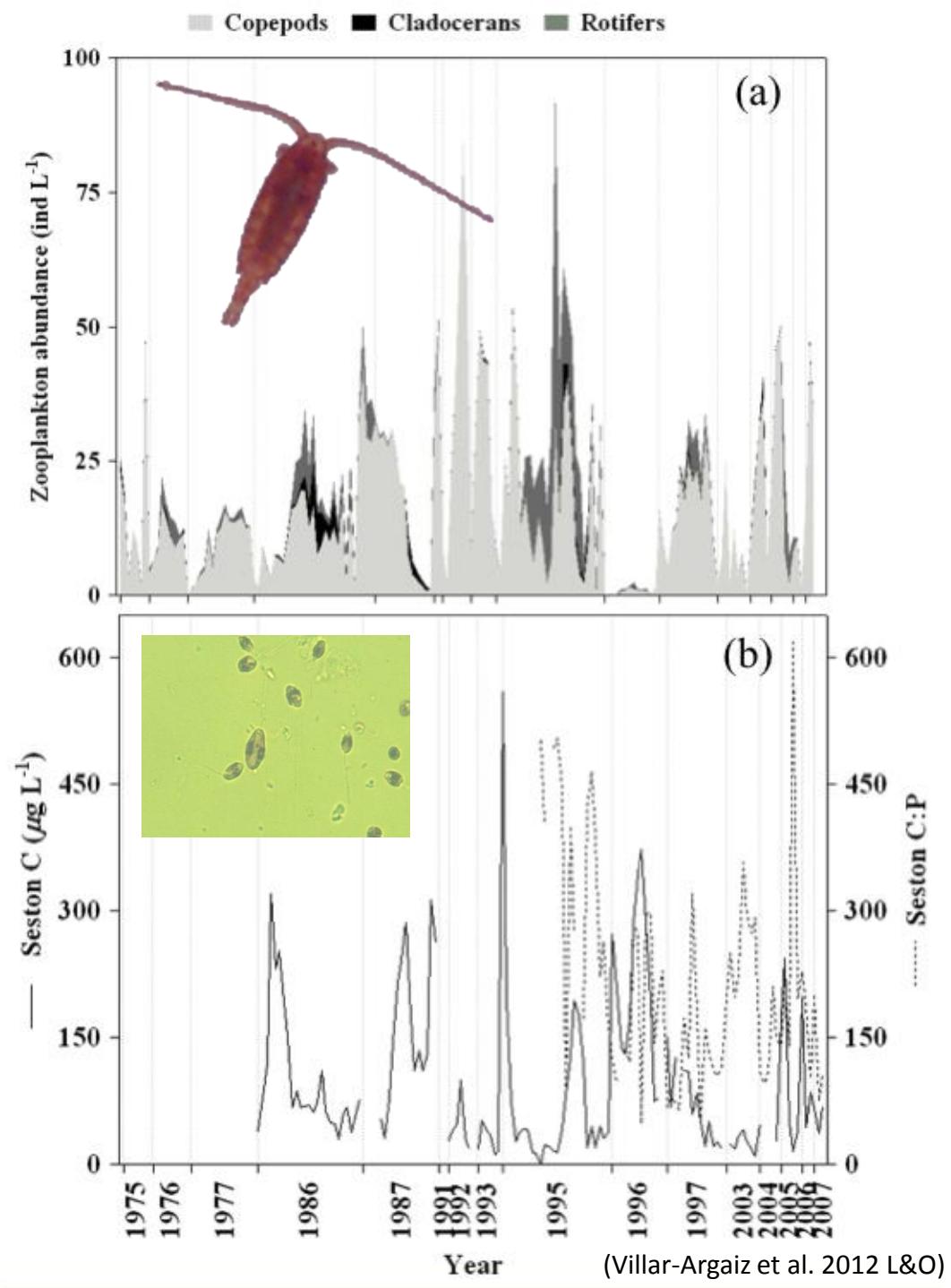


JUNTA DE ANDALUCÍA

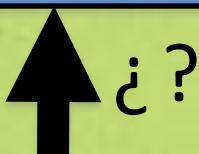
Consejería de Medio Ambiente



