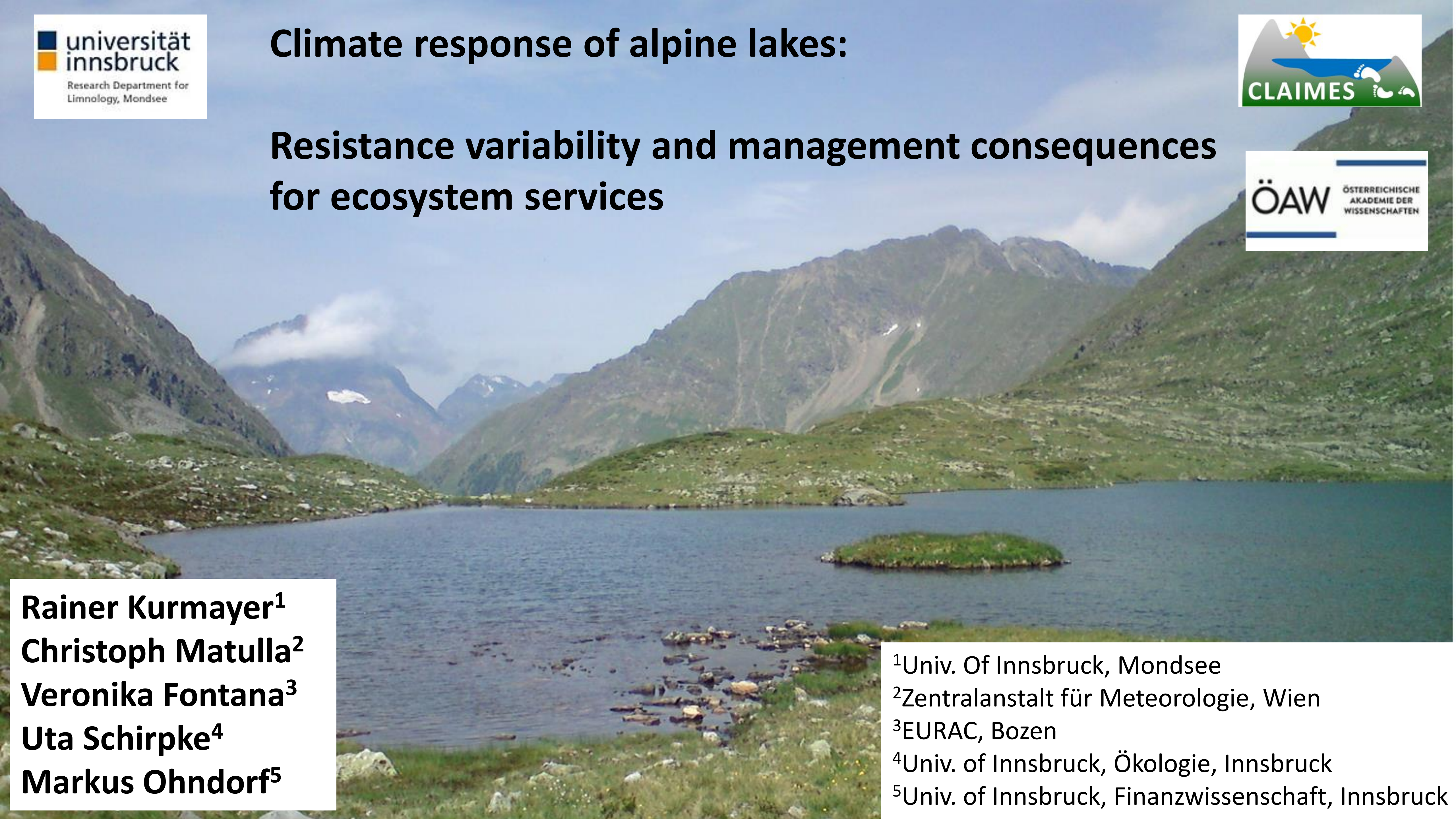

Climate response of alpine lakes:

Resistance variability and management consequences for ecosystem services

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Expected effects of CC until 2050 in the Alps

- Rise of air temperatures around 2°C
- Increase of winter precipitations around 5%
- Frequent drought periods during summer
- More extreme events
- Shorter snow and ice cover duration at higher elevations

+ Higher vulnerability of alpine ecosystems

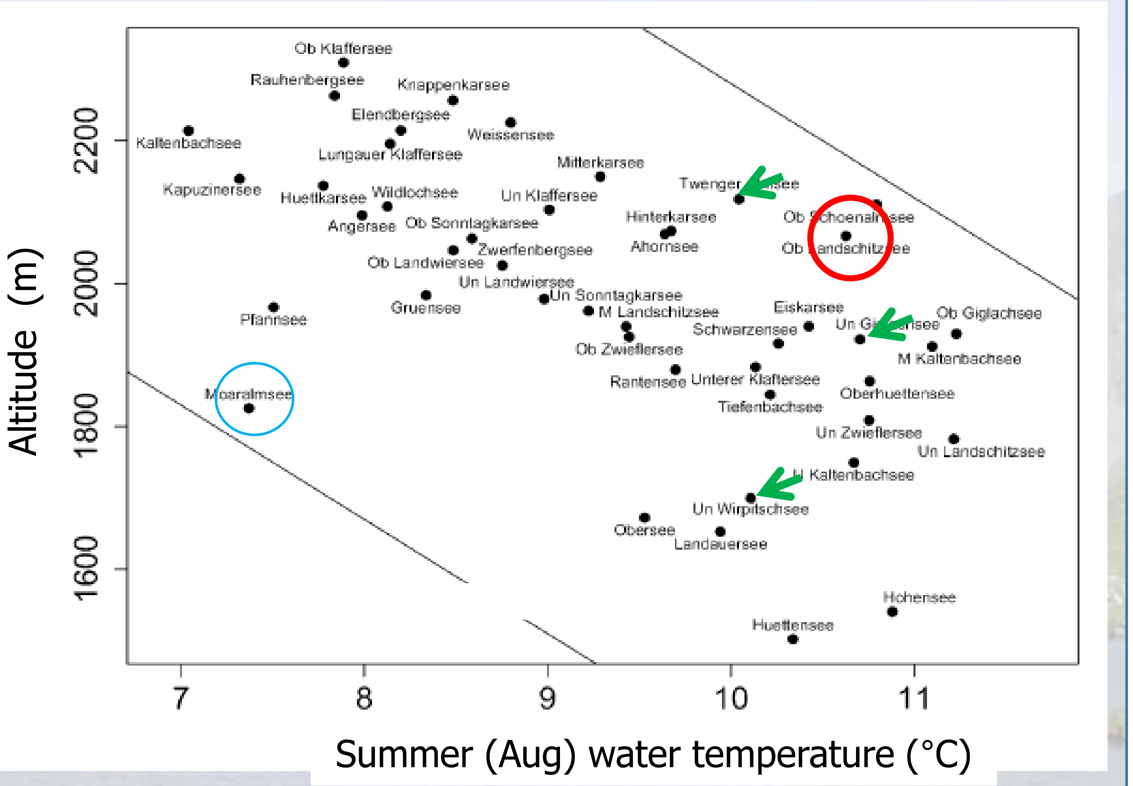
+ Anthropogenic influences (agriculture, tourism) add pressure

How do this CC effects impact the ecosystem alpine lake?

