OCEANS ON THE RISE

Dear 2050

Art and Science Exhibition

Kunst(Zeug)Haus Rapperswil / 12.12.21 – 30.1.22

Kammgarn West Schaffhausen / 12.2.22 – 12.3.22

Climanosco

A creative initiative for a critical challenge of our times

FOREWORD

Dear 2050

70% of the Earth's surface consists of oceans. They contain 97% of the Earth's total water and give the planet its blue colour when viewed from space.

More than 78% of the Earth's total biomass lives in the sea. The oceans regulate the climate. They store half of all CO_2 emissions and 90% of the excess heat from the atmosphere. All of the Earth's water flows into the sea.

2021 was the year that tourists flew into space for the first time. And believe it or not, there are actually voices claiming that space tourism will create "awareness of the environment, of climate change and of the worthiness of protecting our planet".

2021 is also the year the UN launches the "Decade of Marine Scientific Research" with the goal of increasing public awareness of the ocean and its central role in climate and promoting sustainable ocean development by 2030.

The artists and scientists of *Dear2050: Oceans on the rise* bring us closer to the ocean without rocket science. They have researched algae, measured the coast, documented the tides and built coastal cities of the future. The exhibition is a message to the year 2050 – the year in which the world is supposed to be climate neutral according to the Paris Agreement. It shows how closely human society is connected to the sea and how climate change is already affecting it. And how our future could look together with more sea.

Bettina Rohr
Curator

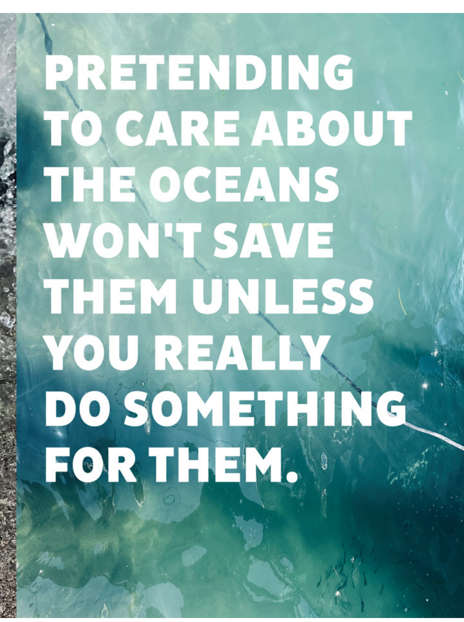
FEATURED

Selma Kozak

Speaking of the oceans

Selma Kozak is an artist, graphic designer and academician working in the area of public art, video installation and projection. The artist is inspired from activist art based on human emotions, emotional and psychological problems, social issues, feminism, environmental problems and the abuse of natural environment. While creating the artworks, the artist uses language and links usually between typography (discourse) and photography and so, the protagonists of her works are those three elements.

"Speaking of the Oceans" is a projection show that consists of rhetorical discourse. The work includes eight different card designs which are distributed among the audience before and during the show. With the text-based public art project, the artist intends to establish a sincere and direct bond between visitors and the oceans through art and language. The work aims to offer poetic content about how the oceans are vital for all living beings, our planet and our interconnected ecosystem, and how human beings have a profound effect on extinction of the oceans and marine pollution.



INTERCONNECTED
INTERCONNECTED
INTERCONNECTED

Anita Yan Wong

Nature's poem

Anita Yan Wong, M.F.A., is an Asian American painter best known for her expressive brush strokes and unique style of "Contemporary Traditional" paintings that defies tradition and modernity. Nature is the main inspiration for the artist. With her background in creating moving imagery, Anita explores the movements of subjects and passage of time with her fast-moving brush, which is why animals and natural elements represent recurrent topics in her work.

The ocean can't speak for herself verbally but she is whispering to us daily. The three visual poems titled "Dance of the ink creature", "The plastic predator" and "Whisper of the winter branch" are part of a larger collection of work titled "Nature's poem". The first and second poems in this collection feature animals (such as octopuses, sharks and sea rays) affected by ocean pollution along with a third poem highlighting abstract calligraphy formed by pieces of driftwood.

Similar to the energy and abstract appearance behind traditional Chinese Calligraphy done with ink and brush, the animals in each poem are supported by a strong skeletal structure – visually simple, dynamic and elegant. The framework highlights the beauty of the subject, at the same time contains and conveys a deeper layer of emotion/reflections of the calligrapher (artist) toward the environmental problems we are facing today.

Whisper of the winter branch

An action of Mother Nature, speaking to us with winds, tides and waves carrying wood/ driftwood that forms the final nature's poem – "Whisper of the winter branch". What is Mother Nature saying to each of us?

Dance of the ink creature

Squid and octopuses sense, sound and experience sound pollution in the oceans. Studies found that squid, octopuses and cuttlefish exhibit massive acoustic trauma caused by the growing noise pollution in our oceans.

The plastic predator

Studies show that there are trillions of microplastics in the ocean. Sharks and sea rays are eating and swallowing hundreds of pieces of plastics every hour because of ocean pollution. Many of the plastic fibers found in these studies were synthetic cellulose, the material found in hygiene products such as face masks during the COVID-19 pandemic.

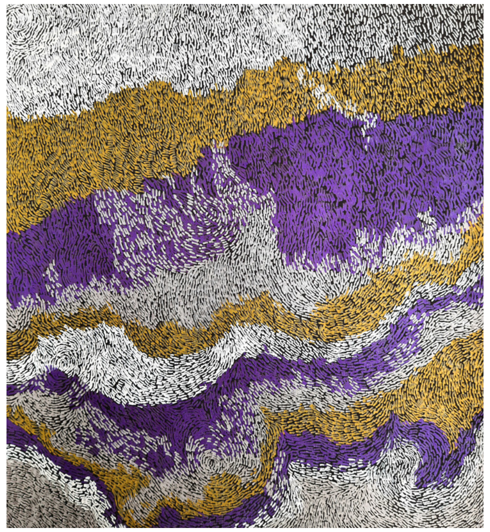
ARTWORK

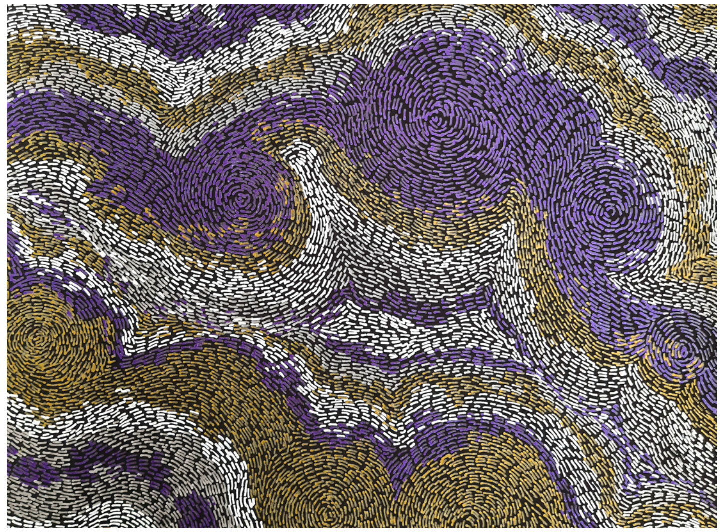
Mitra Tashakori

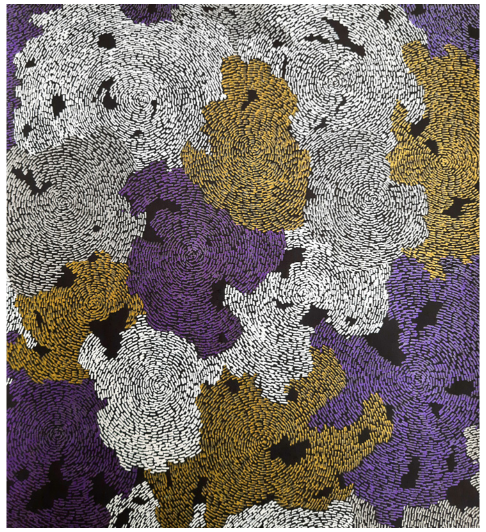
Restless Earth

Mitra Tashakori studied Graphic Design, which shows in her paintings in a mysterious and abstract way. For her, concepts such as love and separation cannot be shown by drawing figures and direct representations of shapes and forms or figures, especially in the surrounding of her religious hometown. The earth, the seas, and the heavens are all in deep crisis and disorder as a result of human indiscriminate intervention. She believes that the earth, while restless and disorderly, tends to return to order and tranquility.

The earth, the seas, and the heavens are all in deep crisis and disorder as a result of human indiscriminate intervention. However, the earth, while restless and disorderly, tends to return to order and tranquility. The warming of the earth, the melting of the ice of the oceans and the pollution of the earth are due to the ignorance and negligence of human beings. The artist thus believes that we need to teach people better, more useful, more up-to-date and more practical information. Maybe tomorrow is too late…







Yona Silvy

Estimating when and where human-induced change in ocean water-masses becomes greater than natural variations

Yona Silvy is finishing her PhD in Paris at LOCEAN-IPSL. In her thesis, she investigated time scales and mechanisms of large-scale temperature and salinity changes in the ocean interior, using global climate models to distinguish changes in response to human-induced climate change, to internal variations of the climate system. She has been particularly involved in a collective effort to engage the lab towards a low-carbon transition, by evaluating and questioning the carbon footprint of research practises, and implementing mitigation measures to reduce greenhouse gas emissions.

