Working in the broad and multifaceted field of Aquatic Science

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On-line

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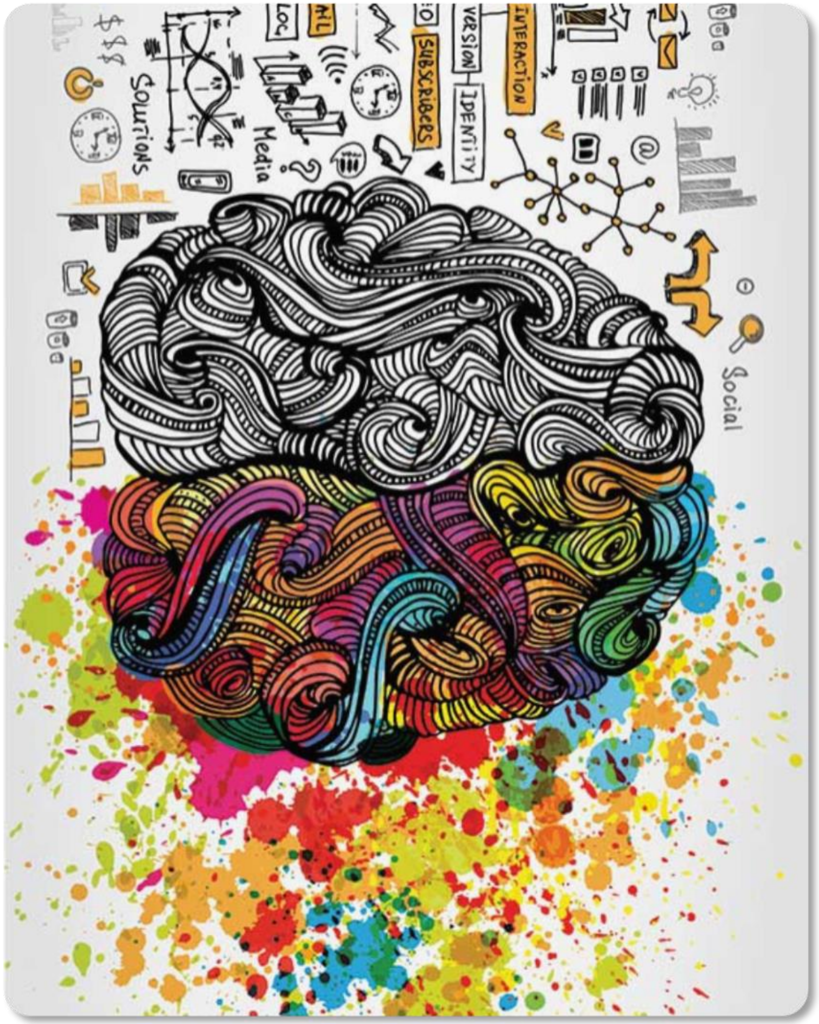
UNIVERSITÀ DI TRENTO

Outline

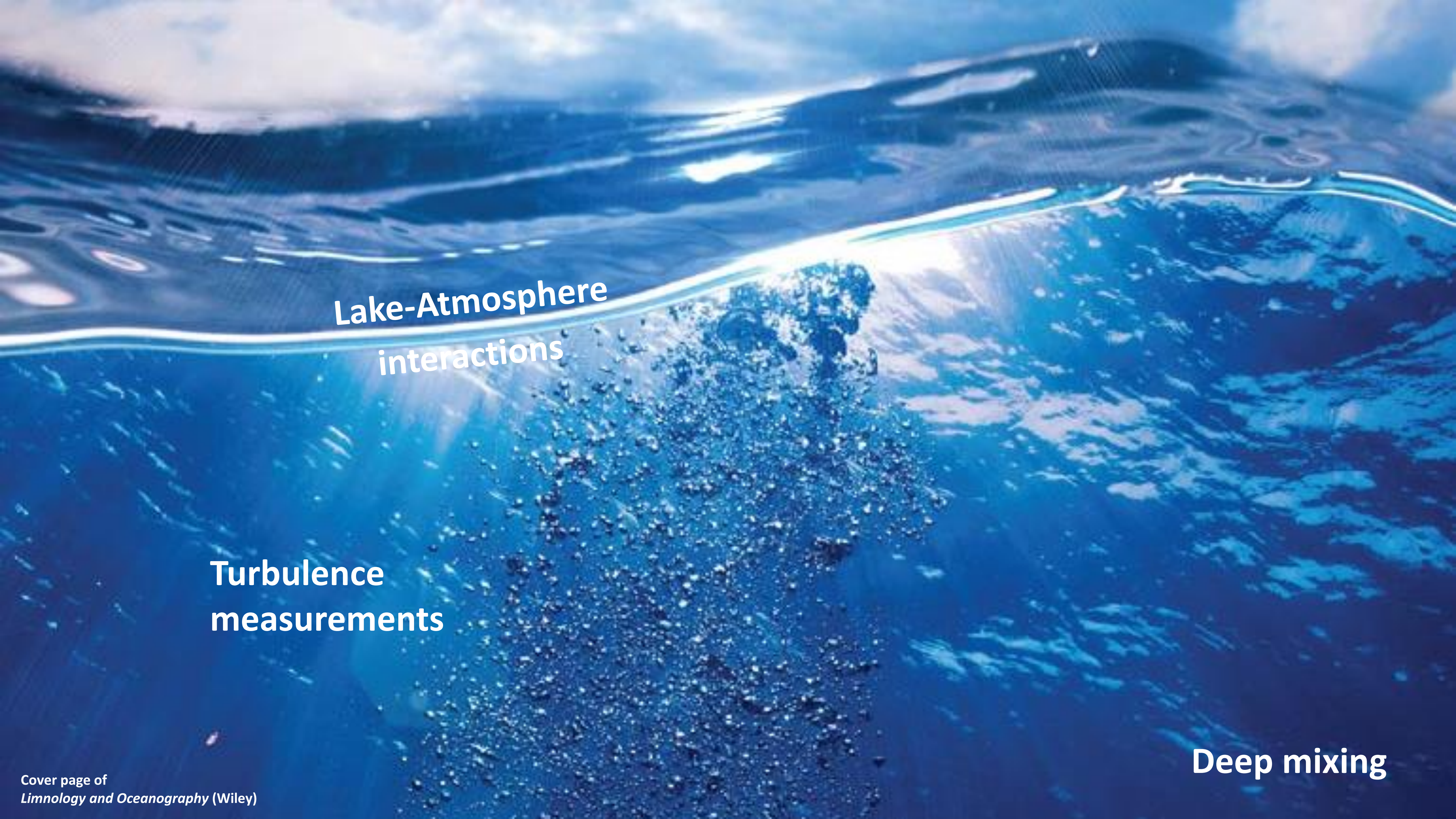
Overview of Aquatic Science + Social experiment

To understand the composition of the young community working on Aquatic Science in Italy



Some examples

Based on my personal experience, to highlight the interdisciplinary nature of Aquatic Science


Lake-Atmosphere interactions
Turbulence measurements
Deep mixing
Cover page of *Limnology and Oceanography* (Wiley)

What is aquatic science?

In 10 words

What is aquatic science?

ASLO Association for the Sciences of Limnology and Oceanography

Aquatic science is the study of the planet's oceanic and freshwater environments. **Oceanography** is the study of the biological, chemical, geological, optical and physical characteristics of oceans and estuaries, while **limnology** is the study of these same characteristics in inland waters (lakes, rivers, streams, ponds, and wetlands).

What do Aquatic Scientists Study?

Aquatic scientists use comparative studies, long term data, models, and theory to address a myriad of questions pertaining to water: water movement, water chemistry, aquatic organisms, aquatic ecosystems, movement of materials in and out of aquatic ecosystems, and the use of water by humans, just to name a few disciplines. Aquatic scientists study processes that cover time scales ranging from less than a second to daily, weekly, monthly, seasonal, annual, decadal, or geological (millions of years), and spatial scales ranging from millimeters to ecosystems to ocean-wide.

Many aquatic scientists work at the boundaries of disciplines and therefore they often work in interdisciplinary groups. For example, physical and biological oceanographers collaborate to understand the effect of physical processes on organisms, while chemists and biologists work together to understand the ways in which the chemical constituents of water bodies interact with plants, animals, and microorganisms such as bacteria.

https://www.aslo.org/what-is-aquatic-science/

Global ocean/Seas | Inland waters

Biology | Chemistry | Optics

Geology | Physics

...


Klicker UZH
What is your background?

What is aquatic science?

Limnology, as Seen by Limnologists
by
William M. Lewis, Jr.
Department of Environmental, Population, and Organismic Biology
University of Colorado, Boulder, CO 80309

Introduction

The science of inland waters is structurally amorphous because it has evolved as a loose collaboration of self-conscious disciplines that have overlapping scope. Disciplines such as hydrology, aquatic ecology, and fisheries science are complementary in an intellectual sense, but have retained their identities through distinctive histories, separate tracks for graduate education and training, and professional societies that serve their interests.

The fortunes of the disciplines that work together do not always rise and fall in unison. Intellectual advances, societal priorities, and a variety of other factors may invigorate or expand a particular discipline while a sister discipline declines in vigor, size, or recognition. Given that science is now supported to a large extent by national governments, invigoration or redirection of a discipline can sometimes occur through a collaboration between governmental support systems and the members of a discipline. For this reason, disciplinary self-analysis can play a major role in the maintenance of a scientific discipline. The field of hydrology provides a current example. A distinguished committee of hydrologists organized by the National Research Council concluded that hydrology has been too much dominated by an applications perspective and needs to be stimulated with

Limnology has entered a phase of self-analysis within the last several years. Distinguished limnologists and members of other disciplines who are familiar with limnology have written a series of articles and commentaries that raise questions about the present and future of this discipline, and the need for change. This commentary has dealt with a range of subjects, including education of limnologists in universities, support for basic research in limnology, and recognition of limnology by other disciplines.

The ASLO Challenges Report

Widespread interest in the status of limnology has been reflected in discussions of the Board of Directors of the American Society of Limnology and Oceanography, which is the largest of the societies representing limnological interests in North America. Members of the ASLO Board have shared concerns of the Society's membership that limnology is losing its unity and sense of direction, and that scientific societies representing it should seek some beneficial change. This matter was also discussed by the membership, which passed a resolution calling for the U.S. National Science Foundation to establish a designated program in limnology in order to improve and consolidate support of limnological research (Lewis et al. 1995).

"The science of **inland waters** is structurally **amorphous** because it has evolved as a **loose collaboration of self-conscious disciplines** that have overlapping scope … [that] have retained their identities through **distinctive** histories, **separate** tracks for graduate education and training, and professional societies that serve **their interests**."

"**Ecosystem science is the root of limnology**. Within the last few decades, however, limnology has become **more specialized** and **increasingly fragmented** into subdisciplines that focus on specific components of ecosystems. Such studies are essential to the framework of limnology, but their utility is greatly **weakened** without **integration at the system level**. Limnologists need to find solutions to this dilemma."

IRSA CNR

Istituto di ricerca sulle acque (IRSA)
già *Istituto per lo studio degli ecosistemi*
e in precedenza *Istituto italiano di idrobiologia*

Lewis (1995), *Limnology as seen by limnologists* (https://opensiuc.lib.siu.edu/jcwre/vol98/iss1/)


Klicker UZH
Did you attend any
limnological course?

What is aquatic science?

Limnology, as Seen by Limnologists

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"

Limnology is **not well connected** to some of the disciplines whose specialists would best be able to work with limnologists. Some **ecologists** have even come to view limnology as irrelevant to their interests … **hydrology** may at present have weakening connections to limnology. In contrast, the **connection to oceanography** appears to remain **strong**.

"

A.I.O.L. ASSOCIAZIONE ITALIANA DI OCEANOLOGIA E LIMNOLOGIA

ASLO Association for the Sciences of Limnology and Oceanography

"

More pertinent than any formal definition, however, is that **limnology deals with inland waters as ecological systems**. This requires the use of information on all components of the system. Limnology thus might be considered an **umbrella discipline** supported by information from all other disciplines contributing to the science of inland waters.

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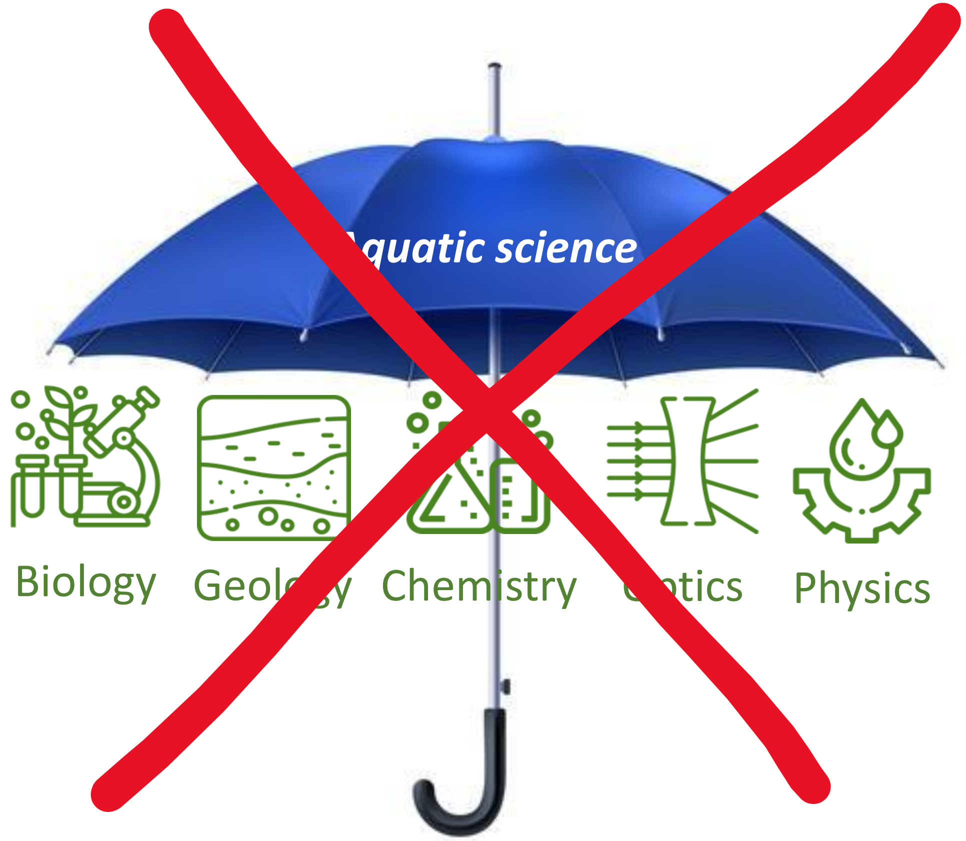
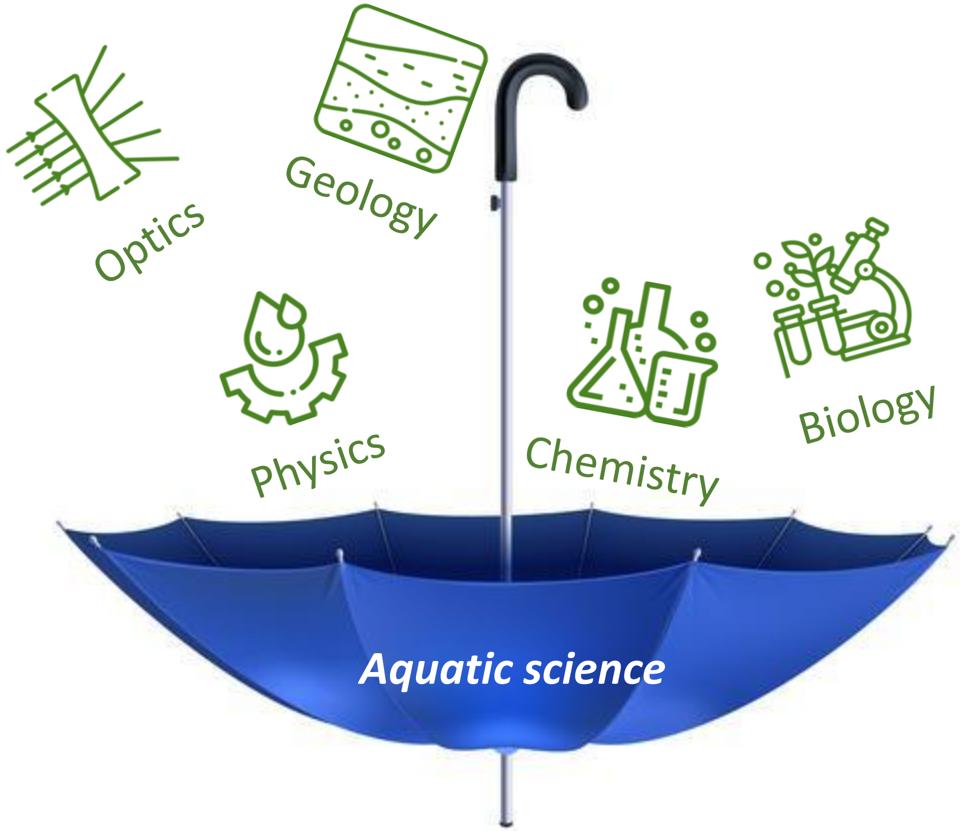
Lewis (1995), *Limnology as seen by limnologists* (*https://opensiuc.lib.siu.edu/jcwre/vol98/iss1/*)

What is aquatic science?



Limnology is not a super-discipline encompassing contributions from classical disciplines



Limnology is the product of contributions of expertise from those trained in a variety of specific areas

Kaufmann (1988), *A Materials Society*, DOI:10.1557/S0883769400065350

How do (would) you classify lakes?

What is aquatic science?