- Variations in lake's water temperature
- Changes in ice cover duration
- Annual mixing and stratification of water layers will change or disappear
- Availability of nutrients will change
- Concentration of oxygen will change
- Diversity and composition of organisms will change

→ variable and individual lake responses, due to local habitat specific influences (e.g. topographic shading, bathymetry, altitude)

Water temperature in alpine lakes in the Niedere Tauern (Austria), 1998-1999



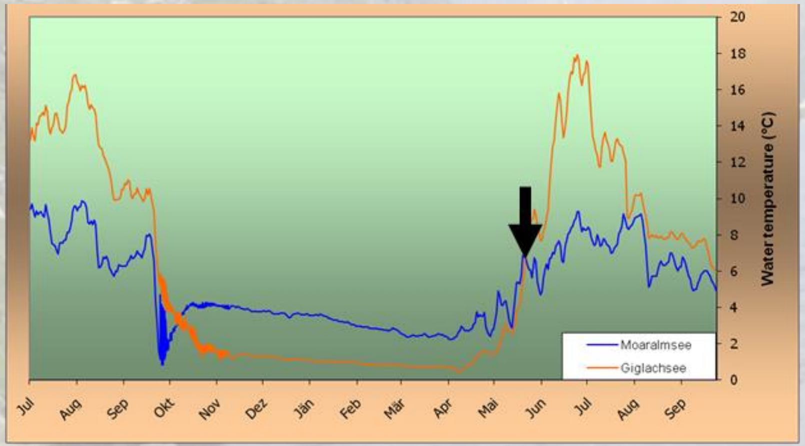
Thompson et al. 2005, J. Limnol.

