Lakes 17

5th Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling

Berlim, Germany, October 16 – 19, 2017

Biological and Physico-Chemical profiles of a large reservoir (Alqueva, Southern Portugal)

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18th October 2017

Outline

- ✓ Lake classification: **Trophic state and mixing patterns**
- ✓ The **Alqueva** reservoir
- ✓ **ALEX** Project
- ✓ **ALOP** Project
- ✓ **Final remarks and next steps**

Lake types

Carlson's Index: based on its **trophic status**: **phosphorus** and **nitrogen**

Oligotrophic

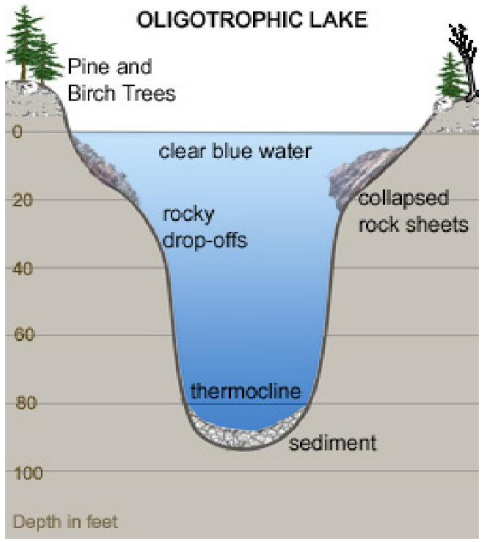
- Low nutrients (P&N)
- Low algal concentration
- Less decomposition
- Clear water
- Highly oxygenated waters

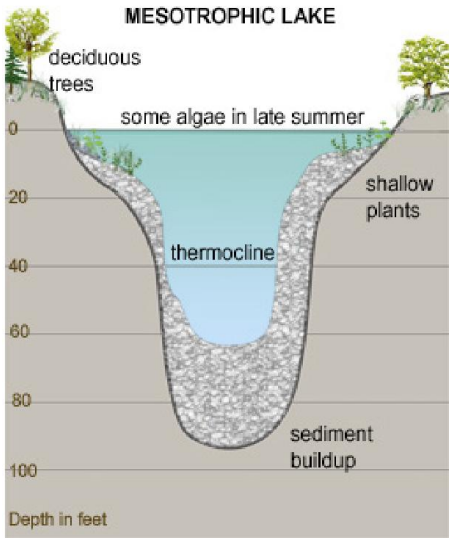
Mesotrophic

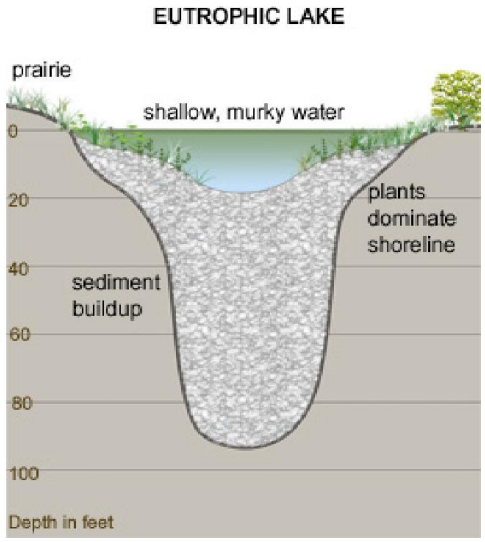
- Intermediate level of productivity
- Stratification
- Oxygen concentration high at the surface, bottom layer anoxic during summer

Eutrophic

- High nutrient levels
- High primary production
- Murky, green water
- Usually shallow
- Lots of plants and algae



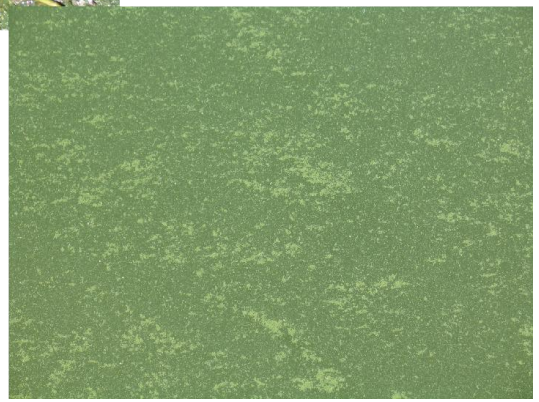




Lake types

Carlson's Index: based on its **trophic status**: **phosphorus** and **nitrogen**

Cyanobacteria are an important group of algae often appearing a dominant part of the phytoplankton of lakes and reservoirs. They tend to form a **dense bloom rising to the surface.**



Alqueva reservoir,
June 2014

Lake types

Classification by mixing patterns

Meromictic lake:

Lakes that have layers of water that do not intermix.

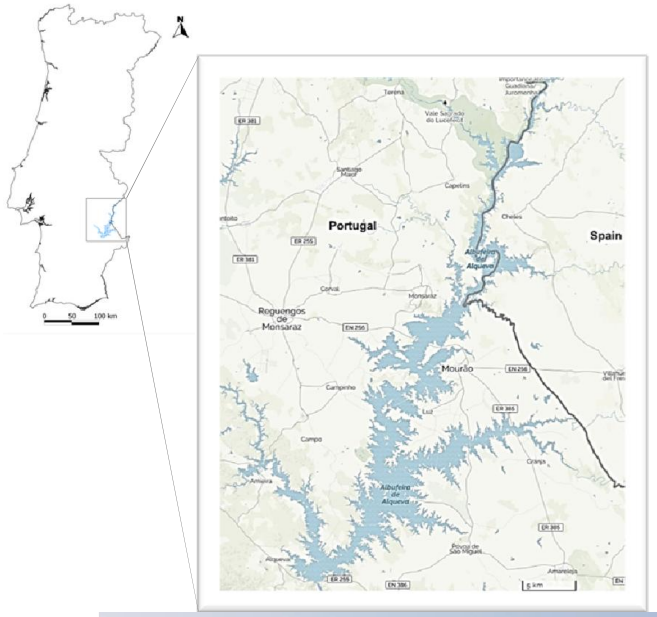
Amictic lake:

Lakes that are permanently covered by ice. Glacial lakes. Exhibit inverse cold water stratification.

Holomictic lakes:

Lakes that have a **uniform temperature and density** from **top to bottom** at a specific time during the year, which allows the lake waters to completely mix.