There is not a unique classification of lakes. *Some* examples are:

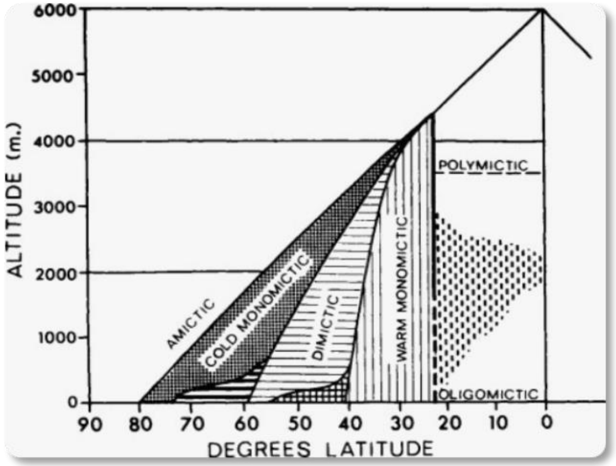
Origin

Bengtsson (2012), *Classification of Lakes from Origin Processes*, DOI: 10.4319/lo.1977.22.2.0361

Trophic status

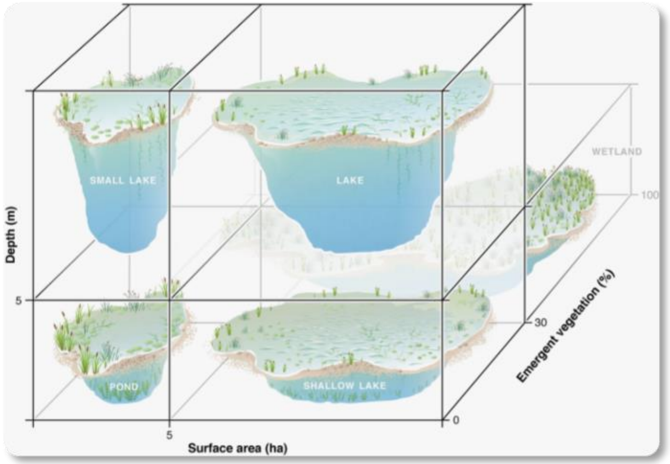
Carlson (1977), *A trophic state index for lakes*, DOI: 10.4319/lo.1977.22.2.0361

Mixing regime



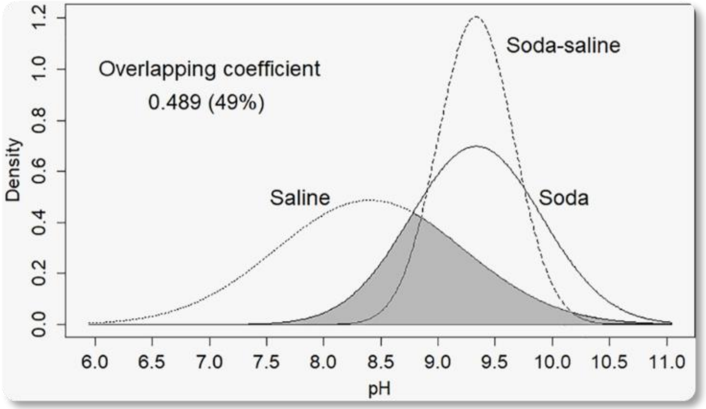
Hutchinson and Löffler (1956), *The thermal classification of lakes*, DOI: 10.1073/pnas.42.2.84

Depth/Size



Richardson et al. (2022), *A functional definition to distinguish ponds from lakes and wetlands*, DOI: 10.1038/s41598-022-14569-0

Chemistry



Boros and Kolpakova (2018), *A review of the defining chemical properties of soda lakes and pans: An assessment on a large geographic scale of Eurasian inland saline surface waters*, DOI: 10.1371/journal.pone.0202205

Regulation

EU directive 2000/60/CE
Source: www.appa.provincia.tn.it/

What is aquatic science?

SPECIAL FEATURE: LIMNOLOGY IN THE 21ST CENTURY

LIMNOLOGY AND THE PERFECT STORM

***Brian Moss**, University of Liverpool, UK*

Limnology is a demanding environmental science. To understand lakes and rivers, limnologists have to know things from geology to food growing and land management, with a lot of biology, physics and chemistry on the way. The detail can be daunting; the archive now runs to millions of publications. A distinguished freshwater ecologist once told me that when he went into a bookshop, he became quickly depressed by the welter of new information, and came out without buying anything. I had felt the same way, and was heartened for, nonetheless, he was productive and influential because he saw that there were fewer, larger themes, and that, so long as he dealt with these, most details could be left in the books. One of our problems may be that we are becoming buried in the details of our own particular interests. In the business of making a career, finding funds, surviving in science, worrying about our individual futures (all of them real worries and not to be trivialized), we may sometimes lose the bigger plot that otherwise gives meaning and pleasure. The three articles in this edition of the *L&O Bulletin* are about the bigger plot.

The recently retired chief scientist to the UK government, a population ecologist, John Beddington, has described the world as heading for a 'perfect storm' of climatic, population, food, and water problems. If I take analogy from the book from which the phrase is borrowed, the storm could be devastating. As scientists, a group generally much better trusted by the public than, for example, journalists, businesspeople, and politicians, we have had some influence (much of the sane part of the population, at least, accepts that climate is changing, that rivers and lakes have been much abused and that the ocean is overfished), but not nearly enough to change the way that society is managed so that the storm may be avoided or at least weathered. One reason for this might be in our increasingly isolated approach, our intense digging for more and more arcane details (with the detriment on arcane, not detail) and also the ways in which we organize our own societies.

In the past, scientific societies have been politically influential. The British Association for the Advancement of Science, in the nineteenth and early twentieth centuries, was a force with which to be reckoned, as measured by its role in the acceptance of Darwin's ideas on the one hand, and the creation of a major freshwater laboratory on Windermere on the other; the meetings of the American Association for the Advancement of Science still raise some dust, at least for a day or two, in the world's quality newspapers. But in every capital city, lobby groups much more effectively whisper in the ears of government, covertly feeding their views and using their money to plot the courses that lead us into the heart of the perfect storm.

Meanwhile science has split into thousands of small societies, each now to some extent struggling for its own survival and thus deflected from the bigger issues.

Many, perhaps most, scientific societies have declining memberships. Some of the reasons for which they were set up (cheap access to a printed journal; convenient meetings in the subject area) have been usurped: the first by electronic publication and bundling of journals to libraries, which now gives access to almost anything; the second by e mail and SKYPE and a proliferation of small workshops and meetings by many different groups. There remains some sense of collegiality in belonging to a society of like-minded people, but even that is threatened as young people consider the many demands on their cash and the older of us join the cycles of biogeochemistry. You can associate with like-minded people without paying a subscription to do so.

There is also a new trend – of open access publication. Those of us associated with the libraries of large universities or research institutions can find most of what we need without even thinking of the cost. Other people, whose taxes pay for much of the research, and those in less well-endowed countries, can not, and the large profits of commercial journals, subsidized by a largely voluntary system of refereeing and editing, are increasingly seen as unacceptable. At least in the UK, all publications that can be submitted for future assessments of the quality of universities will have to be open access, and the European Commission has indicated its intention to follow. The United States has been more cautious, but the trend will snowball. Unfortunately scientific societies, presently ploughing back into science the surpluses they make from well-established journals, could suffer. Many library subscriptions will disappear, but society-based journals can use their intellectual prestige and favorable pricing structures for their members to compete very effectively for the best papers. We could gain more than we suffer.

But if we are to be faced by a publishing revolution that will certainly change how we operate, perhaps then this is the time also to look outwards at how we are organized. Can we do more to avert 'the perfect storm' as a flotilla of randomly- moving small boats, borne down upon by the battleships of the rich and powerful consumptive industries, or as fewer but bigger ships, or at least by a well-coordinated fleet? Will we be more effective pottering in the safe backwaters of esoteric curiosity or by circling the storm on the open sea?

We have a lot to offer in the aquatic sciences. Our subject demands a long and broad view, and global problems are nothing if not wide-ranging and set in a long history. We know much about the really important issues of the future; our metier is very much a planet that runs on a water-based biological system; we know that economics is ultimately the servant of biogeochemistry. We are not infallible; we have our human subjectivities, but I believe that we are honest people, and despite the cynics among historians, the truth eventually emerges. Yet we allow ourselves to be overridden by the narrow, the selfish and the downright dishonest. The three articles in this issue emphasize the importance of long and broad views, and the urgency of strong and courageous advocacy. Perhaps we should take some cues from them; perhaps we should examine more deeply the ways in which we organize ourselves.

“

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Moss (2013), *Limnology and the perfect storm,* DOI:10.1002/lob.201322369

What is aquatic science?

Eos, Vol. 95, No. 44, 4 November 2014

MEETINGS

Crossing the Boundaries of Physical Limnology

17th International Workshop on Physical Processes in Natural Waters; Trento, Italy, 1–4 July 2014

PAGE 403

Scientists who study the physics of inland and coastal water bodies met in Trento, Italy in July for the 17th in a series of workshops that seek to expand cooperation with researchers in related fields. The workshops aim to facilitate the dialogue among physical limnologists, modelers, and colleagues from other disciplines, such as biologists, chemists, and engineers. This year's workshop was attended by 47 participants from 17 different countries.

One major issue discussed was the increasing demand for a reliable modeling of ecological dynamics and their interaction with the classical transport processes (e.g., lakes' circulation, mixing, and sediment and particle transport). Several presentations focused on the capability to predict water temperature changes both at short and long time scales, also in order to develop realistic scenarios for climate change studies. With thermal stratification being a crucial aspect of lake dynamics, a hot topic was the mixing in deep lakes, which occurs through a wide range of processes (e.g., downwelling, increased turbulence and double diffusion) and drives the long-term response of deep water temperature.

Another issue that emerged from the works presented was the need to have reliable measurements both for an in-depth understanding of the processes—for supporting the increasingly complex numerical models—and for the growing trend of metadata analysis merging different lake systems. To this end, a special session on Standard Operation Protocol was organized, as a first step toward the establishment of suitable protocols for field measurements and data analysis. These protocols, which should address the specific difficulties of measurements in lakes, may allow non-expert users to avoid basic errors and misinterpretations and experts to agree on use of instruments and data analysis in lakes.

The two keynote speakers embodied the interdisciplinary outlook characterizing the workshop. Andreas Lorke (physicist, University of Koblenz, Landau, Germany) and Nico Salmaso (ecologist, Fondazione E. Mach, Trento, Italy) have tackled the problem of managing lake ecosystems from different perspectives, always recognizing the strong interactions among physical, biogeochemical, and ecological processes.

Program details and extended abstracts are available at http://events.unitn.it/en/ppnw2014. To promote collaboration among researchers interested in physical limnology, a distribution list was set up after the workshop. This list is a particularly valuable resource for a scientific community that, although spread all over the world, is relatively small and divided into groups that often rely on a limited number of members. To subscribe to the "lakes list," send an email to sympa@list.dicam.unitn.it with "SUBSCRIBE lakes" in the subject line.

The next workshop will be held in Landau, Germany, in August 2015 (http://www.ppnw.uni-landau.de). For details, please contact the local organizing committee (Andreas Lorke, lorke@uni-landau.de).

—MARCO TOFFOLON, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy; email: marco.toffolon@unitn.it; and SEBASTIANO PICCOLROAZ, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy; and DAMIEN BOUFFARD, Physics of Aquatic Systems Laboratory, Margaretha Kamprad Chair, École Polytechnique Fédérale de Lausanne, Switzerland

> … facilitate the **dialogue** among physical limnologists, modelers, and colleagues from **other disciplines**, such as biologists, chemists, and engineers.

> … scientific community that, although spread all over the world, is relatively **small and divided into groups** that often rely on a limited number of members.

The "lakes list":
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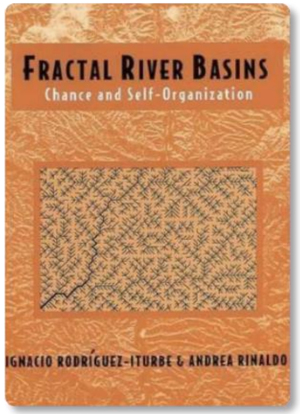
with "SUBSCRIBE lakes" in the subject line

Toffolon, Piccolroaz, and Bouffard (2014), *Eos,* DOI:10.1002/2014EO440009

The Stockholm Water Prize 2023 (Nobel Prize of water)

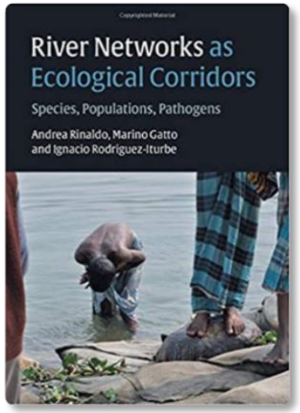
> Andrea Rinaldo is a thought leader in hydrologic science whose conceptual and quantitative models have provided in-depth understanding to the fields of **hydrogeomorphology** and **ecohydrology**. In his research he has showed the key **connections** between **river networks** and the **spread of solutes, aquatic species, and diseases**.

> At a time when **hydrology** was mainly associated with **fluid mechanics** and **hydraulic engineering**, he creatively searched for alternative approaches and eventually developed new conceptual and quantitative models to describe how water shapes the **earth surface and ecosystems.**



1997

Hydrogeomorphology:
river systems self-organized into dynamically accessible optimal states



2020

Ecohydrology:
rivers as ecological corridors for species, population and pathogens

The Stockholm Water Prize 2011 (Nobel Prize of water)

Stockholm Water Prize

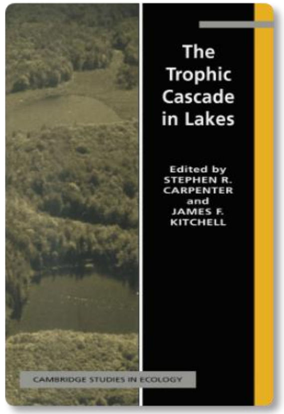
Laureates Nominate History FAQ News

2011: Professor Stephen R. Carpenter

Professor Carpenter's ground breaking research has shown how lake ecosystems are affected by the surrounding landscape and by human activities. His findings have formed the basis for concrete solutions on how to manage lakes.

"By combining **theoretical models** and **large-scale lake experiments** he has reframed our understanding of freshwater environments and how lake ecosystems are **impacted by humans** and the **surrounding landscape** … Professor Carpenter has shown outstanding leadership in setting the ecological research agenda, integrating it into a **socio-ecological context**, and in providing **guidance** for the **management of aquatic resources.**"

"Professor Carpenter is best known for his research on **trophic cascades** in lakes – a concept which describes how **impacts on any species in an ecosystem will cascade down, or up, the food chain**. For example, overfishing of large fish in a lake can result in an increase of small fish, thus decreasing the abundance of zooplankton further down the food chain. In extension, this would increase the growth of algae and amplify the effects of eutrophication."



1993

A multidisciplinary research team tests the "trophic cascade" idea by manipulating whole lakes experimentally, and coordinating this with palaeolimnological studies, simulation modelling, and small-scale enclosure experiments.

"This book is of interest to workers in ecology, aquatic ecology, resource management, and limnology" (Environment International)

Aquatic science: a science based on multiple disciplinarity

Intra-, cross-, multi-, inter- or trans-disciplinary?
Let's try to unravel the confusion.

These terms have been used to denote efforts that involve **several disciplines**. However, these terms are **ambiguously** defined and often used **interchangeably** – a situation that has been referred to as a '*terminological quagmire'.*

'*Discipline*': a branch of knowledge, instruction, or learning.

'*Multidisciplinary*': found in the US dictionary of 1975

'*Interdisciplinary*': found in the UK, US and Canada dictionaries of the 1970s

'*Transdisciplinary*': not found in the UK, US and Canada dictionaries of the 1970s

'*Intradisciplinary*' and *'Crossdisciplinary'*: not considered by Choi and Pak (2006).

> The practical argument for interdisciplinarity is that problems of the world are not organized according to academic disciplines…

Complex problems require us to look outside disciplinary boundaries in order to shape new modes of knowledge production.

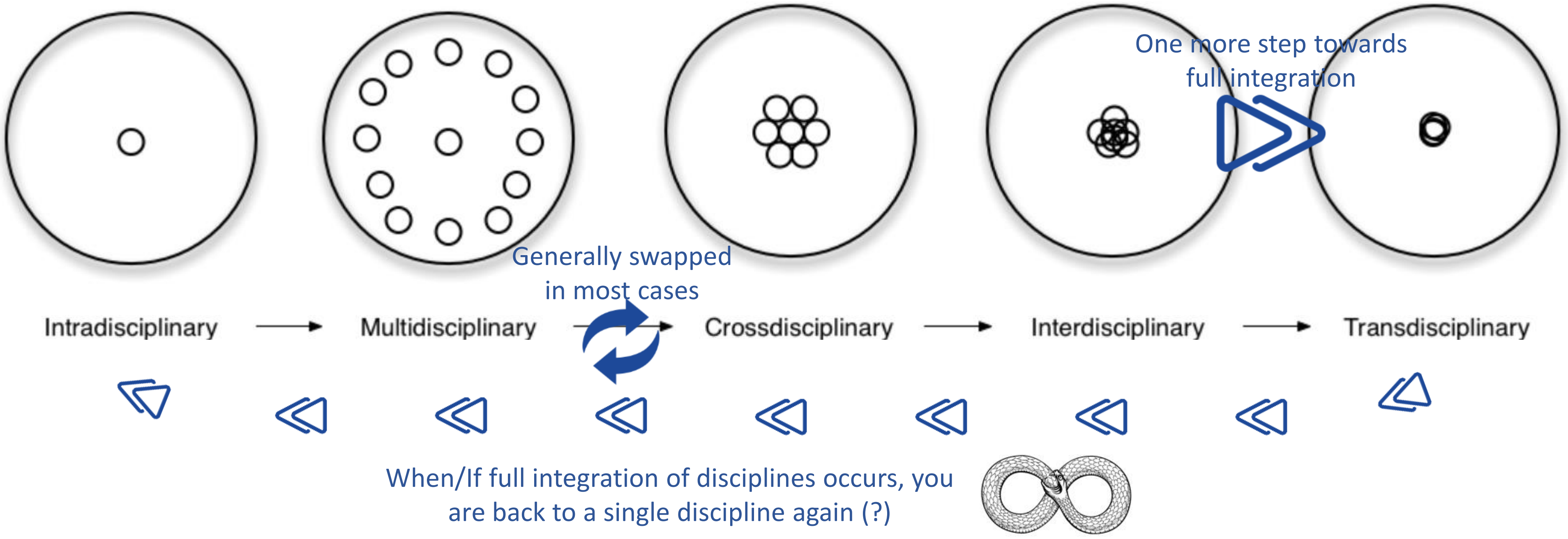
Choi and Pak (2006), *Clin Invest Med*, https://pubmed.ncbi.nlm.nih.gov/17330451/

Stember (1991), *The Social Science Journal*, DOI: 10.1016/0362-3319(91)90040-B

Aquatic science: a science based on multiple disciplinarity

- *Intradisciplinary*: working within a **single discipline**.
- *Crossdisciplinary*: viewing one discipline from the **perspective** of another.
- *Multidisciplinary*: people from different disciplines **working together**, each drawing on their disciplinary knowledge.
- *Interdisciplinary*: **integrating knowledge and methods** from different disciplines, using a real synthesis of approaches.
- *Transdisciplinary*: **creating a unity of intellectual frameworks** beyond the disciplinary perspectives.