Long term population dynamics

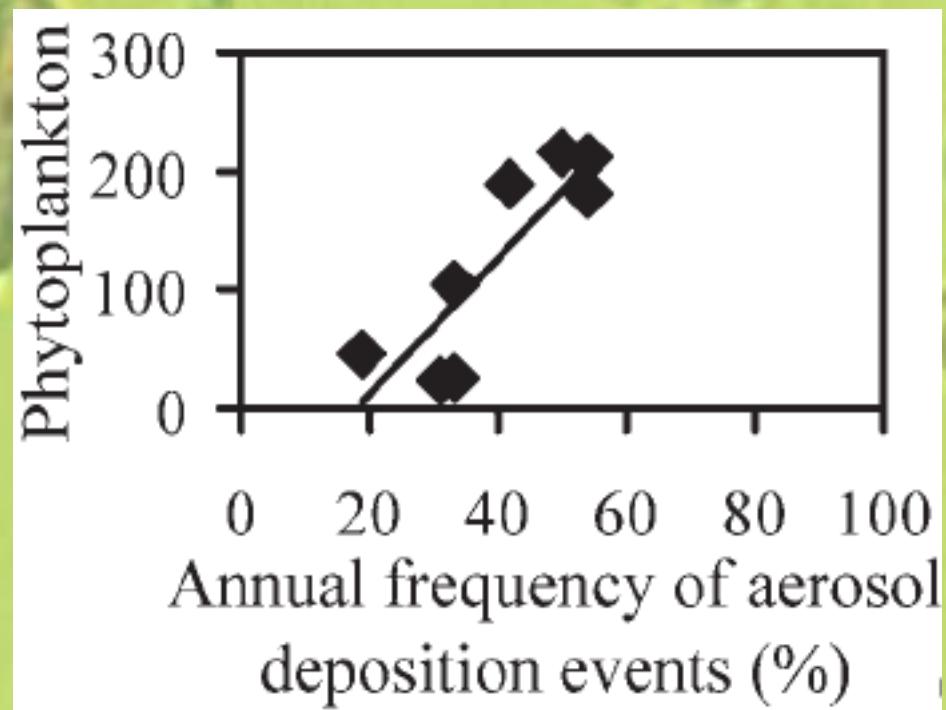
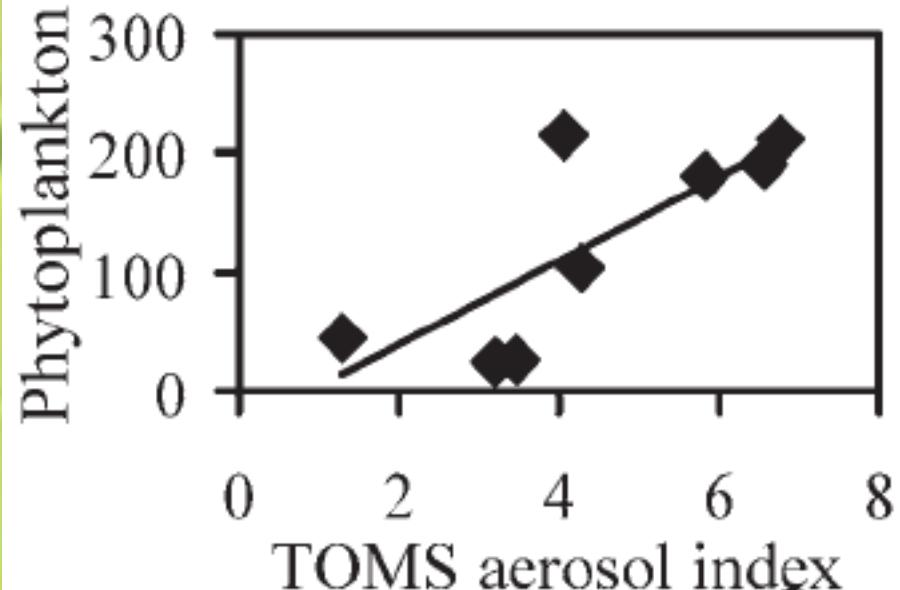