The World Ocean is a major regulator of global climate and acts to damp the ongoing Earth surface warming by absorbing large quantities of excess heat and carbon from the atmosphere. This comes at a price as this heat and carbon uptake lead to a number of severe impacts for ecosystems and societies, some of them irreversible on very long time scales such as sea level rise. Under such pressure, the temperature and salinity of the ocean, key variables to monitor climate variability, have been changing at the surface and at depth since the 1950s, and will continue to change in the future.

It is however tricky to distinguish whether these changes are only due to the influence of human activities, or partly driven by natural variations of the ocean. Here, we present the work published by Silvy et al. (2020), which aims to investigate when and where we can expect human-induced changes in oceanic water-masses to become greater than background natural variability. They find that by 2020, a human-induced change can be unambiguously discriminated in 20-55% of the Atlantic, Pacific and Indian Oceans, rising to 55-80% by 2080.

Ocean temperature and salinity: key markers of climate variability and change

The ocean is a central player in the Earth's water cycle, with about 80% of precipitation and evaporation fluxes occurring at the ocean surface [P. Durack, 2015]. In regions where precipitation exceeds evaporation, there is a net input of freshwater, making surface waters less salty and vice-versa, impacting how salt is distributed in the surface and subsurface waters. Any change in the water cycle is thus reflected in ocean salinity patterns. Since the 1950s, changes in the surface and subsurface salinity field have been observed and manifested as an amplification of climatological patterns, reflecting an intensified global water cycle caused by a warmer atmosphere associated with global warming (e.g. [S. Hosoda et al., 2009;, P.J. Durack and S.E. Wijffels, 2010; K.P. Helm et al., 2010; P.J. Durack et al., 2012; N. Skliris et al., 2014; N. Skliris et al., 2016; J.D. Zika et al., 2018; L. Cheng et al., 2020]). Furthermore, the ocean is where the majority of the excess heat due to human activities is stored, illustrated by rising ocean temperatures and heat content (e.g. [L. Cheng et al., 2021]) since the mid-20th century. Monitoring ocean salinity and temperature on decadal-long time scales is therefore a useful means to track how human activities are impacting the climate system.

In the ocean, we can define different water-masses by the temperature and salinity characteristics that they acquire at the surface through air-sea and ocean-ice exchanges. Together, these characteristics define the water-masses volumetric mass (also known as "density" in the field of oceanography). It is mainly along these levels of equal density that water-masses flow in the ocean interior. Temperature and salinity are thus central variables for the ocean water masses and control the thermohaline circulation (ocean currents driven by temperature and salinity gradients). Changes in both temperature and salinity affect global ocean circulation and sea level rise, which together have widespread impacts for human societies and ecosystems.

How can we be sure, however, that these changes are truly caused by human-induced climate change and not by natural variations in the climate system?

Disentangling human-induced changes from natural variations

Finding out if human-induced changes in temperature and salinity are large enough to overcome the natural variations of the ocean requires a disentanglement of the intensity of these changes (what can be referred to as the "signal") from the amplitude of their background variability (the "noise"). It thus becomes a signal-to-noise problem. Anomalies in ocean surface heat and salt can be directly transmitted by the atmosphere and sea-ice via physical exchanges (heat and freshwater fluxes). They are then spread to the ocean interior along ventilation pathways. An example of this is when surface waters become heavier than the underlying water layer and are subducted into the ocean depths. Some water-masses are thus very well connected to the surface via these circulation pathways and ocean mixing, while others will not see the surface for decades to centuries, potentially isolating them from human-induced changes for a long time. The changes in temperature and salinity are greatest near the surface, but natural variations of these variables are smaller in the deep ocean, because these areas are more isolated from high-frequency chaotic oceanic and atmospheric variabilities.

Using a combination of observations and climate model simulations, a number of studies have partially attributed observed ocean temperature and salinity changes to human activities by investigating their globally-averaged fingerprint or focusing on specific regions. There is, however, a lack of knowledge regarding what occurs at the local scale.

Furthermore, there are still vast areas where anthropogenic change remains undetected, which can be due to too few observations, high natural variability or small magnitudes of changes. The study discussed here [Y. Silvy et al., 2020] proposes to investigate where and when we can expect a human-induced signal to emerge against the background variability in the ocean interior, at the local and regional scale. The authors consider the entire ocean, below the surface layer directly in contact with the atmosphere, in order to focus on the part of the ocean where changes are more persistent.

Using climate models, we can reconstruct the climate of the past century and a half and its variations, in simulations including and excluding human influence. Human activities (greenhouse gas emissions, aerosols and land use) act as external forcings on the climate system. We can choose whether or not to include these forcings in climate simulations, spanning from ~1850 (pre-industrial period) to today. We can also provide future scenarios for these human activities so as to make climate projections for the rest of the 21st century. Other external forcings of the climate system include volcanic eruptions (which act to cool the Earth's surface temperature by releasing aerosols into the stratosphere which in turn reflect more of the sun's incoming radiation), and the solar radiation cycle. They are called natural external forcings, for which we know the variations and intensity in the past century and a half. The models are provided with the information associated with these natural forcings so as to reproduce the climate from 1850 to today. Other than these human and natural external forcings, the variations of the climate are governed by internal physical processes within the climate system.

By considering sister simulations of climate models with and without human activities, we can isolate the anthropogenic (i.e. human-induced) component of change by looking at the difference between the two simulations. This provides an estimate of our "signal", while we can estimate the background natural variability envelope ("noise") by the simulations without human forcings.

The definitions of signal and noise can vary but this methodology has been used for many variables (e.g. surface air temperature, [E. Hawkins and R. Sutton, 2012]; sea level rise, [K. Lyu et al., 2014]) and is applicable in a multi-model framework.

In this study, we look at anthropogenic change in the ocean and the associated time of emergence in an ensemble of 11 models from the fifth phase of the Climate Model Intercomparison Project (CMIP5). The framework of analysis adopted is to look at temperature and salinity changes along ocean density levels, which is a more water-mass centric view of the ocean, and along which temperature and salinity changes are, by definition, correlated.

When and where does a human-induced signal emerge in ocean water-masses?

First, the changes in temperature and salinity simulated by the models are compared against the observed changes since the 1950s. The models are good at reproducing most of the global scale multi-decadal changes in water-masses, even if they present some biases in their mean state. Several studies have suggested that these changes were caused by the patterns of anomalous freshwater exchanges between the atmosphere and the ocean (illustrating the water-cycle amplification) and by global surface warming [P.J. Durack and S.E. Wijffels, 2010; P.J. Durack et al., 2012; V. Lago et al., 2016].

Our next step is the extraction of the "signal" and "noise" from each model simulation as

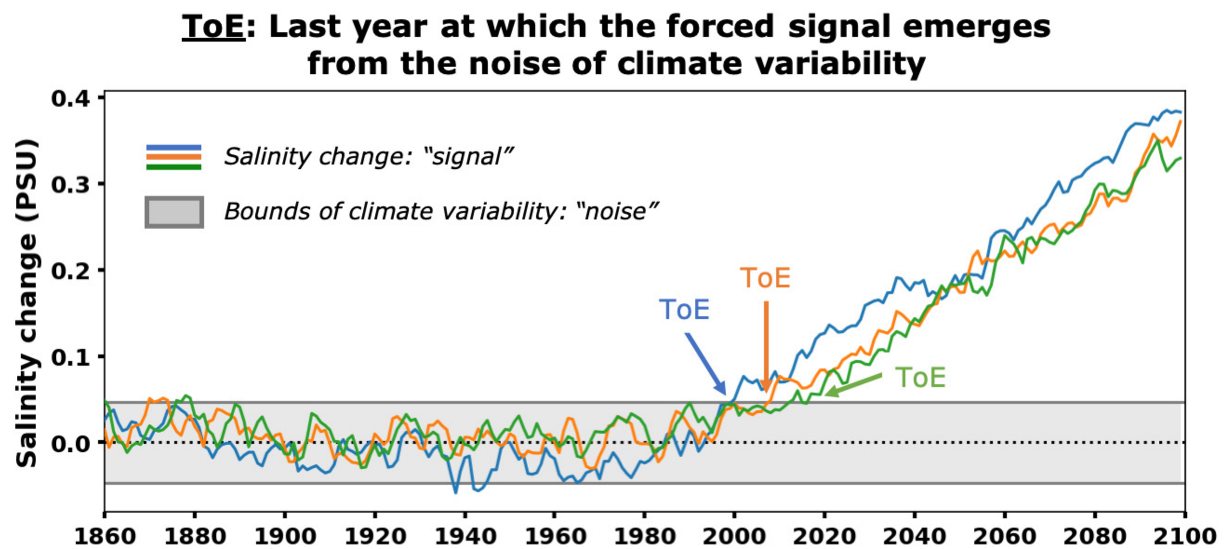


Figure 1 gives an example of three different time series (colored lines) for salinity signal, where we can see that the signal is confined within the bounds of natural climate variability (grey area) from 1860 to the end of the 20th century, and thereafter slowly rises beyond these boundaries at different moments in time. The Time of Emergence (ToE) is defined as the year when the signal departs from the threshold of the noise envelope and remains above (or below) it for the rest of the period considered. Here, for our three examples, the signals emerge between 2000 and 2020 and keep on increasing until the end of the 21st century.

MANUSCRIPT

explained above for the periods 1861 to 2100, 1861-2005 (historical simulations) and 2006-2100 (the “business-as-usual” scenario of current ongoing global warming). This allows us to infer the time of emergence. We do this calculation both locally (i.e. for each grid point of the model data) and regionally, in 9 regions where the pattern of change is well identified and reproduced compared to the observations.