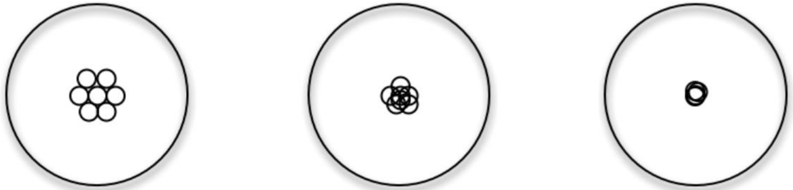
Many people believe they work interdisciplinary, while in fact, it is more common to work multidisciplinary.



Disciplinarities: intra, cross, multi, inter, trans http://www.arj.no/2012/03/12/disciplinarities-2/

Aquatic science: a science based on multiple disciplinarity

	Multidisciplinary	Interdisciplinary	Transdisciplinary
Keyword	Additive	Interactive	Holistic
Mathematical example	2+2=4 (linear combination)	2+2=5 (deviation from linear combination, requiring an interaction term	2+2=yellow (the outcome is of different kind)
Food example	a salad bowl (you can still see the individual ingredients)	a fondue or stew (melting pot) (ingredients are partially distinguishable)	a cake (the output is entirely different to the individual ingredients)

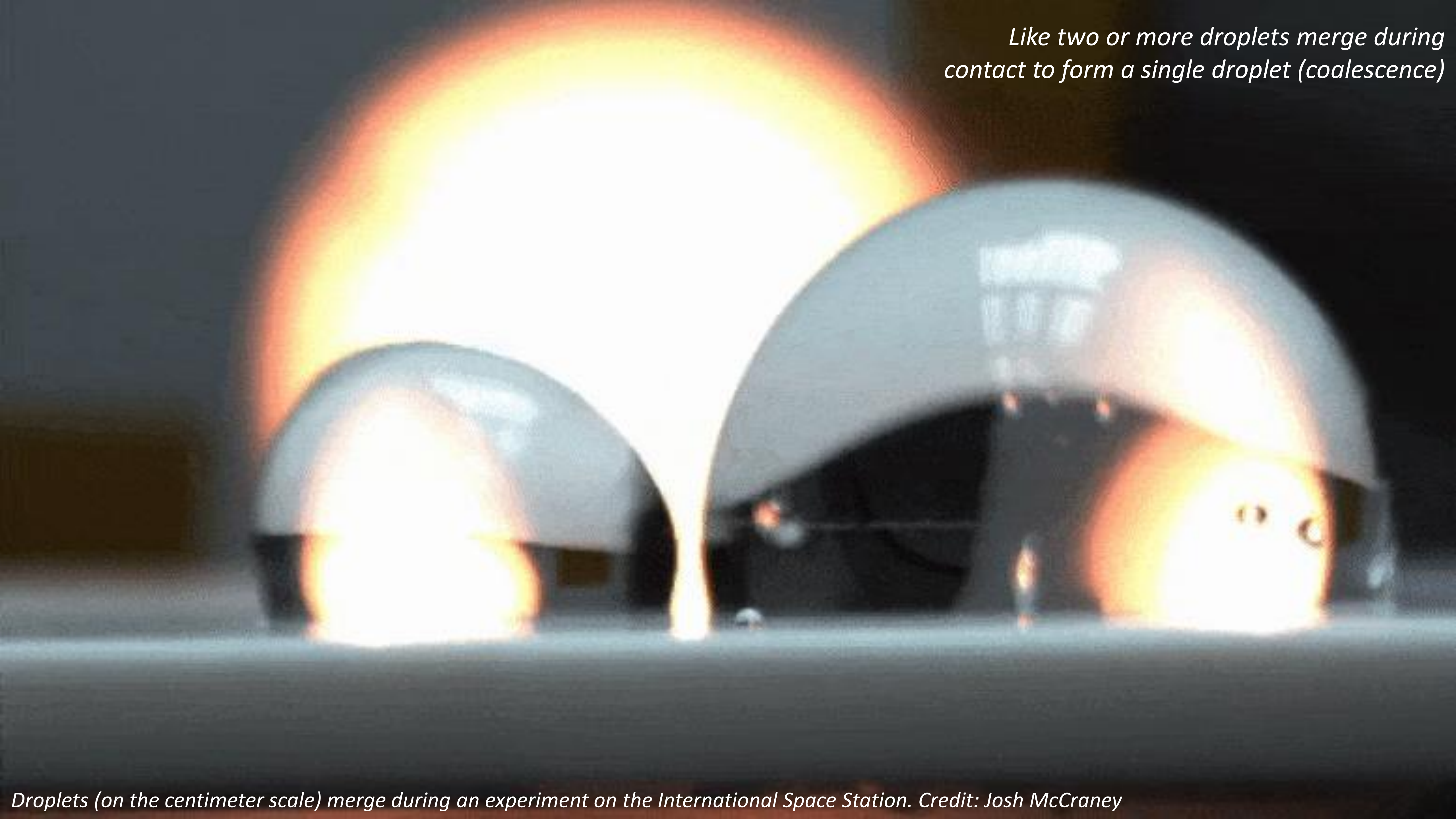


Something graphically more captivating, but the sense is the same.

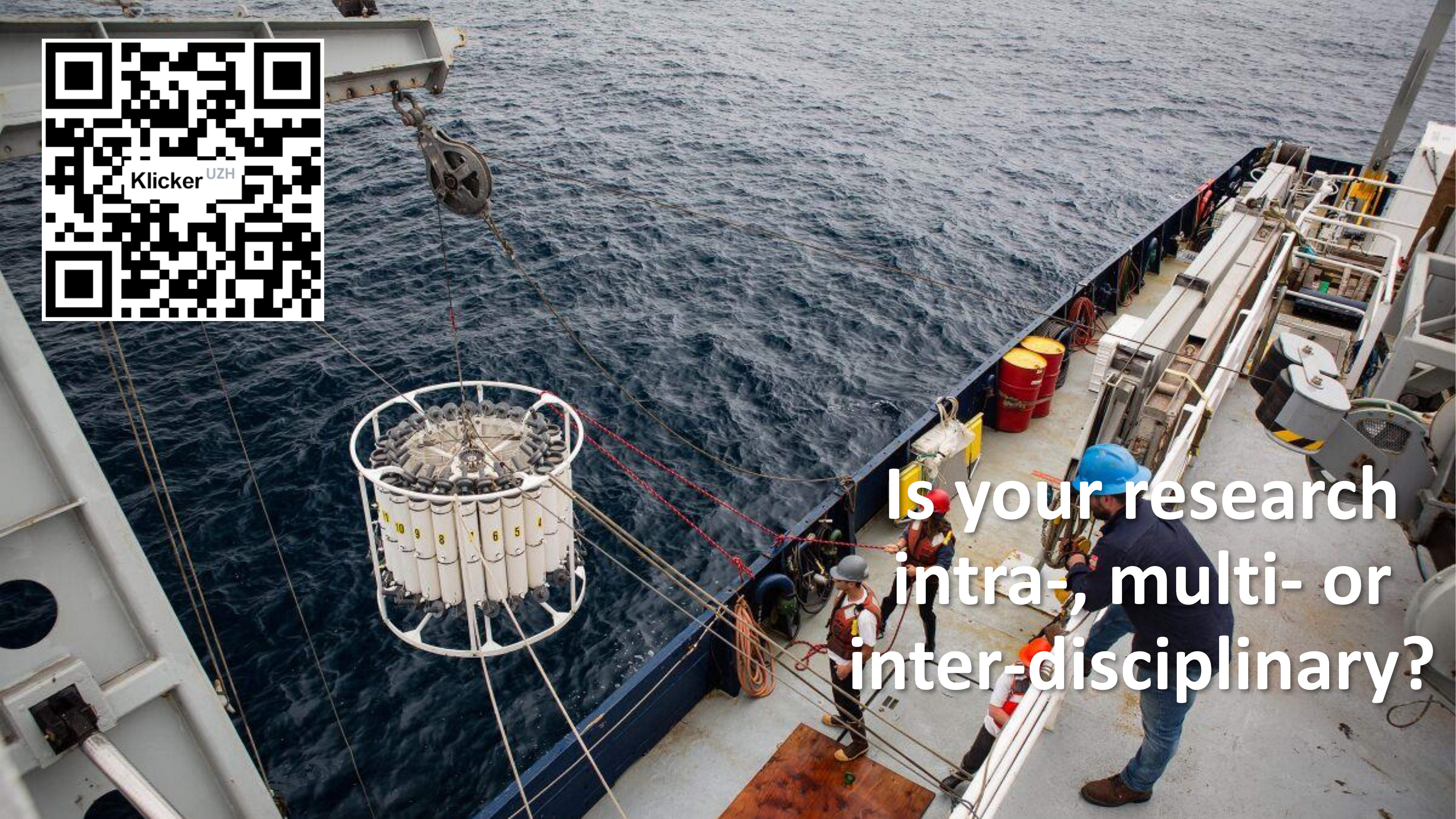
Choi and Pak (2006), *Clin Invest Med*, https://pubmed.ncbi.nlm.nih.gov/17330451/

Disciplinary recipes: a visual guide! https://makinggood.design/thoughts/tasty

Like two or more droplets merge during contact to form a single droplet (coalescence)



Droplets (on the centimeter scale) merge during an experiment on the International Space Station. Credit: Josh McCraney



Is your research intra-, multi- or inter-disciplinary?

Aquatic science: a science based on multiple disciplinarity

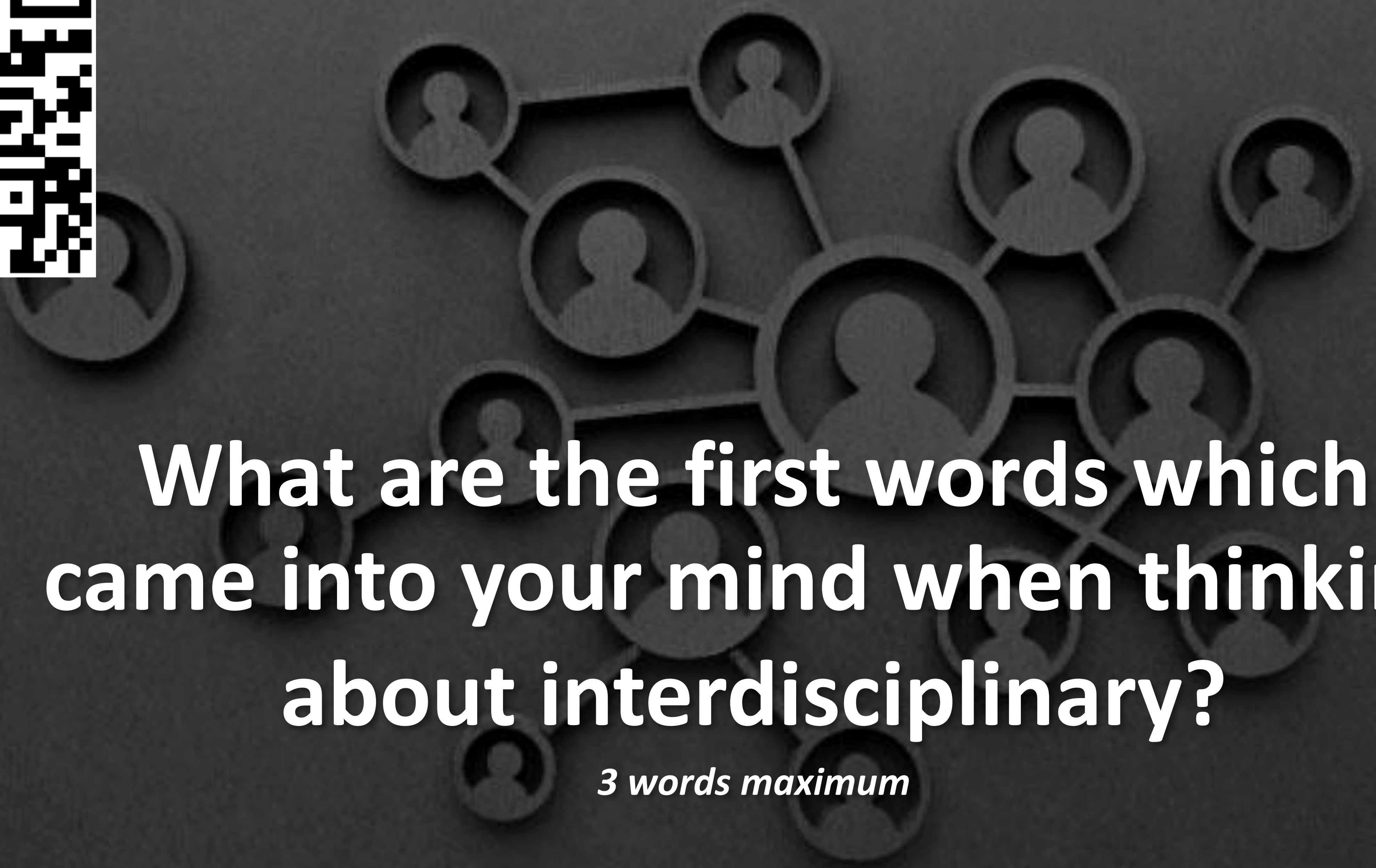
Why pursue multiple disciplinarity?

- *To resolve a real-world problem*:
  Life is multiple disciplinary. Real world problems are rarely confined to the artificial boundaries of academic disciplines. This is a time of unprecedented change, thus transformative approaches are needed.
- *To resolve a complex problem:*
  The complexity of problems is increasing at a time when pace and complexity of science and technology is accelerating.
- *To provide different perspectives on a problem*:
  Experts from different disciplines read thing differently.
- *To create comprehensive research questions and interpretations:*
  In general, interdisciplinary works have been documented to provide better problem identification, better solutions and better engagement with stakeholders.

Is multiple disciplinarity always effective? Evidence indicates conflicting results:

- Some projects are complex and multiple disciplines is a requirement.
- In some cases, such expertise may not be available (or even exist).
- During the project, team conflicts, discipline conflicts and other factors can lead to failure.
- Some projects are so simple and straightforward that they are best performed by experts from one discipline.
- Some reviews reported weaknesses in research rigor and rated the state of interdisciplinary teamwork as poor.

Choi and Pak (2006), *Clin Invest Med*, https://pubmed.ncbi.nlm.nih.gov/17330451/



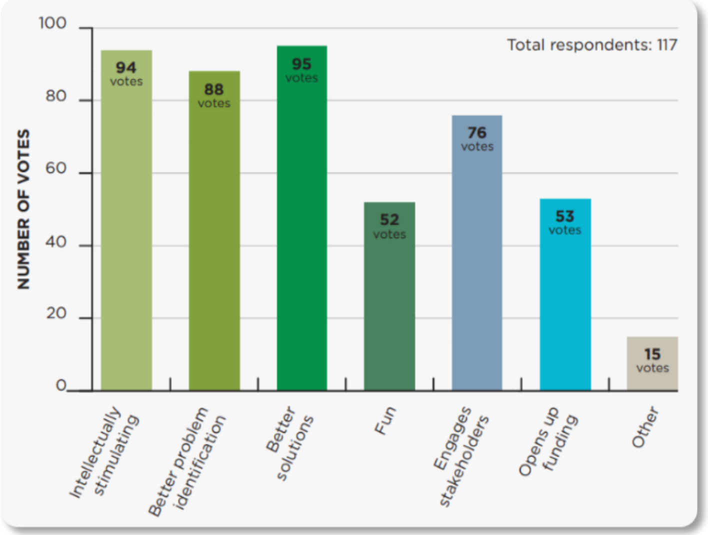
What are the first words which came into your mind when thinking about interdisciplinary?

3 words maximum

Aquatic science: a science based on multiple disciplinarity

The same question asked to the audience of the Valuing Nature Annual Conference (2019)

What are the positives of interdisciplinary working?



Establishing a shared language between researchers and policymakers.