Moaralmsee

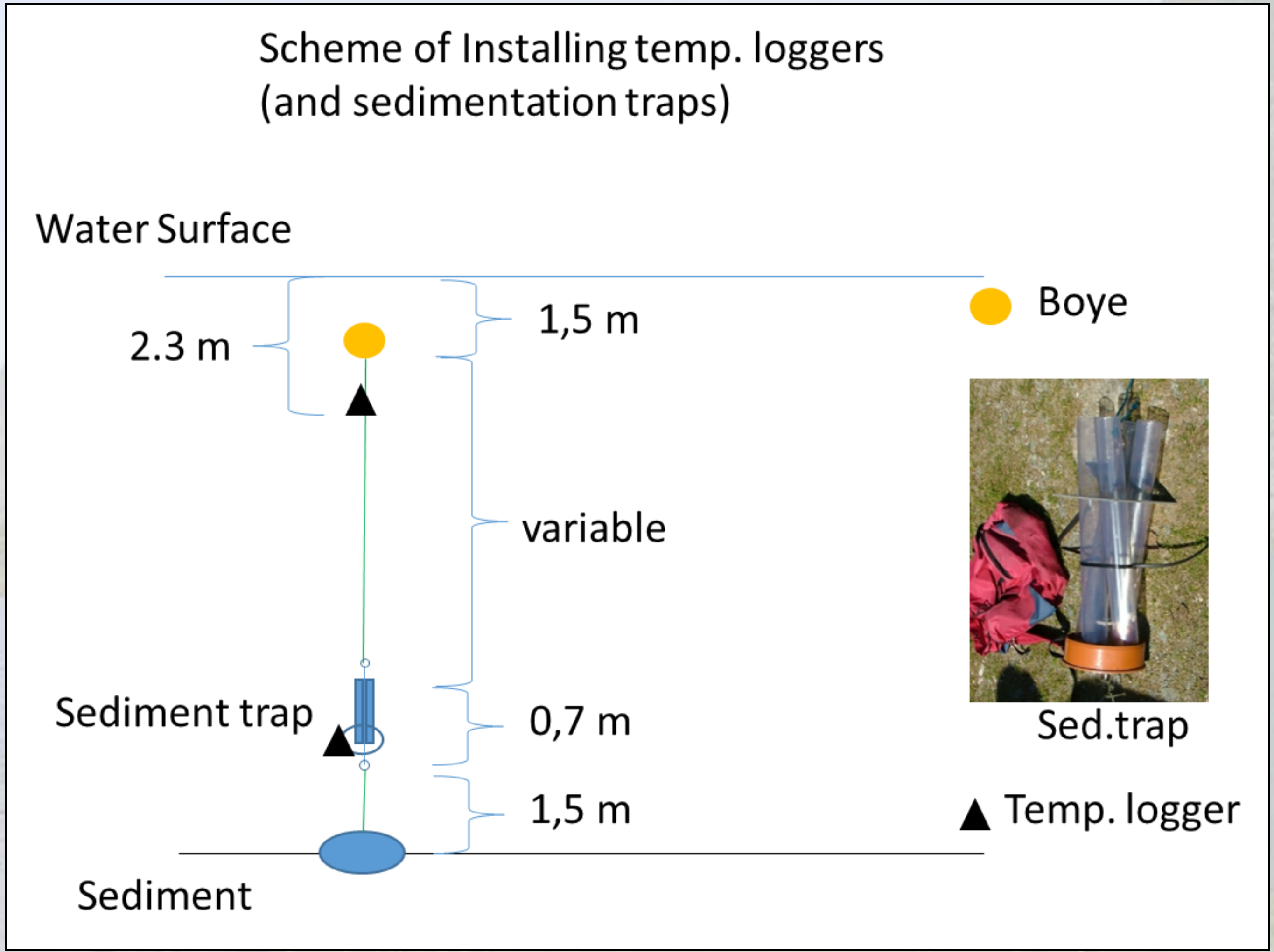
Oberer Landschitzsee

Estimation of temperature response and ice cover duration

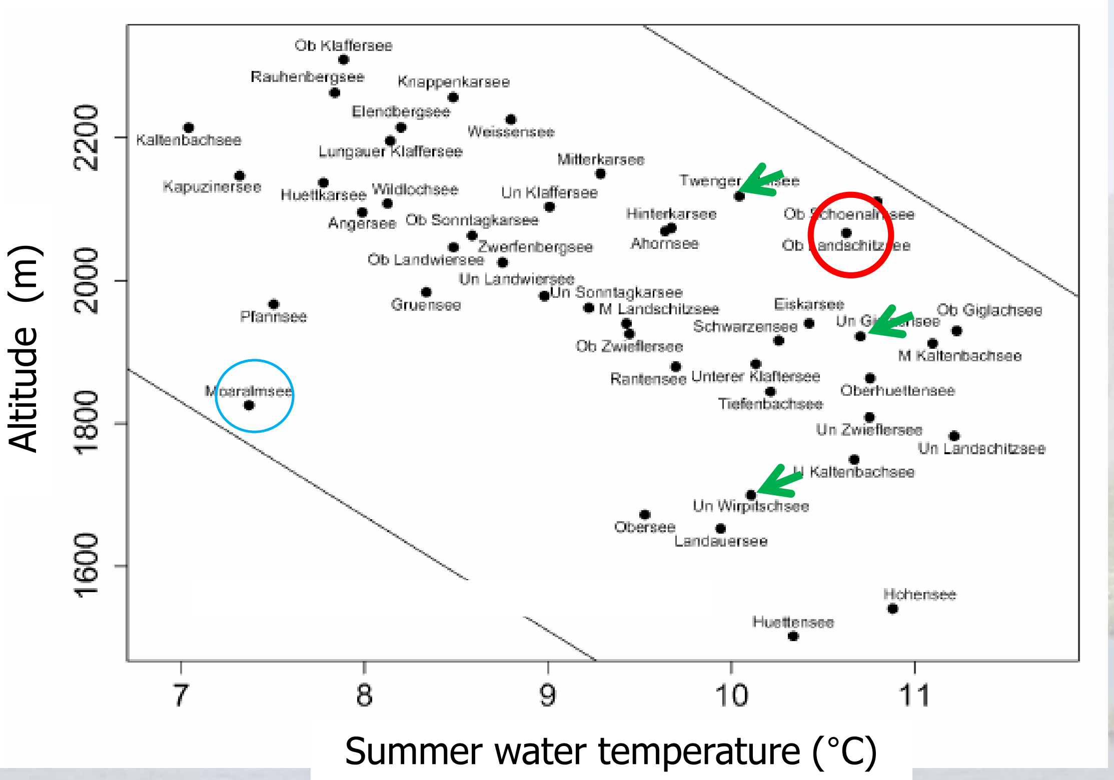
Ice break up in Twenger Almsee, 16 June 2012



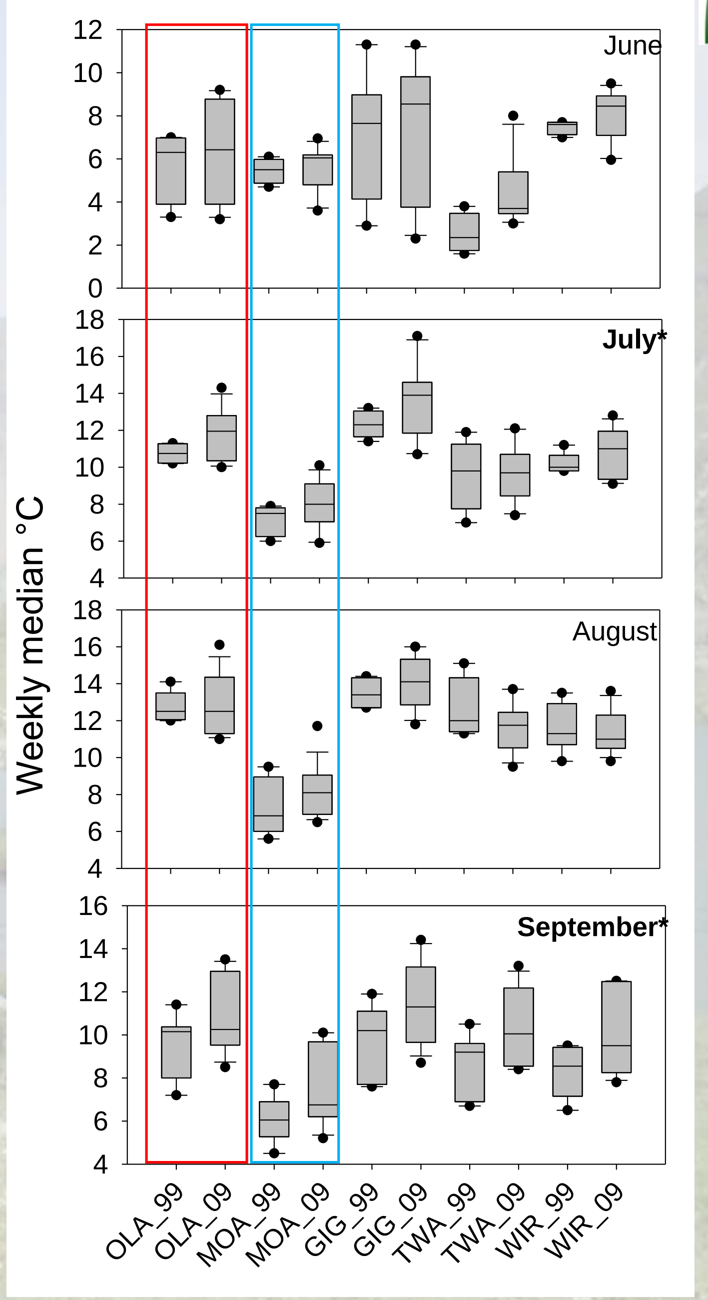
Temperature read out



Water temperature in alpine lakes in the Niedere Tauern (Austria), (1998-1999, 2009-2012)