Alqueva reservoir



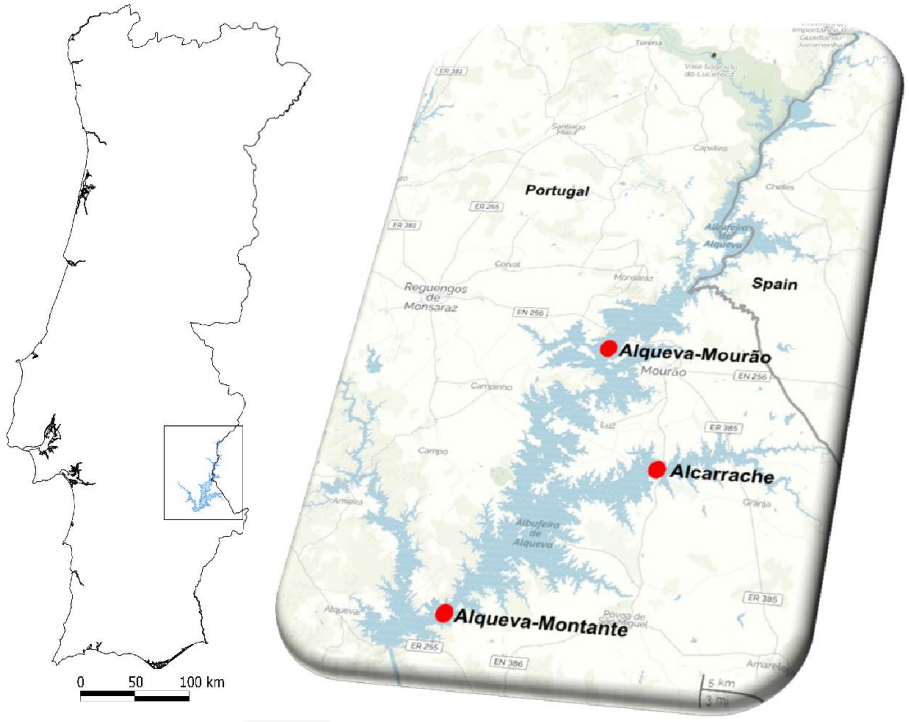
- Located in the water course of **Guadiana river**;
- Closure of floodgates on 8 February 2002;
- **Largest artificial water reservoir in Western Europe**, also called the **Great Lake**;
- Built with the objective of **irrigation** for the entire Alentejo area and **production of electricity**, in addition to other complementary activities;
- Classification in terms of **trophic state**: **Mesotrophic**;
- Classification in terms of **circulation**: **Warm monomictic**
- Ecological Potential: **Good**

ALEX Project

ALEX: ALqueva hydro-meteorlogical Experiment 2014

ALEX2014

ALqueva hydro-meteorological EXperiment



Sampling period	From June to September 2014
Sampling sites	Alqueva-Montante Alcarrache Alqueva-Mourão
***In situ* parameters**	Temperature (ºC) pH (Sorensen scale) Dissolved Oxygen (% O_2 saturation) Electrical Conductivity (µS/cm) Redox Potential (mV)
Chemicall parameters	Nitrates (mg/L NO3-N) Total Nitrogen (mg/L N) Phosphates (mg/L PO4-P) Total Phosphorus (mg/L P)
Biological parameters	Water samples at different depth for Phytoplancton identification and quantification

