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Catalogue of Grand Challenges

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Table of Content

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1. Abstract

In the AQUACOSM-plus project a symposium on grand challenges in aquatic ecology was organised as a series of webinars, back-to-back with round table discussions that were named "World Café" sessions. The aim of this event was to create awareness on critical topics, which should eventually stimulate novel and innovative research on highly relevant problems in aquatic ecology. To this end, a committee was appointed including members from several AQUACOSM-plus partners (WCL, GEOMAR, UOL, AirClim, METU, CSIC, FVB-IGB) selecting topics and eventually inviting speakers for planned incentive talks and on the general format of the event.

The four webinars & World Cafés were held in October 2020. While the first webinar covered general problems related to global change (incentive talk: HO Pörtner), the three subsequent events addressed nature-based solutions to greenhouse-gas emissions (A Oschlies), global salinization of inland waters (E Jeppesen), and environmental variability as a threat to ecosystems (M O'Connor).

The webinars and the world café discussions gave rise to two manuscripts in prep for publication ('A research agenda on salinization', Cunillera Moncusi et al. outlined in Deliverable D6.3; 'A global perspective on variance', Gerhard et al. outlined in Deliverable D6.2). Furthermore, a series of joint experiments on salinization is being planned on the SITES facility (SLU, SE), and a general discussion was initiated within WP8 (all data as of May 2021).

2. Catalogue of grand challenges - overview

Below we provide a bullet-point overview of grand challenges. They are outlined in more detail in section 3.

World Café	Challenge
1	**Consequences of global changes on aquatic ecosystems - current gaps** • Geographic gaps & biases • Majority of studies address rather forecasting than mitigation • Thresholds mostly derived from autecological studies, need more info at community and ecosystem level • benthic-pelagic coupling

2	**Assessing the potential and risks arising from nature-based solutions to greenhouse gas emissions** 1. Global cooling through artificial upwelling 2. Iron fertilization 3. Injecting CO_2 into deeper layers of the world's oceans 4. Ocean alkalinisation. For #1 and #2, the risks seem to outweigh the benefits. For #3, the long-term consequences are unclear. #4 is most promising; experimental research is missing and will be mandatory to assess implementation strategies on CRS
3	**Salinization of inland waters** ● Aridification, elevated evaporation due to GC ● Water loss & salinization through irrigation ● Salinization of inland waters through mining & industrial activities ● Salinization through application of road salt Salinization is a multi-faceted problem, at present we do not even have a common language to define the problems. Biases exist with regard to which ecosystems are studied, geographic regions, and functional groups.
4	**Changing mean and variance in ecosystems under global change** ● Sources of environmental variation in aquatic systems? ● How do organisms and communities cope with variability? ● How do we address variability in a multifactorial context? ● How can we use mesocosm experiments for addressing environmental variability?

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3. Summaries of the World Café discussions

3.1 *Consequences of Global Climate Change*

Host & provider of summary: Marko Reinikainen (AirCLim)

The World Café consisted of a joint introduction and general discussion, followed by discussions in three break-out rooms[1], and lastly by presentations of the break-out room discussions (including comments and discussion). This summary presents topics that emerged in the break-out rooms, in the form of Q&As.

- Q1: What are the limitations/gaps of current aquatic mesocosm experiments in a global change perspective?

A1: **Technically or methodologically**, mesocosm studies are often limited by available time and space, with consequences for the duration of experiments and the complexity of communities or ecosystem components that are included (e.g. communities are truncated and lack higher trophic levels such as fish).

Conceptually, mesocosm studies that address the forecasting of global change are overrepresented in relation to those that address mitigation issues. This highlights a historic dichotomy of mesocosm studies.

Geographically, while most mesocosm sites are found in European and North American temperate areas Figure 1, there are markedly fewer mesocosm sites at high and especially lower latitudes, which is naturally also reflected in availability of data from different regions, and relatively fewer studies are available from habitats in extreme environments than from major temperate biomes. Benthic habitats in general (especially in freshwaters) and more specifically benthic-pelagic coupling also represent understudied realms.

