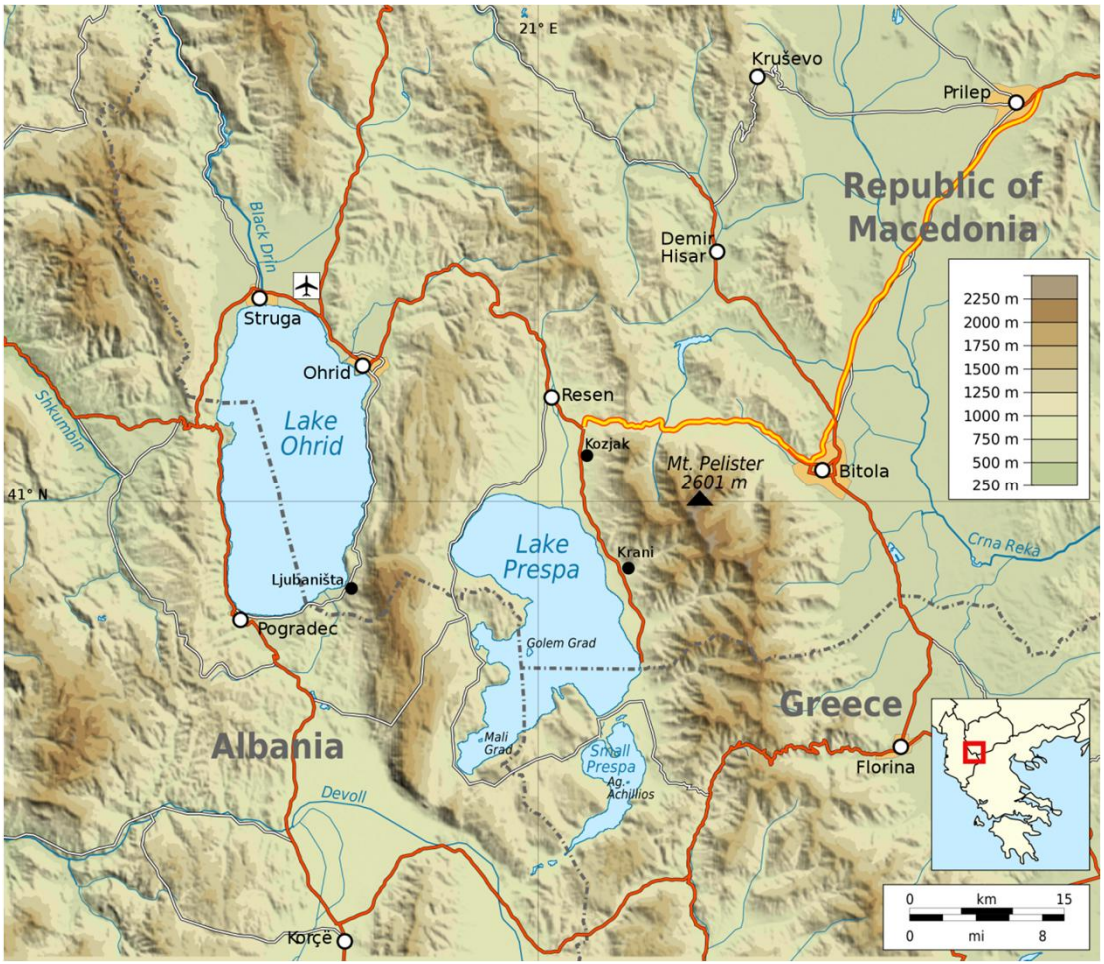
Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