herbivores



plants

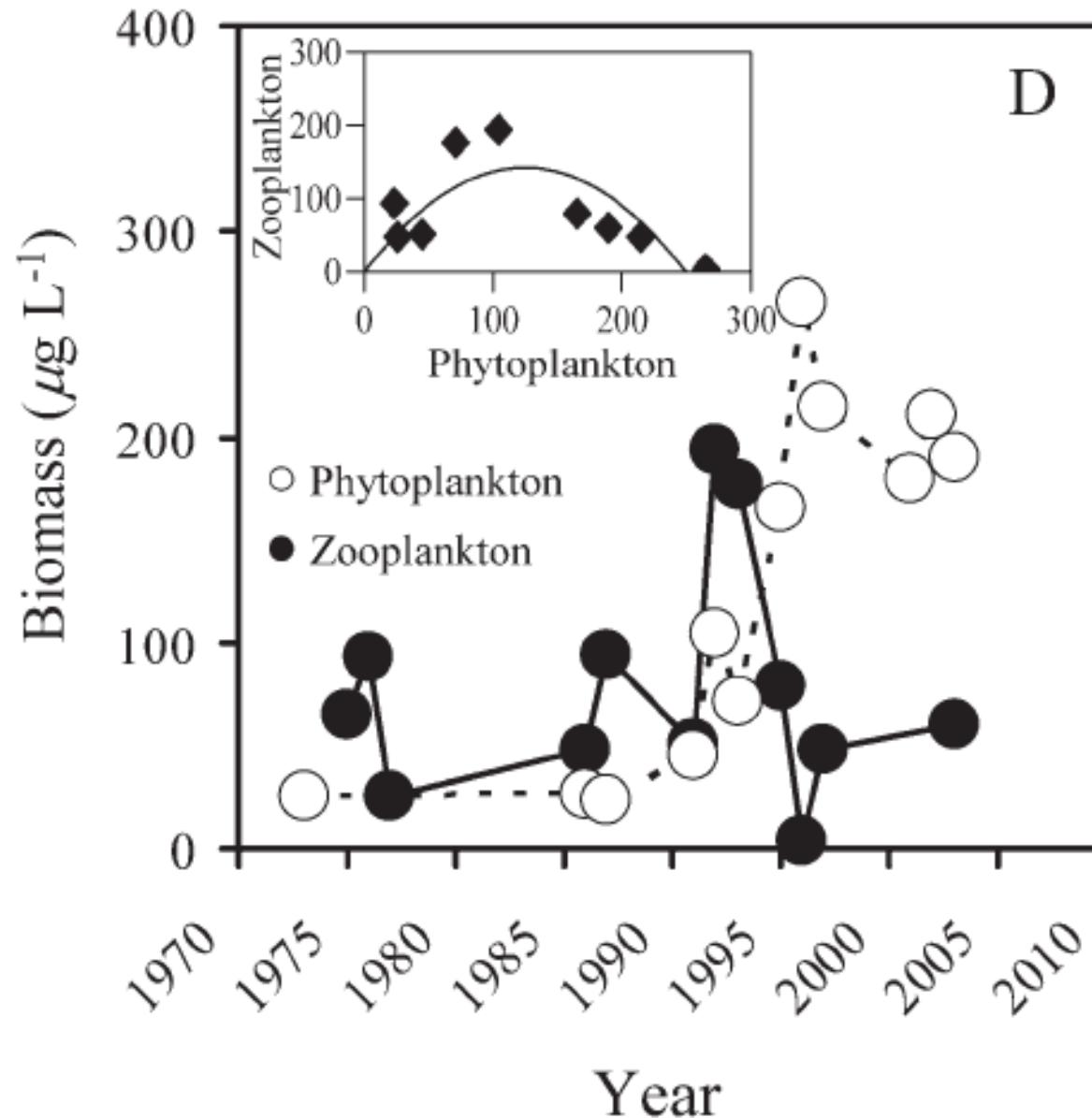
resources



herbivores

plants

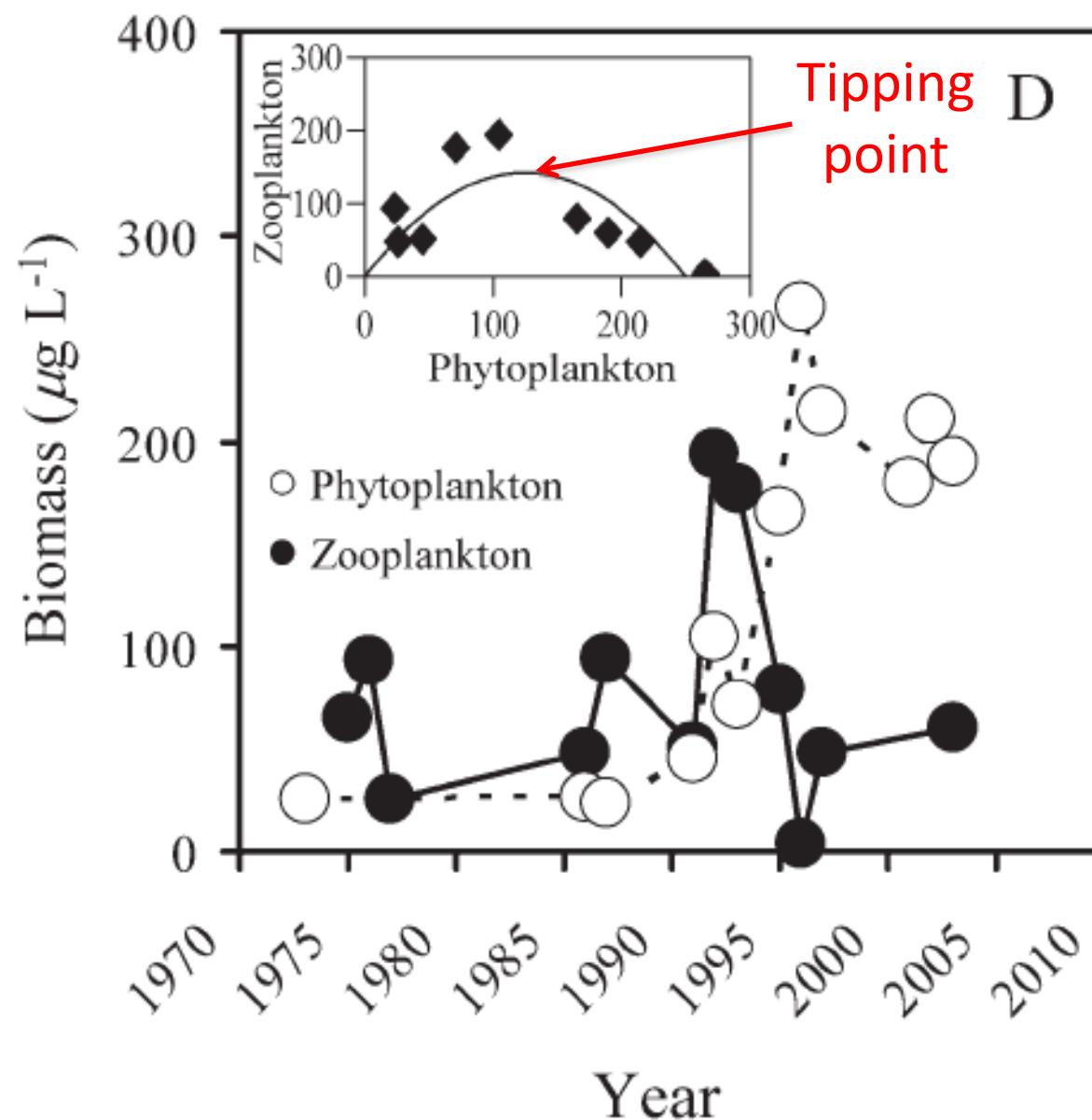