[1] Topics: ”Knowledge-gaps that could be addressed through Aquatic Mesocosms”; ”Underrepresented Habitats or Ecosystems”; and “The Outlooks for Societal Relevance of Aquatic Mesocosms”

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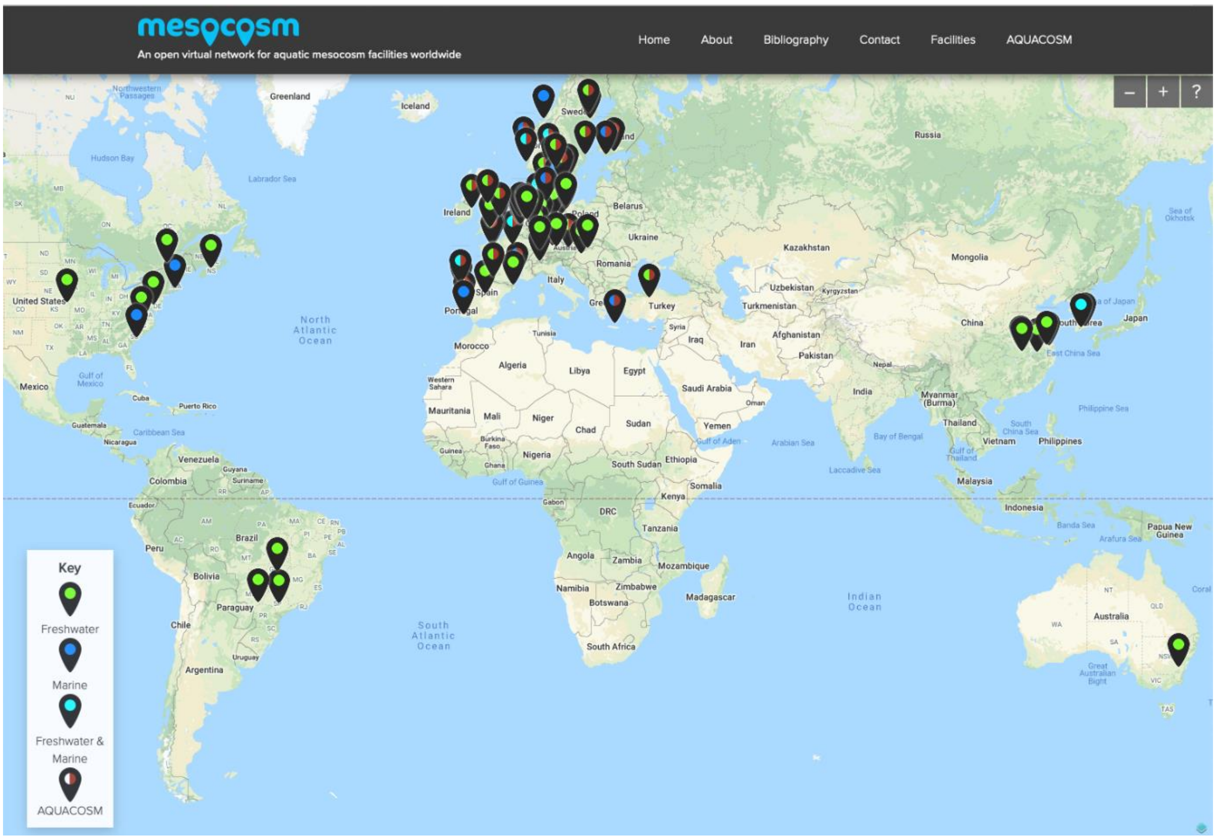

Figure 1: *Map from the virtual network mesocosm.org illustrating the uneven distribution of mesocosm facilities world-wide. The network is coordinated at FVB-IGB (S Berger, J Nejstgaard and K Makower), web page design at BLIT (S Keeble and K Keeble).*

- Q2: What are the strengths of aquatic mesocosms in order to address knowledge gaps in a global change perspective?

A2: Mesocosms can be used to study a priori defined ecological interactions, multiple stressors, and the buffering and resilience capacities of ecosystems or communities, as well as their tipping points. Mesocosm studies can further be combined with e.g. meta-analysis, long-term data and modelling. Mesocosms can also be used to generate long-term data.

Mesocosms are a key element to study ecological questions related to e.g. global change, and are in this respect not only an intermediate step between laboratory studies and analyses of real-world ecosystems, but can rather be seen as "the missing link" that allows to connect the two.

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- Q3: What are the future opportunities for aquatic mesocosms in a global change perspective?