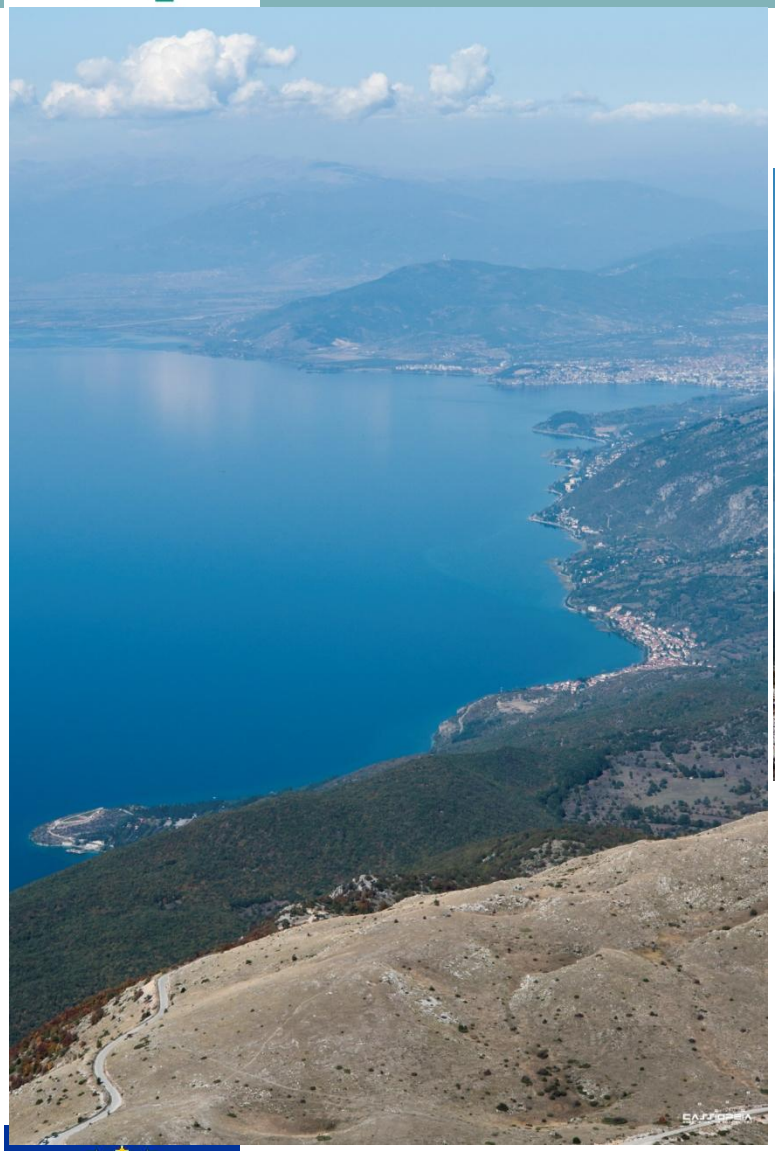


The Region of Ohrid and the Prespa Lakes, situated in south-western Europe (40 ° 40'-41 ° 2N latitude; 20 ° 23'-21 ° 16'E longitude), extends across the borders of Albania, Greece, and Macedonia. Lake Ohrid and Prespa Lakes belong to a group of Dasseretes basins that originated from a geotectonic depression 2 to 5 million years ago on the western Dinarides.

Lake Ohrid, a major European biodiversity hotspot, is a prime example for a lake with a magnitude of narrow range endemic taxa that are under increasing anthropogenic pressure. Unfortunately, evidence for a "creeping biodiversity crisis" has accumulated over the last decades, and major socio -political changes have gone along with human-mediated environmental changes.