Results

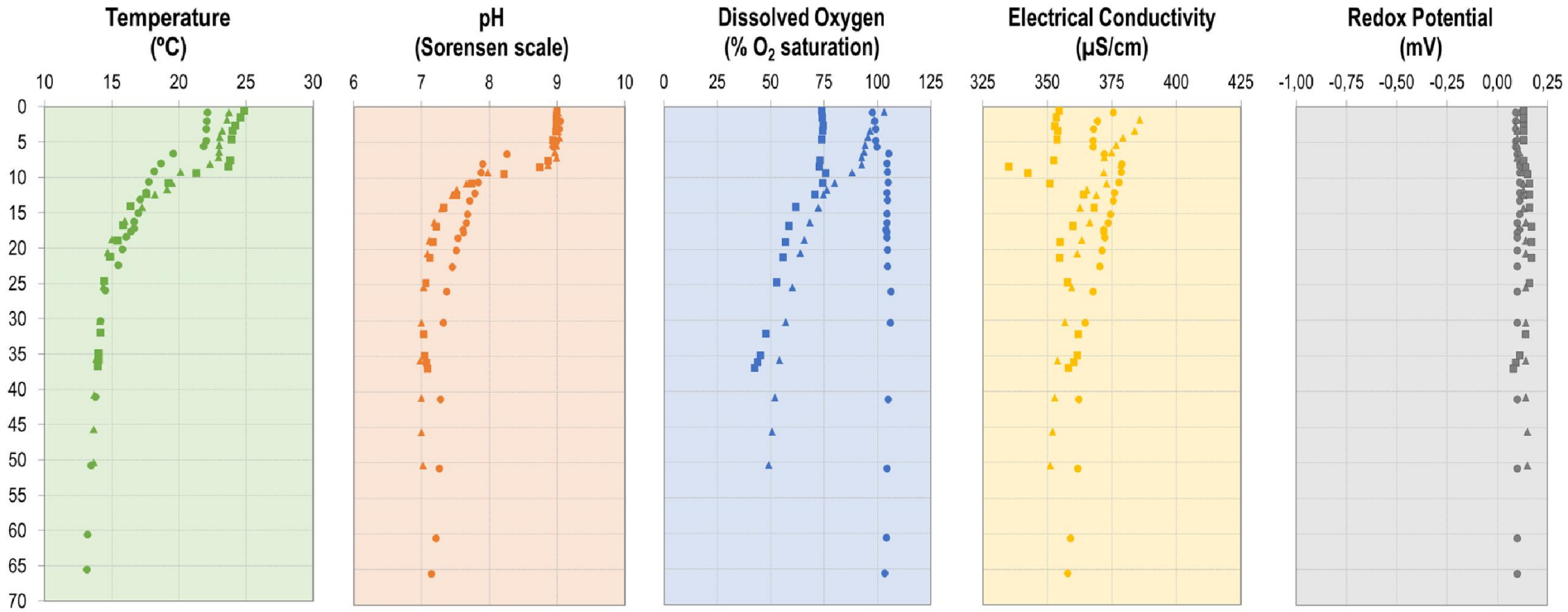
In situ parameters – Vertical profiles

○ Montante

△ Mourão

□ Alcarrache

June



Results

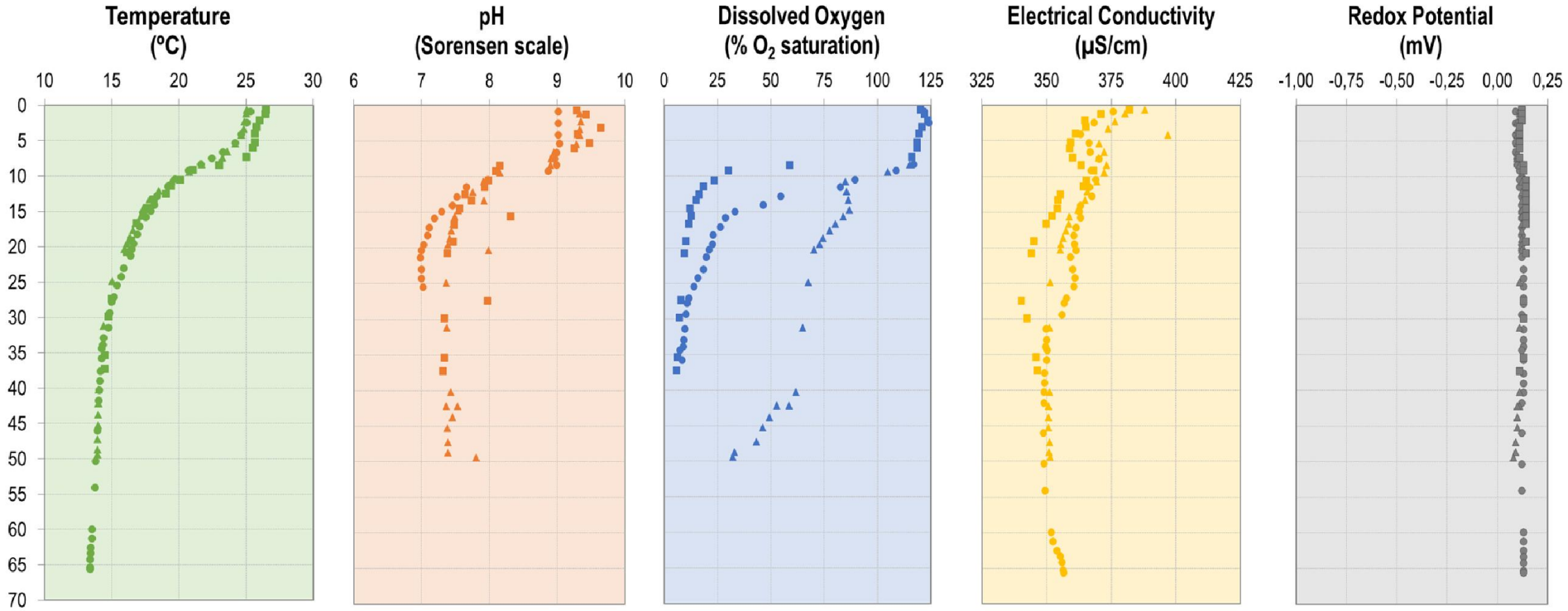
In situ parameters – Vertical profiles

○ Montante

△ Mourão

□ Alcarrache

July



Results

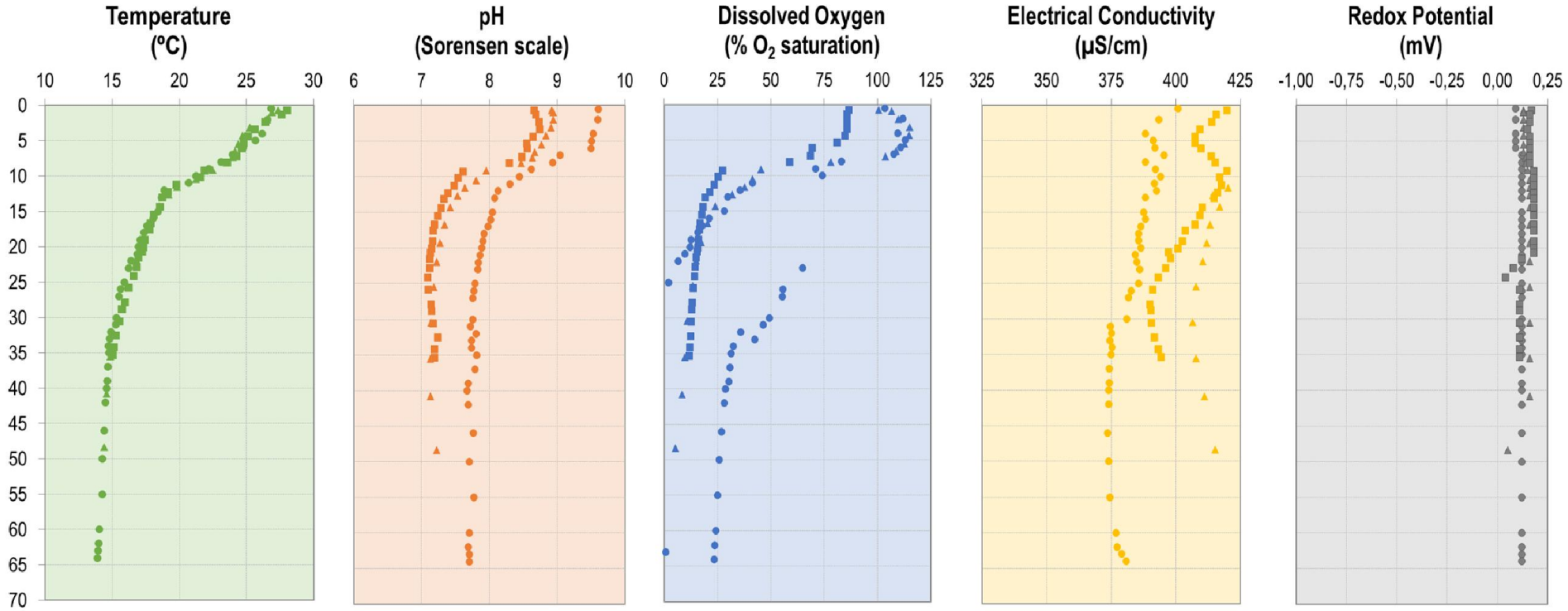
In situ parameters – Vertical profiles

○ Montante

△ Mourão

□ Alcarrache

August



Results

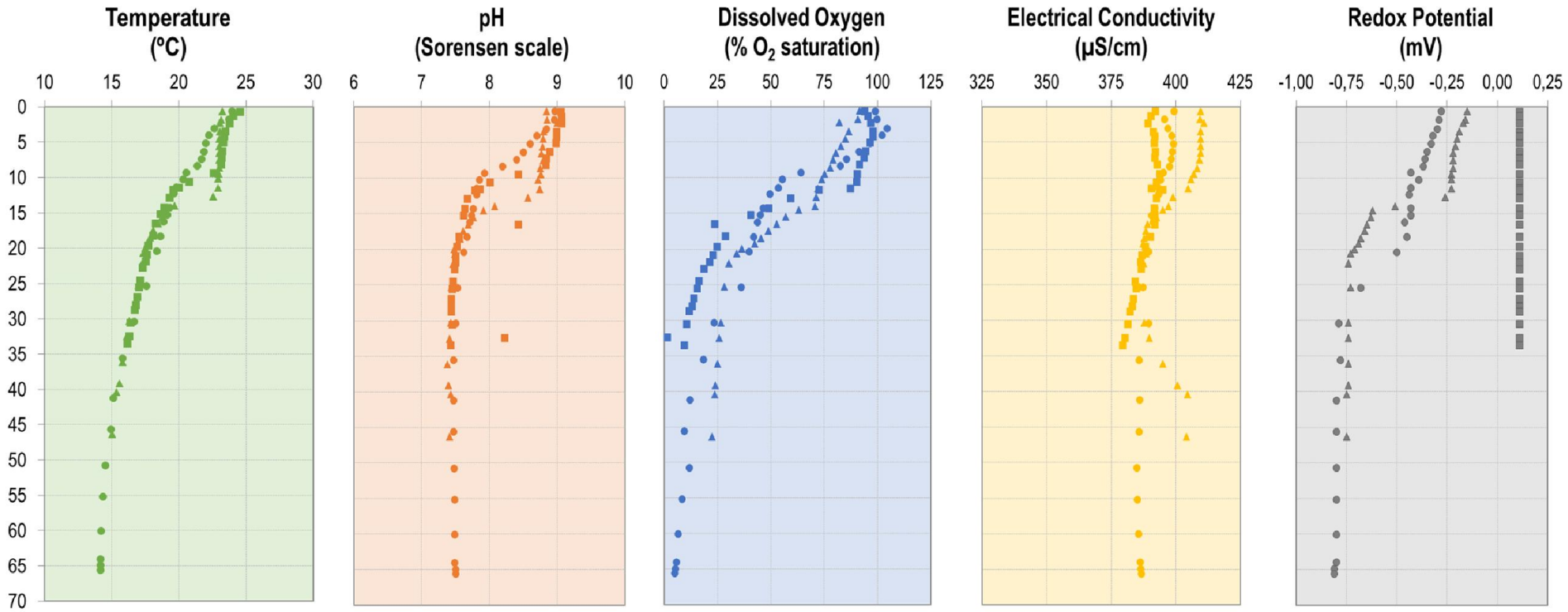
In situ parameters – Vertical profiles

○ Montante

△ Mourão

□ Alcarrache

September

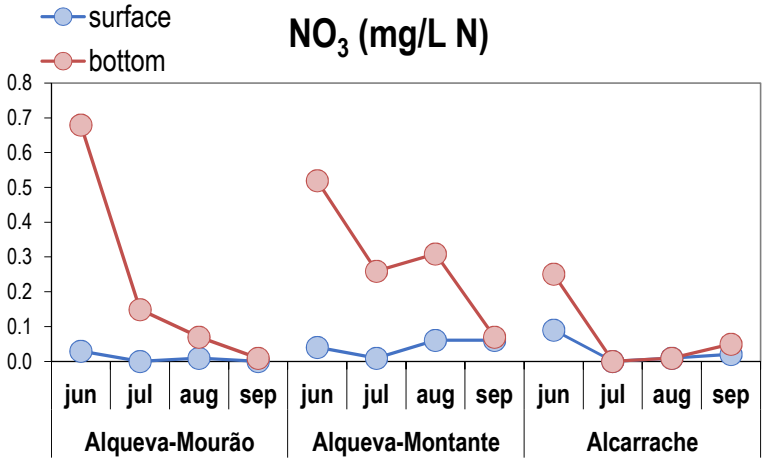