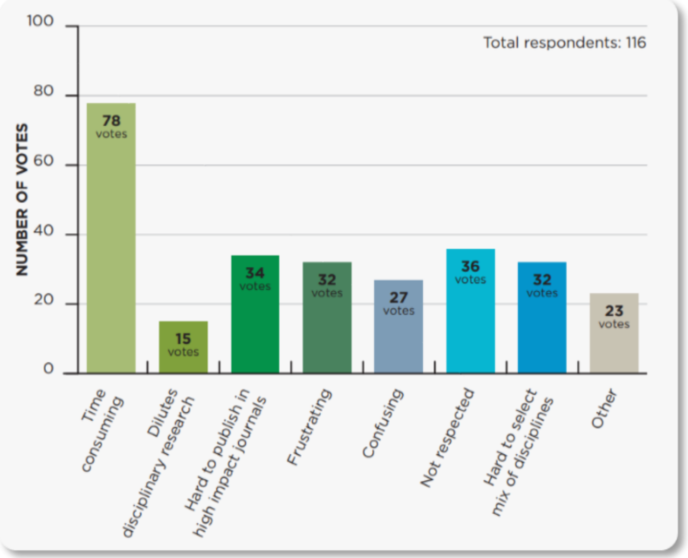
82% positive

5% negative

12% neither positive not negative

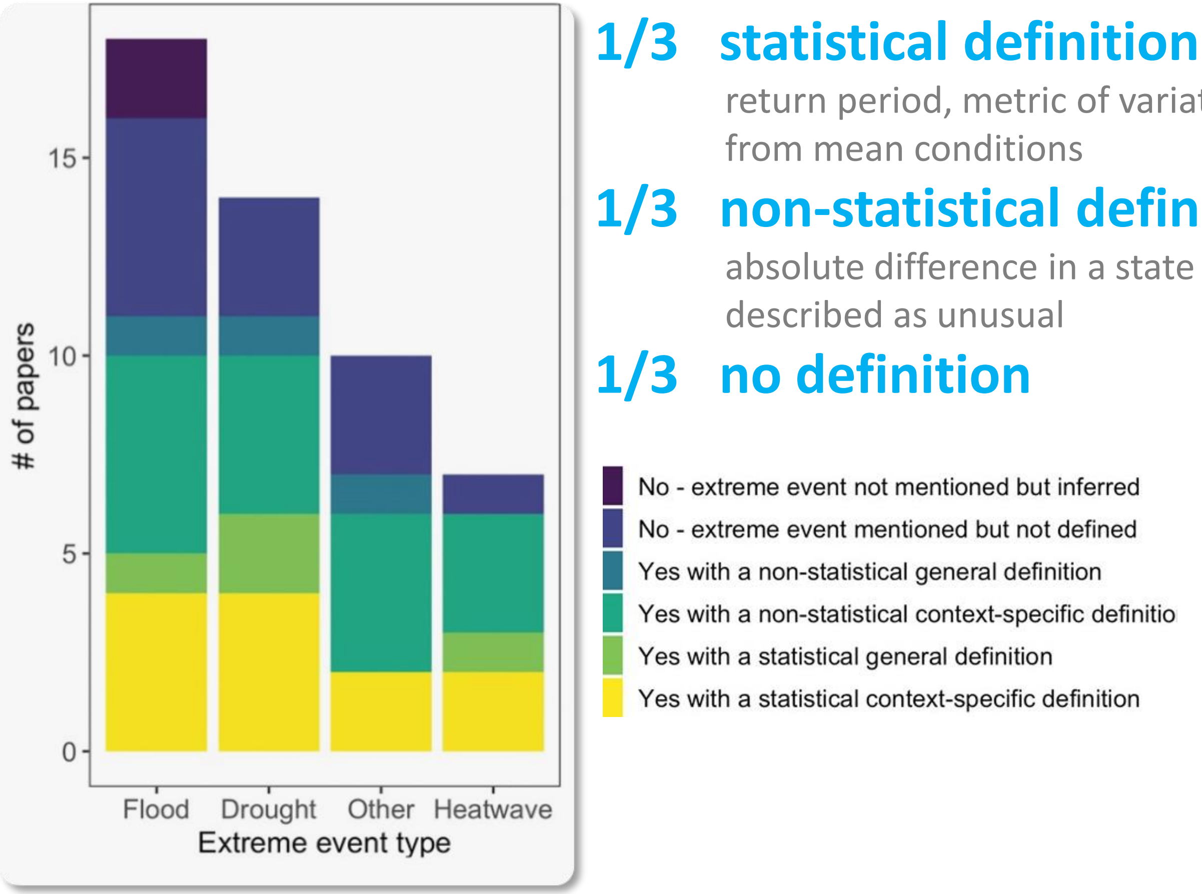
Frustrating, as sometimes language and different concepts can make progress slow and communication difficult.

What are the negatives of interdisciplinary working?



Demystifying interdisciplinary working (in Valuing Nature) https://valuing-nature.net

Aquatic science: a science based on multiple disciplinarity



1/3 statistical definition
return period, metric of variation from mean conditions

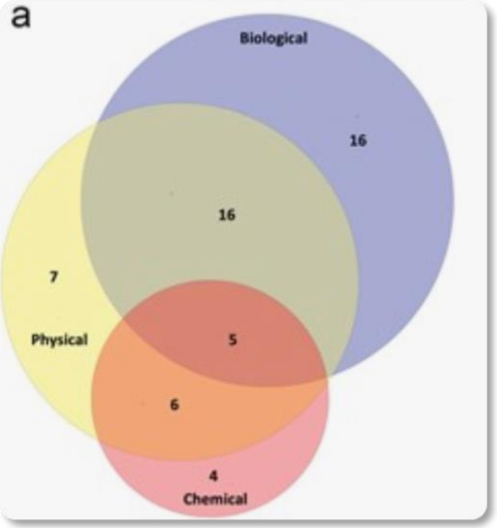
1/3 non-statistical definition
absolute difference in a state variable described as unusual

1/3 no definition

“

Extreme events have increased in frequency globally with a simultaneous surge in scientific interest about their ecological responses … however progress is hindered by **unclear definitions** of extreme event **among and within disciplines** and event types … The resulting lack of clarity impedes research on extreme events and on the responses of socioecological systems, with **negative consequences** for **communication**, **policy**, and **management**.

”



88% biological response

10% bio., phys., chem. response

Moving to the level of ecological organization:

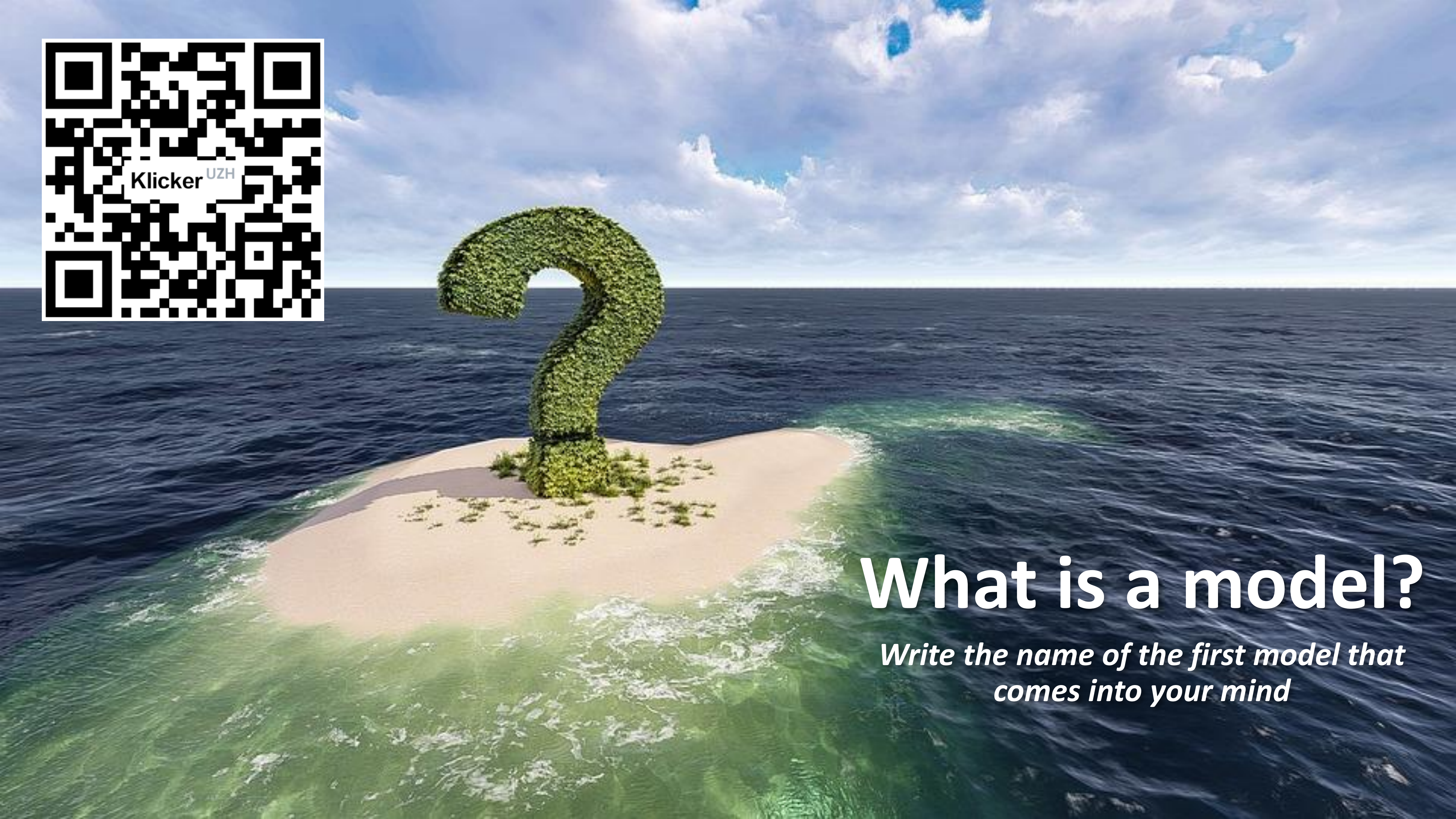
73% population level
density, abundance

45% community level
species richness, food web structure

22% ecosystem level
enhanced vegetation index biomass

7% pop., com., eco. levels

Aoki et al. (2022), *BioScience*, DOI: 10.1093/biosci/biac020



What is a model?

Write the name of the first model that comes into your mind

Aquatic science: a science based on multiple disciplinarity

7 Principles of Interdisciplinary Working

PRINCIPLES	TOP TIPS
1 Respect: Disciplines and activities should not be considered in a hierarchical fashion.	Keep an open mind, listen deeply and ask questions; avoid pre-conceptions, assumptions and patronisation; co-develop project guidelines for respect and equality; acknowledge and demonstrate appreciation for all contributors involved in achieving goals; write an early joint publication to provide an immediate shared goal.
2 Take time: Additional time is required to learn and understand different backgrounds, methods and language.	Build additional time into project timelines, both overall and for specific interdisciplinary activities; build additional time into meetings for extended discussions; explicitly budget for the extra time, resources and activities required.
3 Communicate: Don't assume that the forms of communication within your discipline are universal, different disciplines may use the same words but with very different meanings.	Collaboratively develop a project-specific dictionary; do not be afraid to admit that you do not understand; listen actively and repeat back what you have heard in your own words to ensure that you have understood; visit a field site and ask each team member to explain what they see – listen to the differences; remember that simplicity in communication is not the same as being simple, explaining complex issues to non-experts requires skill.
4 Embrace personalities: * Successful interdisciplinary working is not just about bringing two or more disciplines together; it is about bringing two or more people harmoniously together.	Create opportunities to get to know each other outside of the usual work place, e.g. outreach and STEM events are valuable as they place people in an impartial space, often outside their comfort zone, and create a shared experience; remember that no one person embodies an entire discipline and it can take time to find a suitable disciplinary representative for your team/project.
5 Prepare: * The development of an interdisciplinary collaboration can require unfamiliar procedures which need additional consideration.	Take time at the beginning of a collaboration to determine if an interdisciplinary approach is required, what disciplines are needed, and how they will be organised; ensure roles and responsibilities are clear including who will be delivering what and to whom, and when; have an agreed publication strategy with an emphasis on inclusivity.
6 Adapt: * Interdisciplinary working can be unpredictable requiring adaptability.	Jointly develop and regularly revisit a Gantt chart, if an activity is struggling be proactive and do not be afraid to change direction if needed; include risk management strategies in the proposal to address delays and non-delivery, or the delivery of alternative outputs; maintain open communication and encourage partners to vocalise concerns without the risk of reprimand.
7 Share: * To support success, the sharing of experiences is critical before, during and after a project is undertaken.	Discuss with other people who are working in an interdisciplinary context; keep a record or diary of what works well and what works less well; take time to read some of the extensive interdisciplinary literature; write up and publicise your own interdisciplinary experiences.

VALUING NATURE PROGRAMME

An extract from: Beaumont, N. (ed), 2020
Demystifying Interdisciplinary Working (in Valuing Nature),
Valuing Nature Paper VNP25.

* Common to effective team working principles

Demystifying interdisciplinary working (in Valuing Nature) https://valuing-nature.net

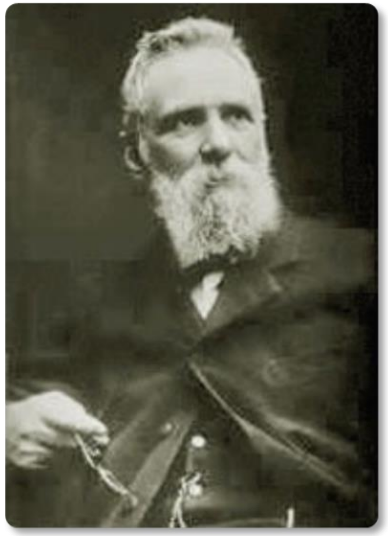
Aquatic science: a science based on multiple disciplinarity

Stephen Alfred Forbes
1844-1930

Often referred to as the **founder** of **aquatic ecosystem science**.

Forbes outlined not only the premise that a **lake** is an integrated system (**ecosystem**) with emergent properties, but also that lake ecosystems can be studied through analysis of **biogeochemical cycles**, system **metabolism**, **food webs**, and **physico-chemical** gradients. He also understood the influence of terrestrial exports to aquatic system.

The Lake as a Microcosm (Forbes, 1887):
Lakes are '*a little world within itself, a microcosm within which all the elemental forces are at work and the play of life goes on in full, but on so small a scale as to bring it easily within the mental grasp*'



François-Alphonse Forel
1841-1912

Often referred to as the **father of limnology**.

Forel studied the physical, chemical, and biological attributes of Lake Geneva from an **integrative perspective** (also including anthropology and economics) that is **characteristically limnological**.

I wanted to achieve a generalisation, an overview of all the detailed facts, where each specialised study would be supported by the data from other studies. The theme of my description being partly terrestrial, this subject might be considered Geography. But the geography of waters is called Oceanography; I could therefore call the discipline Freshwater Oceanography. But a lake, no matter how large it might be, is not an ocean … it is necessary to forge the word limnology. Limnology is thus the oceanography of lakes.

Klicker UZH

What is the keyword that better describes your research?

Aquatic science: a science based on multiple disciplinarity

Results based on the abstract presented to the *2023 AIOL meeting for young PhD students and researchers.*

A clear multiple disciplinarity nature emerges, especially from the affiliations.

It is present, but hidden, in the titles of the abstracts.

Word cloud based on the titles of the abstracts

Word cloud based on the affiliations

What is your (main) research method?

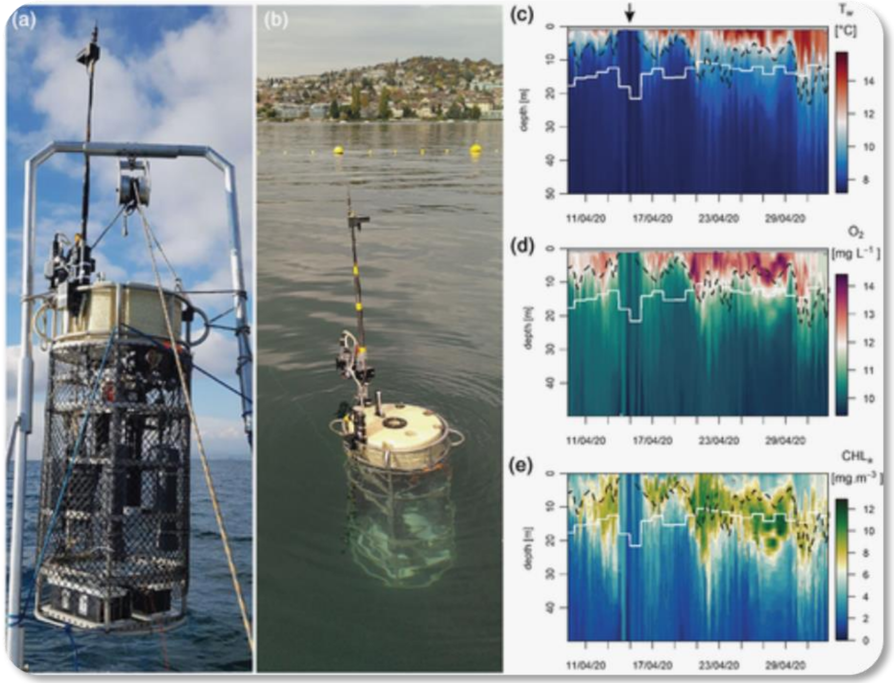
A floating lab to foster interdisciplinary research

What is the LéXPLORE?

- an interdisciplinary *in-situ* **floating laboratory**
- anchored at **Lake Léman** and operational since **2019**
- equipped with state-of-the-art instrumentation to obtain simultaneous observations of **physical**, **chemical** and **biological** processes at high temporal and spatial resolutions

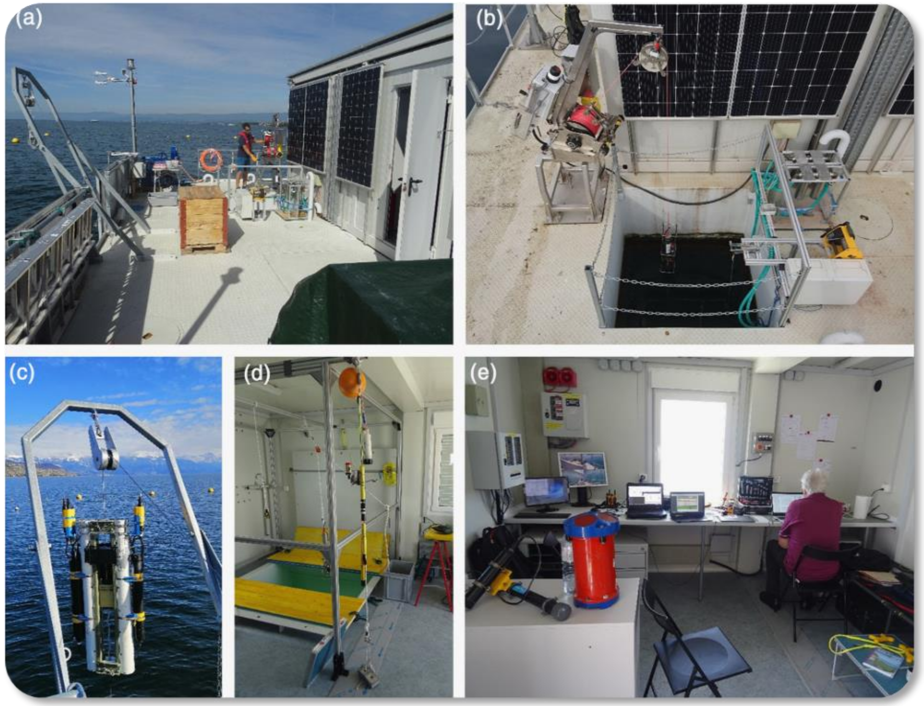
https://lexplore.info/

> The types of measurements possible on the platform can **support interdisciplinary project teams** working simultaneously on the same question while using different techniques …
> The question of what regulates **primary production** is an example of a prescient, systems-level science question requiring **integrated, multidisciplinary approaches**. Primary production depends on both vertical distribution and vertical flux of nutrients and algal communities, as well as on carbon cycling and light regimes.