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

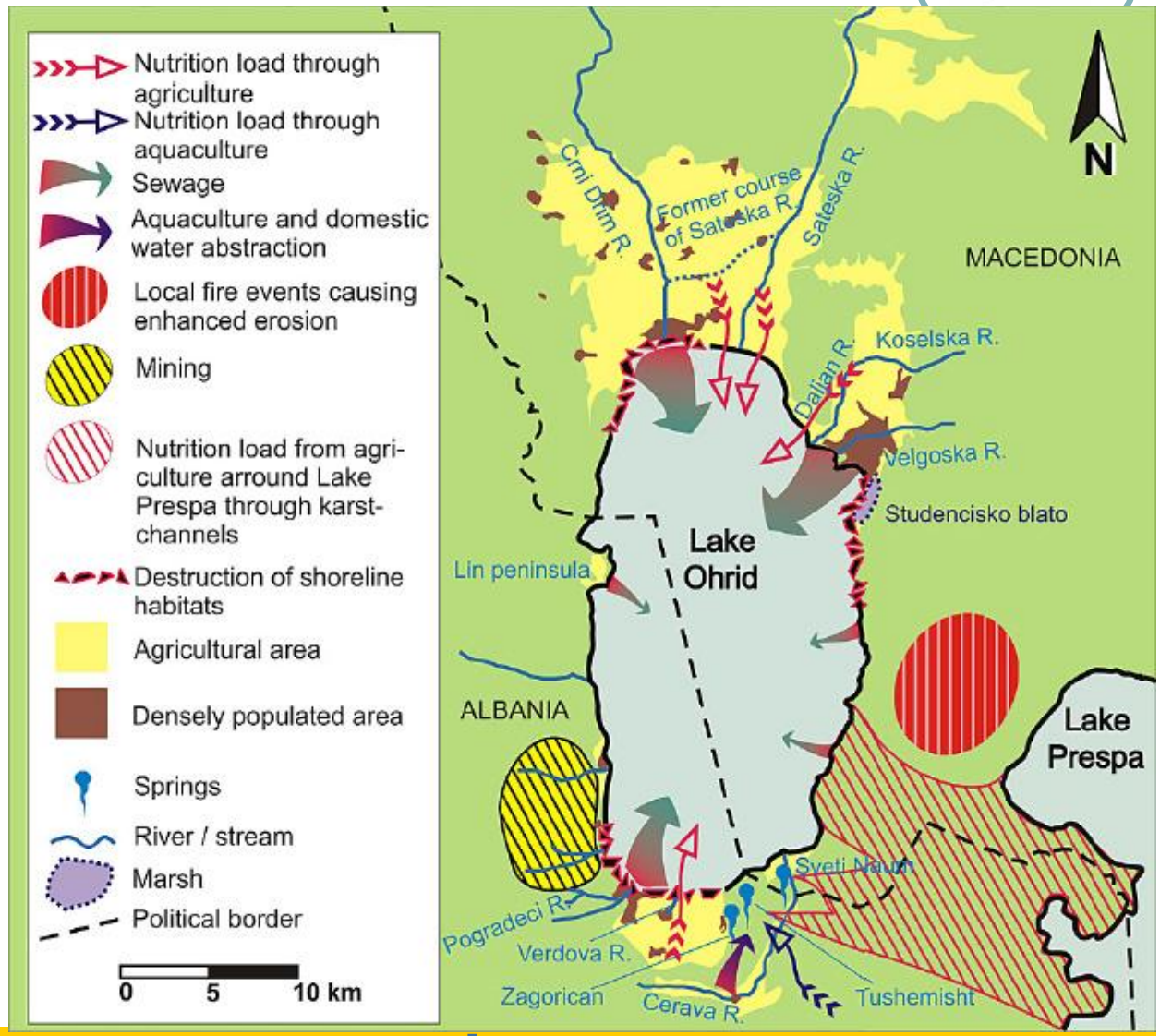


This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

The major threats:

- Eutrophication (intensive agriculture, industrial and domestic wastewaters, improper solid waste disposal);
- Urbanisation (habitat destruction; conversion of the wetlands to agricultural land and building plots);
- Water level decrease (inexistent or inappropriate water management);
- Tourism (increasing and uncontrolled tourism development);
- Introduction of alien species;
- Overfishing;
- Climate changes



This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

Main ecosystem services considered and ecosystem characteristics that support them:

Habitat for endemic species of economic and/or cultural value	• Resistance and resilience to invasive species • Reduction of the impact of invasive species • Dependence of species dynamics and ecosystem structure on chemical (e.g. nutrient enrichment) and physical water properties • Hydrological balance (O/P)	• Presence of invasive species • Trophic web structure • Species and community population dynamics • Chemical and physical properties of water • Lake hydrology • Precipitation and temperature regimes (including seasonal)
Sustainable tourism	• Water quality • Biodiversity and uniqueness of communities and environments • Conservation of clean and natural beaches	• Chemical and physical properties of water • Species presence (e.g. *Salmo letnica* and *Ochridospongia rotunda*) and abundance • Land characteristics
Food production	• Fish stock • Resistance and resilience of supporting food web • Synchronised phenology • Habitat diversity (spawning sites, nurseries)	• Chemical and physical properties of water (in particular, oxygen, temperature, stratification and mixing patterns) • Food web and keystone species • Fish species distribution and abundance