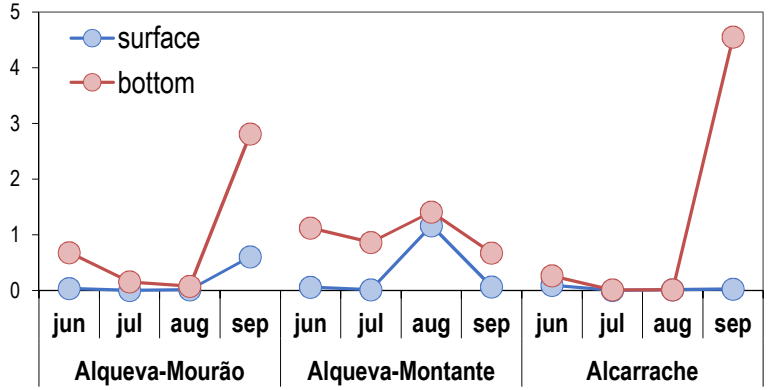
Results

Chemical parameters - Nitrogen

Water Frame Work Directive
(reservoirs for South Portugal)

Good Ecological Potential ≤ 25 mg NO_3/L





- **Bottom** levels generally **higher** than **surface** levels;
- **Decrease** of NO_3 at the bottom **over time**, at all sampling sites.

- **Bottom** levels **higher** than **surface** levels in June and September at all sampling sites.

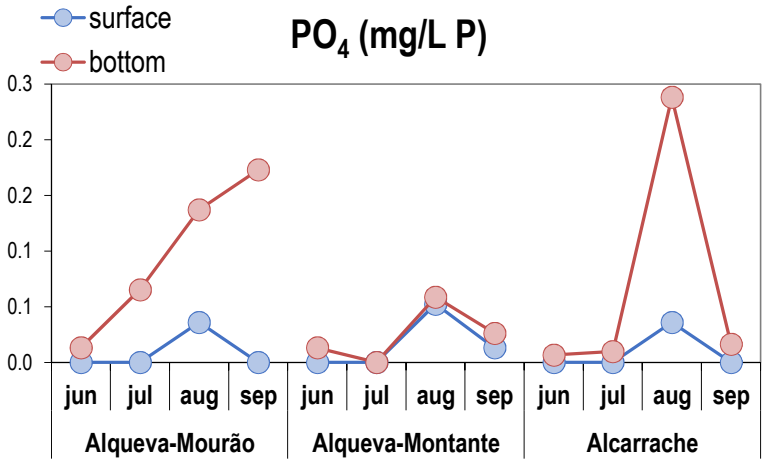
Results

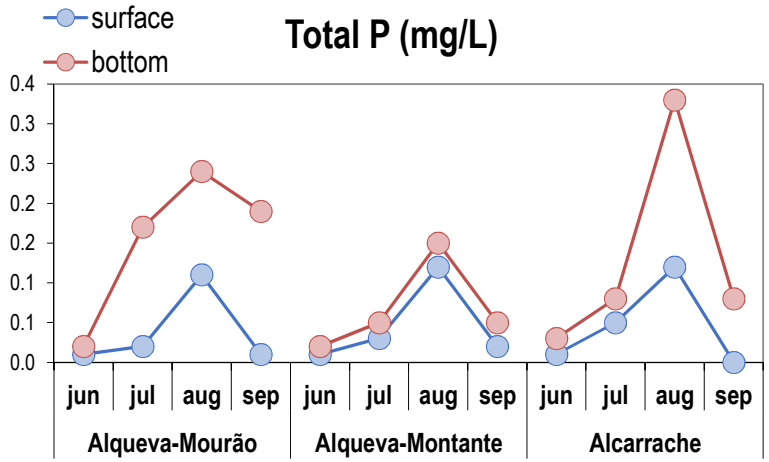
Chemical parameters - Phosphorus

Water Frame Work Directive
(reservoirs for South Portugal)