We find that in these regions of the ocean, the anthropogenic signal emerges between the late 20th century and the first decades of the 21st century, all before a +1.5 or +2°C warming, indicating the ocean’s extreme sensitivity to human activities, even at depth. The earliest emergence is seen as soon as the 1980s for the Southern Ocean water-masses, confirming this region’s essential role in sequestering heat and carbon through the meridional overturning circulation connecting the ocean surface to sub-surface water-masses.

Performing the analysis on several models allows us to explore the spectrum of possibilities, and offers a range of probabilities for the emergence of the signal, since all models are different in how they try to reproduce the real world (amplitude of recent changes and of natural variability). In the identified regions, there is a very good agreement between models on the direction of the change, and on its time of emergence. Inversely, the parts of the oceans that do not emerge (i.e. the signal does not exceed the noise before the end of the 21st century) are also regions where there is no agreement between models, meaning there are more uncertainties concerning these areas, and the anthropogenic signal probably cannot be detected yet.

Across all models, we find that by 2020, a human-induced signal is detectable for 20-45% of the area of the Atlantic Ocean, 25-55% of the Pacific Ocean and 20-50% of the Indian Ocean. The ranges of the percentiles represent the model spread (1st-3rd quartile of the distribution). Towards the end of the 21st century, the area of each ocean basin that exhibits an anthropogenic signal augments, reaching 55-65% for the Atlantic, 45-65% for the Pacific and 60-80% for the Indian Oceans.

Even though the 21st century scenario for anthropogenic emissions used here was the “worst-case scenario” (i.e. the “business-as-usual” scenario: continued greenhouse gas emissions at the current rate), this study demonstrates that the sensitivity of the results on the type of scenario used is limited. Indeed, most of the signal structures that emerge do so before the second half of the 21st century, i.e. before the difference between the scenarios becomes impactful.

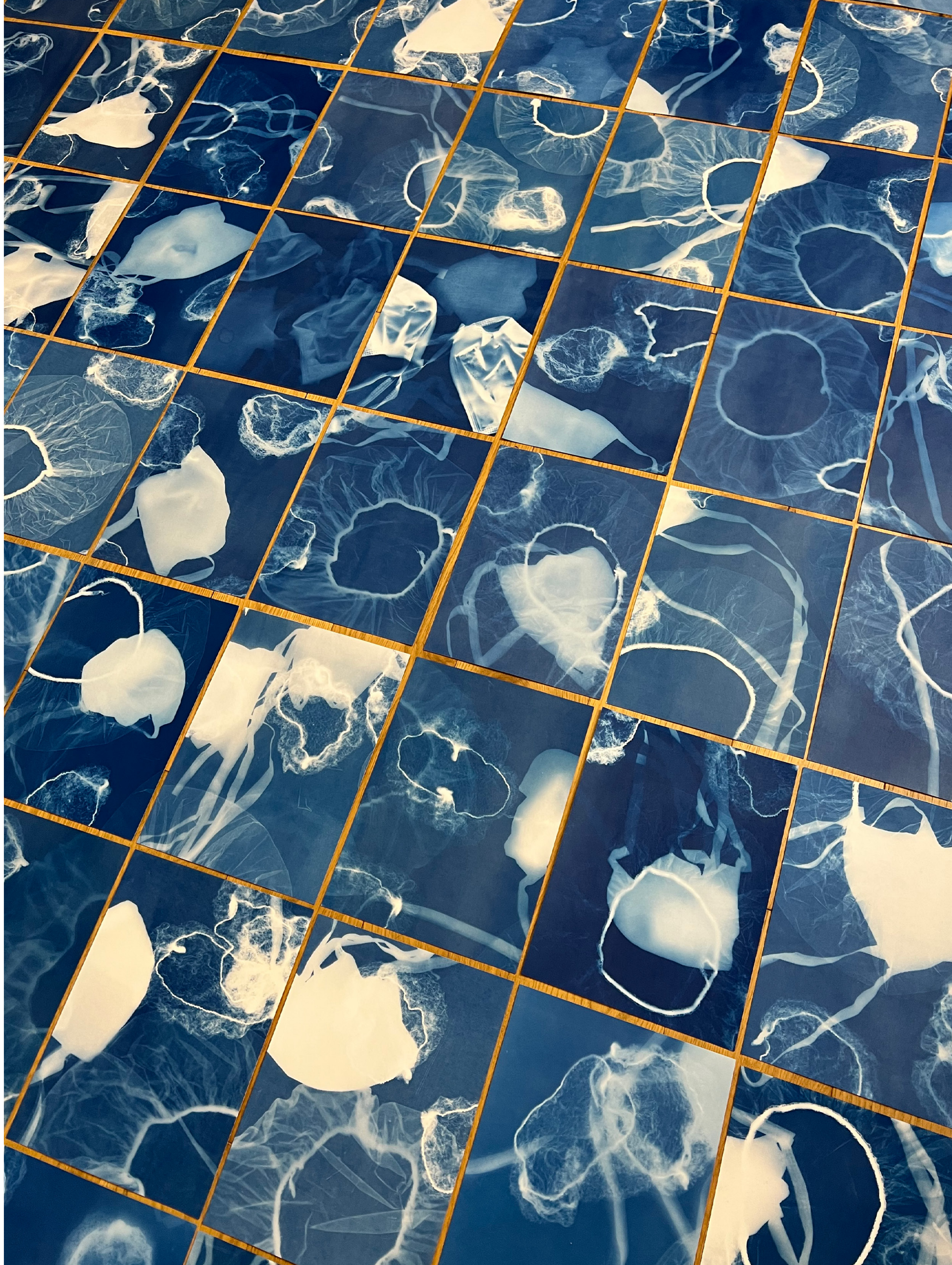
Looking at when human-induced changes in the ocean will emerge from background variability offers a different view onto the climate system’s response to human activities compared to simply considering surface variables. For example, surface temperature has been found to emerge quickly in the tropics and later in the Southern Ocean (e.g. [E. Hawkins and R. Sutton, 2012]), whereas we find that the Southern Ocean water-masses are the first to show an emergent signal at depth. This illustrates the very different roles and interactions that distinct variables can have and supports the investigation into a diversity of indicators when looking at forced change in the Earth System and when we can expect to detect it in the observations.

Aindreas Scholz

Seasick

Scholz studied photography at the Technological University Dublin, developing a keen interest in visual narratives. Moving on, he relocated to London in pursuit of further postgraduate studies at Goldsmiths College, deepening his understanding of critical and contemporary art-making theories and practices. Recently Scholz qualified as a teacher at University College London, developing specialist subject-specific skills in teaching art to young people.

The WWF is concerned that our demand for plastics – currently ca. 100 million tonnes per year and growing – threatens marine species and pollutes oceans, thereby accelerating climate change. The WWF reminds us that almost all plastic is a byproduct of extracting and processing fossil fuels, which creates billions of tonnes of greenhouse gases. Once discarded, plastics continue to break down thus releasing more gases, further increasing the rate of climate change.



Jessica Giannotti,
Renuka Ramanujam und
Taynuilt Primary (P6/P7 Students)