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

Supply and regulation of freshwater

- Water quality
- Water budget

- Chemical and physical properties of water
- Lake hydrological regime
- Lake area
- Community composition (particular cyanobacteria, filter feeder)
- Organic matter and nutrient retention/export across the catchment

Carbon balance/storage

Carbon cycling between lake, watershed, sediment and atmosphere (source versus sink)

- CO_2 and CH_4 exchanges
- Inorganic and organic carbon exchanges through the lake-sediment-watershed system
- Macrophytes and phytoplankton dynamics
- Chemical and physical properties (in particular stratification and mixing pattern, light attenuation)

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

List of Control factors and the corresponding Indicator Variables

Presence and abundance of invasive species	Number of invasive species (in-situ)
Species richness and abundance	Species richness index (in-situ)
Physical ecosystem size	Habitat modification (land use) (in-situ)
Food web stability	Nutrients (in-situ, RS)
Physical (Temperature (profiles), oxygen (profiles), pH, transparency…) and chemical (inorganic and organic) water state	Chemical (inorganic and organic) compounds pH, Oxygen and DOC Presence of urban waste/ discharge (In-situ, lab. surveys)
Microbiological parameters	Microbiological indicators (including indicators of urban wastewater) (in -situ, RS, M)
Hydrological balance	Hydrological lake measurements (input, outputs, level) (in-situ, M)
Meteoclimatic conditions	Precipitation and temperature measurements (in-situ, RS, M)
Land use	Land cover (in-situ, RS)
Human pressure (fishing)	Fish abundance Fishermen Number/licences (in-situ)
Lake trophic level	Phytoplankton abundance Nutrients (in-situ, lab., RS)
Dissolved inorganic carbon (DIC)	DIC measurements; Eh measurements CO_2/CH_4 fluxes (In-situ)
Organic carbon (OC) contents in superficial sediments	OC measurements in sediments (Lab.)
Macrophytes abundance	Macrophytes abundance (In-situ, lab., RS)

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

List of state of the ecosystem variables that describe the ecosystem characteristics of interest or is a proxy to those

SoE	Indicator	Method [reference]
• Spatial structure and distribution of endemic and invasive species • Trophic web structure • Fish and invertebrate biodiversity • Fish abundance • Water quality • Water budget • Carbon budget	• Species and community population dynamics • Nutrient concentration • Chlorophyll *a* concentration • Macrophytes, phytoplankton/zooplankton and fish dynamics • Biodiversity indicators • Physical-chemical water parameters • Industrial and urban discharges • Hydrological indicators • CO_2 and CH_4 fluxes	• in-situ surveys (I) • in-situ and laboratory data (I), remote sensing and modelling output (R, M) • in-situ and laboratory data (I), remote sensing and modelling output (R, M)

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

List of drivers of change/pressures and corresponding indicator variables that can describe the main (human-induced) pressures.

Driver of change	Indicator	Method [reference] (type)*
Pollution	• Metal/organic compounds concentration in lakes, streams and groundwaters of the watershed • Bacteriological and organic contamination	• In-situ measurements of the physical, biological and chemical water properties (I) • Carbon and water fluxes (I, M)
Eutrophication	• Trophic web structure • Nutrient concentration and Chlorophyll *a* in lakes • Phytoplankton dynamics and phytoplankton species/size distribution • Water transparency	• In-situ measurements of the physical, biological and chemical water properties (I, R)
Land use changes	• Land cover changes • Organic carbon • Nutrient load	• Land cover and land use (R) • In-situ measurements of the physical, biological and chemical water properties (I, R)
Presence of invasive species	• Presence and abundance of invasive species • Presence of endemic species (invertebrates, amphibians, fish)	• Phytoplankton and zooplankton quantitative measurements (I) • Seasonal species population dynamics (M) • Fish abundance (I) • Estimates of the abundance of endemic species (I)
Water exploitation	• Lake area, water level change	• Lake area, water level (I, R)
Loss of habitat and habitat diversity	• Macrophyte cover and diversity • Reed stands • Wetlands	• Macrophyte cover (I) • Quantification of natural habitats (R) • Beta diversity (I)