Good Ecological Potential ≤ 0.07 mg P/L

Limit for **Eutrophic state ≤ 0,035 mg/L**





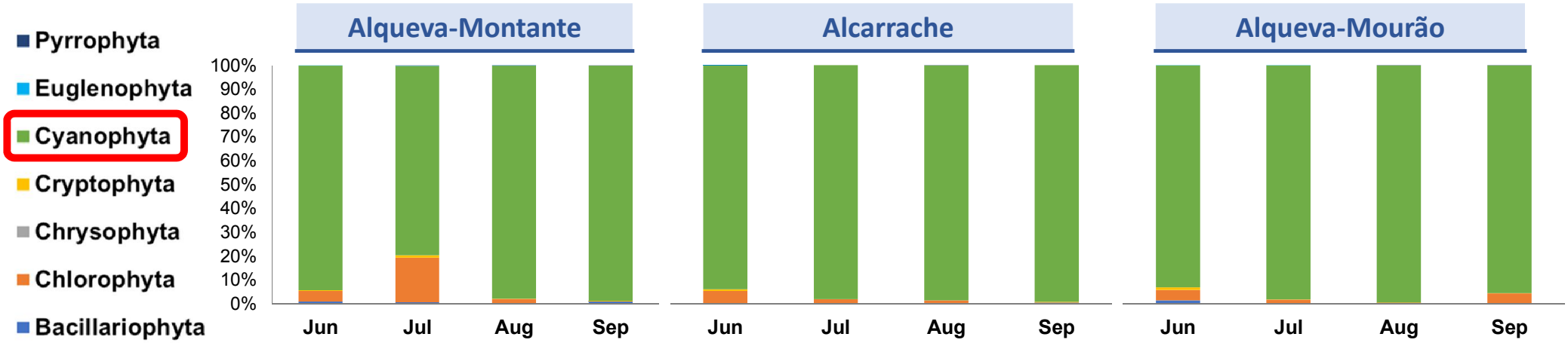
PO_4 and Total P:

- **Bottom** levels **higher** than **surface** levels, with an **increase over time**, at **Alqueva-Mourão**;
- **Alqueva-Montante** with **no difference** between surface and bottom levels;
- **PO_4 peak** at **Alcarrache** in **August**.

Results

Biological parameter - Phytoplankton

Abundance, Diversity and Richness



- Succession of phytoplankton species, mainly cyanobacteria, thus representing a **temporal dynamics**, typical of reservoirs that are **not under the influence of severe anthropogenic pressure**;
- **Cyanobacteria dominated in abundance throughout the experiment**, whilst **Chlorophyta** were the **taxa richest group.**

Results

Biological parameter - Phytoplankton

Abundance, Diversity and Richness

Most commons species

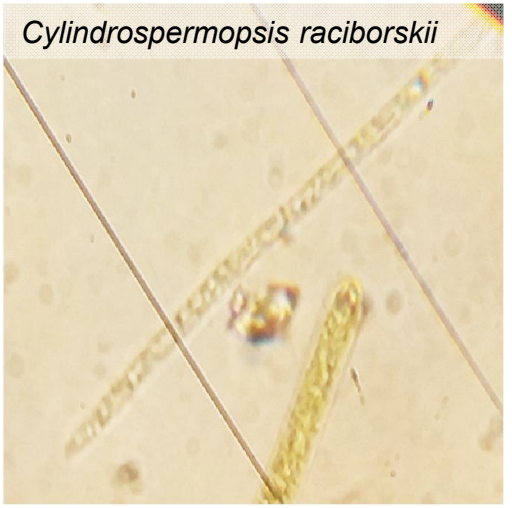

Woronichinia naegeliana


Aphanizomenon flos aquae


Anabaena solitaria


Anabaena spiroides


Microcystis aeruginosa


Cylindrospermopsis raciborskii

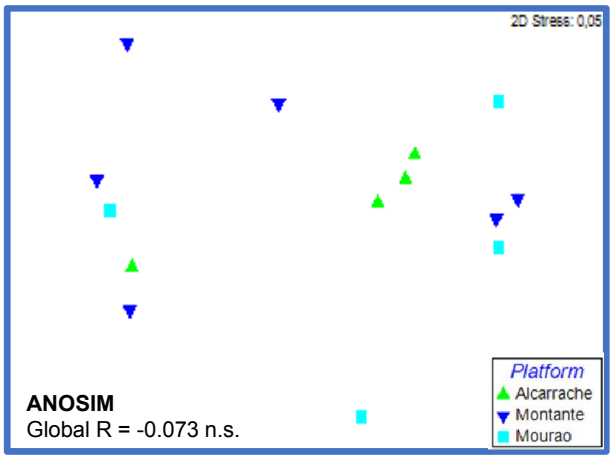
Results

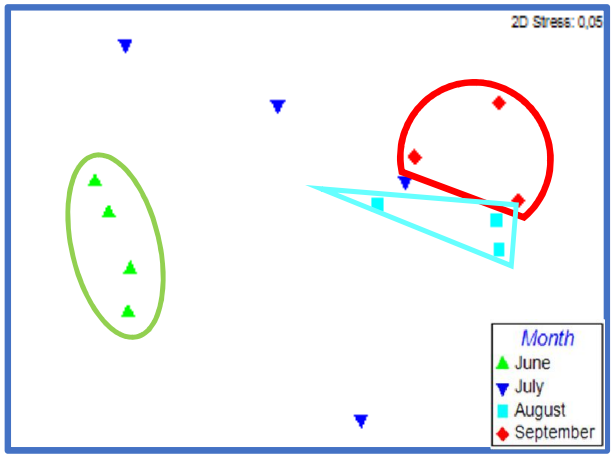
Biological parameter - Phytoplankton

Integrated samples

(representing the euphotic zone)

Multidimensional Scaling (MDS)





ANOSIM
Pairwise Tests R
Jun/Jul=0.563*
Jun/Aug=1.000*
Jun/Sep=1.000*
Pairwise Tests R
Jul/Aug=0.111 n.s.
Jul/Sep=0.286 n.s.
Aug/Sep=0.000 n.s.

➢ **No differences between platforms**

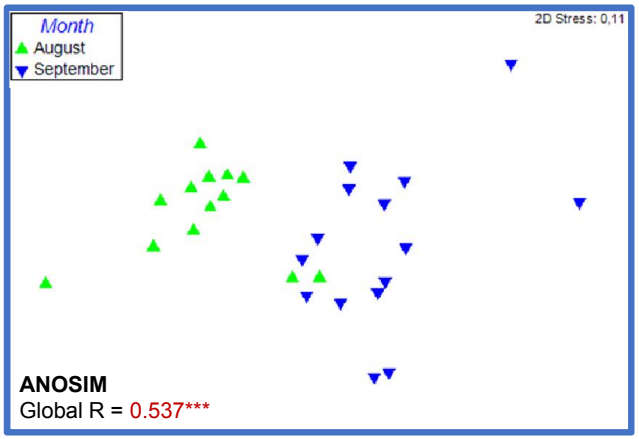
➢ **nMDS ordination** shows a **clear separation** of phytoplankton assemblages in relation with **sampling campaigns.**