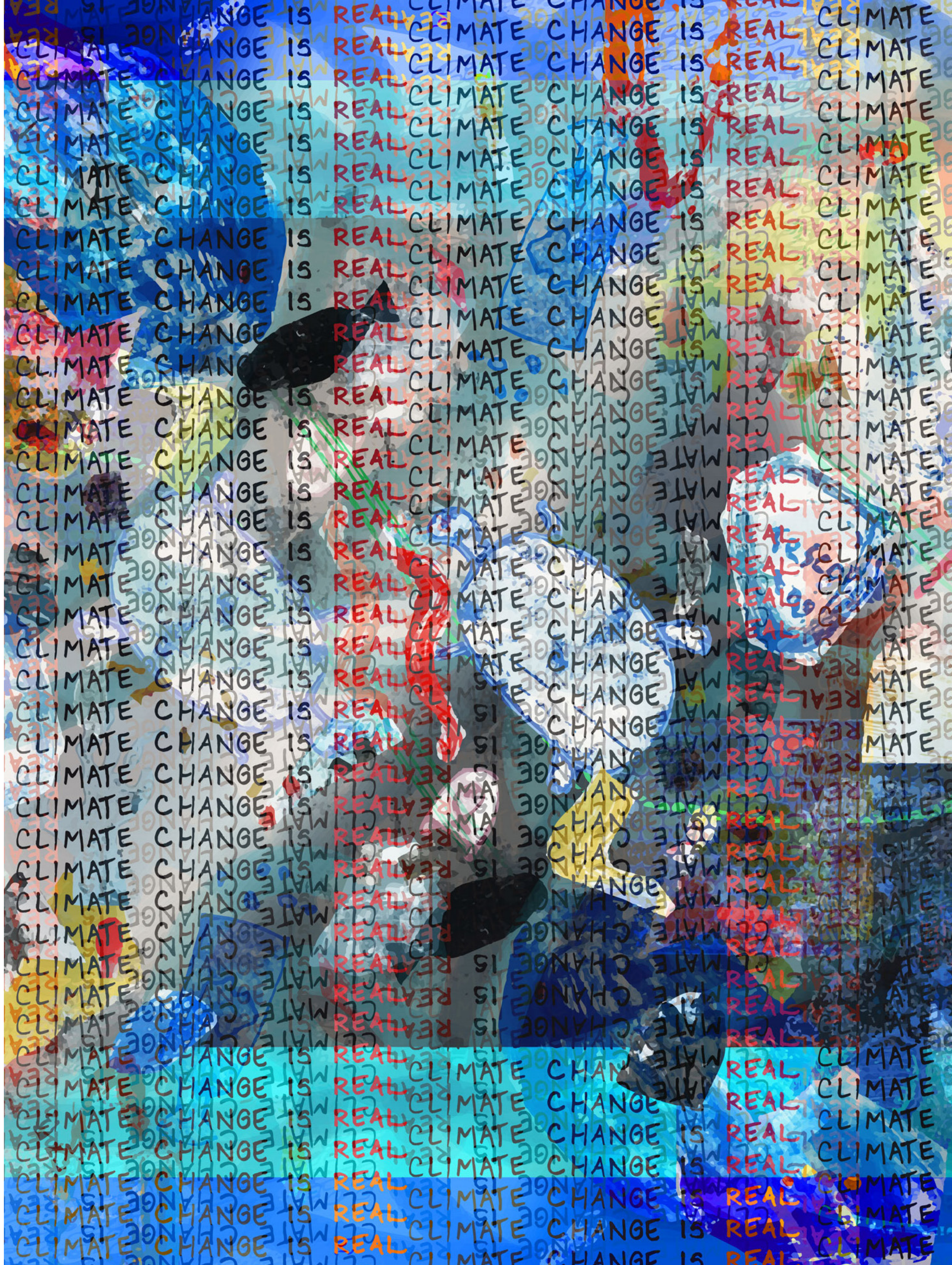
Plastic Futures

In her multi-disciplinary art-led design studio Renuka Ramanujam works between the worlds of printmaking, bio-based design and textile techniques, aiming to raise questions that will move us to a more caring and inclusive society.

Jessica Giannotti is a marine scientist, artist and fashion entrepreneur. She founded Crùbag in 2013, a Scotland-based interdisciplinary textile design studio and materials innovation lab merging ocean sciences and art. Crùbag's mission is to celebrate the unseen beauty of our planet, promote marine science education and the sustainable use of the ocean.

***Plastic Futures* is a collaborative vision questioning the future of our marine ecosystem. The piece was made as part of an ongoing collaboration about microplastic pollution between designers Jessica and Renuka, with the fresh insight of primary school pupils of Taynuilt, Scotland. Using monoprinting and collage techniques, a selection of the students' thoughts, hopes and fears were meshed with Jessica's and Renuka's responses to create a chaotic ensemble of hope, desperation and uncertainty. Add climate change to the mix, and the ensemble becomes explosive and potential scenarios imminent.**

Coloured frames add structure and a link between nature and a more urban environment as well as the shifting boundaries in habitats caused by climate change. The children are the future, and we as humans have important choices to make. The future is still undecided.



Martine van Lubeek

the mountain that got stuck in the delta works

Martine van Lubeek is a facilitator, an archivist, an artist with a strong focus on working place-based. Her practice is revolved around questions of relationality, place and the more than human. She plays with the relations within an environment by bringing in exotics to interfere with the existing agents and extracting materials from a specific place. The materials she uses are most often carriers of more than humans. Her installations work as subjective archives of a specific place.

The mountain that got stuck in the delta works **is an ever-continuing archive of sand along the Dutch seashore and visualizes the possible (hi)stories that are embedded within these single grains of sand. The carriers of the sand are the remains of mechanisms to prevent coastal erosion and perform their final task: the safekeeping of the sand, for in the future we may not have any left.**

ARTWORK

Laura Donkers

Land Radius / 2

Laura Donkers is an ecological art professional specialising in strategic community engagement and behaviour-change projects to transform public perception of ecology, sustainability and climate change. She generates new modes of insight through her expanded drawing practice that uses paper, sculpture and digital mediums. Her work seeks to engender understanding of connections between human and nonhuman communities to engage and inform eco-mindfulness, mutuality, and kinship.

Land Radius2 **is an audio/visual work presenting the rising tide and the startling impact of the encroachment of water on land that asks what will happen when the tide no longer recedes? The HDV video is supported by audio testimonies from the Māori community, citizens, management bodies, social and climate scientists, all talking about the expected impacts of projected high tide levels by 2050.**

Land Radius/2 presents a collaborative audio/visual exchange on rising oceans produced by ecological artist Laura Donkers. A Browning Trail camera was placed, as a proxy human sentinel, amongst the mangrove trees that sit at the edge of the shore on Aotearoa, New Zealand's Hauraki Gulf, aka Tikapa Moana (the Mournful Sea). The imagery captures the ubiquitous tide, natural phenomena (moonlight, gravitational forces, atmospheric conditions, sunlight) and the creatures who dwell there. A blue plastic tube shaped into a circle demarcates the area, drawing our attention to the multiple and often clashing claims made upon this environment. In 'making' the video, the artist can only set up the camera and point it in the desired direction; the subsequent gathering of footage relies on a combination of favourable atmospheric conditions (wind causing movement and temperature change) to activate the motion sensor that triggers the trail camera to begin recording. The video is accompanied by a sound work of recorded testimonies from an array of human actors in an unfolding assemblage of verbal perspectives that amplify each contributors' knowledge, observations, practices, concerns, doubts, fears, and frustrations in relation to established scientific and colonial perspectives about irreversible sea-level rise. This includes teachings from the tūpuna (ancestors) that are voiced through two Māori attestants.

As an ecological artist, Donkers wishes to advance collective ecological responsibility. She does this to inform eco-mindfulness, mutuality, and kinship by documenting societal and ecological exchange as evidence of connection between humans and nonhumans. By calling on others to contribute their knowledge, she attempts to find out what there is 'to know', 'be said', or 'shown' beyond her own perceptual limits. This increases multivocality and fosters pluralism through an ongoing 'listening-observing-not-knowing' process, to expose what sits in-between established positions. The resultant audio/visual language evolves in the spaces of conversation, mutual connection, and elemental freedom to reveal a complex image of what extraction, biodiversity loss, and sea-level rise pose for human society in Aotearoa, New Zealand.

The voices that you will hear were recorded during the busy working days of each contributor, via Zoom or telephone calls as the only means of communicating during a period of region-wide lockdown due to the Covid-19 outbreak in Auckland (Aug-Nov 2021). These testimonies were initiated through a broad 'call for contributions' on the subject of sea-level rise awareness. Openness to dialogic process across different epistemic positions produced a contributor-led approach to defining areas of local concern, ensuring that this collaborative audio/visual exchange was not directed but gathered, making visible new layers of connection. The resulting network of exchange developed its own agency (outside of the artist's control), as individual contributors, who self-identified as connected to important issues affecting their immediate environment and communities, became personally responsible for voicing their knowledge and experiences.

ARTWORK

01
Craig Turvey

is a sea swimmer, project developer and cultural worker. He describes his experiences of swimming amongst the mangrove forests of the Hauraki Gulf's shoreline.

02
Alex Rogers

is the Executive Officer of the Hauraki Gulf Forum. He shares his knowledge around the politics of protecting and restoring the Hauraki Gulf Marine Park.

03
Stephen Perry

is a fine art photographer based in Devonport, Auckland who has a passion for documenting coastal concrete structures along his local beach.

04
Dr Michael Allis

is a coastal engineer with NIWA (National Institute of Water and Atmosphere) who discusses adaptation responses in communication with communities affected by sea-level rise.

All interviews are online for listening.

The artist sincerely thanks these contributors and all the other voices who connected along the way, as well as Screen Auckland and Wenderholm Regional Parks for their support.

07
Bianca Ranson (Ngāti Kahu ki Whaingaroa, Ngāpuhi)

grew up on Waiheke Island on the Hauraki Gulf. She is founder and director of Potiki Adventures which offers tours and outdoor adventures within the natural environment from a Māori perspective. She is also a founding member of Mauri o te Moana, an organisation established as a collective Māori voice calling for urgent action for the protection of the moana (ocean). She presents a comprehensive Māori overview of the challenges faced by many communities affected by sea-level rise along the Pacific rim.

05
Sharley Haddon (Ngāti Wai)

is a horse woman and Pakiri Beach resident who attests to the impact of sand extraction on the biodiversity of her local beach.

06
Dr Paula Blackett

is an environmental social scientist with NIWA (National Institute of Water and Atmosphere) who talks about decision-making on sea-level rise using Serious Games to activate timely adaptation measures with communities.

Levke Caesar

Reconstructing the evolution of the Gulf Stream system

As a climate physicists Dr Levke Caesar studies climatic changes in and around the North Atlantic with a special focus on the role and the evolution of the Atlantic Meridional Overturning Circulation, commonly known as Gulf Stream System. She completed her PhD in 2019 at the Potsdam Institute for Climate Impact Research (Germany) and then started a postdoctoral position at the Irish Climate Analysis and Research UnitS at Maynooth University (Ireland).

As one its most important heat transport systems, the Gulf Stream system has a significant influence on the Earth's climate. The system is predicted to weaken under global warming, and scientist have wondered for years whether this slowdown has already begun. As direct measurements of the system are rare, one has to look at indirect, so-called proxy data, to answer this question. One promising proxy data of the Gulf Stream system are the sea surface temperatures of the North Atlantic: they are highly affected by the northward heat transport associated with the Gulf Stream system and reach back as far as 1870. And indeed, a unique region of cooling temperatures south of Greenland provides evidence that the system has weakened by about 15 percent since the middle of the 20th century.

This is in line with the trends found in other proxy data like the grain sizes or the composition of coral shells found in ocean sediments, that all indicate that the Gulf Stream system in recent decades has been weaker than ever before in at least 1600 years.

The ingenious Gulf Stream system

Have you ever wondered why cities like Stockholm or Dublin are on average about ten degrees warmer in winter than Canadian cities like Montreal or Quebec, even though the latter lie about 1,000 kilometres further south?