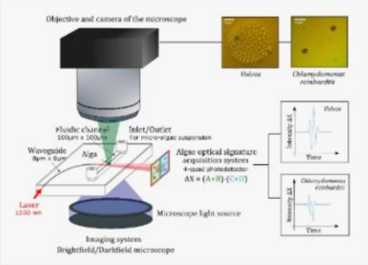
Wüest et al. (2021), *WIREs Water,* DOI: 10.1002/wat2.1544

A floating lab to foster interdisciplinary research

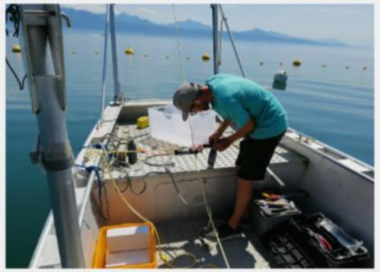


LéXPLORE elements (from top left to bottom right): (a) outdoor work area, (b) outdoor moonpool with electric crane (left) and pump system (right), (c) Wirewalker deployment using an A-frame, (d) partially covered indoor moonpool, and (e) office work area

Some of the current projects:

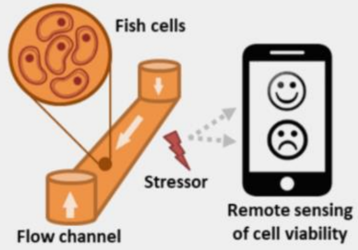


NEW TECHNOLOGY
GENEVA LAKE MICROALGAE MONITORING

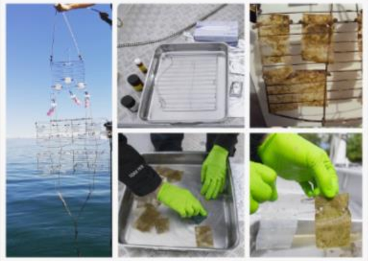


BIOGEOCHEMISTRY
CARBON CYCLING IN LAKE GENEVA

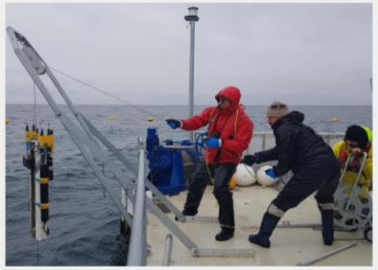
HYDROLOGY
INSTALLATION OF A DRIP-BASED RAIN GAUGE



NEW TECHNOLOGY
A BIO-SENSOR TO MONITOR WATER QUALITY



ECOLOGY
AQUA-GAPS/MONET IN LAKE LEMAN



PHYSICS
LÉWALK: AUTONOMOUS TURBULENCE PROFILING

BIOGEOCHEMISTRY
FLOATING CHAMBER – GAS FLUX MEASUREMENTS

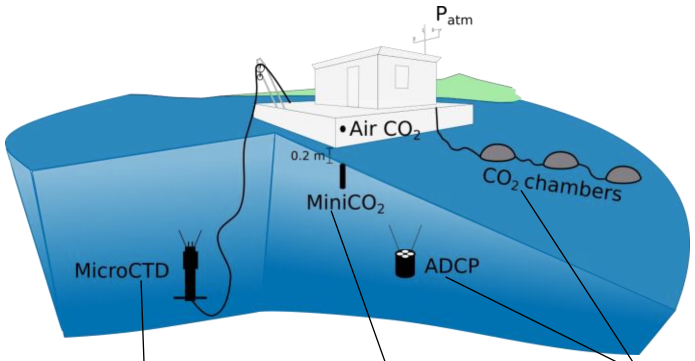
REMOTE SENSING
SKIN2BULK: INVESTIGATING THE SURFACE LAYER

NEW TECHNOLOGY
SUBMULE: EASY ACCESS TO SUBMERGED DATA

Wüest et al. (2021), *WIREs Water,* DOI: 10.1002/wat2.1544

A floating lab to foster interdisciplinary research

Instruments and setup:



- 3 **CO_2 chambers**
- 1 **CO_2 sensor** in the air
- 1 in-water CO_2 sensor (MiniCO2, by ProOceanus)
- 1 **microstructure profiler** (MicroCTD, by RSI)
- 1 **ADCP** (Monitor, by Teledyne)
- 1 **meteorological** station

Microstructure profilers

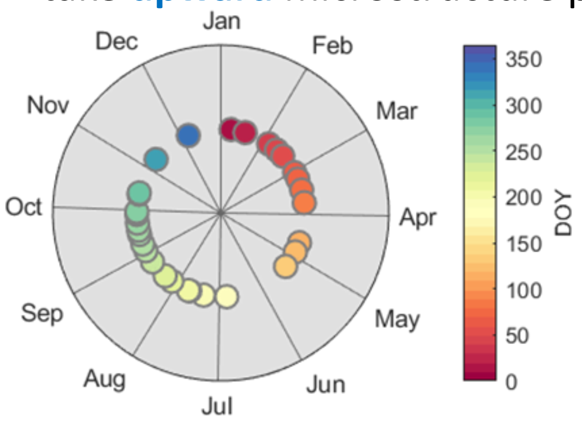
$MiniCO_2$ and CO_2 sensor in the air

CO_2 chambers

ADCPs colonized by quagga mussels

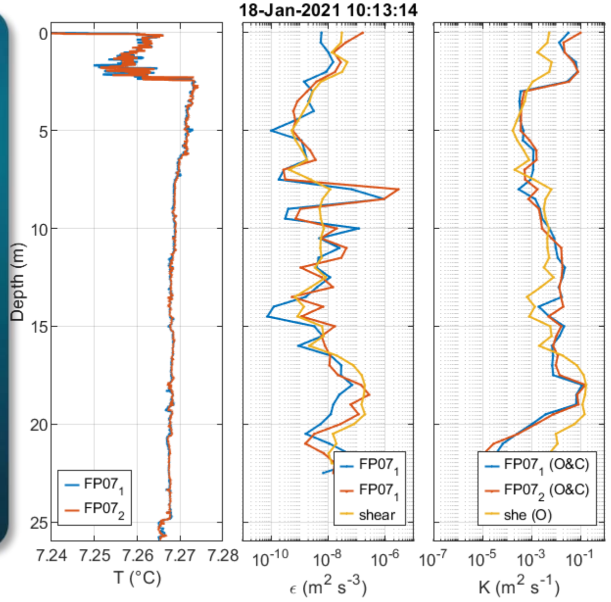
Preparation and operation:

- install the $MiniCO_2$ close to the surface within the **Active Mixed Layer (AML)**
- take **upward** microstructure profiles

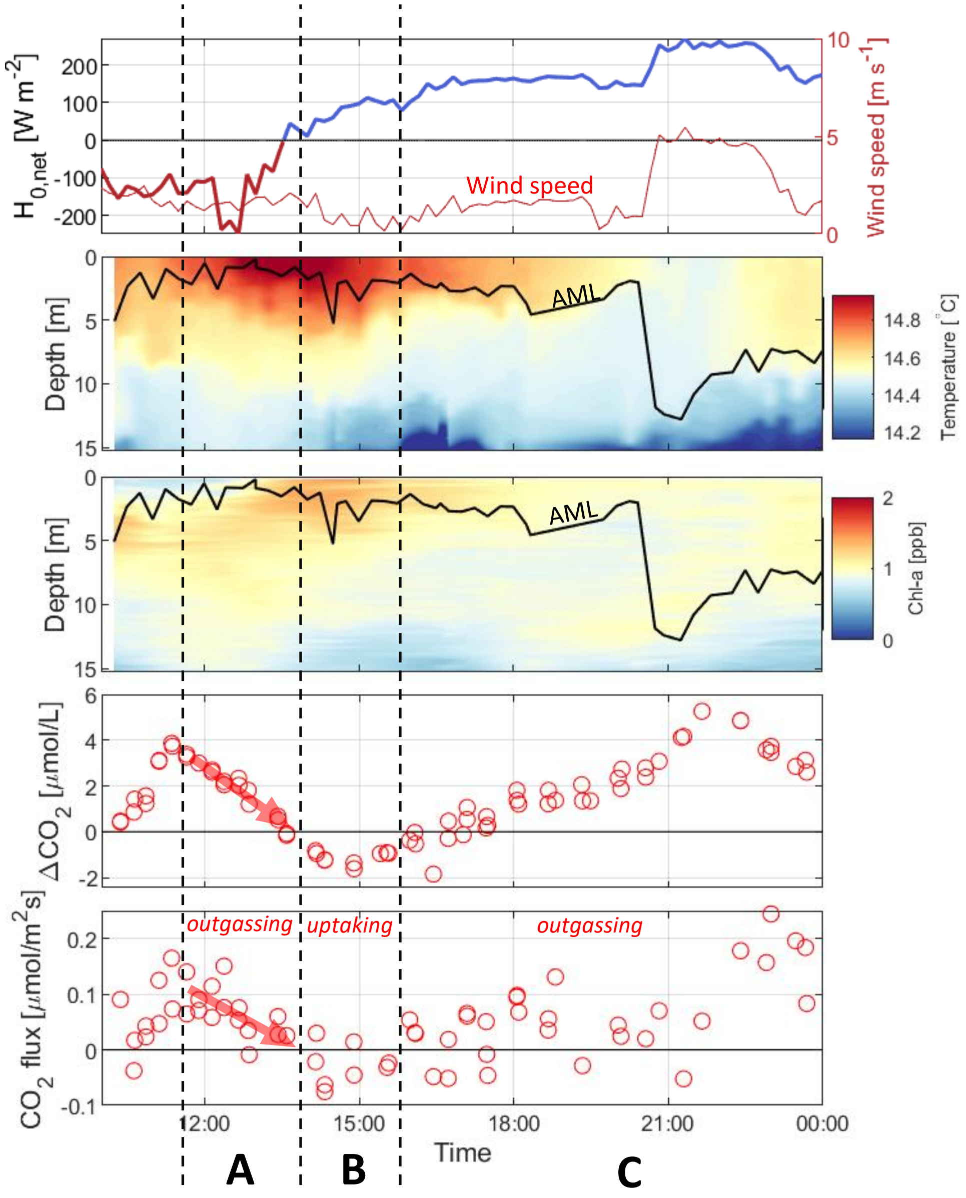


Fieldwork 2020/2021
30 days including
2 x 24h campaigns

Measurements every 10'
Profiles for the upper 30 m



A floating lab to foster interdisciplinary research



A sub-daily pattern controlled by stratification and phytoplankton dynamics:

A: as the lake warms, **stratification** gets **stronger**, and the Active Mixing Layer **(AML) reduces**. The CO_2 in the AML is progressively **depleted** (outgassing). CO_2 in the water decreases because stratification **inhibits replenishment** from below (small vertical diffusivity $O(10^{-5}$-$10^{-4})$ m^2/s)

B: Eventually, CO_2 in the water tends to **equilibrate** with the atmosphere. However increasing **phytoplankton** contributes to consume CO_2 in the AML, **inverting** the CO_2 **flux** (slight uptake).

C: As soon as **stratification weakens** and the **AML deepens**, CO_2 is entrained in the AML from below, progressively restoring an **outgassing** behavior.

Highly variable sub-daily dynamics
Importance of relying on high temporally resolved measurements

Contribution of local knowledge

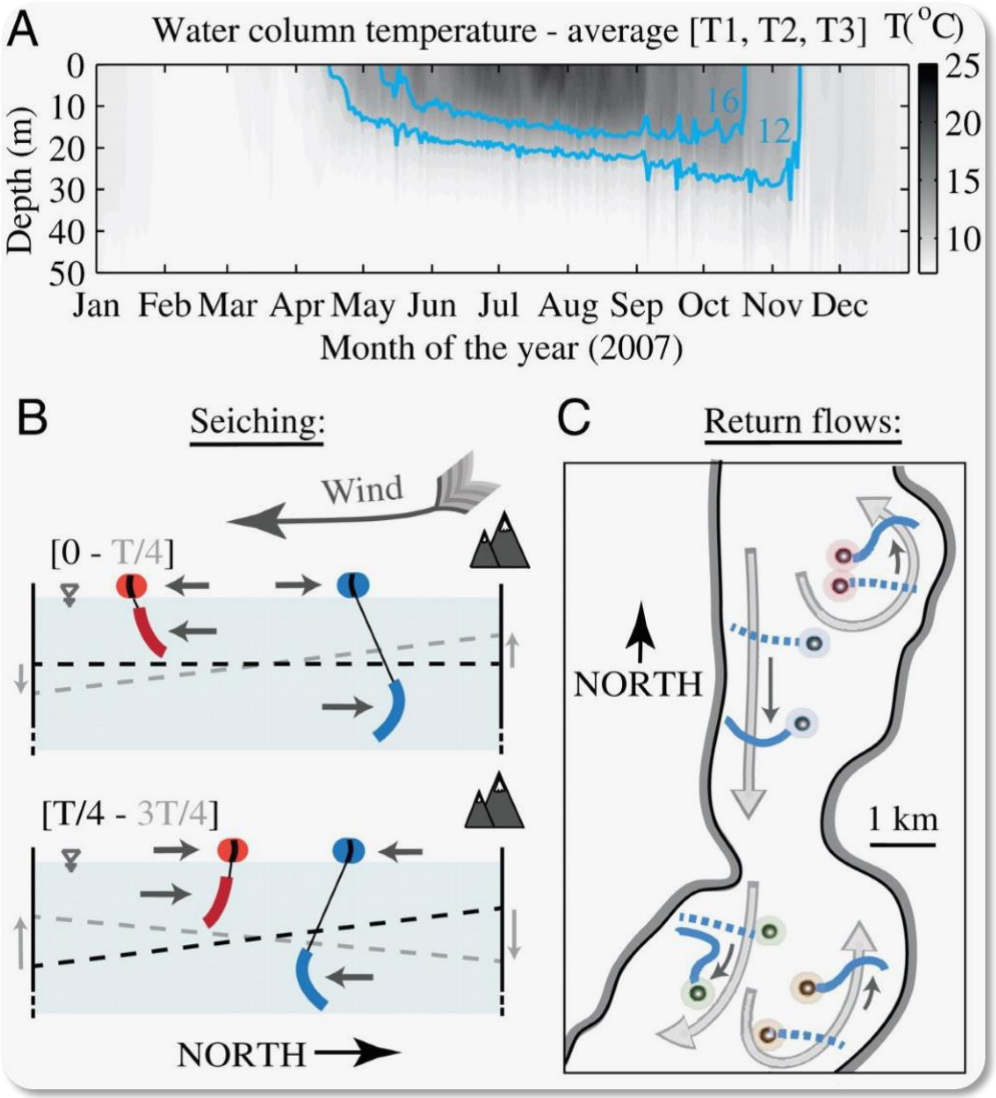
"System of concepts, beliefs and perceptions that people hold about the world around them" [Warburton and Martin, 1999]

The use of Local Knowledge scientific research is a common practice in human sciences, but its potentialities have been explored in climate and water science only recently.

Note: S. Forbes was a pioneer also in integrating local knowledge into science for an in-depth study of complex (eco)systems such as lakes.

Fishermen's narratives were found to describe with **accuracy internal wave motions** that were evident in water column temperature records, which revealed their **practical knowledge** of the lake's **hydrodynamics** … local knowledge accounts emphasized the recurrent formation of mesoscale gyres and return flows in certain zones of the lake, which **did not appear in the physical data** because of limitations of sampling resolution … **Numerical simulations** corroborated the fishers' descriptions of the flow paths... the **collaboration** between scientific and local knowledge groups, although an **unusual approach for a physical discipline** of the geosciences, is worth exploring in the pursuit of a more comprehensive understanding of complex geophysical systems such as large lakes.

Laborde et al. (2012), *PNAS,* DOI:10.1073/pnas.1113740109



Contribution of local knowledge

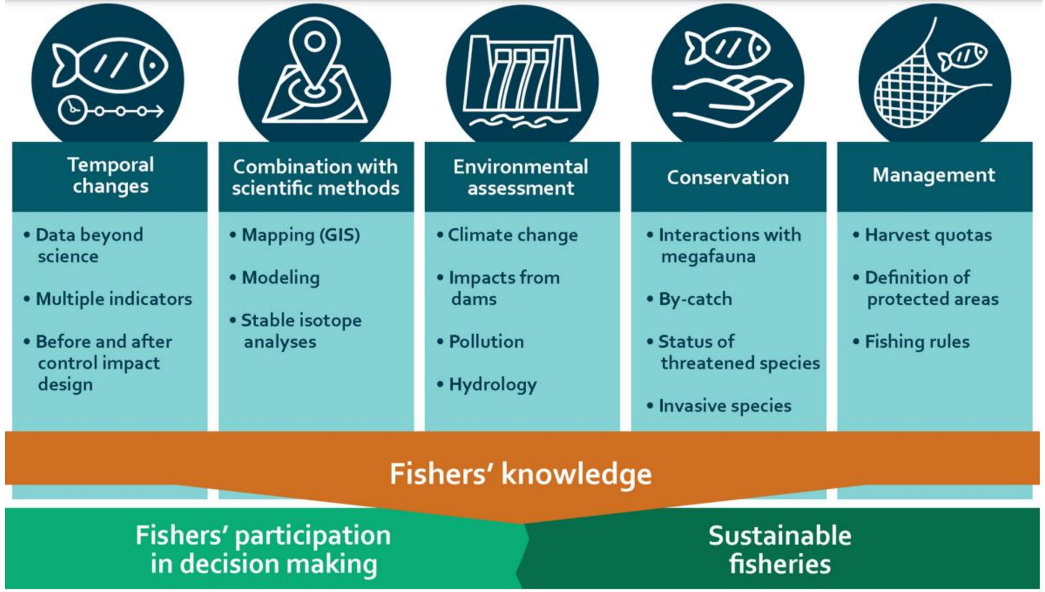
The use of Local Knowledge in other disciplines of aquatic science is more usual.