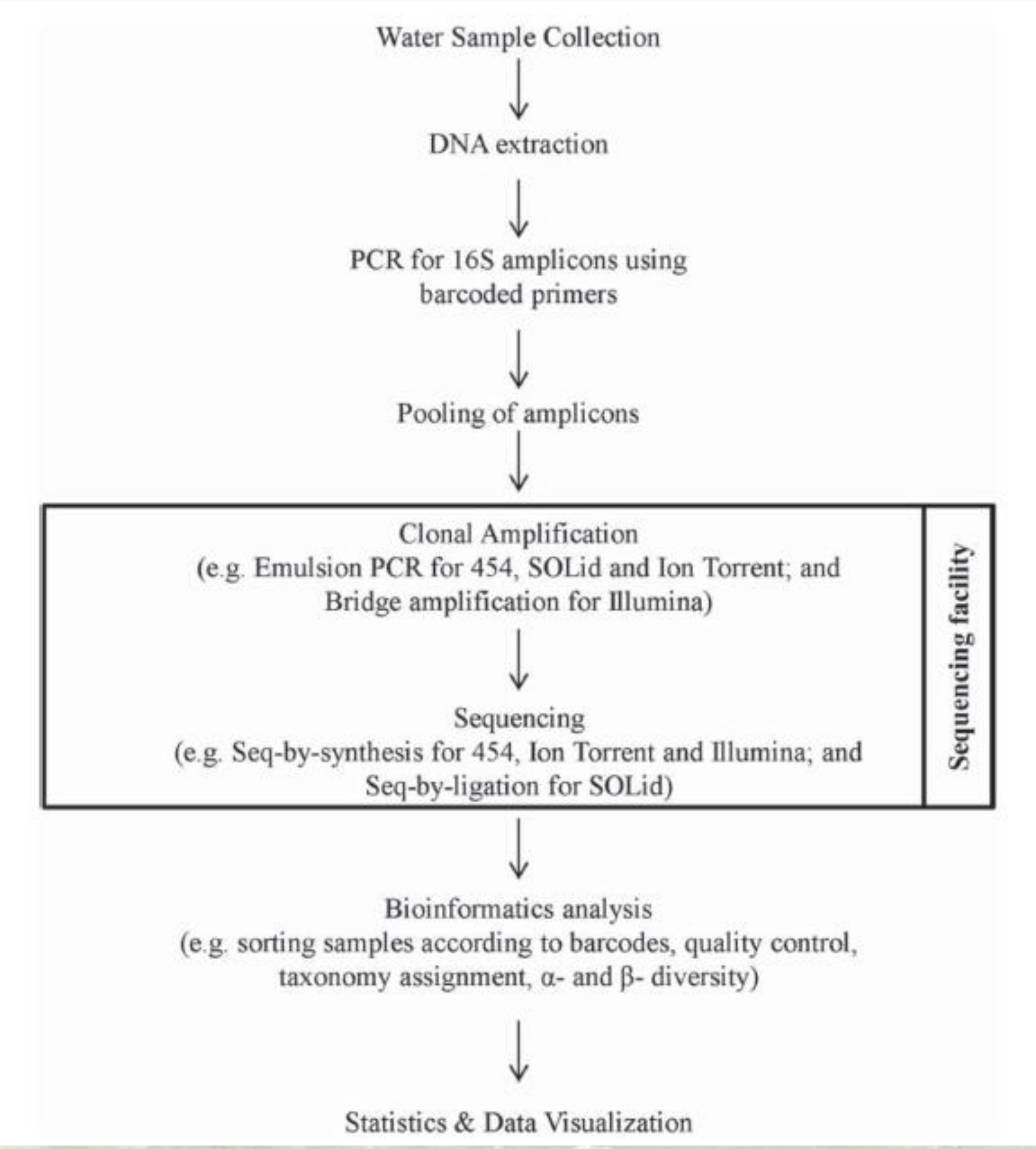


Decadal re-investigation



Hypothesis:
Undercooled lakes will show most dramatic changes in plankton community as a function of regional temperature rise

Standard workflow for the NGS of 16S rRNA amplicons



On site filtration

Collecting depth-integrated samples

+) early (56 ± 16 (SD) days after ice break up)

+) later (88 ± 16 days) in the growing season.

Protocoll:
+) Filtration of water samples in two fractions: >1.0µm; 0.2µm – 1.0µm

+) Amplification of 16S including V3 – V6 region 338F & 1046R (726 bp)

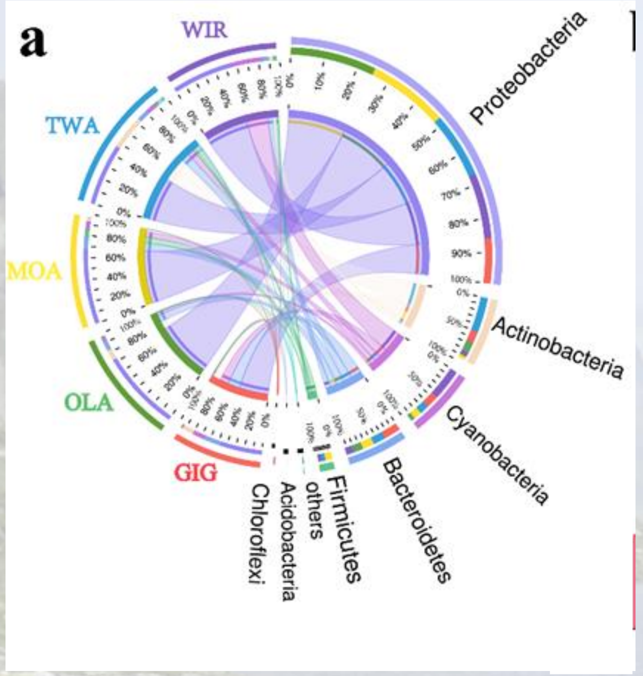
+) Amplicon high throughput (454-) Sequencing (mean 534 bp) from both directions

+) Analysis with Pipeline – QIIME (Quantitative Insights Into Microbial Ecology), Pick up of OTUs (sequence similarity > 97%); Assigning of taxa:

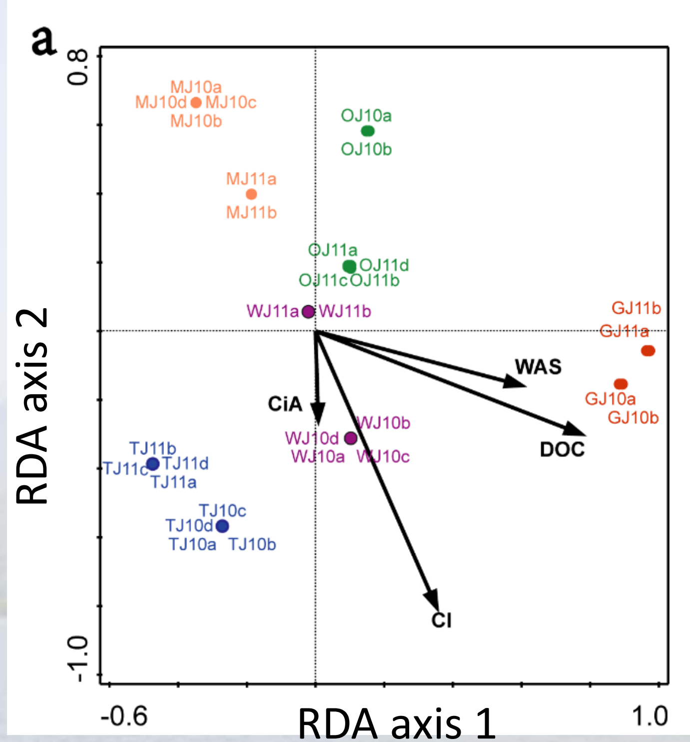
Deng, L. et al. (2017) in Kurmayer et al. (Eds), John Wiley & Sons Ltd, & Jiang et al. 2017, Front. Microbiol.