A3: To exemplify, some of the following opportunities exist to address limitations/gaps highlighted in Q1: To deal with questions related to ecosystem/community complexity, future mesocosm experiments can to a larger degree than before include reliable top-down and bottom-up controls. Coordinated mesocosm experiments at multiple sites can be used as a space-for-time approach and to better understand global responses at different temporal scales. Larger international experiments also allow to focus resources to conduct larger experiments, e.g. to test ecosystem-level interactions. Current biases with regards to the geographic distribution of mesocosms and with regards to the habitats they cover, can be addressed by reliable, low-cost mobile mesocosms. (Both coordinated experiments and the use of mobile mesocosms are part of the work developed within AQUACOSM and AQUACOSM-plus.) Additional benefits from studies with large geographic coverage can be achieved via coordinated efforts in combination with other research infrastructures, such as LTER and GLEON.

From a societal perspective and as a resource for policies, efforts to address global issues through mesocosm studies can support coherent consensus on ecosystem responses and studies can be put in a broader societal context by also considering the calibrated language that is needed in such a context. For instance, the IPCC produces reports as support for global climate policies, and in earlier reports, work by partners within AQUACOSM/AQUACOSM-plus has been included in the material used by the IPCC. At present, the IPCC is working on its sixth assessment report, including its working group contributions and synthesis report, providing an opportunity for mesocosm studies to further contribute to the scientific basis of global policies.

3.2 *Ocean-based carbon dioxide (CDR) removal strategies*

Host & provider of summary: Ulf Riebesell (GEOMAR)

Questions – Answer format

- Q1: What are the critical obstacles to ocean-based CDR research?

A1.1 - **Funding**: Traditional research funding schemes do not include ocean-based CDR. A new funding sector has to be initiated that encourages and enables academics of the different science disciplines to direct their focus on ecosystem based negative emission technologies.

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Whilst funding opportunities are becoming available (e.g. European Green Deal), they need to be expanded considerably to enable a multidisciplinary global research network. To move forward, ocean CDR needs to be seen as a conservation measure with benefits to societies that can be measured economically (e.g. CO_2 credits). This would encourage support from the industry for research projects, either directly or through provisioning of expertise, materials, facilities and instrumentation.

A1.2 - **Legal**: The legal situation in many countries is hampering the initiation of research into CDR. Either the legal side is not clearly defined or it explicitly prohibits any kind of research on CDR in the ocean (e.g., London convention). Even relatively small-scale enclosed systems like mesocosms may fall under these legislations. Experimental work beyond the laboratory, however, is key in determining the effectiveness and negative side effects of ocean-based CDR. The legal situation has to be adjusted quickly and in a way that explicitly allows small scale manipulations for research purposes. The London convention could provide the framework to update the international standpoint on ocean-based CDR.

A1.3 - **Scientific**: Our current understanding of ocean CDR is primarily based on modelling work. Whilst physical and chemical consequences may be modelled with some confidence, the response of ocean ecology is often too complex and unpredictable to be captured properly. When modelling artificial upwelling, for example, Redfield stoichiometry is assumed, and yet in nature we observe prominent deviations from Redfield affecting the CO_2 sequestration potential. Larger-scale experiments on whole food webs are thus essential to parameterize and validate models. Gathering sufficient information quickly from several ecosystems for multiple CDR techniques will be challenging.

A1.4 - **Public perception**: The public is overall suspicious when it comes to purposefully meddling with the earth system, and interfering with natural systems rarely brought good results in the past. To convince the public about the necessity of research into ocean CDR, we as a science community need to reach some sort of consensus and report to the public accordingly. The communication has to stimulate an objective mindset/perspective on ocean CDR, i.e. "a restoration and conservation measure that counters the geoengineering threat of human CO_2 emissions".

A1.5 - **Political/governance**: Successful climate change mitigation requires long-term initiatives at a global scale. Yet, politics are driven by regional or national short-term goals that, at best, aim at re-election. Only a general shift in the zeitgeist of our civilization could sustain political support for expensive ocean-based CDR research and implementation over the century. The political movement would have to reach international agreements, mobilize

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research funding, and adjust legislations within the necessary time frame for climate action (~10 years).

- Q2: What are the strengths and weaknesses of mesocosm experimentation in CDR research?