We adopted a scientifically rigorous ethnographic research methodology to **incorporate local knowledge** into understanding a natural limnological phenomenon in the Brazilian Pantanal. Known locally as 'dequada', it is associated with **fish kills.**

Calheiros et al. (2001), *Journal of Applied Ecology,* DOI: 10.1046/j.1365-2664.2000.00524.x,

Silvano et al. (2023), *Trends in Ecology & Evolution,* DOI: 10.1016/j.tree.2022.10.002

Fishers' knowledge can provide **unique information on a range of topics** that are beyond the reach of most conventional scientific studies, enabling assessments of long-term changes to resources, fisheries, and the environment.



Castello (2023), *Aquatic conservation Marine and Freshwater ecosystems,* DOI: 10.1002/aqc.3937

The potential of using local knowledge to address global gaps in monitoring data seems **real**, **but it is not yet readily available**. The notion of using local knowledge to produce monitoring data is still **emerging**, **poorly studied and poorly known**. Uncertainty about the reliability of this approach still fuels widespread **scepticism** and dismissal … Realizing the potential of local knowledge to fill global gaps in monitoring data depends on addressing several fronts.

Ethics
Reliability
Biases
Know-how

Contribution of local knowledge

In this work we gathered qualitative data about **lake breezes** and **surface currents** in Lake Garda. The survey took place between October 2017 and December 2017.

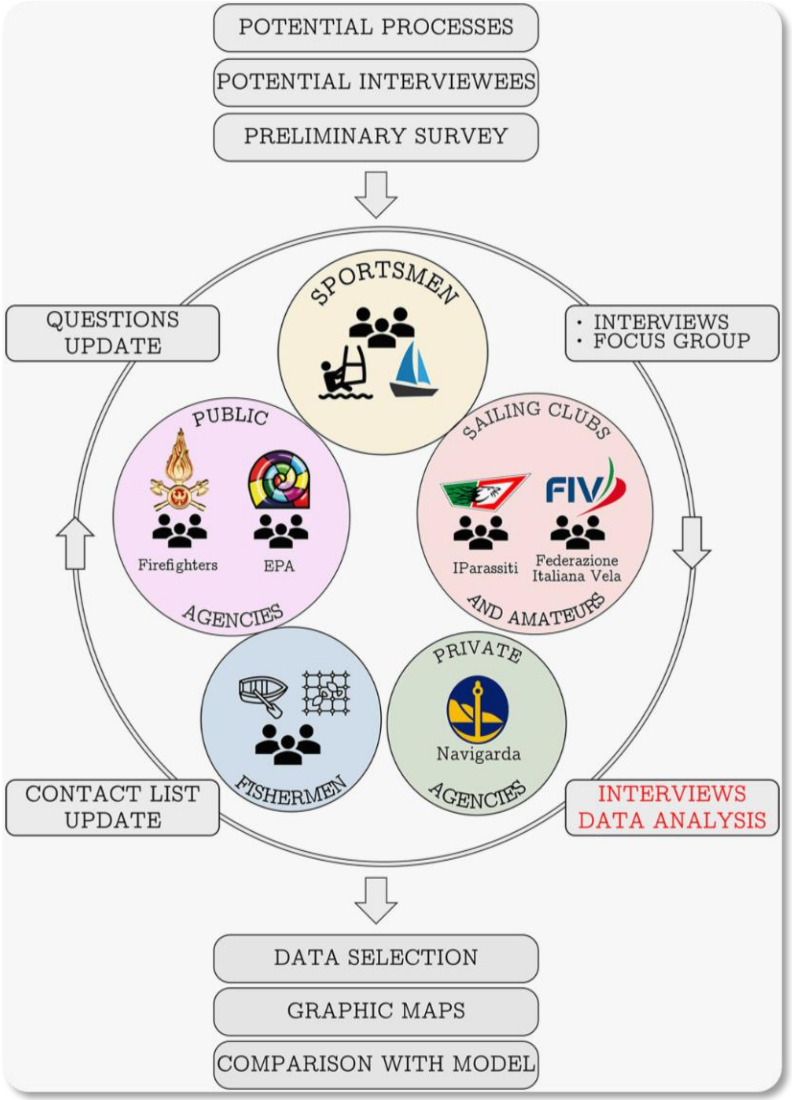
- What is the local community's **perception** of the surface processes occurring in the lake and how close is it to the explanation provided by physical modeling?
- Are there any chances to **combine** the local knowledge with a traditional scientific method (for model validation but also to identify new processes)?

A **one-way coupled atmospheric-hydrodynamic model** of Lake Garda was set up to test the data obtained via local knowledge survey.
The WRF model provided the atmospheric forcing on the lake surface, which were interpolated on the hydrodynamic domain.

WRF:	*Delft3D-Flow:*
Spatial res: 1 km	Spatial res: 0.1 km
Time res: 15’	Time res: 1’

Amadori et al. (2020), *Science of the Total Environment,* DOI: 10.1016/j.scitotenv.2020.137720

Contribution of local knowledge



First step:

Selection of the potential holders of local knowledge and list of the possible physical processes they might be aware of/expert of.

Potential knowledge bearers: people living or working in the lake region but also sportsmen.

Second step:

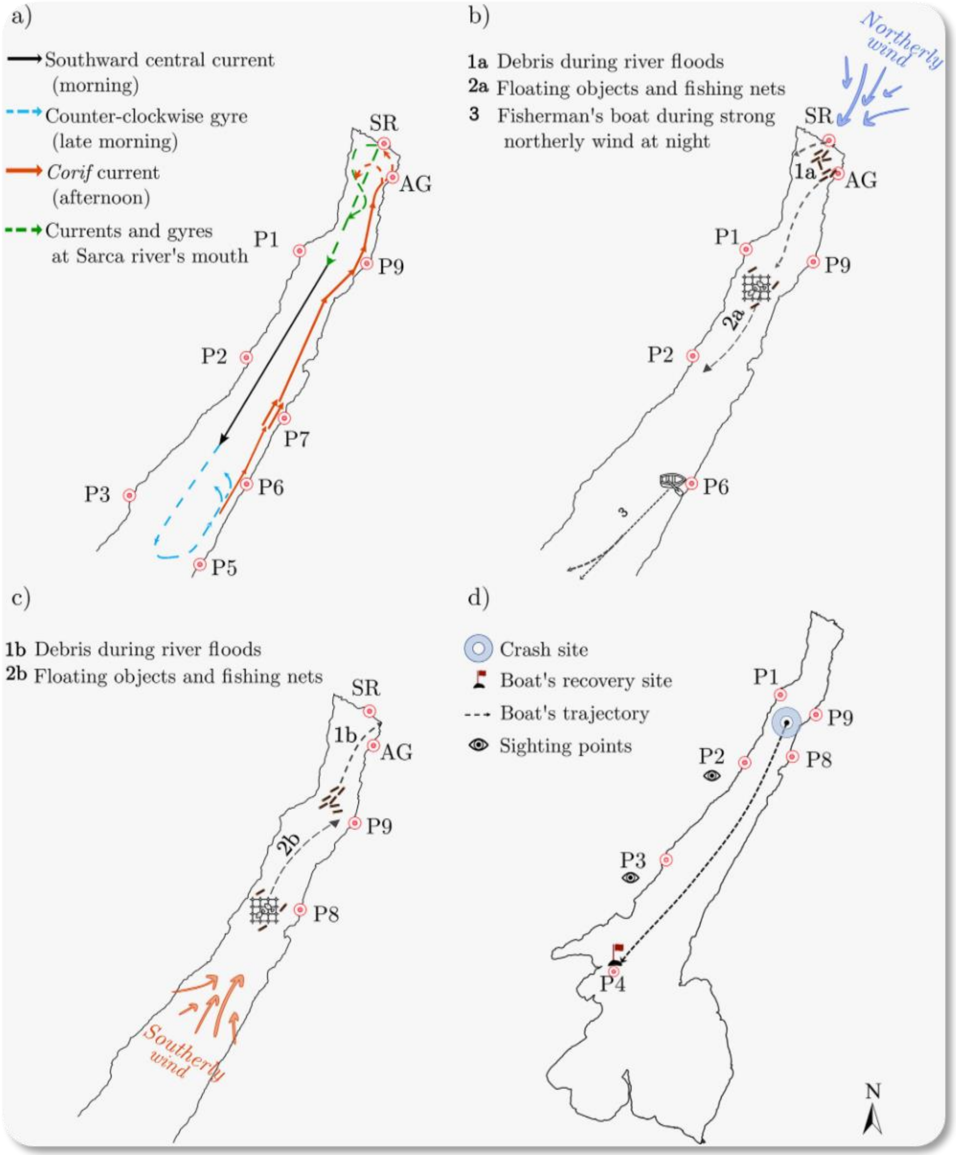
Preparation of a preliminary set of questions according to the expected knowledge of the interviewees, with the aim of first testing the reliability of the witnesses on well-known processes, and then identifying recurrent surface patterns.

The data gathered during the preliminary survey were analyzed for internal consistency, new questions were added and the contact list was updated.

General questions	- What is your 'relationship' with Lake Garda? - How often do you go to the lake and where do you spend more time? - Do you practice your activity in other lakes? Do you find similarities or differences from one lake to another? What are the most fascinating and peculiar aspects of Lake Garda?
Currents	- Assuming to drop something at a certain point of the lake and letting it be carried by the currents, can you predict where it will be headed? - Do you observe surface currents in the absence of wind? - How do the currents change from the shores to the center of the lake? Are there any recurring patterns? - In which direction do fishing nets move in the presence of northerly/southerly wind?
Stratification	- At what depth do you place your fishing nets? Do you modify their displacement during the year?
Up/Downwelling	- Do you notice differences between the eastern and western shores of the lake in terms of temperature or turbidity after strong winds?
Wind field & Climate changes	- Where does the wind blow stronger/weaker? - Have you noticed a change in the wind intensity or direction in the last decades?

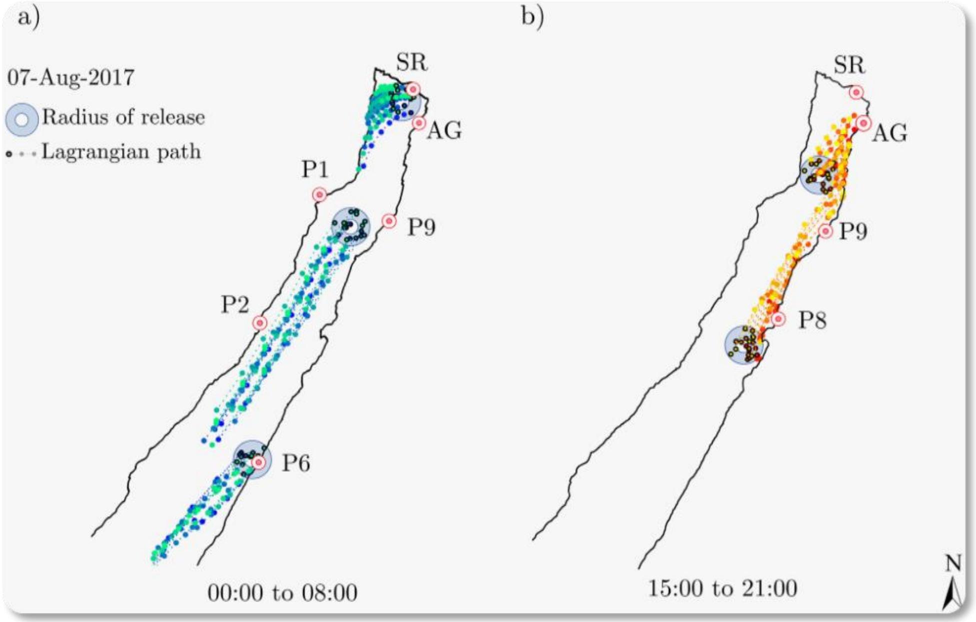
Amadori et al. (2020), *Science of the Total Environment,* DOI: 10.1016/j.scitotenv.2020.137720

Contribution of local knowledge



The local knowledge survey provided a wide range of data, from **wind to lake thermal dynamics** (spatial gradients, vertical stratification), including **surface flow field** and **transport processes** during exceptional events.

The interviews highlighted the existence of the 'Corif' current towards north along the eastern shore (P6–P7), mostly developing in late morning and in the afternoon after storms. The existence of this current was unknown to the scientific community.

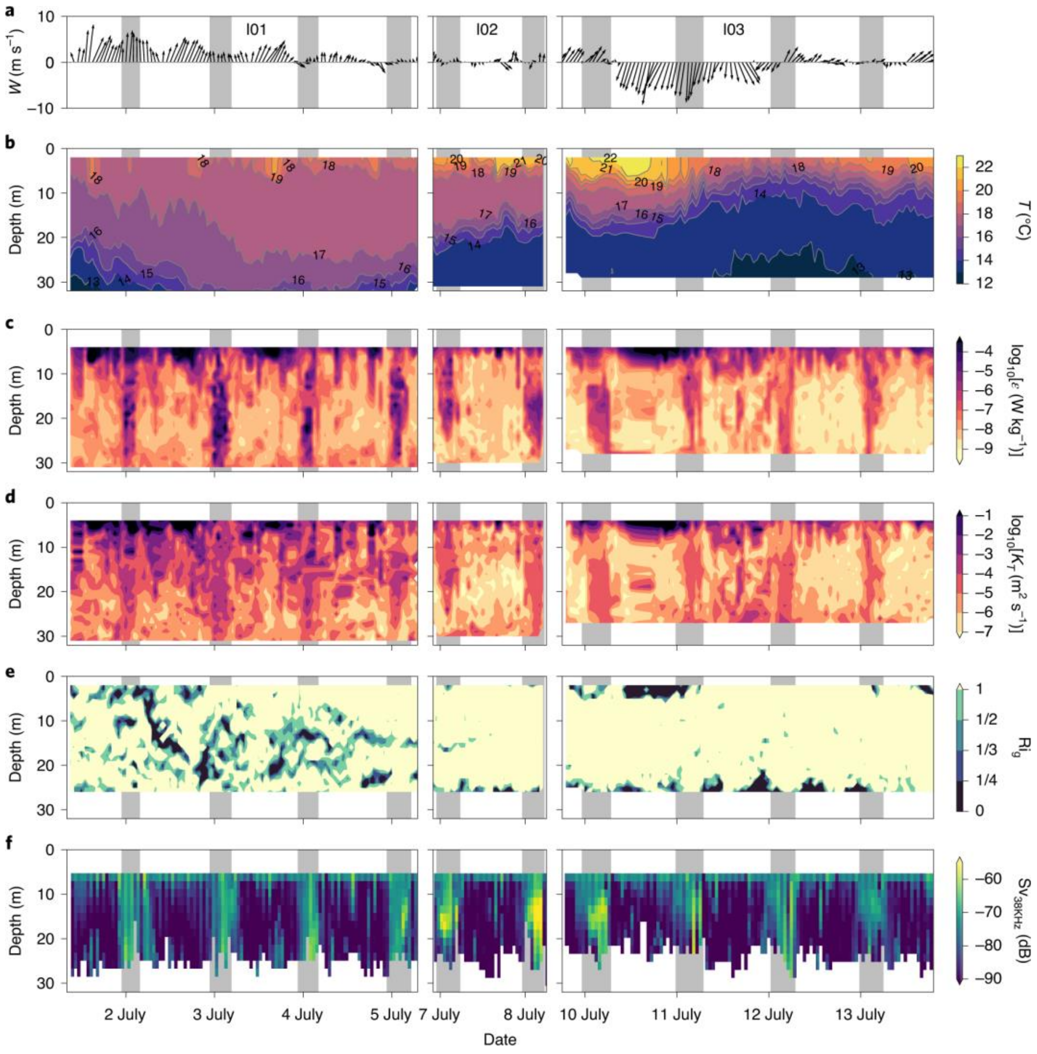


Numerical simulations confirmed the qualitative information extracted from interviews.

Explanation of the transport patterns highlighted during the interviews.