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

The most critical ecosystem characteristics, functions and processes that are potentially harmed by the pressures and corresponding describing variables

* type: R – remote sensed; M – Modelling output (based on EO); I – in-situ/field collected data

Critical characteristics	Indicator	Method [reference] (type)*
Low tolerance of endemics to invasive species, eutrophication and habitat loss	• Presence and abundance of invasive species and of endemic species through time • Strength of food web connections • Changes in keystone species	• In-situ surveys and measurements (I)
Water quality	• (Micro)-Biological and chemical-physical water parameters	• In-situ surveys and measurements (I)
Water budget	• Hydrological parameters	• In-situ surveys and measurements (I), modelling (M) and remote sensing imagery (R)

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Ohrid/Prespa lakes

Available in situ data:

Meteorological parameters	Precipitation and temperature measurements
Physico-chemical water parameters	Water quality and nutrients
Hydrological balance	water level input/output outflow
Macrophytes and phytoplankton dynamics, zooplankton dynamics	Species composition, dynamics, abundance, biomass, diversity indices
Taxonomic data-time series of species richness Fish abundance, Presence of invasive species	•Biodiversity •Species and community population dynamics •Presence and abundance of invasive species

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

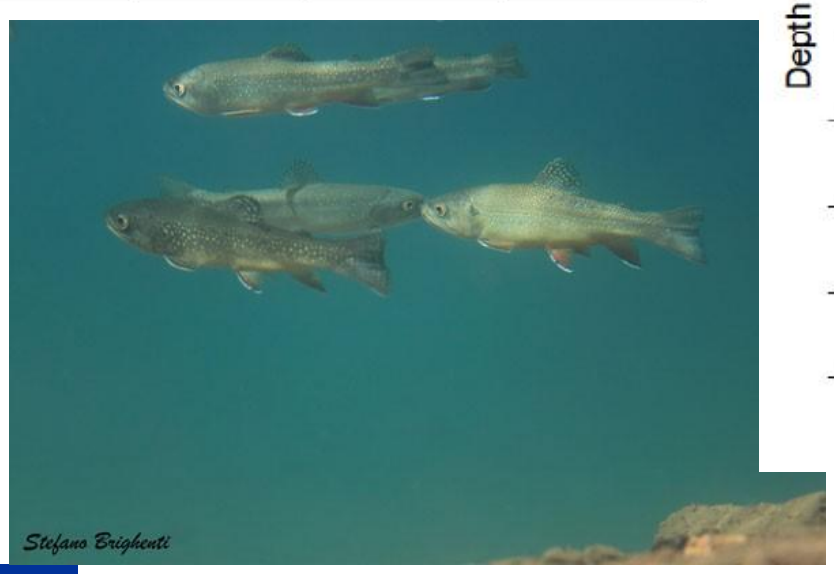
Ecosystem services and biodiversity crisis across mountain lakes; PA Gran Paradiso National Park