resources



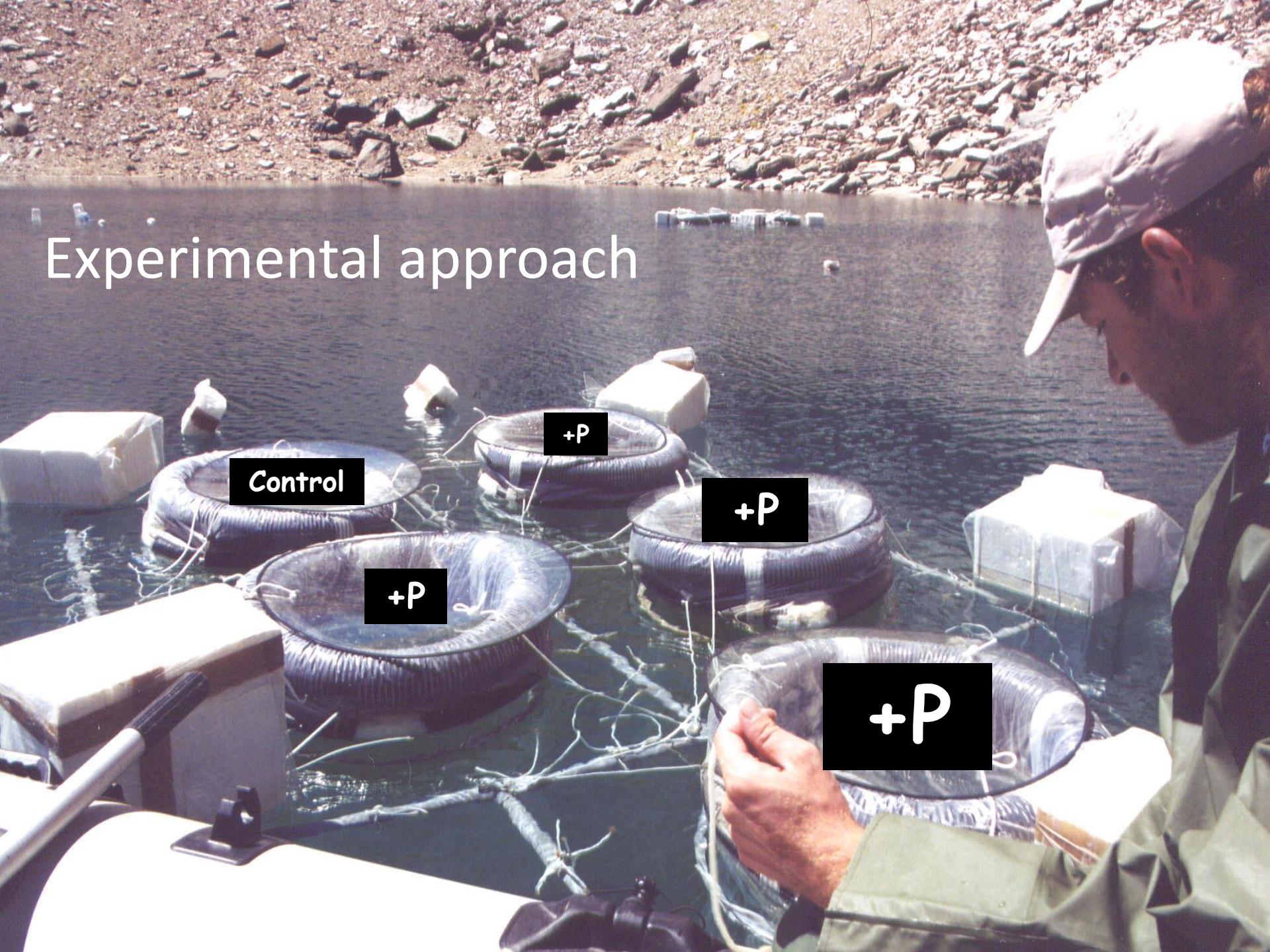
herbivores

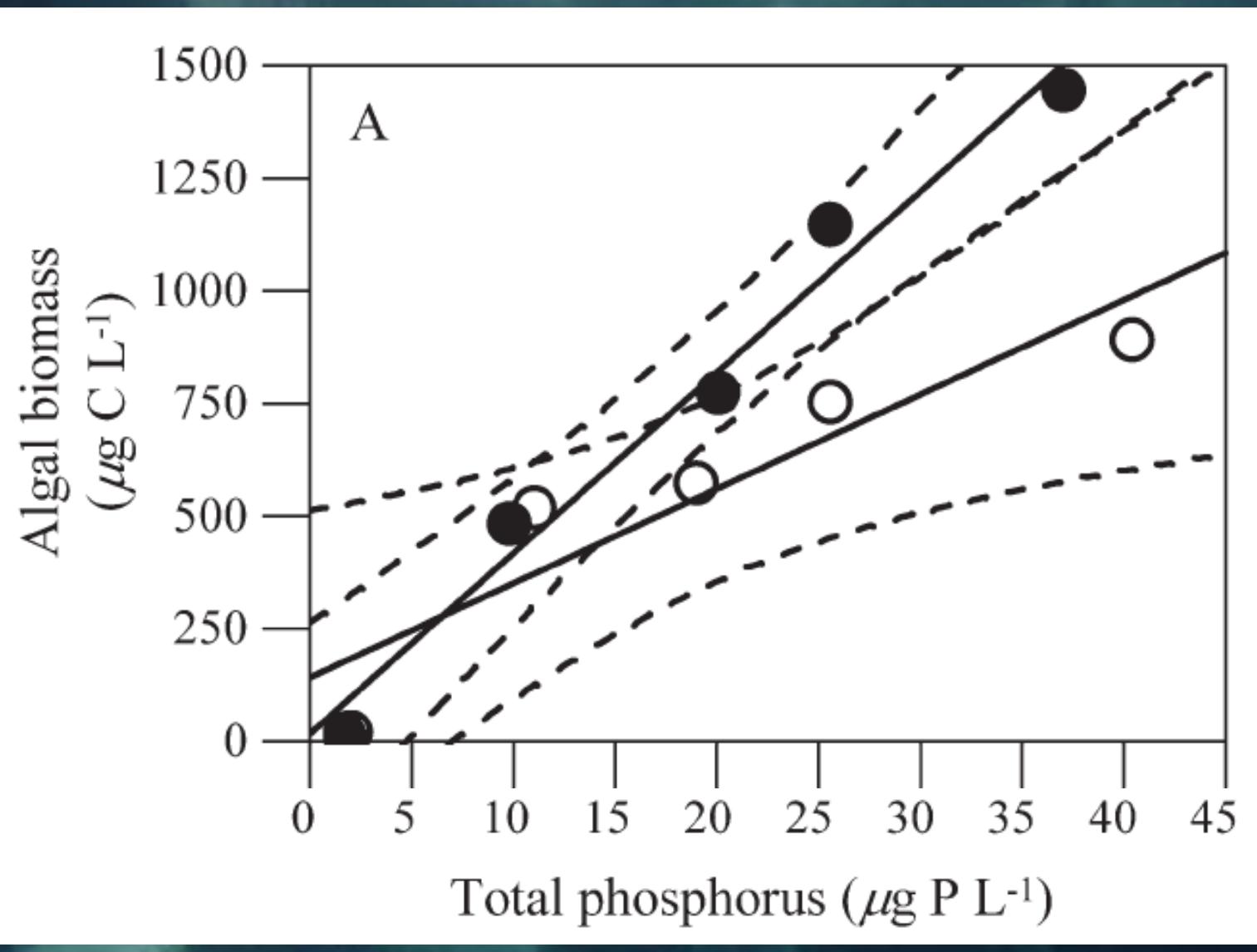
plants