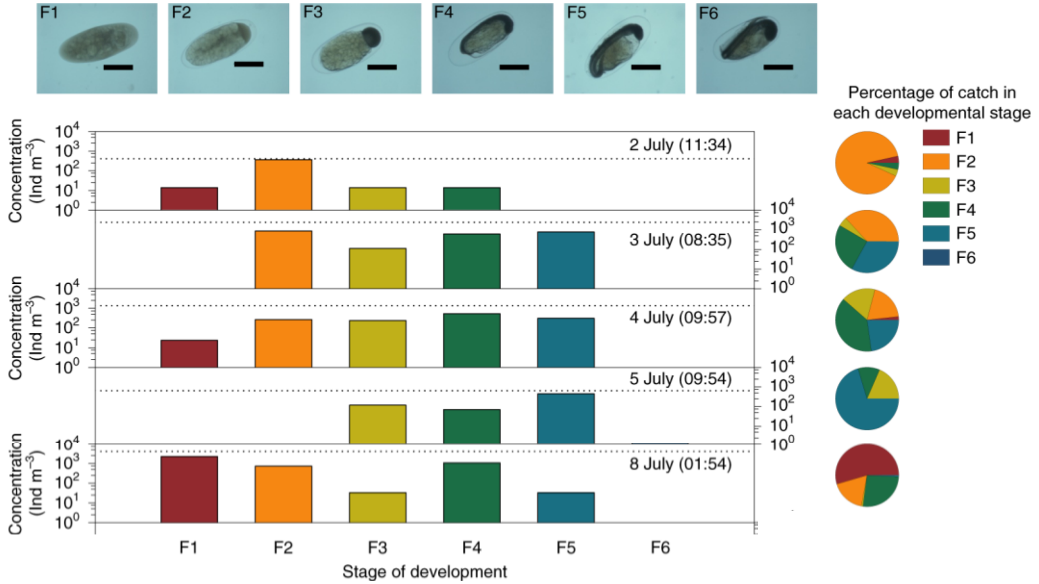
Amadori et al. (2020), *Science of the Total Environment,* DOI: 10.1016/j.scitotenv.2020.137720

The tight connection between physics and biology



Fernández Castro et al. (2022), *Nature geoscience*,
DOI: 10.1038/s41561-022-00916-3

Turbulent dissipation is elevated 10- to 100-fold (reaching 10^{-6}–10^{-5} W kg^{-1}) every night of the survey due to the **swimming activity** of large aggregations of anchovies that gather regularly over the **spawning season** … biologically driven turbulence can be a highly effective mixing agent.



Morning hauls: eggs at stage F2

(indicative of a time elapsed since spawning of 4–14 h)

Night-time haul: eggs at stage F1

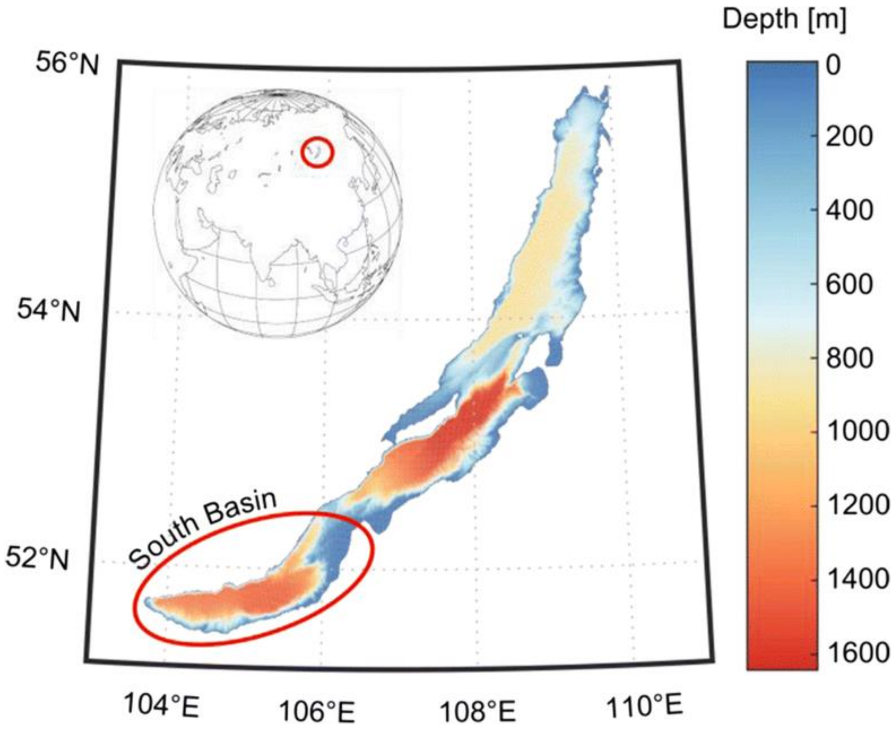
(corresponding to a time since spawning of <4 h).

The tight connection between physics and biology

Lake Baikal (Siberia) The Lake of Records: the **oldest**, **deepest** and most **voluminous** lake in the world. It contains nearly **20%** of world's fresh surface water.

Volume: 23 600 km^3 **Max. depth:** 1 642 m

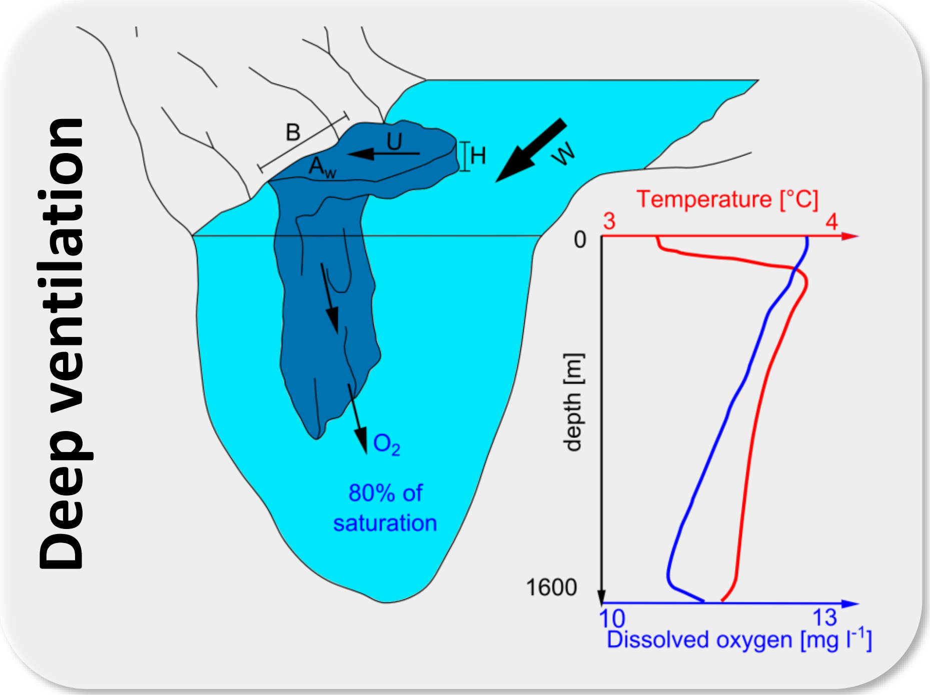
Surface area: 31 700 km^2 **Mean depth:** 744 m



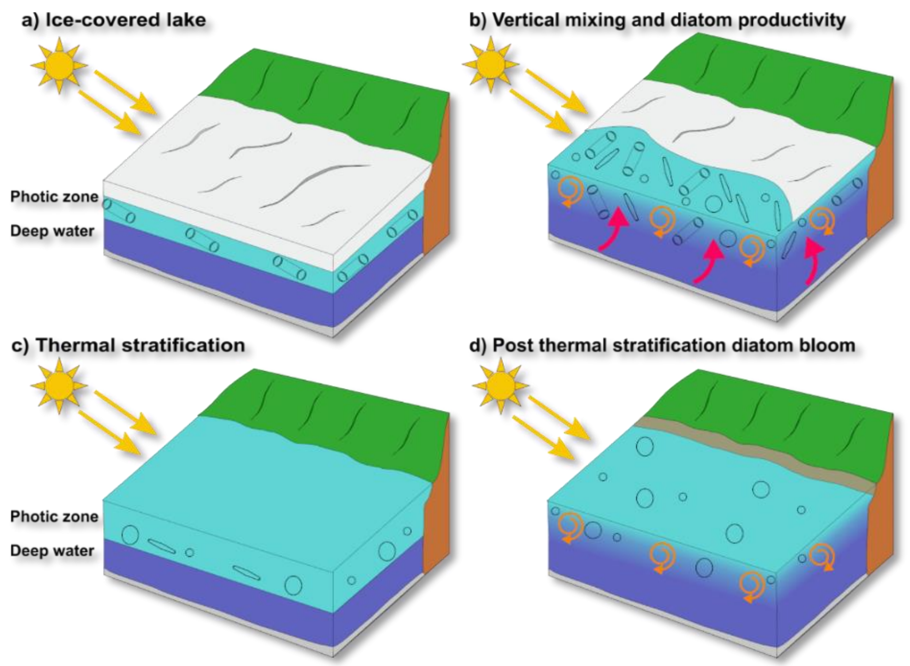
Wind

Earth rotation

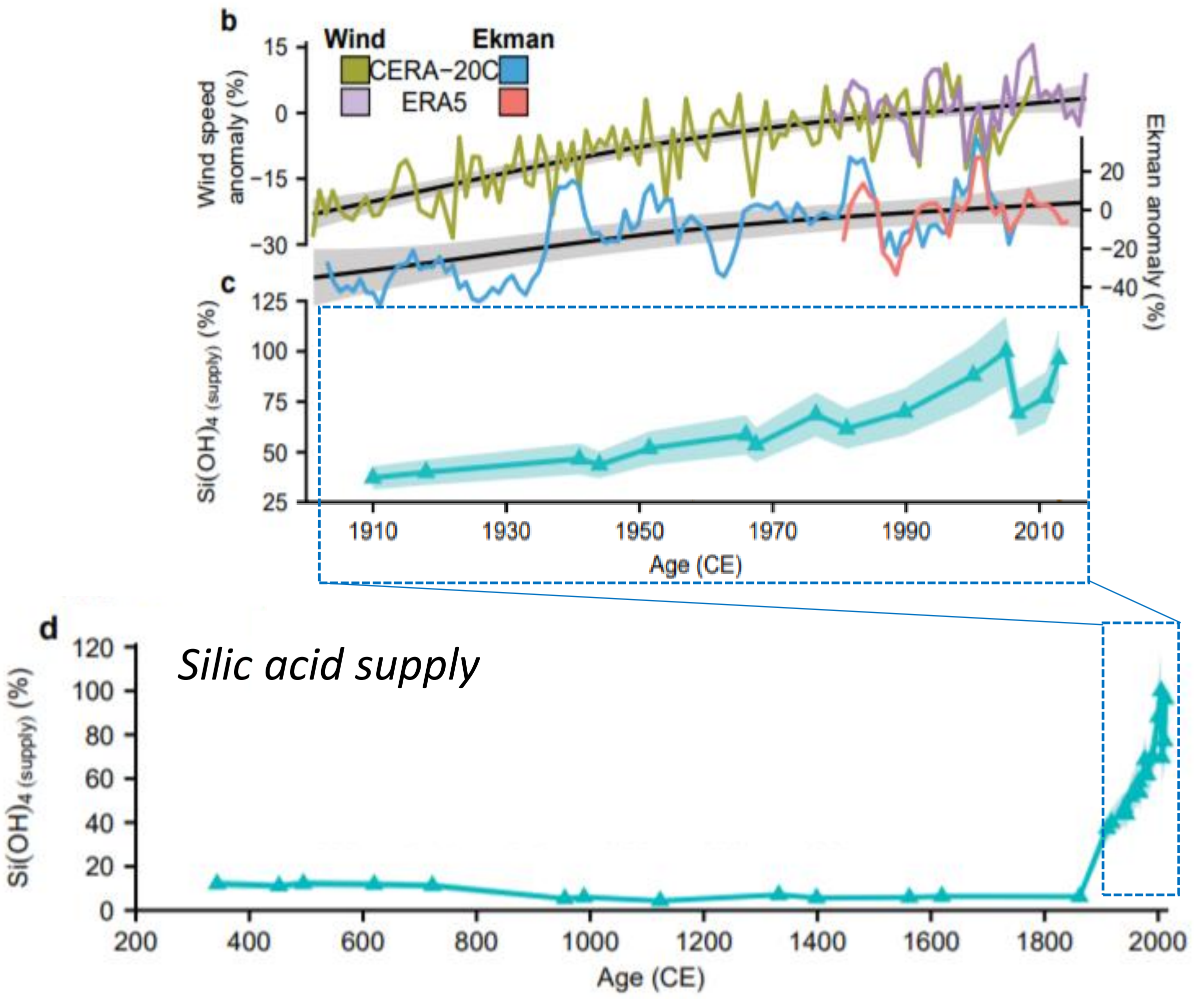
Thermobaricity



The tight connection between physics and biology



… significant consequences for the lake's **biogeochemical** cycling and **ecosystem**.



Seasonal controls on diatom productivity:

a) ice/snow cover over the lake (Jan-May) inhibits diatom blooms,

b) after ice break-up, along-coast winds generate **deep ventilation** and the associated upwelling of nutrient-rich deep waters in the photic zone, promoting large diatom blooms.

c) thermal stratification in summer reduces nutrient availability

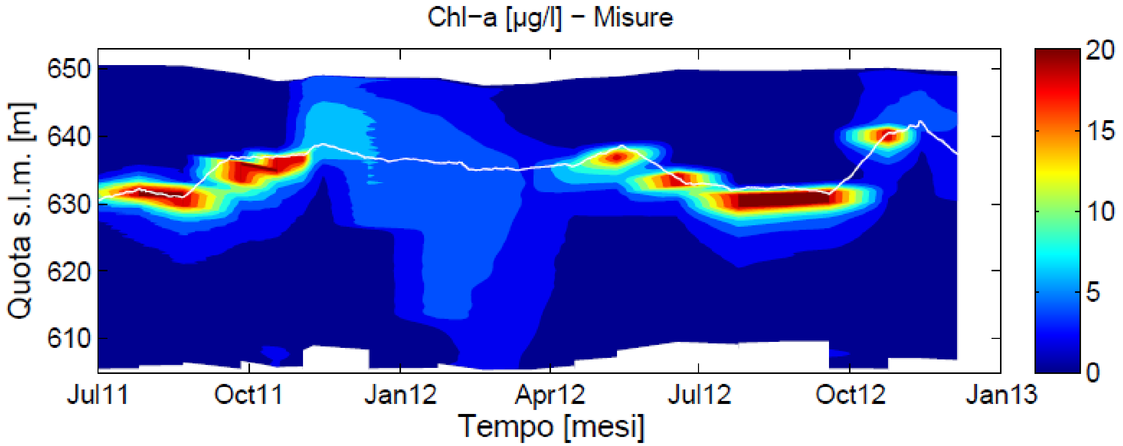
d) breakdown of stratification in fall restarts the surface mixing of nutrients into the photic zone, but due to the absence of deep ventilation the autumnal bloom is smaller than the spring bloom.

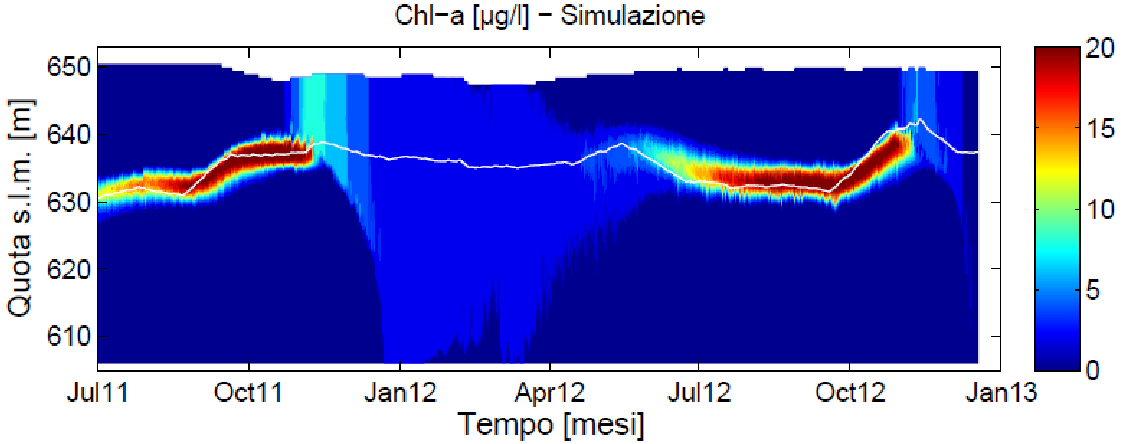
Swann G, V. Panizzo, S. Piccolroaz, ... A. Mackay. (2020), *PNAS*

Consultancy projects: opportunities for doing interdisciplinary research

- Groundwater-fed lake
- Relevant hydropower withdrawal
- Substantial input of Phosphorous from the wastewater treatment plant (WWTP)

CE-QUAL-W2
(modified version to simulate *Planktothrix rubescens*)





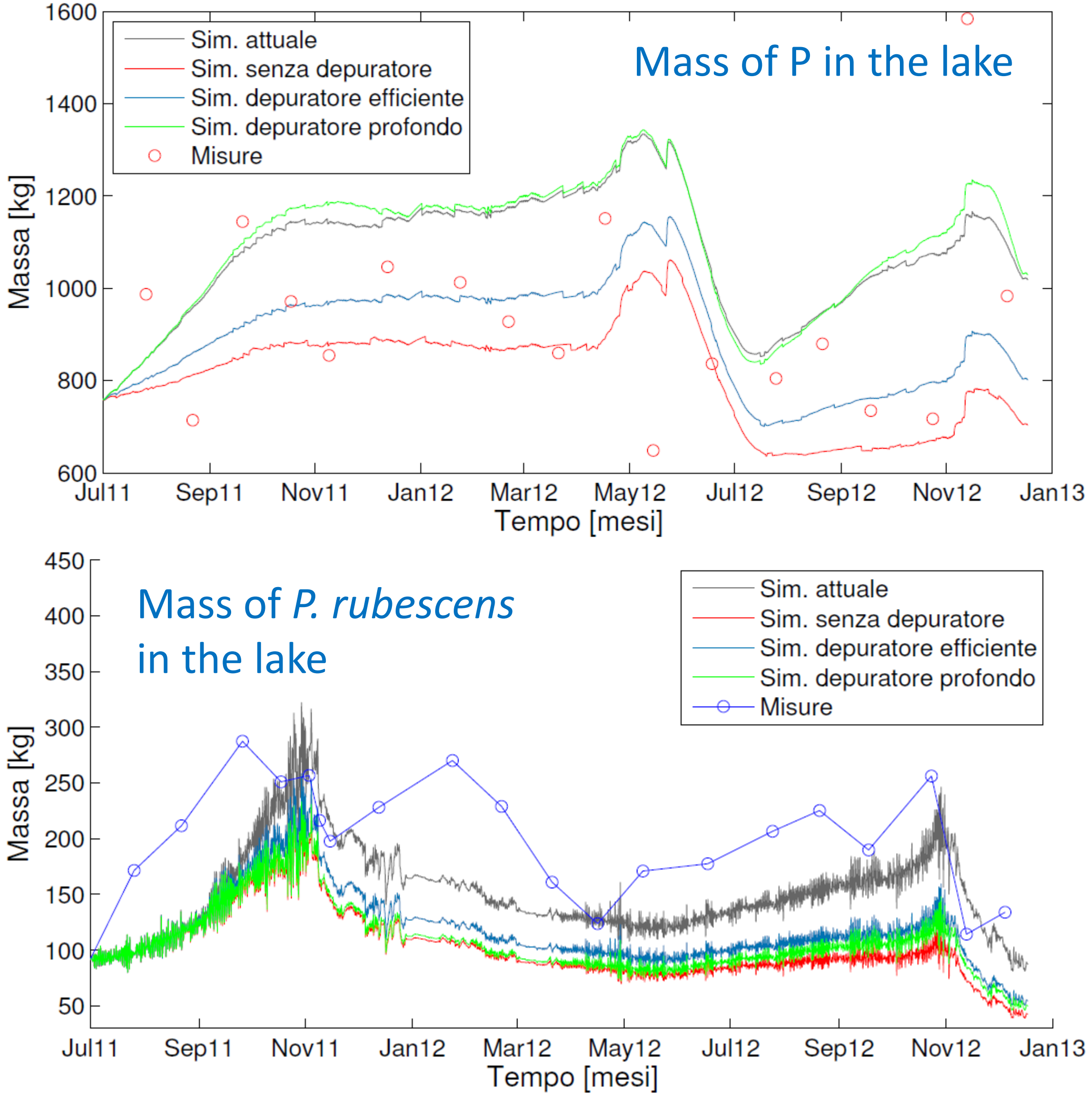
Massive blooms of *Planktothrix rubescens* (2014)
Optimal conditions and characteristics:

- Low light conditions
- Low temperature (10-15° C)
- Able to move along the water column

Consultancy projects: opportunities for doing interdisciplinary research

Scenario 1: reduction of P input

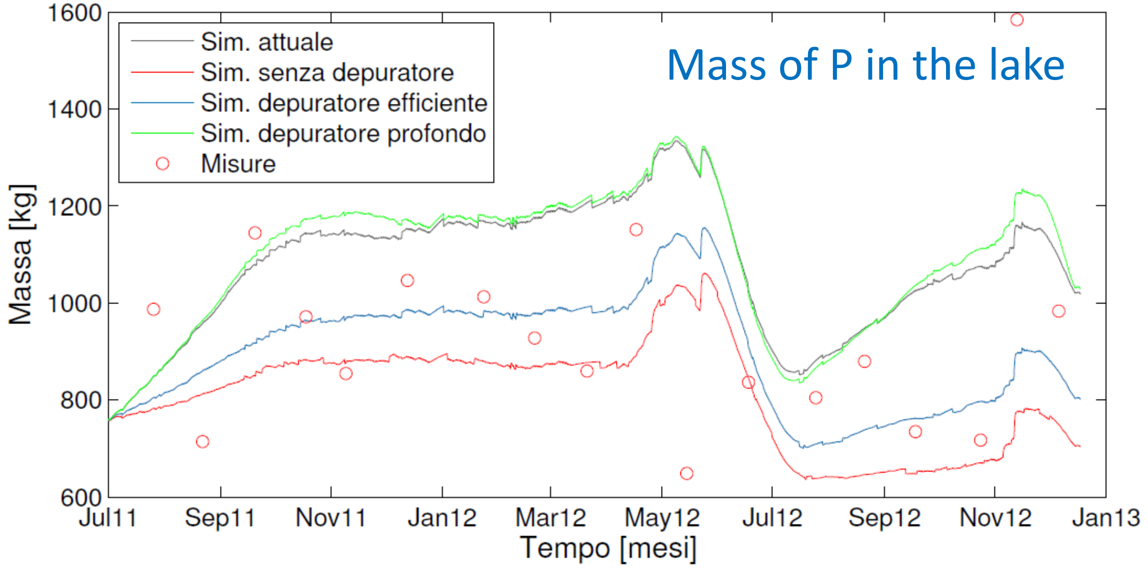
No WWTP, efficient WWTP, deeper release of WWTP

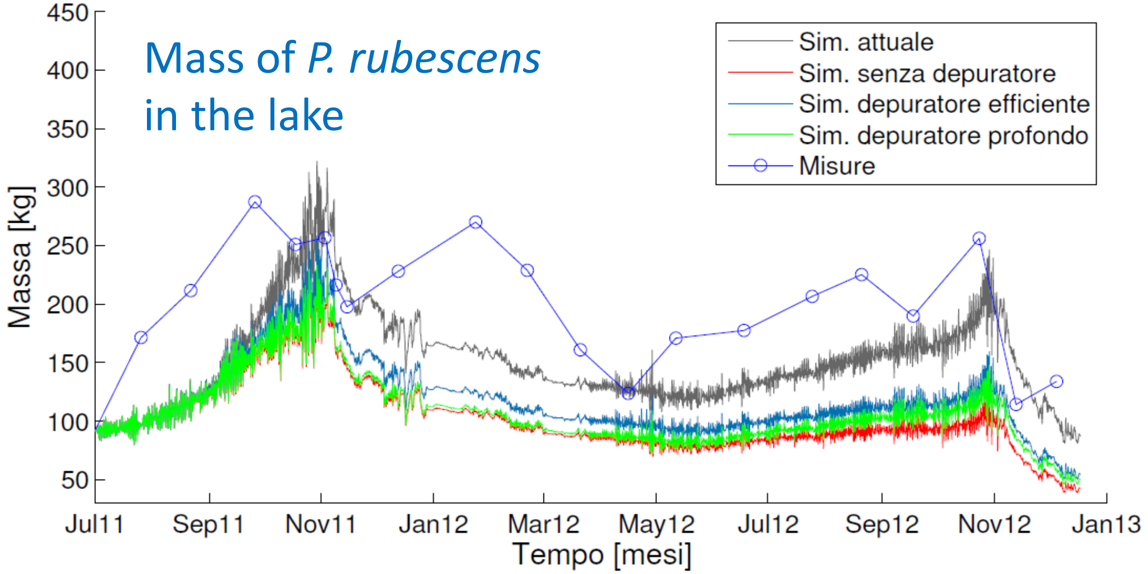


Consultancy projects: opportunities for doing interdisciplinary research

Scenario 1: reduction of P input

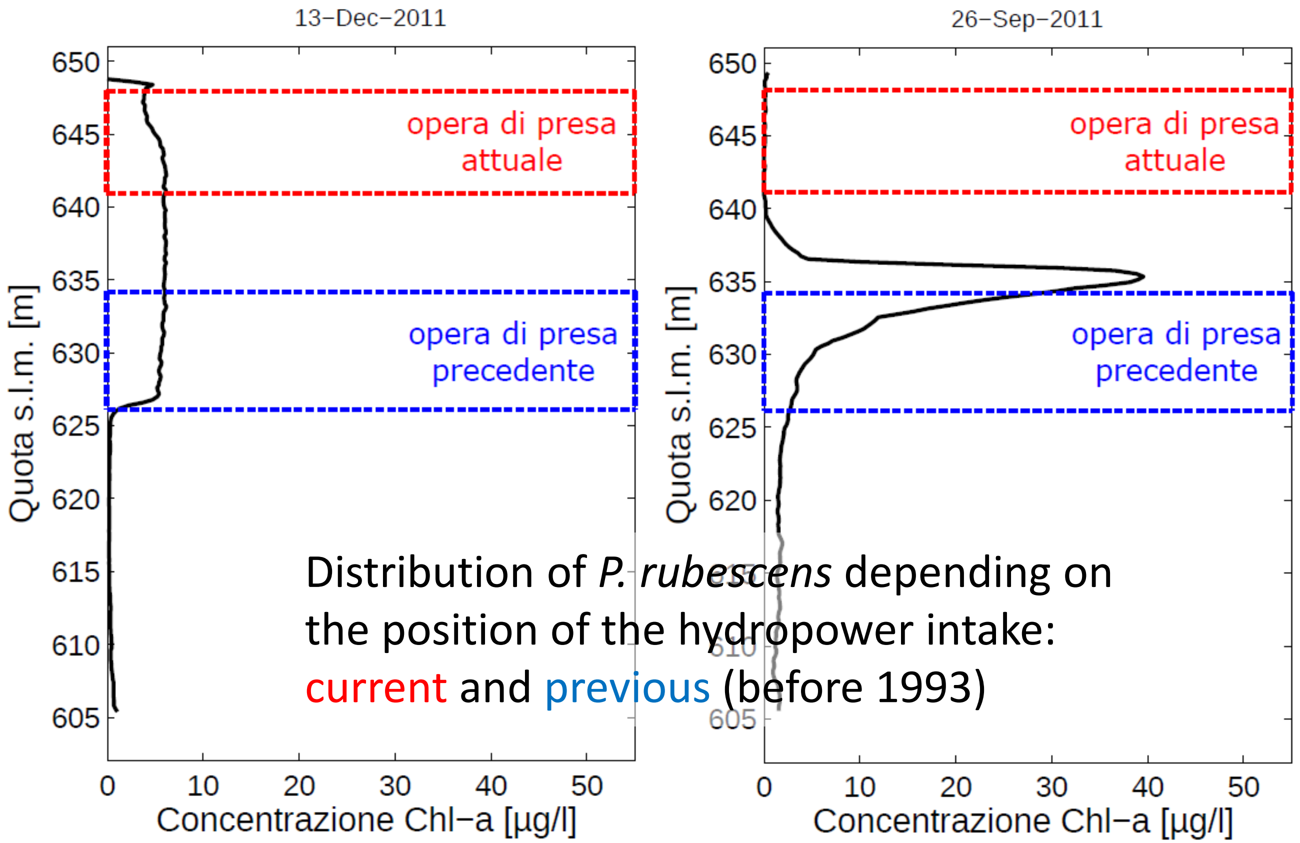
No WWTP, efficient WWTP, deeper release of WWTP





Scenario 2: position of the hydropower intake

Deeper intake (before 1993)

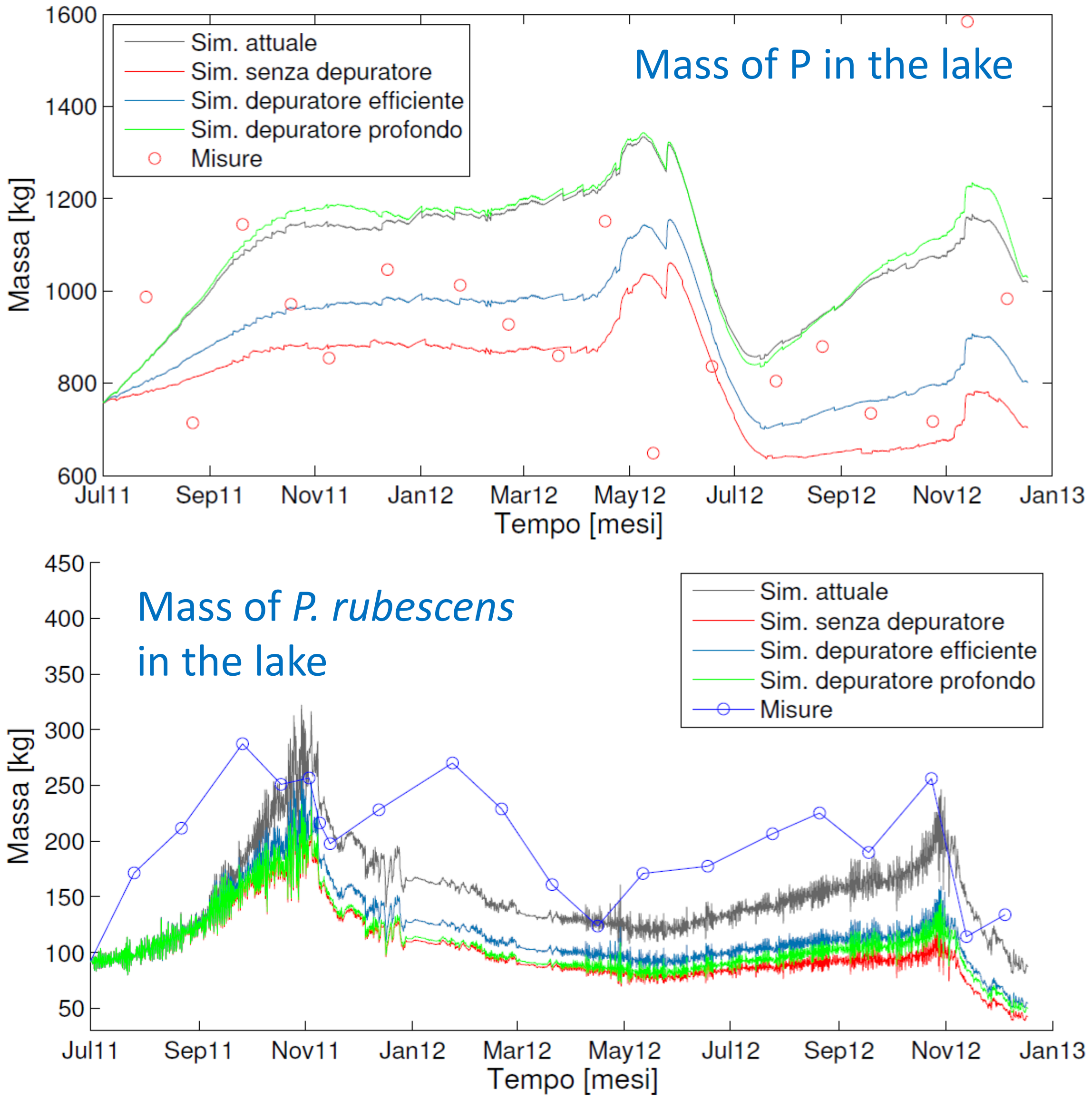


Distribution of *P. rubescens* depending on the position of the hydropower intake: current and previous (before 1993)

Consultancy projects: opportunities for doing interdisciplinary research

Scenario 1: reduction of P input

No WWTP, efficient WWTP, deeper release of WWTP



Scenario 2: position of the hydropower intake

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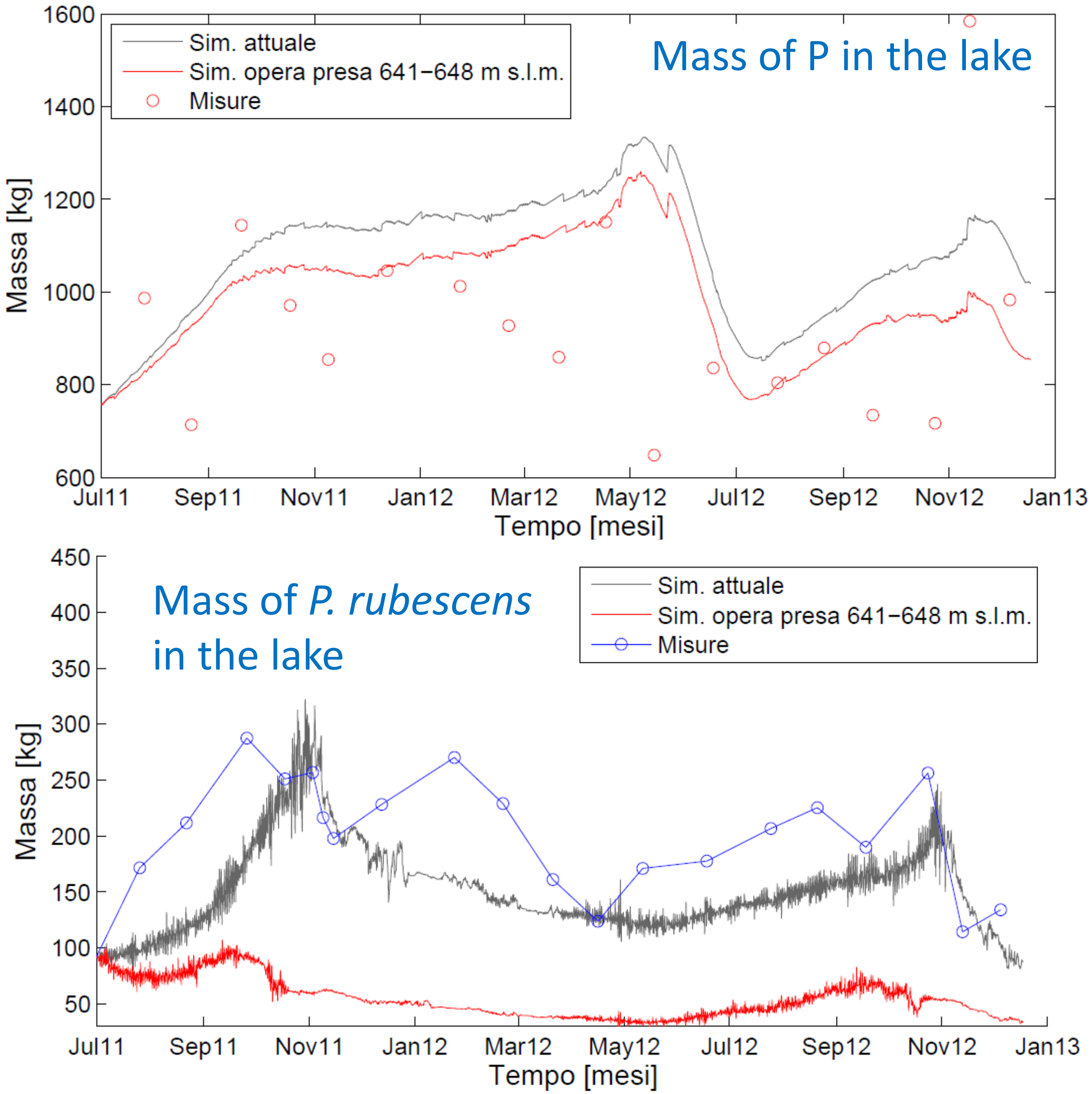

Working in the broad and multifaceted field of Aquatic Science

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