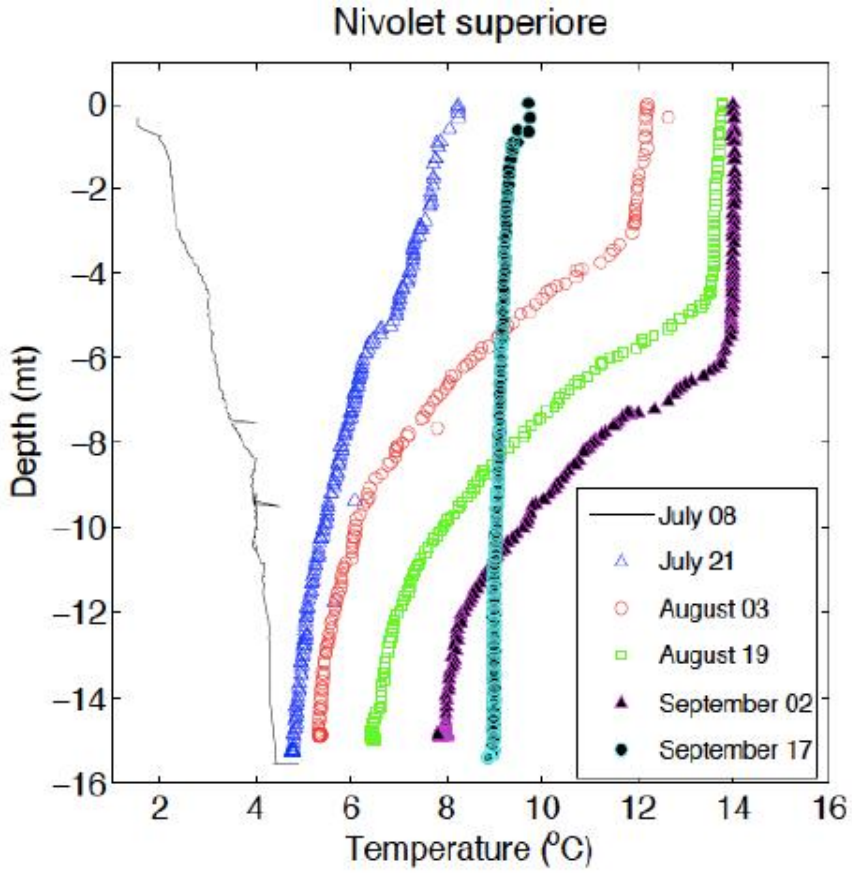
Highly oligotrophic lakes
Strongly seasonal dynamics

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Gran Paradiso National Park

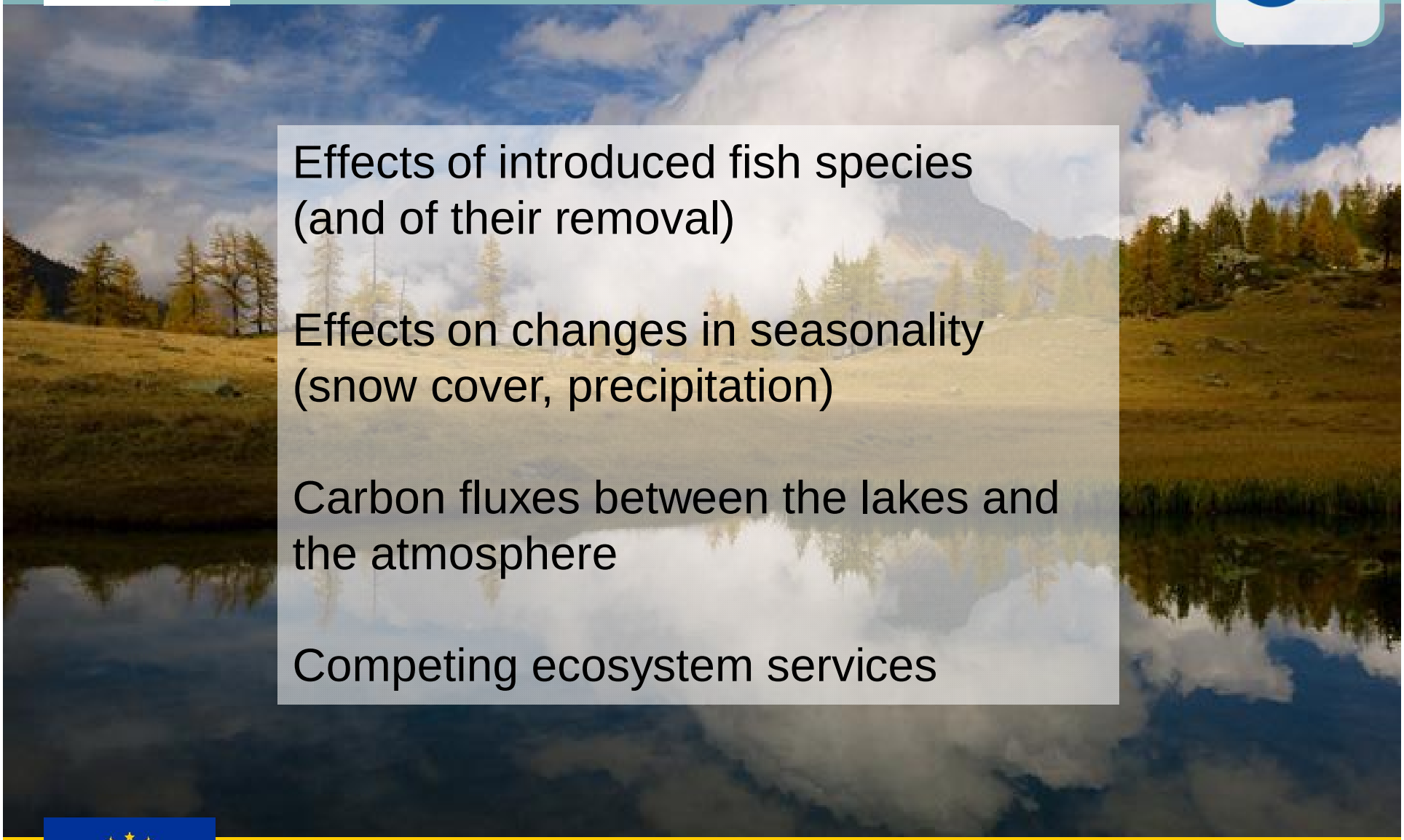
Lake	Altitude (m a.s.l.)	Mean depth (m)	*Salvelinus fontinalis*
Nivolet Superiore	2538	4.70	
Trebecchi Inferiore	2723	4.17	
Trebecchi Superiore	2729	3.45	
Losere	2568	3.29	
Lillet	2765	6.43	
Motta	2656	12.40	
Leità	2701	3.93	×
Nero (Leynir)	2747	10.44	×
Nero (Djouan)	2671	2.43	×
Djouan	2515	1.48	×
Dres	2087	3.30	×
Rosset	2703	19.85	×