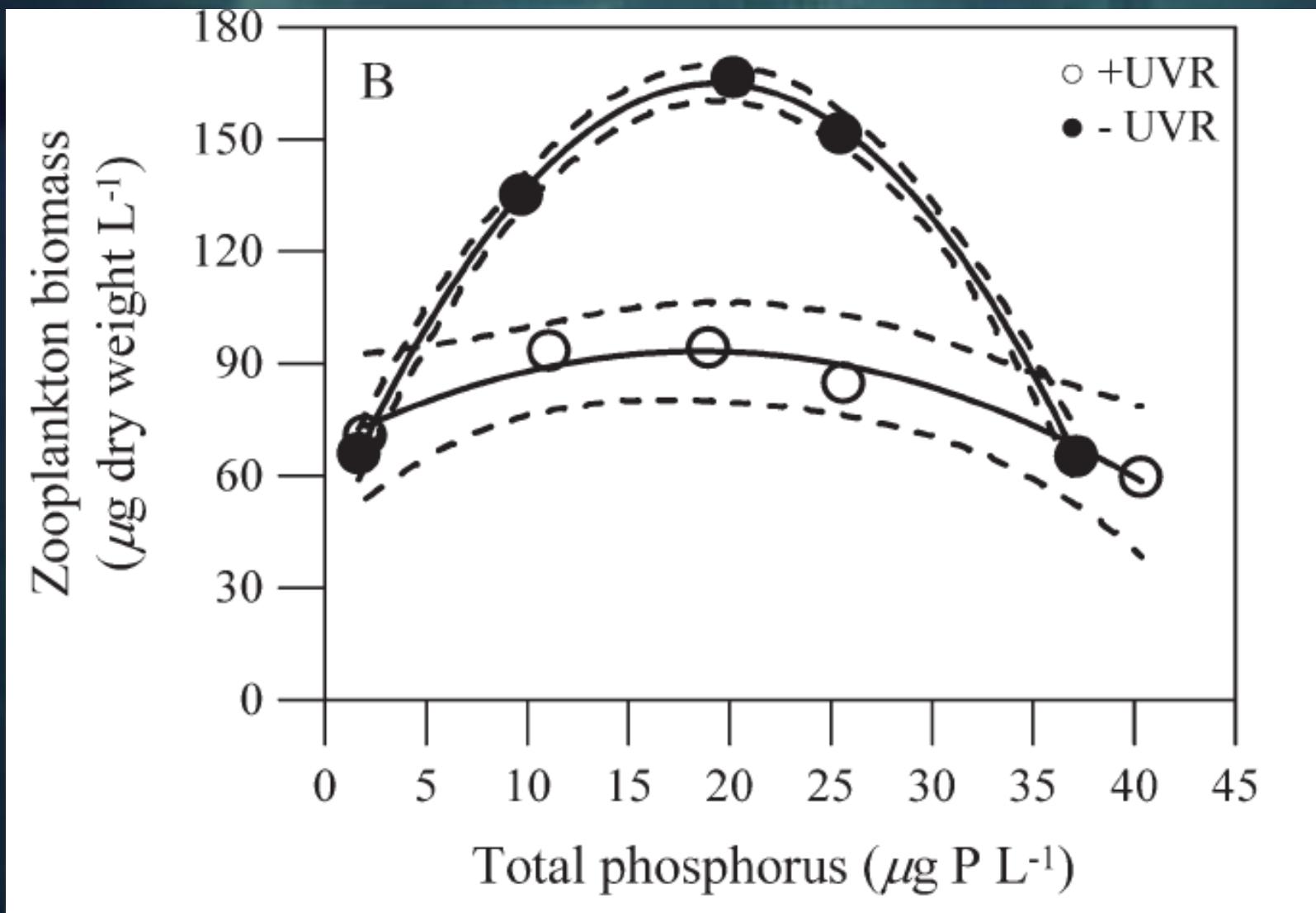
resources

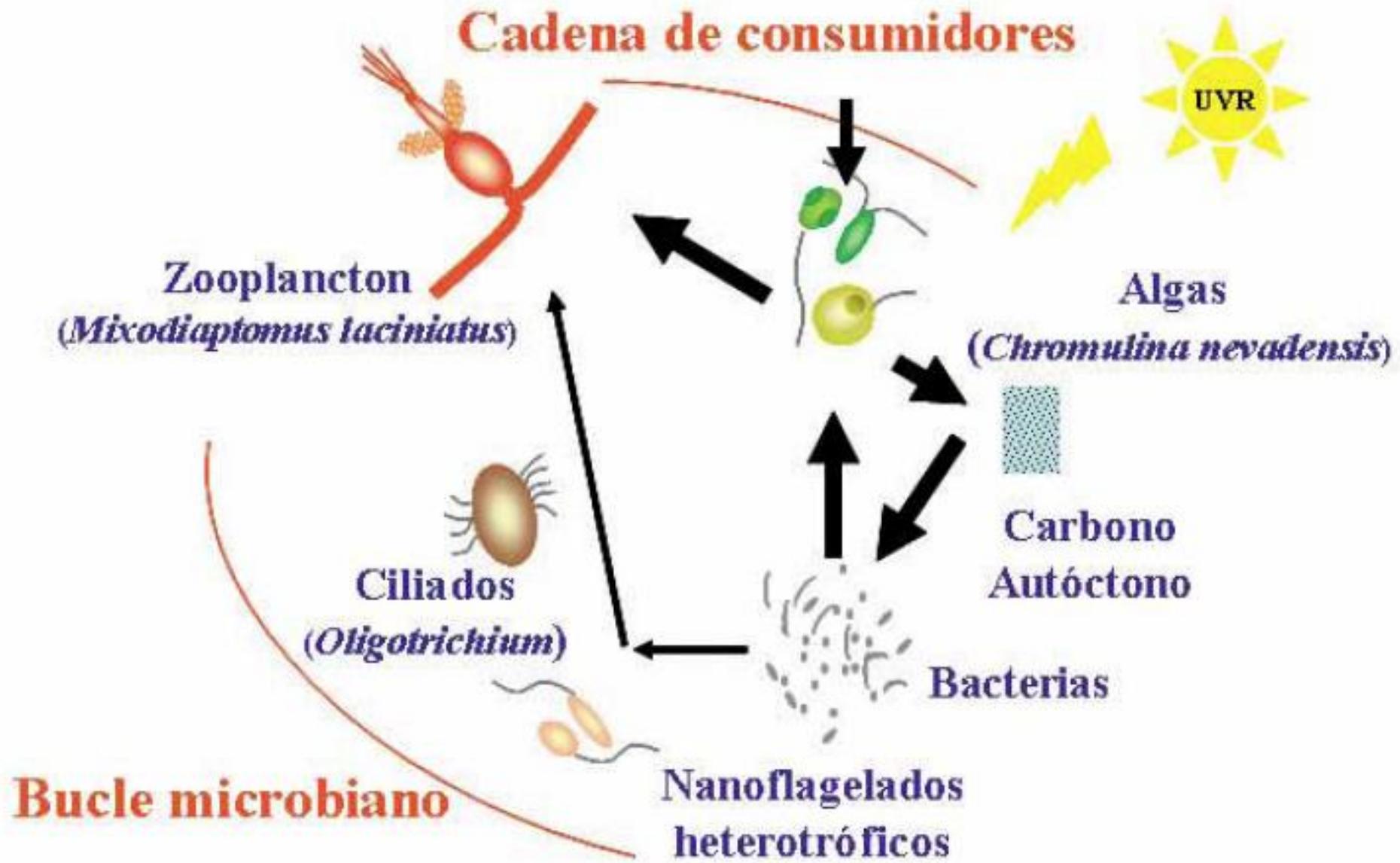


Experimental approach

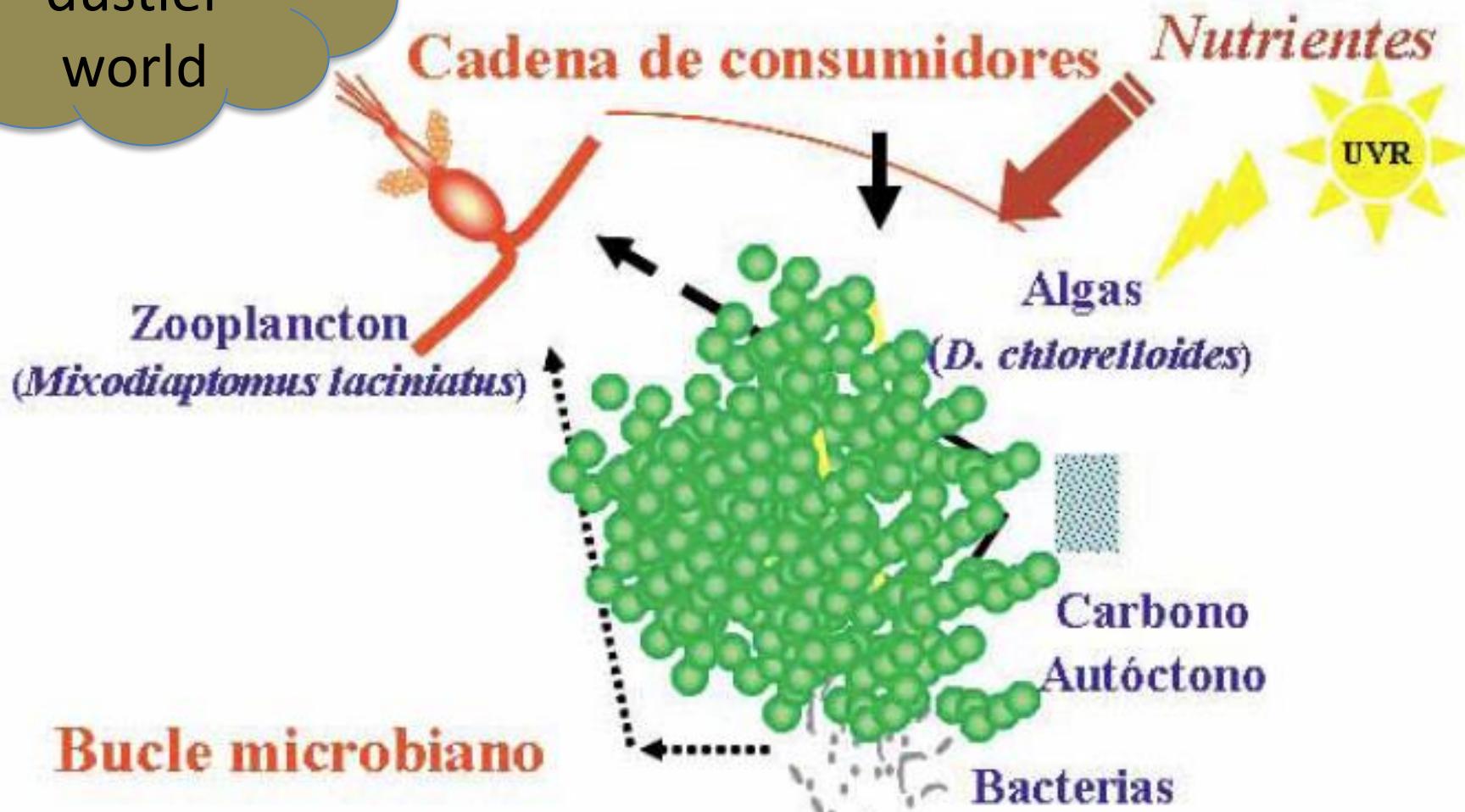








Living in a
dustier
world





...but also due to their
high vulnerability and
sensitivity are
**Sentinels of Global
Change**

The lakes of S. Nevada
are authentic relics
that still survive
hanging at an altitude
of 3000 m



...What's next?