Multivariate ordination analysis to identify relevant environmental factors

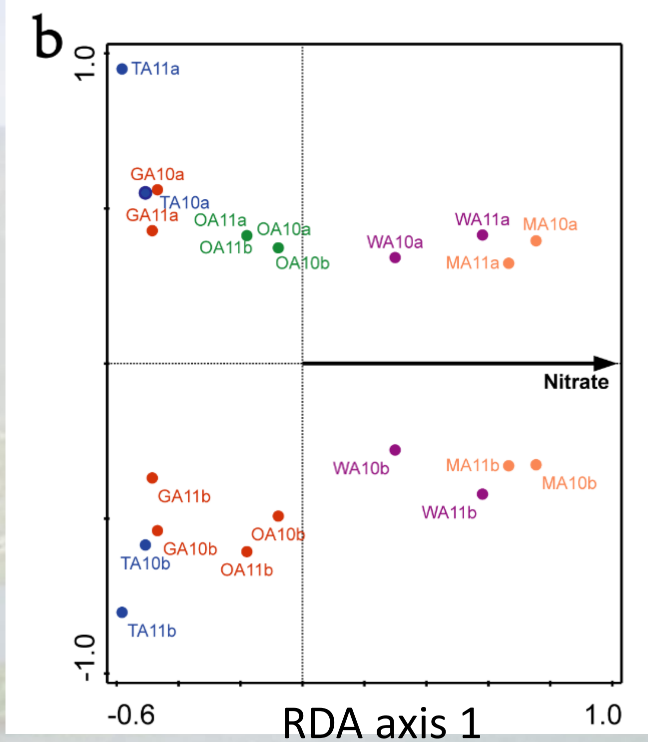
Circos plots showing bacterioplankton at phylum level



Earlier growing season



Later growing season



CiA, Calendar day of circulation in autumn; WAS, average water temperature between calendar day of circulation in spring until the sampling date; Cl^-, Chloride; DOC, dissolved organic carbon

+) in early growing season planktonic microbiota structure was found significantly related to WAS, DOC, CiA, and Cl^- (18.4% of the total inertia in OTU distribution)

+) during the later growing season, only one variable ($NO3^-$) explained 6.9% of the total OTU variation

Relationships between taxonomic richness and average water temperature after spring circulation

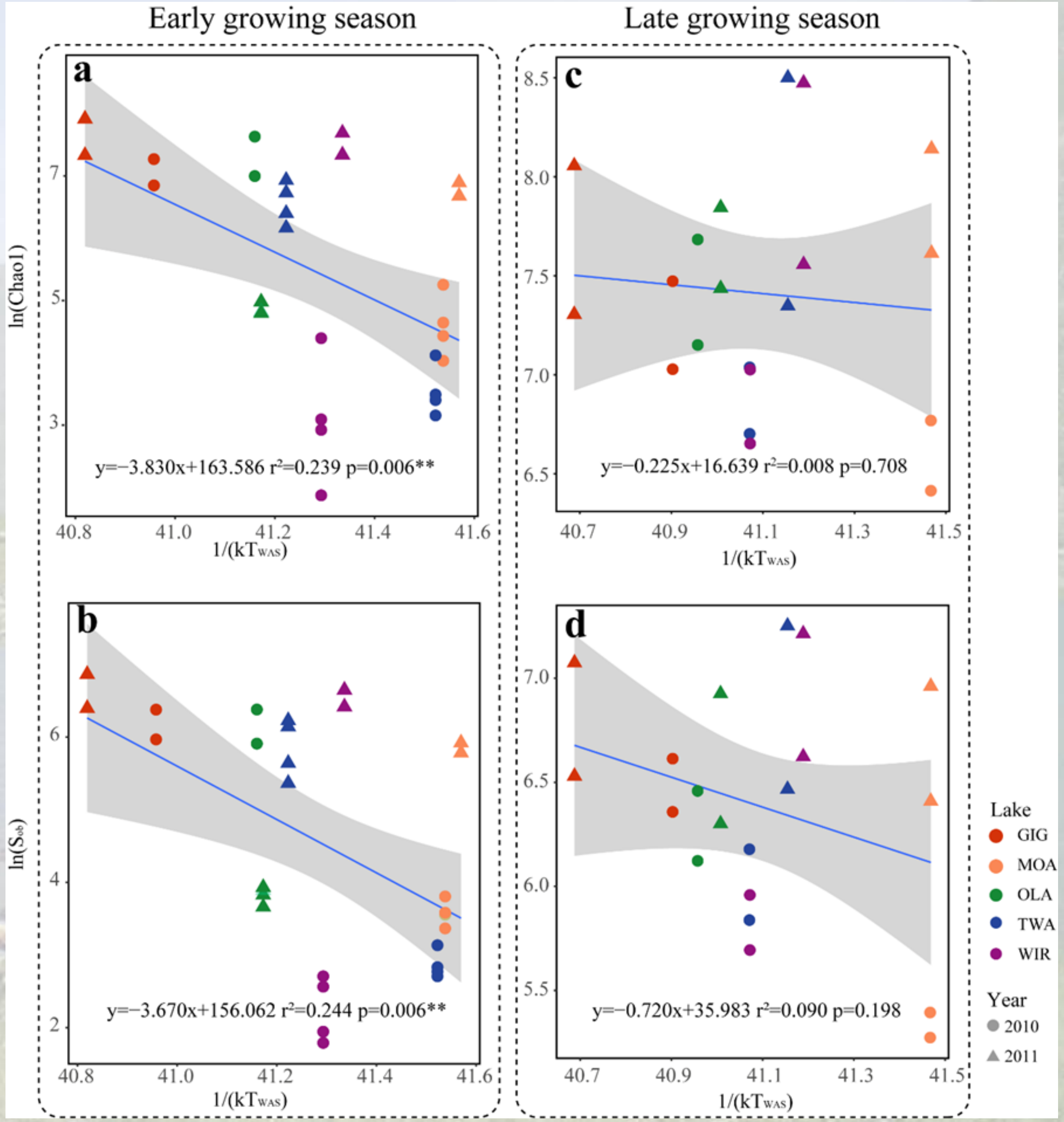
+) Use of MTE (Metabolic Theory) to explain the dependence of taxonomic richness on the bacterial metabolic activity.

$$ln(S_{chao1\ or\ obs}) = a - E_a \times \frac{1}{kT}$$

+) based on the energetic-equivalence rule (i.e. Allen et al., 2002), assuming that the total energy flux of a population per unit area does not depend on body size.

+) The activation energy is calculated from the inverse slope of the regression curve and expected in the range of -0.65 equivalent to a Q_{10} of ~2.5.