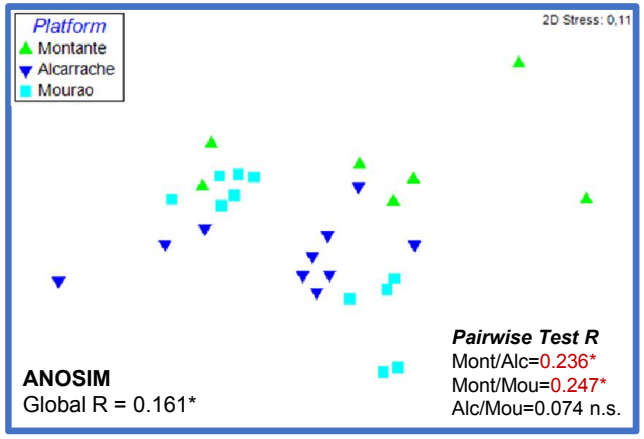
Results

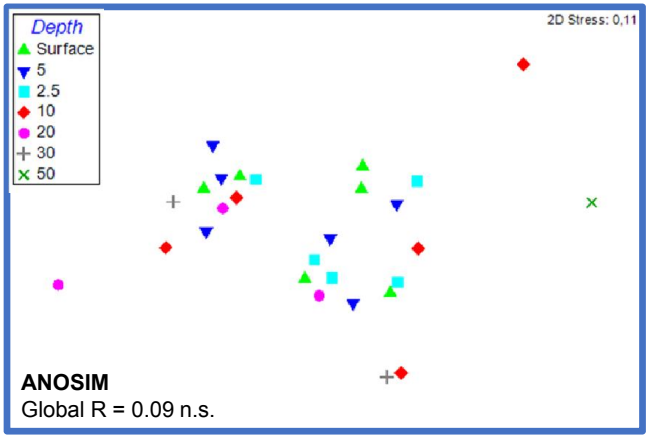
Biological parameter - Phytoplankton

Samples at discrete depths

Multidimensional Scaling (MDS)







➢ **Clear separation** between **sampling campaigns**;

➢ **No differences between platforms**;

➢ **No differences between depths**;

	Correlations (Phytoplankton with in situ parameters and depth Marked correlations are significant at p<0.05 N=28 (Casewise deletion of missing data)					
	pH	**Temp. (ºC)**	**Dissolved O_2 (%O2sat)**	**EC (µs/cm))**	**ORP (Volts)**	**Depth (m)**
H	-0.33	-0.33	-0.34	-0.20	-0.05	**0.46**
Richness	**0.48**	**0.65**	**0.48**	0.37	**0.47**	**-0.54**

Results

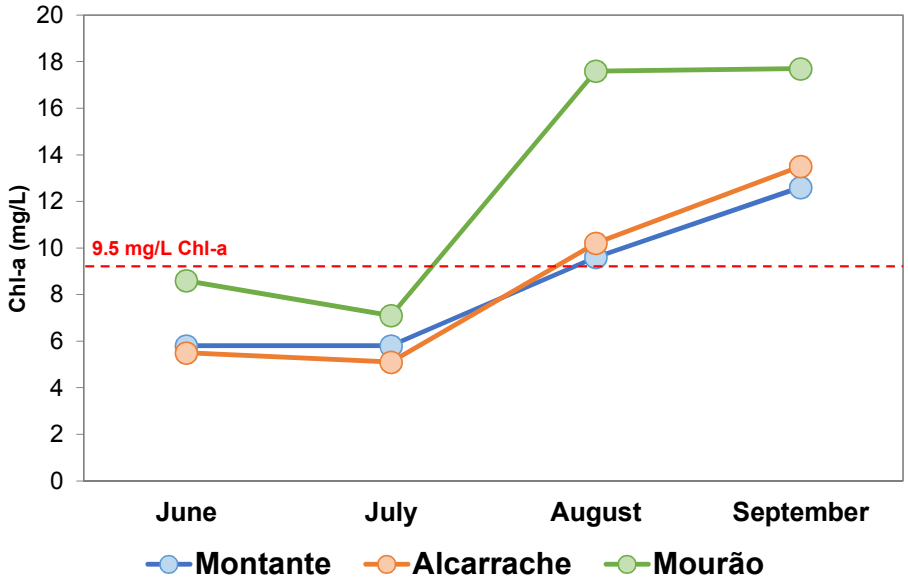
Biological parameter – Chlorophyll-a

Chlorophyll-a over time

Water Frame Work Directive
(reservoirs for South Portugal)

Good Ecological Potential ≤ 9.5 mg/L

Limit for **Eutrophic state ≤ 8 mg/L**

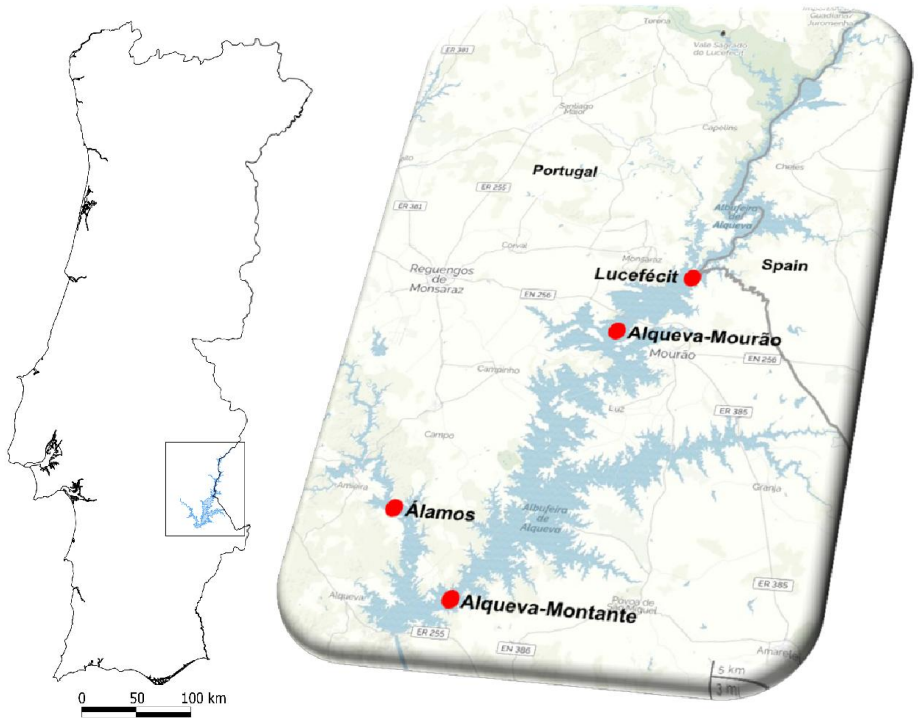


- In **August** and **September**, Chlorophyll levels **higher than 9.5 mg/L** at **all sampling sites**;
- **Mourão** with the **highest values**.