One important reason is the so-called Gulf Stream system [J.B. Palter, 2015], a huge network of ocean currents flowing in the Atlantic Ocean, one of which is the name-giving Gulf Stream. Some might even have heard its scientific name: Atlantic Meridional Overturning Circulation, short AMOC, which briefly describes the main properties of the system: It flows through the Atlantic in north-south (aka meridional) direction and is defined by an overturning of water masses, that is, it carries warm, saline surface waters from the South towards the subpolar North Atlantic and returns cold, deep water southwards. The amount of water turned over in this way is measured in Sverdrup, where 1 Sv equals 1 billion litres of water per second. The average strength of the Gulf Stream system is about 20 Sv, which equals about 100 times the amount carried by the world's largest river, the Amazon.

Due to this massive exchange of warm and cold water the system transports up to more than one petawatt (1 with 15 zeros) of heat northward in the Atlantic [W.E. Johns et al., 2011]. For comparison, this equals the energy production of about one million nuclear power plants. Since some of this heat is released into the atmosphere and transported toward Europe by the westerly winds blowing over the North Atlantic, the Gulf Stream system exerts a major influence on Europe's climate.

Impact of climate change

One of the drivers of the Gulf Stream system is the so-called deep convection: As the warm, saline waters of the Gulf Stream system flow North they are cooled by the atmosphere and thus become denser and heavier. If the water at the surface is denser than the water in the ocean layers below, it sinks. This vertical movement, driven by density differences, is called convection. Climate models predict that this process will slow down a result of global warming leading to a significant weakening of the Gulf Stream system [W. Weijer et al., 2020]. There are multiple possible reasons for that: an increase of precipitation over the high-latitudes of the North Atlantic [S. Manabe and R.J. Stouffer, 1999], as well as melting of Arctic sea ice [W. Liu et al., 2019] and the Greenland Ice Sheet [J. Bamber et al., 2012] add freshwater to the northern Atlantic, lowering the salinity of the upper ocean. This, along with increased warming of the ocean surface, reduces the density of the upper water masses and therefore, suppresses deep convection.

But climate change is already in full swing: due to the emission of greenhouse gases the Earth has warmed on average by about 1 degree [IPCC, 2018]; within less than 20 years the multiyear sea ice in the Arctic has more than halved [R. Kwok, 2018]; and the Greenland Ice Sheet is melting faster than at any time in the last 12,000 years [J.P. Briner et al., 2020]. All of this is affecting the Gulf Stream system. Scientists have therefore been wondering for years whether these ocean currents have already started to slow down. A question that can only be answered with measurement data.

How do we get to the bottom?

To get this data, in 2004 an array of more than 190 instruments was deployed in the Atlantic at about 26°N [G.D. McCarthy et al., 2015], spanning its entire width (approx. 6,500 km) and providing measurement data on the Gulf Stream system on a daily basis [S.A. Cunningham et al., 2007].

These data show a reduction in strength of about 30% from April 2004 to until April 2010 [D.A. Smeed et al., 2014], which is an extreme decrease. Since then, the current has recovered somewhat, but is still below the 2004 level [D.A. Smeed et al., 2018]. However, these data are not sufficient to assess whether the decrease is a result of man-made climate change and whether it represents a long-term trend; the measurement series is simply too short. This is because the Gulf Stream system – like many other components in the climate system – is subject to natural fluctuations. It is therefore quite normal that the currents sometimes flow more strongly, sometimes less strongly. To determine whether there is a longer-term weakening, correspondingly long time series are needed.

To assess the state of the Gulf Stream system for the period before 2004, we have to make do with so-called proxy data. Proxy data are climate data that provide indirect information about a system, e.g., tree rings can give information about the tree's grow conditions, that is mainly temperature and precipitation, in the area where they grow.

In case of the Gulf Stream system, scientists look particularly at the ocean temperatures in the subpolar North Atlantic as proxy data. The advantages are that due to its large heat transport into this region the Gulf Stream system strongly influences its temperature, and measurement series for sea surface temperature date back to 1870. However, the surface temperature of the water is also influenced by other factors, such as the temperature of the overlying air or local, small-scale current changes. The difficulty is to separate the temperature response to changes in the Gulf Stream system from the response to other influencing factors.

To do so, colleagues and I used a high-resolution climate model that simulates the response of the sea surface temperatures in the North Atlantic to a weakening of the Gulf Stream system. In the simulation the carbon dioxide concentration in the atmosphere was doubled over the course of 70 years, leading to a warming of the Earth of about 3 degrees and a weakening of the Gulf Stream system of about 25 percent.

The model shows that the warming does not happen uniformly; some regions warm more others less than the global average. The greatest deviations are found in the North Atlantic: while a narrow area along the US east coast has warmed more than three times as much as the global average, a region south of Greenland that is more than half the size of the US shows virtually no warming and at some place is even cooling. The latter is also referred to as the North Atlantic "cold blob". This dipole pattern of particularly strong and almost no warming is directly related to the weakening of the Gulf Stream system simulated in the model: The significantly reduced northward heat transport in the Atlantic leads to a cooling of the region south of Greenland, counterbalancing the global warming signal. The particularly strong warming along the coast between North Carolina and Newfoundland is due to the warm water masses of the actual Gulf Stream, which shifts northward as the Gulf Stream system weakens. Therefore, this pattern is a kind of "fingerprint" in the sea surface temperatures of a weakening Gulf Stream system [L. Caesar et al., 2018].

An examination of the observed sea surface temperatures since 1870 shows that they contain the same fingerprint. Here, too, the region south of Greenland has warmed significantly less than the rest of the world – or even cooled – and here, too, the waters along the North American east coast have warmed significantly more (Figure 1).

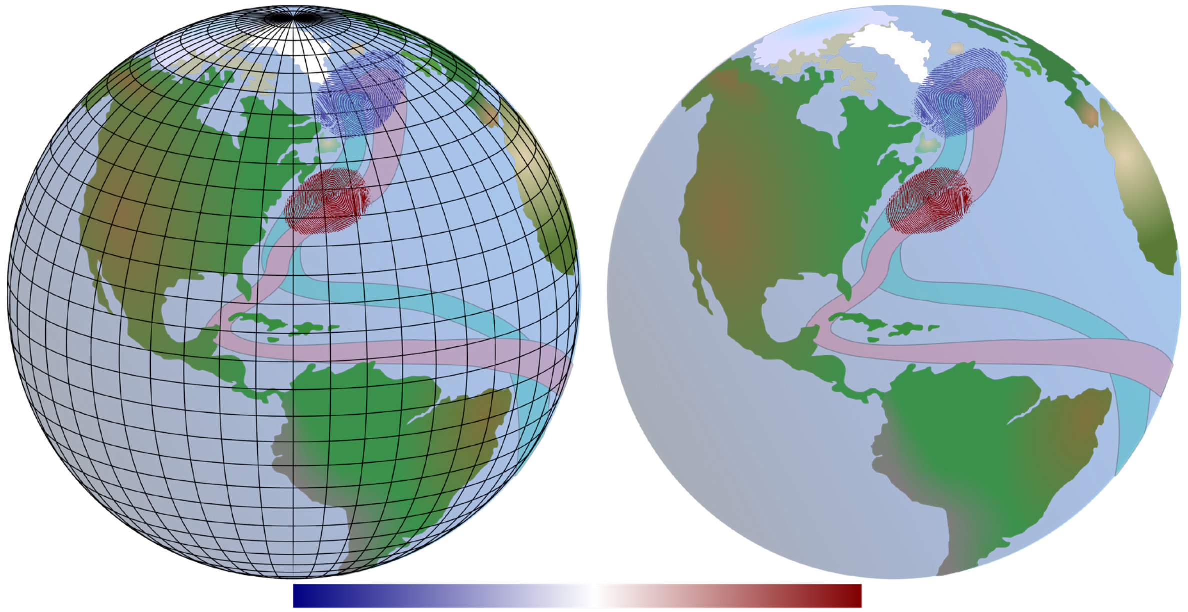


Figure 1. We identified a distinct fingerprint of a slower Gulf Stream System in the sea surface temperature evolution in a climate model (left) which we have also found in the observed temperatures (right). The path of the Gulf Stream systems upper (red) and lower (cyan) branch are schematically shown.

Using these findings, we estimated the temporal evolution of the Gulf Stream system by determining the strength of the North Atlantic cold blob, i.e., we looked for each year how much colder, or warmer, this region was compared to the global mean sea surface. To convert this relative temperature into an actual current strength we studied the relationship between cold blob and Gulf Stream system in a series of climate models. These showed that a reduction of the Gulf Stream system of 1 Sverdrup cools the region south of Greenland on average by about 0.25 degrees. With this conversion factor we were able to reconstruct a time series of the Gulf Stream system that starts in 1870. The time series shows that while the system has been fairly stable over the first part of the 20th Century it indeed started to decline around 1960. And while a short-lived recovery is evident in the 1990s, a further decline starting in 2004 led to the Gulf Stream system being now about 3 Sv (or 15 percent) weaker compared to the first half of the 20th Century (figure 2 black line).

What is special about this reconstruction is that it combines the seemingly contradictory results of previous studies. For example, in 2005 a team led by British scientist Harry Bryden published a study based on single ship measurements, that were taken in 1957, 1981, 1992, 1998 and 2004, concluding that the Gulf Stream system had weakened by about 30 percent during that time [H.L. Bryden et al., 2005]. The results were criticized for two reasons: On the one hand, it was noted that the natural fluctuations of the Gulf Stream system were not taken into account: The direct measurements that were taken since 2004 revealed that the Gulf Stream system flows strongest in autumn and reaches its by about 30 percent reduced minimum strength in spring [T. Kanzow et al., 2010].