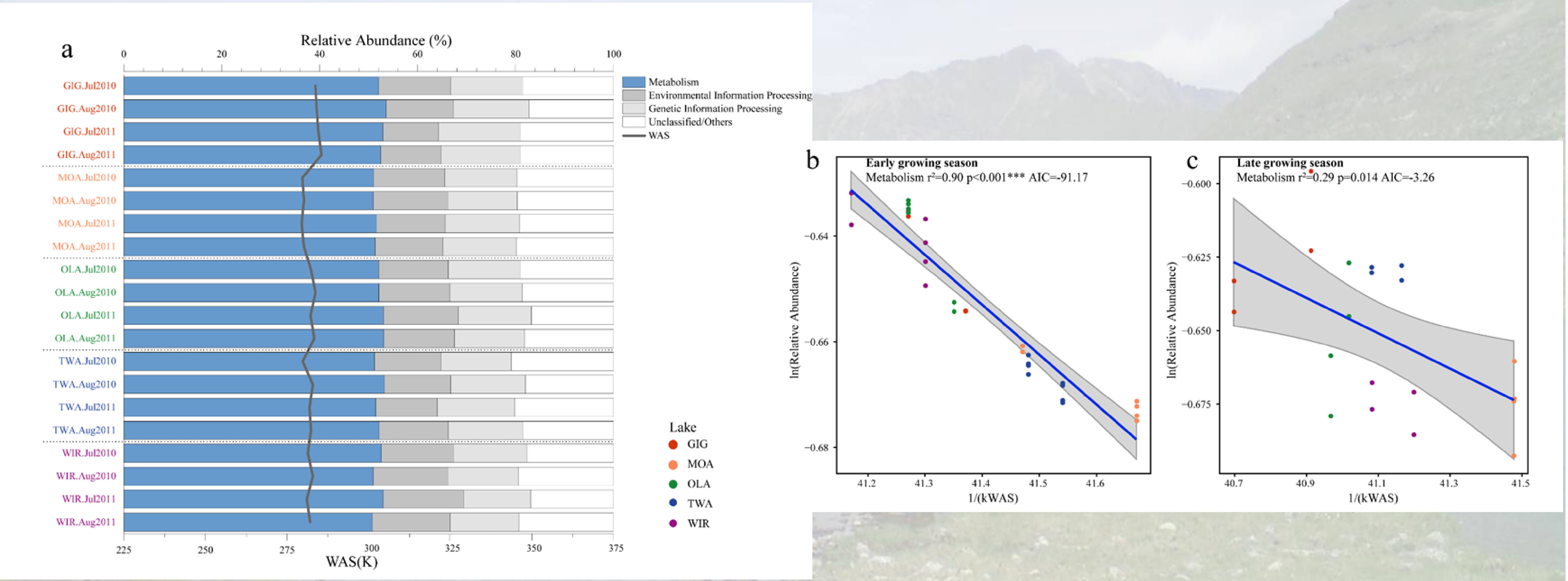
+) The activation energy varied from -3.8 eV for Chao1 and -3.7 eV for S_{obs} to the more frequently reported -0.65 prediction.



Jiang et al. 2017, Front. Microbiol.

Relationship between water temperature and metabolism of the bacterio-plankton community

Composition and relative abundance of predicted metabolism-related genes as a function of 1/(kWAS) during early and later growing season



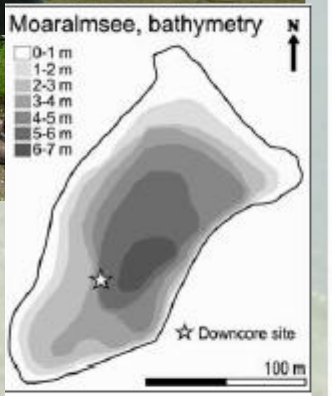
Metabolic genes increased proportional in response to water temperature supporting the more direct role of temperature variation in the study lakes

Jiang et al. 2017, Front. Microbiol.

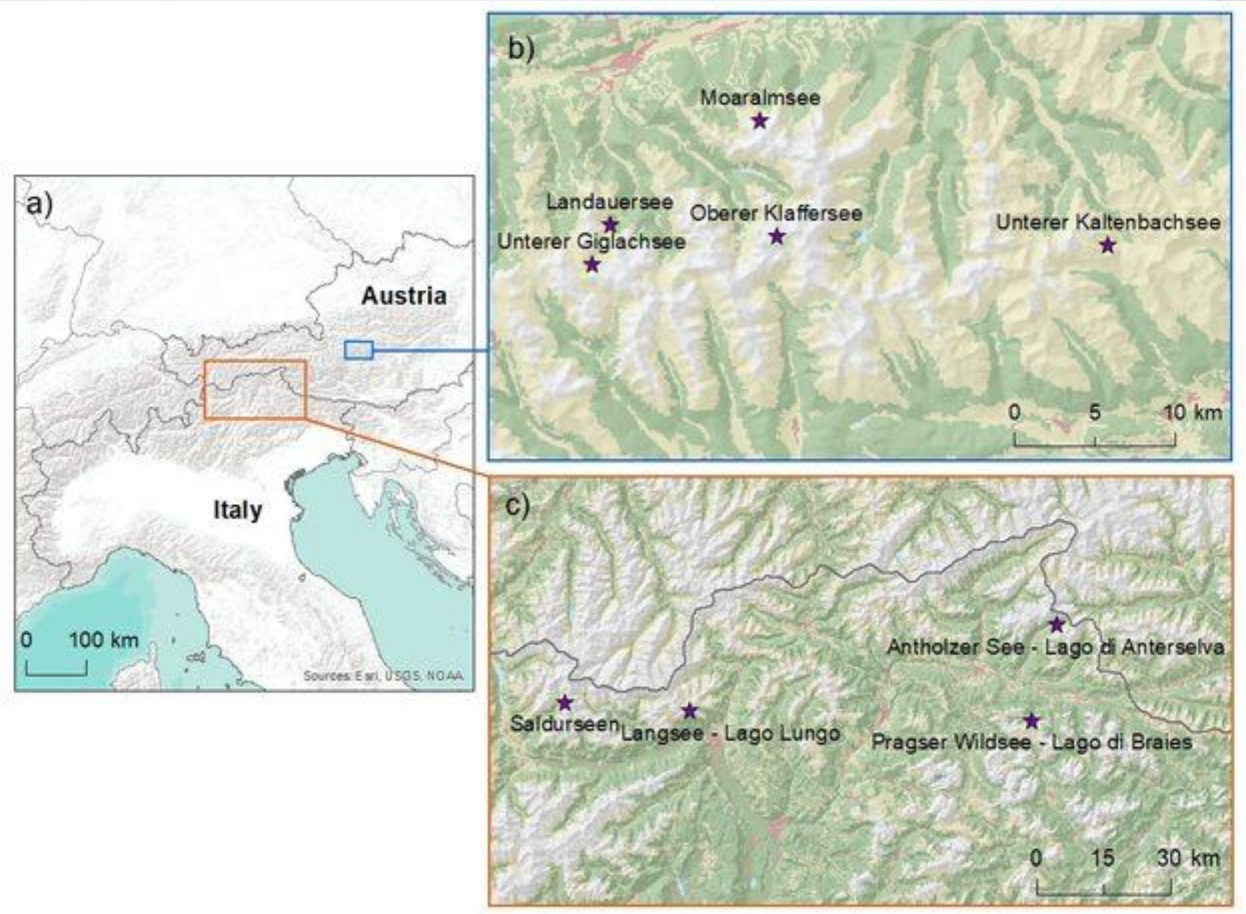
WP 1) Characterization of lakes‘ variability