This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Ecosystem services and biodiversity crisis across mountain lakes; PA Gran Paradiso National Park



Effects of introduced fish species (and of their removal)

Effects on changes in seasonality (snow cover, precipitation)

Carbon fluxes between the lakes and the atmosphere

Competing ecosystem services

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Available *in situ* data:
Meteorological variables
Chemical and physical water properties
Phytoplankton (including size distribution, species)
Zooplankton (rotifers, copepods, cladocerans, size distribution)
Invertebrates, frogs (*Rana temporaria*)
Carbon fluxes (to be done)

Relevant remote sensing data:
Snow cover
Vegetation state
Soil moisture

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Modelling for GPNP lakes:
Process-based biogeochemical
+ population dynamics models

Nutrient (phosphorus)
Phytoplankton (2 compartments)
Zooplankton (3 compartments)
Detritus (various compartments)
Dissolved components
Bacteria
Fish

Vary meteorological drivers and explore mechanisms

Open issue:
Winter ecosystem dynamics

This project has received funding from the *European Union 's Horizon 2020 research and innovation programme* under grant agreement No 641762

Modelling for Lake Ohrid and Prespa

Research focus: Plankton as a basis of food web and sentinel of change
→ cascading effects to higher trophic levels

Potential research questions:
- What are the key drivers of the current/future plankton dynamics?
- How will climate change modify the plankton dynamics?
- How can remote sensing data assist lake monitoring programs and lake management decisions?

Modelling planned: Phytoplankton and zooplankton abundance variability in relation to water parameters, catchment related parameters, climatic conditions

Methodology: Statistical models: e.g. Maximum entropy approach (Maxent), Generalised Linear Models (GLM), Generalised Additive Models (GAM), Artifical Neural Networks (ANN), Classification Tree Analysis (CTA), Flexible Discriminant Analysis (FDA), Boosted Regression Trees (BRT) and Random Forest (RF)

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 641762