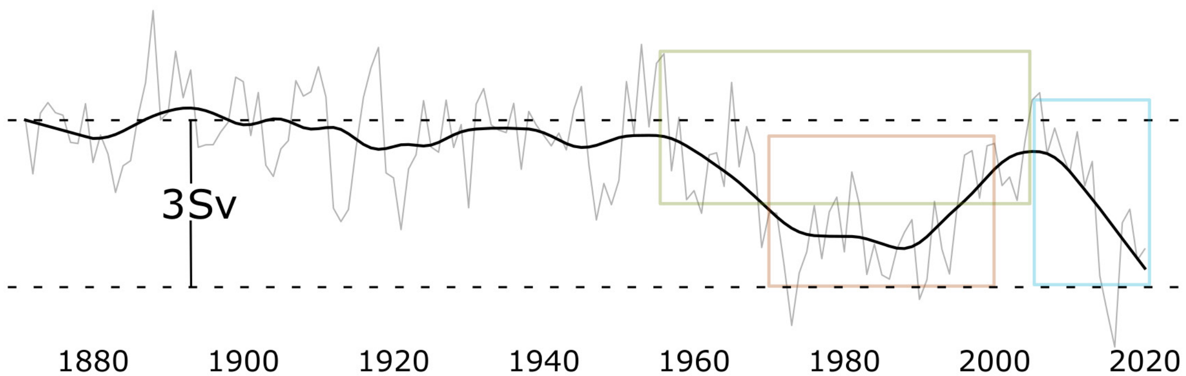


Figure 2. Shown is the evolution of the Gulf Stream system as reconstructed from the sea surface temperatures in the North Atlantic. The thick black line shows the longer-term evolution (for more details see [L. Caesar et al., 2018]), the thin line shows the annual values. The boxes mark the time periods of a decrease based on single year ship measurements (green), an increase based on density measurements (red) and the time period of the direct measurements (blue).

As the single ship measurements were taken during different times of the year, they were not directly comparable. If the shipboard measurements are corrected for the seasonal cycle, they only show a weakening of about 13 percent [T. Kanzow et al., 2010] (figure 2 green box). Another team around meteorologist Mojib Latif, which analysed measurements of ocean density between Greenland and Iceland, concluded that the current system has actually increased in strength from 1970 until 2000 [M. Latif et al., 2006] (figure 2 red box).

Our results indicate that all previous studies are correct and that the difference arose from the consideration of different time periods combined with the fact that the evolution of the Gulf Stream system consists of a long-term weakening superimposed by natural variations. The fact that the sea surface temperature based reconstruction is furthermore capable of capturing the strong decrease measured from 2004-2010 as well as the subsequent slight recovery (figure 2 blue box) reinforces our confidence that ocean temperatures in the subpolar North Atlantic are indeed well suited for estimating the long- term changes in the Gulf Stream system.

In a continuing study, colleagues and I have put the 20th Century decrease in an even broader context: By comparing a variety of different proxy data of the Gulf Stream system, some of which reach back as far as AD 400, we found consistent evidence that the Gulf Stream system over the last decades has been weaker than any time before in the last 1600 years [L. Caesar et al., 2021]. The advantage of using different kinds of proxy data is that as they are all linked to the Gulf Stream system in different ways they are subject to different uncertainties. If they nevertheless show a common behaviour, it largely increases our confidence that the signal that we see is indeed representative of the Gulf Stream system. The proxy data that we considered include for example at a data set that describes the size of the grains in an ocean sediment core taken from a place where the deep return current of the Gulf Stream system flows.

This tells us something about its strength as a faster current can transport large grains and we see that the transported grains got smaller over the last 200 years [D.J.R. Thornalley et al., 2018] indicating a slowing of the current. Another data set contained the composition of coral shells near Iceland. How corals build their shells depends on the water temperature and this data set showed a shift in the water conditions in recent decades, indicating a major change in the ocean circulations [P.T. Spooner et al., 2020]. All in all, we looked at eleven different data sets that all indicated that the Gulf Stream system has gotten weaker over the course of the last one to two hundred years, and that both the rate of the slowdown as well as the current low state are unprecedent in this time period [L. Caesar et al., 2021].

While we did not investigate the causes of this recent slowdown, climate models predict that as a result of global warming, the Gulf Stream system will weaken by more than 30 percent over the course of the 21st Century [W. Weijer et al., 2020]. The full list of consequences of this slowdown are still unknown, but already identified impacts include an enhanced sea-level rise at the US east coast [T. Ezer, 2015], increased storminess in north- western Europe [L.C. Jackson et al., 2015] and an increased risks for drought in the Sahel region [D. Defrance et al., 2017]. Furthermore, the continued slowdown will get us closer to a tipping of the Gulf Stream system, a point after which the full collapse of the system is inevitable and possibly irreversible [T.M. Lenton et al., 2008]. How close we do not know, as the exact location of this tipping point is poorly known [M.W. Buckley and J. Marshall, 2016]. Yet given the importance of the Gulf Stream system, it seems a foolish thing to risk.

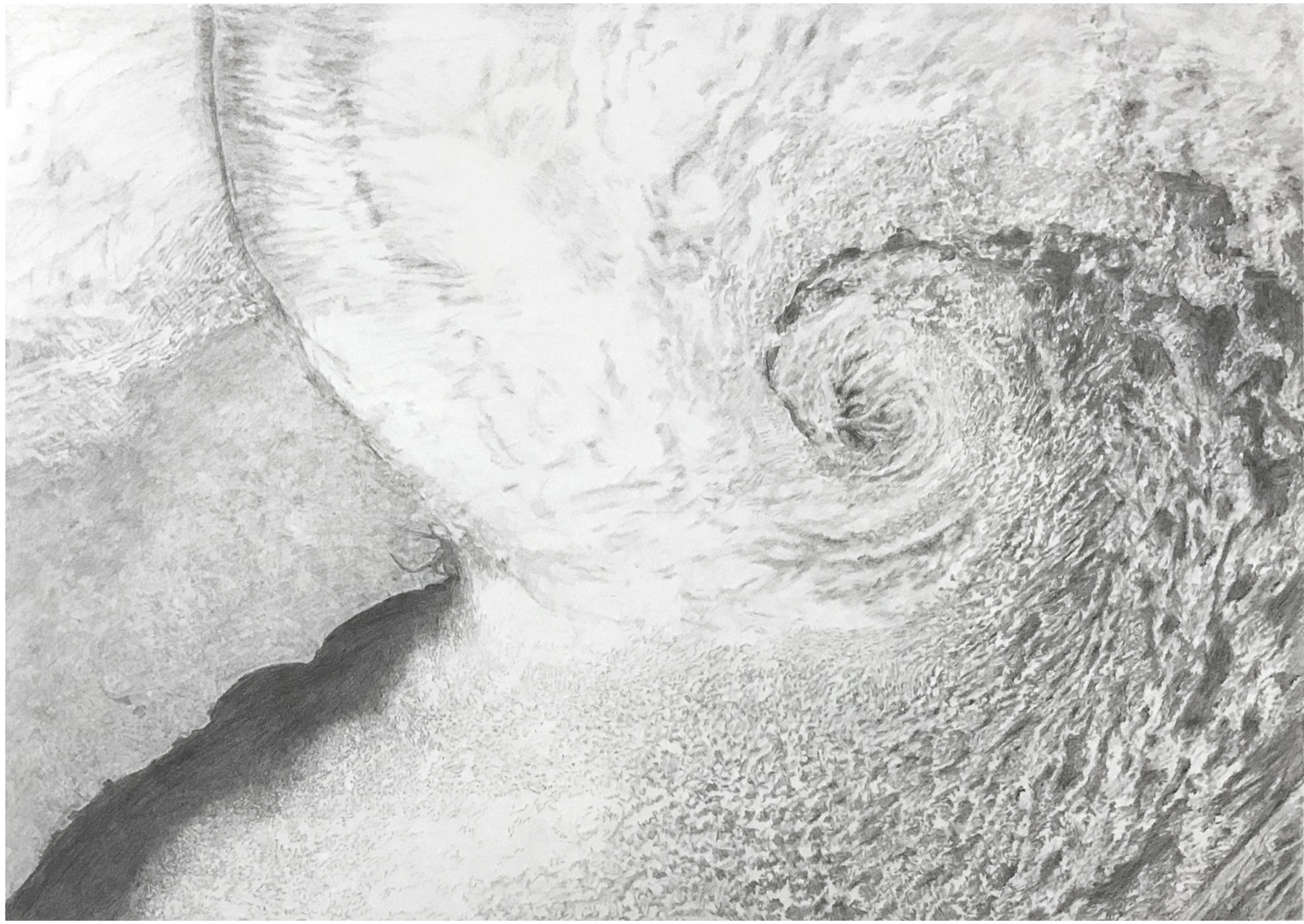
ARTWORK

Timo Herbst

Nor’easter

Timo Herbst is a visual artist from Leipzig and Berlin, Germany. His work explores the choreography of everyday life and politically connotated movements, as well as the use and consequences that bodily movements have for the private person and society. He forms these dynamic spatial systems of social and environmental structures into multimedia installations that use drawing, video and performance.

The winter storm, which rapidly intensifies off of the mid-Atlantic coast, batters coastal areas with a combination of heavy snow, ice, and gusty winds which also cause coastal flooding. The storms are intensifying over an ocean that is (because of climate change) fuller than it used to be.



Buket Yenidoğan

Ritual of rejoin

Buket Yenidoğan is a research-based multimedia artist and speculative designer from Istanbul where East and West melt into each other.