A2.1 – **Representativeness**: Mesocosms have their limitations, of course, as the natural environment has more layers of complexity. This is of particular concern for ocean-based CDR strategies, as these are not restrained in time and space but interact with the earth-system as a whole. That being said, mesocosms are the only stepping-stone we have from the laboratory to nature. We can improve the realism of CDR research through increased size, ecological diversity and experimental duration of the mesocosms units. Considering mesocosm results are needed from different ecosystems around the globe, funding and international cooperation has to be extensive and consistent.

A2.2 - **Controllability**: Mesocosms are to some degree flexibility in the trade-off between realism and control. This is a main advantage over field studies. However, open field studies on ocean CDRs may not be possible for quite some time due to legal issues. We may thus want to invest into mesocosms that are as close as possible to nature, thereby sacrificing some control. As other research approaches, mesocosms have no control over drifting baselines; that is, if the natural community on which we test the effects of ocean CDR today, is not the same community that exists in the future ocean when CDR is applied.

A2.3 - **Comparability**: Variable treatment effects are common in mesocosm studies, caused by the specific properties of the enclosed community, e.g. different ecosystems, seasons or simply chance. This makes it challenging to deduce consistent and clear responses that could inform policy decisions on CDR with an acceptable degree of certainty. To improve the comparability of ocean CDR research, a standardized mesocosm system and protocol could be developed for the deployment in different ecosystems across the world.

A2.4 - **Up-scaling**: Individual mesocosm studies can at the most indicate short-term responses to CDR of a local ecosystem. Replication of mesocosm studies, however, may reveal common principles across ecosystems and point out variability among them. This understanding of ocean CDR can be tested in free ocean trials using research vessels, e.g. conceivable for artificial upwelling or ocean alkalinisation at the scale of square kilometres. These experiments provide the foundation for global models and for projections into the future.

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A2.5 - **Effort for gain**: Mesocosms are worth it! As stepping-stone between the laboratory and field, they may open doors for new questions and increase political and public acceptance for a move to larger-scale experiments in the open ocean. Effort for gain in mesocosm work is often optimized by employing large mesocosm systems that can then be studied thoroughly by different science disciplines. The initial investment is however high and takes time to pay-off. This complexity of large-scale mesocosm work may thus hamper the quick implementation of ocean CDRs that is needed to meet international climate goals.

3.3 Salinization of freshwater ecosystems – an increasing global threat

Host: Meryem Beklioğlu (METU), Robert Ptacnik (WCL)

Summary: Robert Ptacnik (WCL), David Cunillera Montcusi (WCL)

Invited experts: Hilary Dugon, Sandra Brucet, Egor Zadereev, Miguel Cañedo-Argüelles

- General aspects & knowledge gaps

- Changing salinity cannot easily be generalized, as it happens across many different realms, at different spatial and temporal scales.
- Very different types of salinity (ion composition) affect ecosystems; it is important to differentiate e.g. soda vs. chloride vs. other salinity; rather than salinity/conductivity, concentration of particular ions may be important
- De-salinization: some systems are affected by decreasing salinity, e.g. some estuaries (Baltic Sea), but also some glacier fed systems
- At present, there is no general experimental framework to study salinization in context of mesocosm experiments (compare with development of browning experiments, e.g. employ HuminFeed in multiple experiments)

Which systems are at present especially understudied in terms of salinization effects?

- Sites affected by industrial activities (mining), sites seasonally exposed to road salt not necessarily from dry regions.
- Changes in salinity are generally not much studied in wetlands, as opposed to larger aquatic systems. Also, freshwater habitats that have not been historically affected by salinization have received less attention regarding their responses to small rises in salinization, which can deeply change their less tolerant to salinization community.

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- Many potentially affected sites are located in less developed countries, with obvious limitations to their study.

  - Q1: Which ecological concepts and approaches should be considered in the context of salinization?