ALOP Project

ALOP: ALentejo Observation and Prediction systems

ALOP
Alentejo Observation and Prediction systems

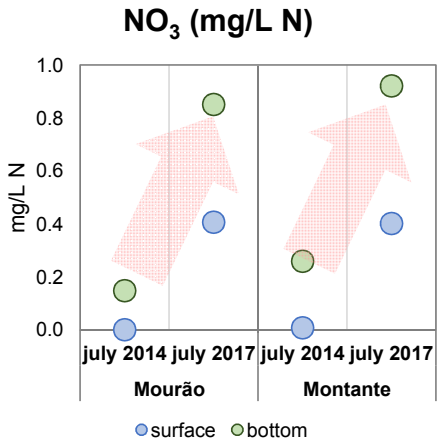


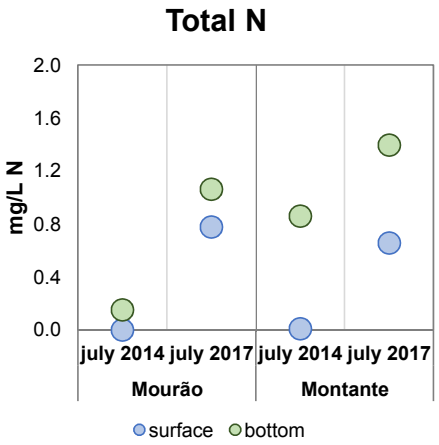
Sampling period	From January 2017 to December 2018
Sampling sites	Lucefécit Alqueva-Mourão Álamos Alqueva-Montante
***In situ* parameters**	Temperature (ºC) pH (Sorensen scale) Dissolved Oxygen (% O_2 saturation) Electrical Conductivity (µS/cm) Redox Potential (mV) Turbidity (NTU)
Chemicall parameters	Nitrates (mg/L NO3-N), Total Nitrogen (mg/L N), Phosphates (mg/L PO4-P), Total Phosphorus (mg/L P), among others
Biological parameters	Identification and quantification of Phytoplankton, Diatoms and photosynthetic pigments at discrete depths

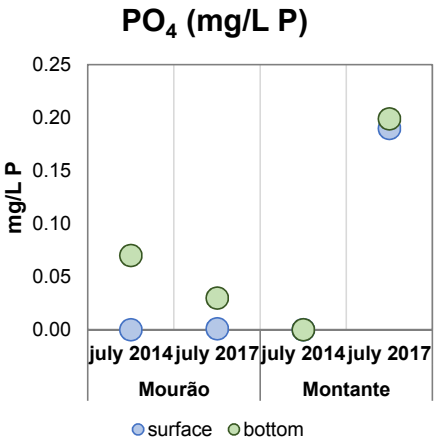
ALOP

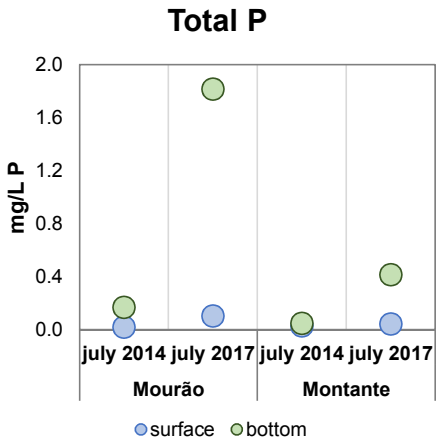
How is Alqueva reservoir in 2017 compared with 2014

- Two common sampling sites: **Alqueva-Montante and Alqueva-Mourão**
- Same sampling month: **July**









	Mourão	Montante
2014 surf vs. bottom	Bottom ↗↗↗	Bottom ↗↗
2017 surf vs. bottom	Bottom ↗	Bottom ↗
Surface 2014 vs. 2017	2017 ↗↗↗	2017 ↗↗
Bottom 2014 vs. 2017	2017 ↗	2017 ↗

ALOP

How is Alqueva reservoir in 2017 compared with 2014

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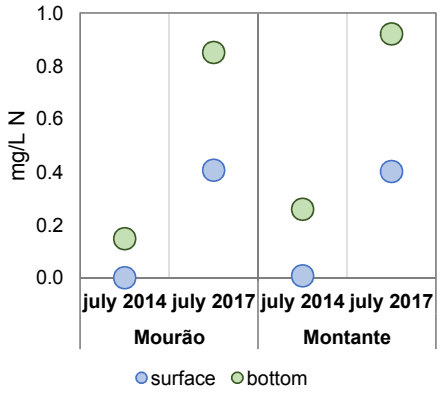
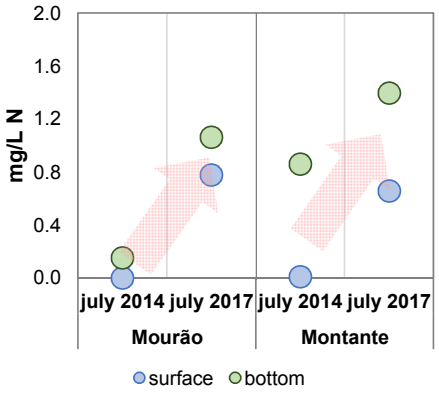
- Same sampling month: **July**

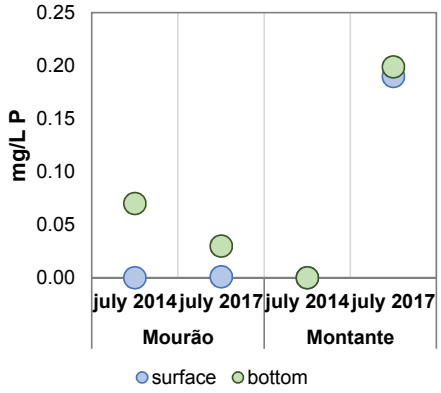
NO_3 (mg/L N)



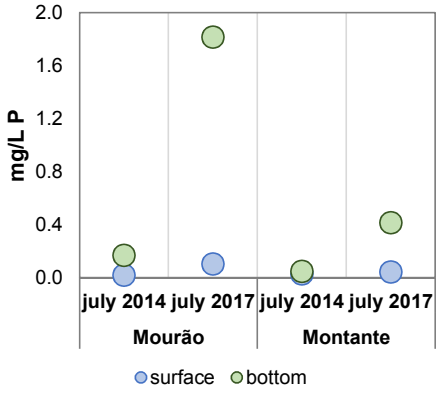
Total N



PO_4 (mg/L P)



Total P



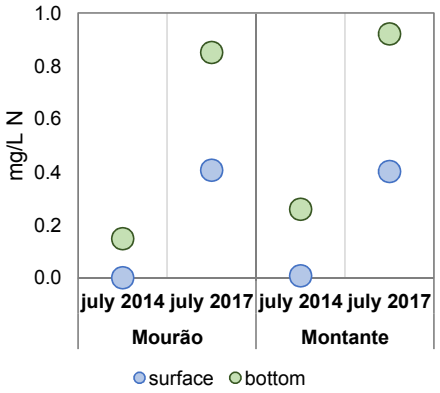
	Mourão	Montante	Mourão	Montante
2014 surf vs. bottom	Bottom ↗↗↗	Bottom ↗↗	Bottom ↗↗↗	Bottom ↗↗
2017 surf vs. bottom	Bottom ↗	Bottom ↗	Bottom ↗	Bottom ↗
Surface 2014 vs. 2017	2017 ↗↗↗	2017 ↗↗	2017 ↗↗↗	2017 ↗↗
Bottom 2014 vs. 2017	2017 ↗	2017 ↗	2017 ↗	2017 ↗

ALOP

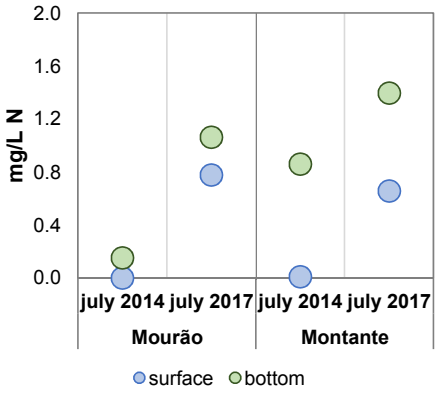
How is Alqueva reservoir in 2017 compared with 2014