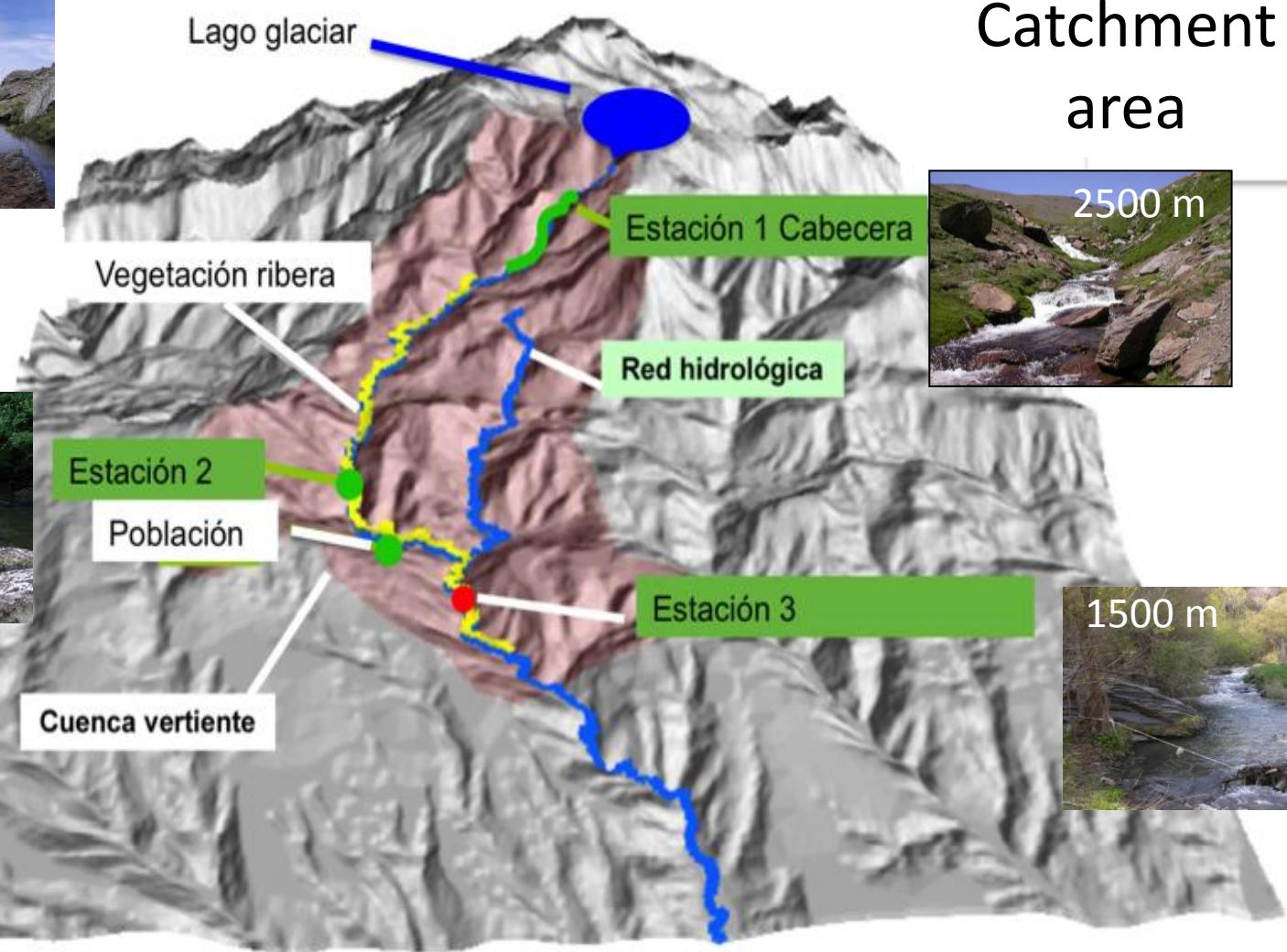
LTER
spain

Observatorio
Cambio Global
Sierra Nevada

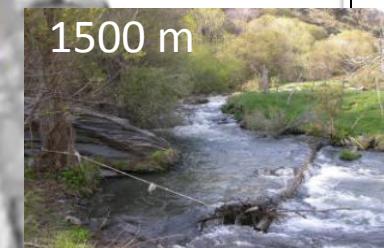
Integration Aquatic ecosystems



3000 m



2500 m



1500 m