- Most organisms will not exhibit linear responses to changing salinity. Thus, it is important to identify thresholds and areas of fast response (e.g. are there general thresholds for macrophytes in aquatic systems; are there thresholds for benthic vs. pelagic processes?)[2]. Ideally, such thresholds can be related to physiological traits.
- It is important to distinguish pulse vs press disturbance[3]. Research in estuaries highlights that fluctuations in salinity provide much more stress to organisms than long-term changes. In this context, it is also important to distinguish organisms that can/not evade local conditions, i.e. sessile vs. motile organisms.
- It is important to consider the problem of salinization within spatial ecology (metacommunity framework, connectivity of habitats, refuge systems etc).
- As global change brings multiple alterations to ecosystems, it is important to embed studies on changing salinity within frameworks addressing multiple stressors, e.g. together with changes in temperature[4], length of inundation phase, change in habitat size/density.
- Salinization affects water chemistry, e.g. remineralization of phosphorus maybe sensitive to salinization (example soda pans, Horváth/Vad).
- GHG and ratio auto:heterotrophy may be sensitive to salinization.

  - Q2: Which projects & initiatives are relevant?

- In AQUACOSM-plus, Transnational Access will provide opportunities for experiments at multiple locations across Europe
- The Project tracker on the AQUACOSM homepage will serve as a tool to discuss and plan joint experiments (to be launched during 2021).

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[2] https://doi.org/10.1016/j.scitotenv.2016.05.121
[3] https://doi.org/10.1016/j.envpol.2016.12.072
[4] https://doi.org/10.1111/j.1600-0587.2009.05823.x

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- The new EU project PONDERFUL (website not available yet) will compile a pan-European database on existing data of pond biodiversity, local environmental conditions and land use and data from brackish and saline ponds is very welcomed (Sandra Brucet).
- Other networks, e.g. GLEON, provide opportunities to build networks for joint initiatives (e.g. https://www.gleon.org/research/projects/global-saltexperiment).

- Q3: Which recent and ongoing developments should we consider?

- Many initiatives are currently developing autonomous sensor systems, e.g. AQUACOSM-plus (Behzad Mostajir - LAMP Sensor System (www.aquacosm.eu/download/deliverables/D8.4-Final-Report-of-LAMP-Sensor-System_final.pdf), Timo Tamminen et al. AQUABOX (https://www.aquacosm.eu/download/deliverables/D8.3-AQUACOSM_-deliverable-Final-AquaBox_final.pdf), SITES (https://www.fieldsites.se/), PlanktoScope (https://www.planktoscope.org/)
- Mobile/deployable Mesocosm facilities (e.g. within AQUACOSM-plus)

3.4 Considering variability as biologically important aspect of global change

Host: Miriam Gerhard (UOL), Helmut Hillebrand (UOL), Maren Striebel (UOL)

Summary: Maren Striebel (UOL), Miriam Gerhard (UOL)

- Q1: What are the major sources of environmental variation in aquatic systems?

Sources of environmental variability can be approached using different criteria and considering different aspects:

- Type of factor. Identification of key factors causing environmental variability: temperature, light, salinity, water level, nutrient availability, stream inputs (hydrology and materials), browning, pollutants, CO_2 and O_2 concentrations. Variability in abiotic factors was identified as relevant for shaping living systems, but also biotic changes like resource availability and quality (for consumers), predation pressure, and

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presence of invasive species are important sources of variability (these might co-vary with abiotic factors).

- Natural dynamics vs. changes in environmental variation caused by disturbances (novel patterns of variability). While organisms are adapted to natural variability, they might need to adjust or develop additional mechanisms to deal with novel environmental variation.
- Type of systems. Different sources of variation have to be considered according to the type of system (e.g. lakes vs. marine environments).
- Frequency of variation. The identified factors vary at different temporal scales, including daily cycles, seasonality, and inter-annual events. Some efforts have been done to identify how the natural variability of different factors at different scales are changing considering ongoing climate change, especially for temperature. The different scales at which variability can be detected are relevant for organisms depending on their life-span.
- Single vs. multiple factors. Multiple factors can vary at the same time generating interactive effects that co-limit organisms/populations/communities in different systems.
- Temporal and spatial scales of variation. Temporal variability and spatial heterogeneity are relevant dimensions of environmental variability. For example, in coastal system, temperature, nutrients, light, and salinity are key environmental data that vary on temporally and spatially highly divergent scales (from sub-daily to inter-annually in time, from (centi-)metres to 100 kilometres. Variation differs among species: the perception of relevant scales of variability has to be scaled to the mobility, range, and life-span of the organisms. Temporal and spatial variability are strongly interrelated, response to temporal variation is often based on the spatial context

- Q2: What are most important knowledge gaps?