20 year old long term data will be compared to data measured in 2019 within the project including:


- Lake temperatures, ice cover duration
- Mixing dates
- Oxygen, pH value, conductivity
- Organismal community
  (e.g. diatoms, chrysophytes, chironomids)

2 study regions: Northern and Southern Alps

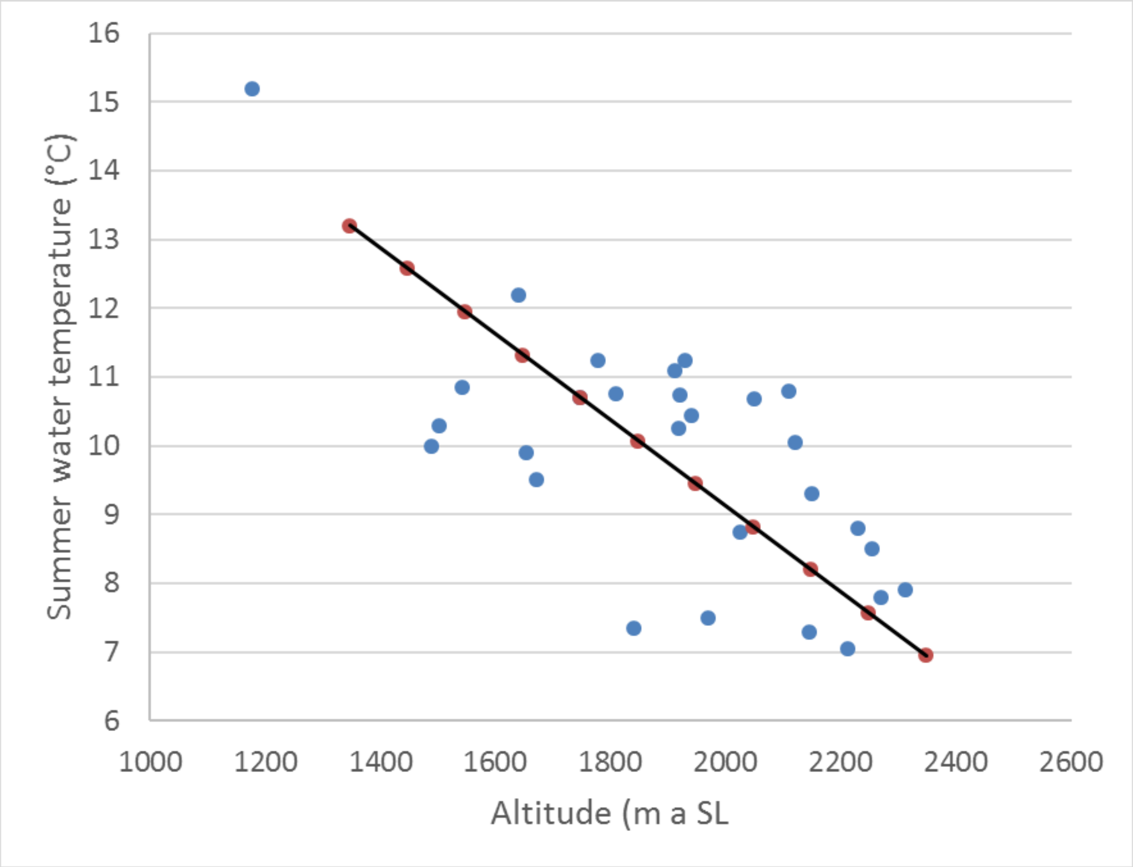


Niedere Tauern

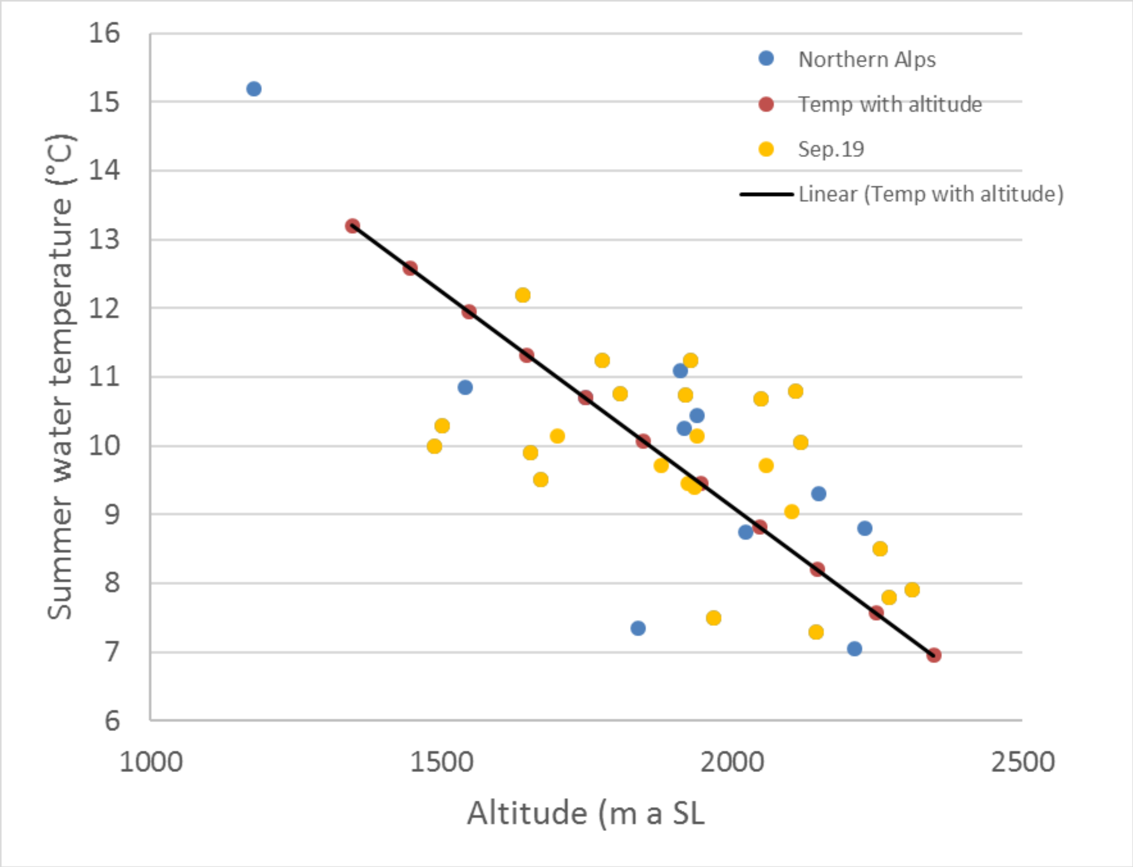
Südtirol

Sampling Activity Summer 2019

Aimed sampling



Sampling Aug + Sept 2019



WP 2) Assessment of Ecosystem service provision

1. **Identification of crucial ecosystem services of lakes**, representing three categories (provisioning, regulating and cultural)

2. Identification of one or more **indicators** for each ecosystem service and **quantitative assessment of relevant supply data** (e.g. literature, field data, existing data bases, own surveys)

3. **Analysis of potential impacts** on ecosystem services under climate change (near and distant future, spatial or statistical scenario analyses).