Following a new materialist school of thought under the posthumanist umbrella, she conceives nature, culture and technology as a continuum and explores this continuum forming experimental research inquiries through feelings, senses and speculation. She continuously seeks new narratives on the climate crises by challenging climate anxiety to avoid disavowal and enact behaviour change starting from the subconscious and spiritual realms.

***Ritual of rejoin* investigates a speculative mythology of an oceanic spirituality inspired by the hydro-feminist posthumanism theory. It is about surrender, fear, re-birth and immigration in the context of a society living on the edge of a global flood.**

Lisa Crozier,
Dylan Gomes & Gordon Axel

Will salmon disappear in a warming world?

Lisa Crozier received a Bachelor of Arts degree in Philosophy from Harvard College in 1991. She earned a Ph.D. from the University of Washington Zoology Department, prior to completing a Post-doctoral Fellowship at the University of Chicago studying climate impacts on butterflies and moths. Since 2004, she has focused on climate impacts on threatened and endangered fish, especially salmon, at NOAA's Northwest Fisheries Science Center in Seattle.

Wild salmon are disappearing from the world's oceans, but it is not entirely clear why or how we can stop it. Chinook salmon, also known as king salmon, is the largest species in the family Salmonidae. And yet, most populations in the contiguous United States are threatened with extinction. In addition to the numerous threats these fish face in their freshwater habitat, recent models have revealed that the ocean stage is at substantially higher risk due to climate change. Warming oceans may push numerous populations over the brink toward extinction.

There are management strategies available, such as reducing fishery pressure on salmon prey, reducing the number of hatchery fish that compete with wild salmon, and restoring habitat. We can save salmon, but we must work together to make the changes at the large scale that wild salmon need.

The Problem

Wild salmon are disappearing from the world's oceans, but it is not entirely clear why or how we can stop it. Atlantic salmon from the eastern United States to northern Europe have nearly disappeared from the wild, and many southern races of Pacific salmon that use the high seas could soon face a similar fate. Chinook salmon, also known as king salmon, is among the largest species in the family Salmonidae. And yet, most populations in the contiguous United States are threatened with extinction. In addition to the numerous threats these fish face in their freshwater habitat from human influences, recent models [L.G. Crozier et al., 2021] have revealed that the ocean stage is at especially high risk due to climate change.

How do we know this?

Cooperatively throughout the Columbia River Basin in the northwestern United States, biologists have tagged millions of fish since 1990 so they could be identified individually over their entire lifespan. For the populations studied here (figure 1), it starts by implanting very small transponders in these fish in their first summer, near where they were born. Teams of scientists and engineers have built electronic devices into dams to detect these small tags even in huge spillways as fish travel downstream (as juveniles), and in fish ladders which adults use to move upstream (1-4 years later). We detect these tags many times, especially during migration, so we know the fish is still alive.

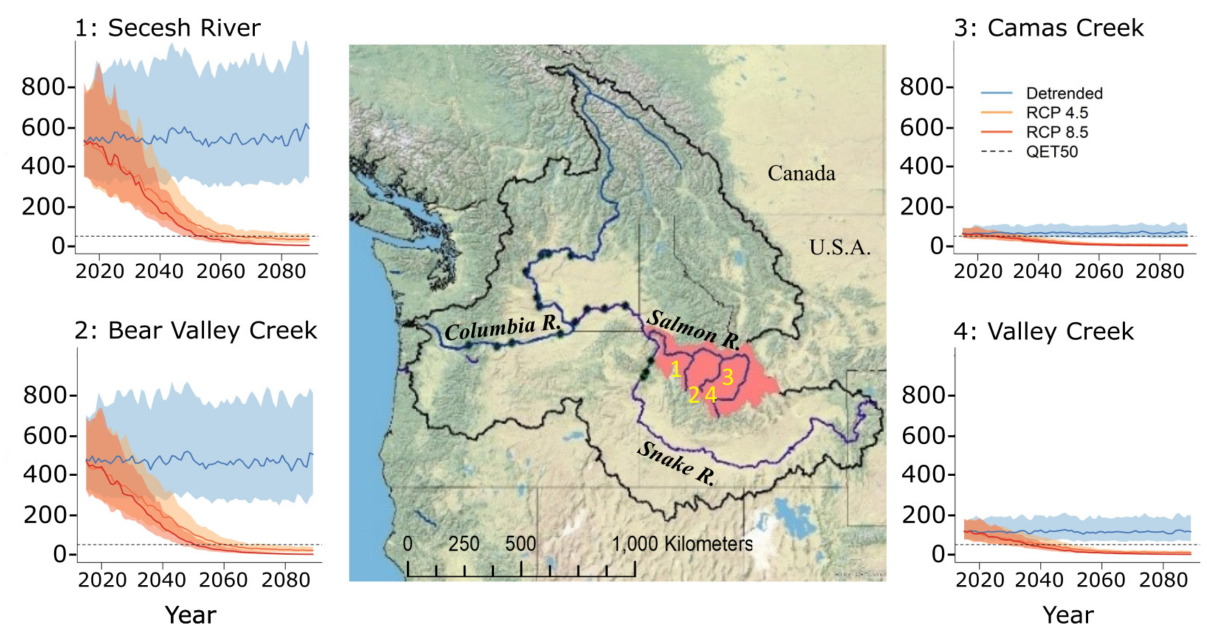


Figure 1. Map of the Columbia River Basin (black outline), with the Salmon River Basin highlighted in red. Model results for four of the populations are shown in the graphs, with locations indicated on the map as 1-4. The graphs show the change in population abundance over time. Solid lines show the median abundance while shading shows the interquartile range of population abundance across simulations for detrended (blue) vs. ensemble-mean global climate model projections for representative concentration pathways (RCP) 4.5 (orange) and 8.5 (red). Each population starts at its current abundance. A reference abundance of 50 spawners, the quasi extinction threshold (QET) is also shown (dashed horizontal line). Adapted from [L.G. Crozier et al., 2021].

This gargantuan effort allows scientists to build complex models of the entire salmon life cycle. These models include information about how many eggs a female of a given age can produce, how many of those eggs hatch, and then survive each year after that. This detailed information allows us to understand where in their life cycle salmon face the greatest threats.

Because we have collected this data over so many years, we can now include environmental variables in these models. Specifically, we are able to characterize how salmon respond to a wide range of environmental conditions in both freshwater and marine habitats. One such model was recently created for populations of wild Chinook salmon that included over 30 years of tag data, enough to characterize likely responses to climate change. These populations belong to the Snake River spring/summer Chinook salmon Evolutionarily Significant Unit, which the federal government listed as threatened under the U.S. Endangered Species Act in 1990. These populations have stabilized since they were protected, but now they face a new threat from climate change.

The fish in these populations migrate in the spring and early summer through the mighty Columbia River. Adults travel 1100-1400 km upstream, and climb up to 2000 m to reproduce in the same relatively pristine wilderness streams in the high mountains of Idaho where they were born. Then they die after spawning.

We have learned that in years with heavy fall rains, more juvenile fish survive until the following spring, where they can get a head start on the migration to the sea. Similarly, higher summer river flows increase the amount of habitat they can access during their prime growing season, helping them survive to the following spring. If they grow to a larger body size in freshwater, they are more likely to survive their perilous ocean stage.

With climate change, fall flows may not change very much on average, although rainfall could come in more intense storms. Fall flows may also increase. Summer flows, on the other hand, will likely reach new lows because of a decrease in summer precipitation, and increased evaporation due to warmer summer temperatures.

Survival during migration also relates to flows and temperatures. After winters with heavy snowfall, a large spring freshet of melted snow carries the juveniles swiftly along their long route to the ocean. The faster they travel in snow-cooled water, the more likely they are to survive the early ocean stage. With a changing climate, more of our winter precipitation will fall as rain rather than snow, causing the spring flows to become smaller and occur earlier in the year.

From the other direction, spring Chinook adults struggle in their migration upstream against raging flows, and they actually have an easier time of it when flows are reduced. Some of the populations included in this analysis migrate a little later than others, toward summer (known as summer Chinook), when stream temperatures start to track air temperatures more closely. Later-migrating fish are at higher risk of encountering stressful temperatures on both their juvenile and adult migrations. To avoid these temperatures, they start their migration earlier as they respond to cues in the environment.

Once salmon reach the sea, they are not free from the impacts of climate change. In the ocean there is a strong correlation between sea surface temperature and their survival. Less than 1% of spring/summer Chinook salmon return to streams as adults after very warm ocean years, as we observed after the marine heatwave of 2014-2016. This is extremely concerning because sea surface temperatures are expected to rise by about 1-2°C by 2060.

Global climate expectations

Global climate models integrate complex physical dynamics to calculate how greenhouse gas emissions are altering the climate. Some models project faster warming than

others, depending on how those models represent the relevant physics. Rates of warming also depend on how much carbon accumulates in the atmosphere. Carbon concentrations in 2100 are about twice as high in the Representative Concentration Pathway 8.5 vs 4.5, which are two possible future scenarios that we explored from the Coupled Model Intercomparison Project organized by the Intergovernmental Panel on Climate Change [R.K. Pachauri et al., 2014].

Part of the novelty of this analysis was our ability to measure the uncertainty in our results that came from differences in climate models. This ability stemmed from direct use of climate projections and the large number of these projections that are now available. Across the two carbon emissions scenarios, we examined 52 projections for ocean conditions and 20-80 projections from hydrological models for freshwater conditions.