Mechanisms by which organisms deal with variability

- Feedback and feedforward framework for mechanisms of dealing with variation: since feedback mechanisms are based on regulation after changes occur as a result of internal state sense and feedforward mechanisms are based on organismal capacity to sense the environment and produce anticipatory responses to changes, would we

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then expect feedback mechanisms to be important under unpredictable changes and feedforward mechanisms to be more extended for predictable changes?

- How would "additional variability" (increase in magnitude and frequency) affect response mechanisms to variation? Many different processes might be involved in dealing with changes in natural variability: the adaptive capacity of organisms, the plasticity of response mechanisms, and the existence of thresholds. Changes in variability and its predictability might increase energy allocation for response mechanisms, decrease fitness or induce maladaptation if environmental cues are no longer reliable?
- What is the role of the environmental history in the capacity of organisms to respond to changes in variability? Would we expect a geographical pattern? Different regions present different structures of natural environmental variability, how might this influence the success to deal with novel expected changes in variability?

Variance in a multi-factorial context

- Synergistic vs. antagonistic effects of combined factors: are the effects of co-limiting factors on organisms/populations/communities additive, synergistic or antagonistic?
- How do given [multiple] stressors co-vary in time and space? Are those patterns expected to change in the future? For having an idea where the relevant changes occur:
- Use species/group specific responses to identify scale of interest
- Identify response curves (convex/concave etc) to identify areas of interest • Do the organisms need to trade-off their acclimatory /adaptive responses between factors?
- Co-variation of different factors is important for anticipatory responses to change, would a potential decoupling of them affect organisms' response systems?

Experienced environmental range in space

- Do typical movement patterns minimize or maximize the range of experienced environmental conditions? Environmental drivers are normally thought to be the main determinants of ecosystem variation (e.g., temperature, salinity, nutrients). However, predation might become more relevant than some environmental ranges as it can foster changes in prey physiology. If a prey has to migrate to avoid predation, the prey organism may have to develop a wider tolerance to temperature ranges (vertical

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migration). Can predation be a stronger driver of adaptation to variability than the environment by itself? Organisms can adapt to environmental ranges/variability by expanding their tolerance to the expanded environmental factor, while predation might be a more "extreme" pressure, causing death if the organisms are not adapted.

- What are the consequences of organisms experiencing different previous environments (e.g. existing in different parts of a particular habitat), before coming into contact with one another? Meta-community theory framework may be fit to test how organisms of different mobility might interact across a hierarchy of patchiness (e.g. sessile primary producers, somewhat mobile herbivores, and highly predators).

Measurements of environmental variability

- How does our capacity to measure environmental variability, variability experienced by organisms and its effects, bias our understanding of environmental change? Small scale variation has been underestimated because for this we need high-resolution measurements that were not available until recently. In addition, lack of wide spatial scales along extended time periods makes the assessment of spatial/temporal variability even more difficult. Monitoring programs with either "snapshot" measurements over extended spatial scales, and/or a single site measurements conducted over a long-time space are needed, for example, through a spatial network of time series (given the current biodiversity monitoring focus).
- Accurately measure dispersal is needed to assess space usage and changes in space use given variability in time and space.

- Q3: How can we use mesocosm experiments for addressing environmental variability?

- Large experiments across sites across countries allow to include a broad background variability. It is critical to clearly define response variables and standardize measurements for comparing results across different studied organisms, source of variation, levels of biological organization, etc. in cooperation efforts.
- How do we deal with experimental limitations? E.g. lack of replication, lack of controlled conditions.

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- Shift from replicates to response surface → shape of response for interaction of factors and effect sizes.
- Which is the scale of interest? Can we pre-define where factors dominate/interact?
- Combine complex mesocosm experiment with controlled laboratory experiments (mechanisms vs complexity). For example, biotic interactions are difficult to measure and thus not measured (inside or extra bioassay experiments can be conducted).
- Indoor vs. outdoor mesocosms: to compare experiments at the same scale but with different degree of controlled variance.
- Use mesocosms for testing a theory – define questions, hypothesis and predictions before designing an experiment

4. Overview of incentive talks

4.1 Hans-Otto Pörtner (AWI Bremerhaven): *Contributions of aquatic experimental ecology to solve consequences of global change*

Time: October 7 2021, 16:00 h CET.