- Two common sampling sites: **Alqueva-Montante and Alqueva-Mourão**
- Same sampling month: **July**

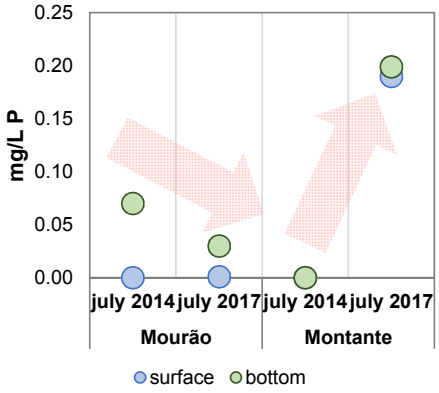
NO_3 (mg/L N)



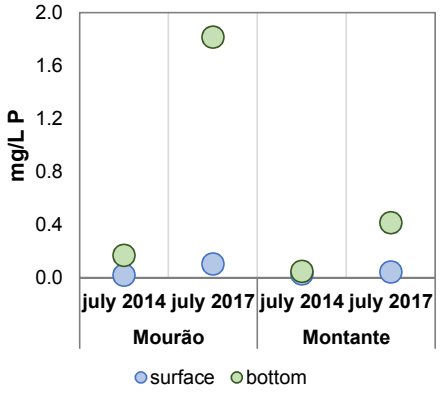
Total N



PO_4 (mg/L P)



Total P



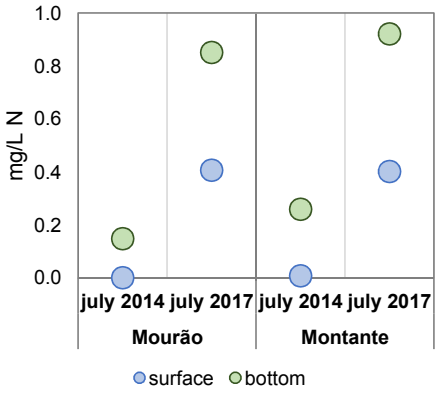
	Mourão	Montante	Mourão	Montante	Mourão	Montante
2014 surf vs. bottom	Bottom ↗↗↗	Bottom ↗↗	Bottom ↗↗↗	Bottom ↗↗	Bottom ↗↗	No difference
2017 surf vs. bottom	Bottom ↗	Bottom ↗	Bottom ↗	Bottom ↗	Bottom ↗↗	Bottom ↗
Surface 2014 vs. 2017	2017 ↗↗↗	2017 ↗↗	2017 ↗↗↗	2017 ↗↗	No difference	2017 ↗↗↗
Bottom 2014 vs. 2017	2017 ↗	2017 ↗	2017 ↗	2017 ↗	Bottom ↘	2017 ↗↗↗

ALOP

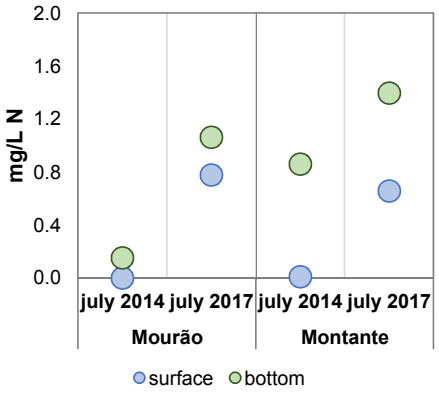
How is Alqueva reservoir in 2017 compared with 2014

- Two common sampling sites: **Alqueva-Montante and Alqueva-Mourão**
- Same sampling month: **July**

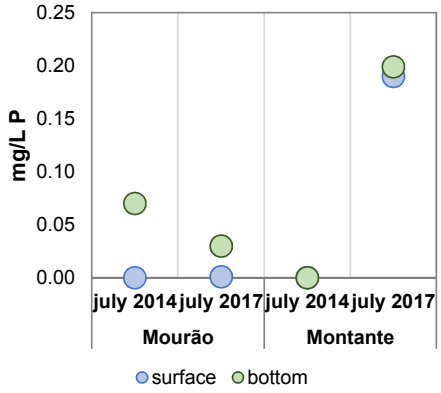
NO_3 (mg/L N)



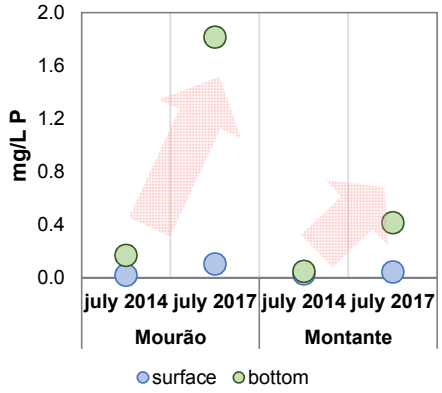
Total N



PO_4 (mg/L P)



Total P



	Mourão	Montante	Mourão	Montante	Mourão	Montante	Mourão	Montante
2014 surf vs. bottom	Bottom ↗↗↗	Bottom ↗↗	Bottom ↗↗↗	Bottom ↗↗	Bottom ↗↗	No difference	Bottom ↗	Bottom ↗
2017 surf vs. bottom	Bottom ↗	Bottom ↗	Bottom ↗	Bottom ↗	Bottom ↗↗	Bottom ↗	Bottom ↗↗	Bottom ↗
Surface 2014 vs. 2017	2017 ↗↗↗	2017 ↗↗	2017 ↗↗↗	2017 ↗↗	No difference	2017 ↗↗↗	2017 ↗	2017 ↗
Bottom 2014 vs. 2017	2017 ↗	2017 ↗	2017 ↗	2017 ↗	Bottom ↘	2017 ↗↗↗	2017 ↗↗	2017 ↗

ALOP

Summary

- **Vertical profiles** of water temperature, pH, dissolved oxygen, electrical conductivity and oxidation-reduction potential, are **similar on the 3 platforms**, and show a temporal evolution;
- **Low values of Nitrates, Total Nitrogen, Phosphates and Total Phosphorus in the 3 platforms and during the whole campaign**, **higher** in **bottom** samples, thus reflecting the **low contribution of external loads to the system**; Although for the same month 3 years later, some of the parameters are **higher**, indicating that the **system is running towards eutrophication**;
- **Cyanobacteria dominated in abundance** throughout the experiment, whilst **Chlorophyta** was the **taxa richest group**. There were **no differences in Phytoplankton** between **platforms** neither **depths**;
- Because of these, taking into account the **size of the reservoir**, its **dynamics is basically similar.**

Next steps

- Because the **biological parameters** are **highly correlated** with ***in situ* parameters**, such as pH, dissolved oxygen, redox potential, it would be **important to predict not only the temperature but also the other parameters**, i.e., the **similarity approach of FLake** may be extended to **model other parameters** related to **water quality.**


Thank you for your attention!!