Definition of Lake types

1) Remote lakes with low nutrient content

Ultra(oligotrophic) Lakes in higher (and lower) elevations which are in remote position and therefore considered least human influenced by humans. Potential Ecosystem services are their aesthetic value, their use for outdoor recreation (hiking) with low extent.

2) **Accessible lakes with low nutrient content**

Oligotrophic Lakes are used intensively for touristic issues (fishing, recreation) and are partially accessible by car or public transport. Potential Ecosystem services are their aesthetic value, their intensive use for outdoor recreation (hiking, swimming, mountain biking, etc.) and their suitability for livestock farming, hunting and fishing.

3) **Accessible lakes with higher nutrient content**

The water of the lakes is used for livestock farming, aquaculture, fishery for recreation and irrigation. The lakes trophic states is **oligo- to mesotrophic**. Because of their lower water temperature and higher nutrient concentrations they are considered sensitive to raising temperatures.

WP 3) Evaluation of Ecosystem service importance and development of future management strategies

1) to assess which ecosystem services provided by alpine lakes are perceived as important by society

2) to estimate future ES provision of 3 defined lake types and to identify lake types endangered to loose or reduce ES

3) to compare the two study regions regarding potential different impact of climate change on ES provision

Multi Criteria Decision Analysis

When multiple, **conflicting objectives**

(such as environmental, economic, social or other)

as well as **stakeholder priorities**, large amounts of data, lack of information or other uncertainties **obstacle a clear decision**,

MCDA structures the question(s) into a discrete number of managable and clear steps.

MCDA is a…

- …set of methods coming from ecological economics
- …non monetary approach
- …combination of qualitative and quantitative data
- …participatory approach

Estimation of possible future ES provision under impact of climate change

Development of policy advices supporting interventions to guarantee future ES provision

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CREAF

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Federal Ministry Republic of Austria Education, Science and Research

Further information
https://www.uibk.ac.at/projects/claimes/

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Lakes sampled in Summer 2019

Temp. trend	Abkürz	See	geogr_Länge	geogr_Breite	Seehöhe	summer water temp	Temperature deviation	max Tiefe	Area (ha)
warm	EIS	Eiskarsee	13,4378	47,1700	1941	10,45	1,0533	14,2	2,3
kalt	HUS	Hüttensee	13,4906	47,2151	1503	10,3	-1,8561	7,7	4,6
kalt	KAP	Kapuzinersee	13,4855	47,1778	2146	7,3	-0,8052	20	1,2
warm	KNA	Knappenkarsee	13,4047	47,1619	2255	8,5	1,0815	8	1,4
kalt	LAN	Landauersee	13,3990	47,1792	1654	9,9	-1,3048	16,6	3,6
warm	OGIG	Oberer Giglachsee	13,3863	47,1681	1929	11,25	1,7777	10,5	3,5
warm	OKL	Oberer Klaffersee	13,4812	47,1759	2311	7,9	0,8343	32,5	5,1
warm	OLA	Oberer Landschitzsee	13,5157	47,1338	2050	10,68	1,97	13,6	8,9
warm	OSC	Oberer Schönalmsee	13,3610	47,1354	2110	10,8	2,468	21,6	5,1
kalt	OBE	Obersee	13,4914	47,2111	1672	9,51	-1,5814	23,4	7,2
kalt	PFA	Pfannsee	13,4847	47,2097	1970	7,5	-1,714	7,7	1,4
warm	RAU	Rauhenbergsee	13,4741	47,1773	2270	7,8	0,476	26,3	2,8
warm	TWA	Twenger Almsee	13,3610	47,1324	2120	10,05	1,781	33,3	3,1
warm	UGIG	Unterer Giglachsee	13,3880	47,1690	1921	10,74	1,2173	18	16,8
warm	ULA	Unterer Landschitzsee	13,5039	47,1535	1778	11,25	0,8264	15,8	12
kalt	WIR	Unterer Wirpitschsee	13,36647059	47,14108108	1700	10,14	-0,775	8	2,7
mittel	MLA	Mittlerer Landschitzsee	13,5090	47,1486	1937	9,4	-0,0219	20,3	6,6
mittel	RAN	Rantensee	13,5376	47,1500	1878	9,72	-0,0736	7,6	2,3
warm	HIN	Hinterkarsee	13,5430	47,1520	2060	9,72	1,073	11,3	1,9
mittel	UKF	Unterer Klaftersee	13,5972	47,1900	1884	10,15	0,3942	11,4	1,6
pending									
warm	UWZ	Unterer Zwieflersee	14,0325	47,1492	1809	10,75	0,5217	19,4	4,6
mittel	OZW	Oberer Zwieflersee	14,0266	47,1497	1925	9,45	-0,0475	18,6	3,2

Ausgewählte ES aus Grizzetti et al. 2016

	Ecosystem services terminology proposed in this study	Examples	Ecosystem services from CICES	Ecosystem services from TEEB
Provisioning	Fisheries and aquaculture	fish catch	Food - Biomass	Food
	Water for drinking	provision of water for domestic uses	Drinking water	Fresh water
	Water for non-drinking purposes	provision of water for industrial or agricultural uses	Non-drinking water	Fresh water
Regulation & Maintenance	Air quality regulation	deposition of oxides of nitrogen on vegetal leaves	Mediation of pollution in air	Local climate and air quality
	Flood protection	slowing down the water flow, coastal habitats protecting from inundation	Flood protection	Moderation of extreme events
	Maintaining populations and habitats	key habitats use as reproductive grounds, nursery, shelter… for a variety of species	Maintaining populations and habitats	Habitats for species, Maintenance of genetic diversity
	Soil formation and composition	rich soil formation in floodplains or in wetlands borders	Soil formation and composition	Erosion prevention and maintenance of soil fertility
	Carbon sequestration	carbon accumulation in vegetation or sediments	Global climate regulation	Carbon sequestration and storage
	Local climate regulation	maintenance of humidity and precipitation patterns by wetlands or lakes, shading effect	Micro and regional climate regulation	Local climate and air quality

Cultural	**Recreation**	**swimming, recreational fishing, sightseeing, boating**	**Experiential interactions with nature**	**Recreation and mental and physical health, Tourism**
	Intellectual and aesthetic appreciation	subject matter for research, artistic representations of nature	Intellectual and aesthetic interactions with nature	Aesthetic appreciation and inspiration for culture, art and design
	Spiritual and symbolic appreciation	existence of emblematic species like Lutra lutra or sacred places	Spiritual and symbolic interactions with nature	Spiritual experience and sense of place