Host: Marko Reinikainen (AirClim, Gothenburg)

https://www.youtube.com/watch?v=aD2d5siBIGE&t=3431s

An incentive talk was given by Hans-Otto Pörtner (AWI, Bremerhaven), who reported from his perspective as member of the IPCC about threats arising from global change especially for marine ecosystems. He outlined the process how the IPCC translates scientific data and evidence into recommendations for policy makers. He also pointed out knowledge gaps, referring to thermal tolerances of species and communities, and the discrepancy arising from defining thresholds for ecosystems from thermal tolerances of individual taxa.

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4.2 Andreas Oschlies (GEOMAR, Kiel): *Ocean-based CO_2 removal strategies*

Time: October 14 2021, 15:00 h CET.

Host: Ulf Riebesell (GEOMAR, Kiel)

https://www.youtube.com/watch?v=DtzGizbnocM&t=3140s

The starting point for this webinar was the fact that a successful management and limitation of greenhouse gas emissions is not in sight – especially emissions of CO_2 are increasing, and the concomitant increase in global temperature is out of control, with direct consequences for ecosystem functioning, human wellbeing, sea level rise etc.

In his talk, Andreas Oschlies outlined four different nature-based solutions to counteract greenhouse gas emissions: (1) Global cooling through artificial upwelling, (2) Iron fertilization, (3) Injecting CO_2 into deeper layers of the world's oceans, (4) Ocean alkalinisation. Of the four topics, especially #4 is promising in terms of being feasible at large scale, while side effects on ecosystem processes seem limited. However, to date the consequences of ocean alkalinisation (aka human induced weathering) have not been studied experimentally.

4.3 Erik Jeppesen (Aarhus University & METU): *Salinization of freshwater ecosystems – an increasing global threat*

Time: October 21 2021, 14:00 h CET.

Host: Meryem Beklioğlu (METU Ankara) & Robert Ptacnik (WCL Lunz)

https://www.youtube.com/watch?v=HJVBNWQYjXU

Erik Jeppesen gave a broad overview on the topic of salinization, addressing various aquatic ecosystems. He outlined causal relationships, especially how food production and global meet demands affect land-use and water consumption. He highlighted the heterogeneous nature of the problem. Irrigation and rising temperatures affect both freshwater lakes but also saline inland waters. Moreover, mining and other industrial activities, as well as road-salt application affect streams and lakes in more temperate areas.

Erik Jeppesen summarised current research gaps, as geographic areas (Like central and eastern Asia), as well as current limitations regarding the actual salts (ions) causing salinization.

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4.4 Mary O'Connor (UBC, CA): *Considering variability as biologically important aspect of global change*

Time: October 28 2021, 17:00 h CET.

Host: Helmut Hillebrand (ICBM, University of Oldenburg)

https://www.youtube.com/watch?v=o94GCbKTfPA

The key message of the talk by Mary O'Connor was that research mostly addresses changes in average levels of environmental factors, while changing their variability is understudied. however, taxa may respond and adapt to fluctuating levels of e.g. temperature or pH in ways different from how they respond to changes in the mean. This is especially relevant when considering threshold responses and asymmetric responses to environmental drivers (e.g. thermal tolerances are typically asymmetric). Mary O'Connor furthermore outlined how hypotheses and models can be developed from first principles, and how models then can and should be subject to experimental test, where combination of multiple stressors is a key challenge. She also illustrated the usefulness of mesocosm based studies for testing the effects of variability on ecological communities.

5. Dissemination Activities Related to this Deliverable

Two manuscripts under preparation emerged from the world café discussions. D6.2 (Opinion manuscript) & D6.3 (AquaSummit concept manuscript)

The Webinars are all available on the AQUACOSM YouTube channel (https://www.youtube.com/channel/UCUJUY-IsOKVVdR6lUGPG5sQ) and were watched >490 times @ 31 May 2021.

The summaries of the World Cafés are available on the AQUACOSM homepage and will be made available on a new project tracker module to be made available under the Transnational Access tab on the homepage during fall 2021.

(https://www.aquacosm.eu/2020/12/15/consequences-of-global-change-on-aquatic-ecosystems-webinar-series/)

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6. Appendix

Figure 2: *Announcement for the webinar series*

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