A second important step was to link the freshwater and marine conditions in a given year, even though the projections came from different climate model runs. We used statistical methods to ensure that conditions faced by an individual fish tracked the transition from freshwater to the marine environment (and back) according to the appropriate migration timing, so that cumulative effects on an individual fish were correctly calculated.

Simulating salmon populations

We then combined these climate projections with our life cycle models and added random variation in year-to-year weather to simulate possible futures. Within this simulated world, we were able to track the number of fish that were born each year and survive long enough to produce the next generation in eight populations. The size of each population over time is critically important. If a simulated population stayed very small (defined as 50 spawning adult salmon and known as a "quasi-extinction threshold") for four years in a row, then that population is at a very high risk of extinction. This is because small populations are much more likely to go extinct than large populations. But even if populations do rebound from these low levels, there are genetic consequences for populations that pass through such "bottlenecks" in abundance. Genetic bottlenecks shrink the potential for future salmon populations to adapt to new environments.

Although populations randomly grow or shrink in any simulation, the average trend across all populations was stable – as long as we assumed there was no trend in climate (blue lines in graphs in figure 1). In the warming scenarios, however, we saw clear patterns in migration timing and survival. The shifts in timing helped them avoid some of the warming in the large rivers and improved ocean survival above what it would have been otherwise.

Nonetheless, when we imposed warmer sea surface temperatures on our modelled salmon, all populations declined (orange and red lines in graphs in figure 1). Even the largest populations eventually dropped below the dangerous quasi-extinction threshold. Dropping below this threshold does not mean that every population dies out. Some populations bounced back up after another year or two. So the model does not say that all Chinook salmon will be extinct in 50 years. It does say, however, that Snake River spring/summer Chinook salmon appear to be more vulnerable to climate change than most other threats, and we can no longer ignore this risk.

In trying to assess how confident we are in these projections, it is important to acknowledge that there are many unknowns when predicting how environmental conditions for fish will change in response to the full suite of impacts from global change. To be thorough, we did examine several possibilities. One possibility is that ocean productivity could go up. Off the shore of the western U.S., where these populations enter the ocean, winds typically pull surface waters offshore in the spring, which allows nutrient-rich deep water to rise to the surface. This upwelling process is a major reason that so many fish grow well in this region. Some climate models project that these winds will be stronger in the future, which might increase nutrients available for the entire ecosystem. Yet, the possible benefits for salmon will still have to overcome other negative effects of warming seas. In our model scenarios, increasing upwelling did help populations survive longer, but ultimately it did not prevent declines.

Summarizing thoughts

After tagging millions of Chinook salmon and tracking them through major hydropower projects in the Columbia and Snake rivers, we can use life cycle modelling to understand how a changing climate might affect salmon populations. These models demonstrate that survival in the ocean stage is the most vulnerable part of the life cycle (ocean survival declined by 80-90% by the 2060s, figure 2). However, the ocean stage is the part that we know the least about.

Our knowledge gap partly reflects the physical challenge of studying the ocean. But even more importantly, it is because salmon interact with so many other species during this life stage. What makes this endeavor even more challenging is that ocean ecosystems

could change into a new state that is unlike any state we have seen in the past – that is, we might see an "ecological surprise." Many of these possible ecosystems are likely to be less favorable for salmon than the ones we have

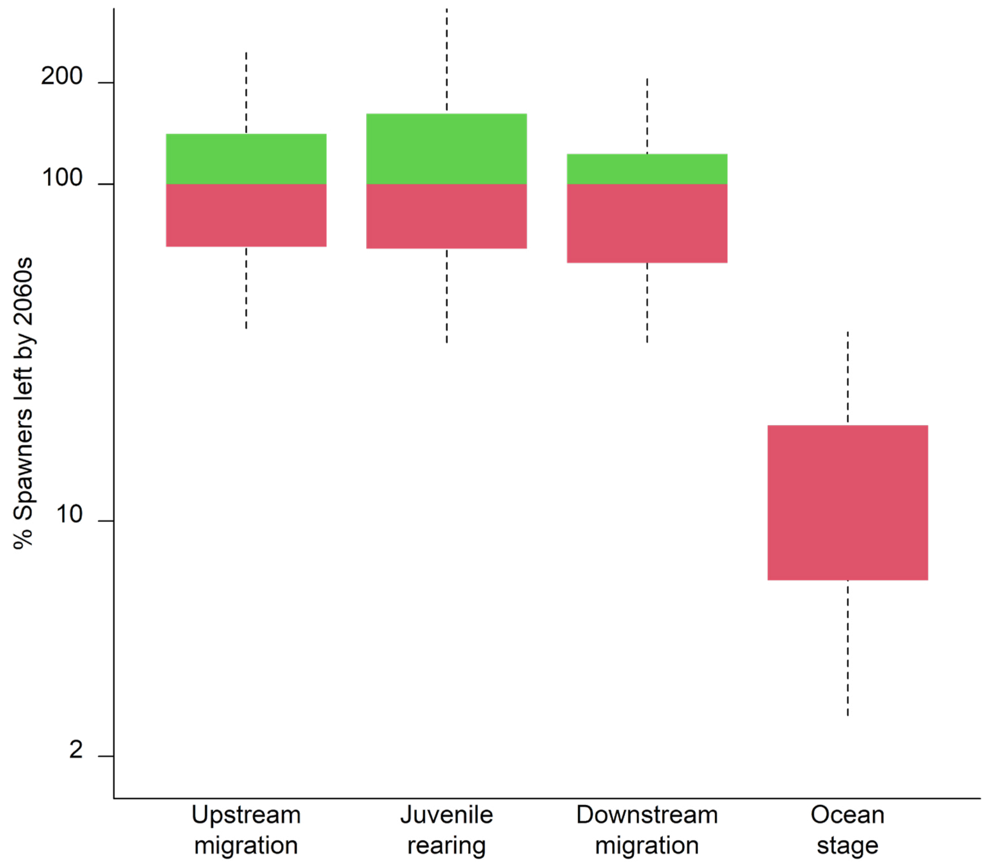


Figure 2. Change in population size in the simulations of all scenarios in which climate change was only included for one life stage of the salmon. If climate change was only included for the three freshwater stages of the fish, the populations increased in some cases (over 100 %; shown in green). In some cases, however, the stocks also decreased (below 100 %; shown in red). However, if climate change was only included in the marine stage, the stocks of all populations declined. The boxes show the range in which 25 % to 75 % of all data of the simulation results of a scenario lie. The dashed line marks the range that covers all results.

modeled. For example, ocean acidification could have ecological or physiological effects on Chinook salmon that reduce their survival or ability to navigate their way home. Furthermore, other species, like jellyfish, are expected to increase in a warming ocean, which might compete with salmon for food.

On the optimistic side, it is possible that some future changes could help salmon to avoid extinction. Many species will change their distributions, and some of them might provide new food sources for salmon. One other option is that warming might occur slower than the average projections we have shown. What actually happens will be like a single simulation, which could go in any direction in the short term. Perhaps simple slowing of further declines will allow us time to improve our understanding of the factors affecting ocean survival, and implement more actions to help them persist. Therefore, it is very important that we do not give up on protecting these threatened species.

Management actions

People have many impacts on the ocean. We usually think of fishing as our primary influence, and we certainly do fish many of the species that salmon eat. Salmon eat krill and the early life stages of crabs and fish of many types, including rockfish, flatfish, herring, anchovy, and sand lance. Many of these species are fished only to support other fisheries as bait, but they could be better left in the ocean. We also affect the habitat where these other species live and reproduce, such as in estuaries and along the coast. Perhaps we are having a greater impact than we currently realize. The plastics and other waste that we produce may be having more profound effects than we now know. We also release billions of hatchery salmon into the north Pacific every year. Hatchery salmon compete for limited feeding areas with wild Chinook salmon. Finally, the sharp rise in marine mammals since they were protected in the 1970s, such as seals, killer whales, and sea lions, has dramatically increased predation on salmon. Those that feed most heavily on endangered salmon but also have other prey choices could alter their feeding areas.

We can also restore freshwater habitats where salmon spawn and grow. The model strongly indicates that freshwater habitat limits the number of juveniles they are able to produce. Much of the historically most productive habitat has been lost to human development, so the remaining habitats are at high elevation and relatively low in nutrition. If we improve existing habitat or increase access to high-quality spawning and rearing habitat, they could produce more young salmon. We could also restore natural stream processes in lower elevations where young salmon grow better, which would improve the ocean survival of individuals, even if the number of juveniles does not increase.

We have learned a lot about how to restore salmon habitat effectively over the past 20 years. We are in a critical position right now where we could cooperate to complete the big projects that salmon need – such as restoring habitat that has already been developed, reconnecting stream channels, reallocating water to remain in streams or cool off underground to create thermal refuges, and removing invasive predators that we have introduced into salmon habitat. We can save salmon. But we have to work together to make these large changes that salmon need. We have no time to waste.

Catherine Euale

Water Warriors: DNA Capsule

Catherine Euale is a textile artist, costume designer, and storyteller. Her work is rooted in eco-feminist principles, ritual encounters, disruptive narratives, speculative design, and challenging systems that are non-compatible with life.

She believes in deepening our connection with the material to raise awareness of our forgotten relationships within more than human worlds. She uses speculative design practices to imagine potentials for resilient and harmonious futures.

***Water Warriors* is a speculative training kit for the future generation of water stewards. A wearable Environmental DNA vial contains information on sampled water and biodiversity of the Great Lakes, the world's largest surface freshwater ecosystem, extracted in 2021 and preserved in a double-sealed sterling silver capsule that keeps it isolated and protected over time.**

The eDNA capsule is accompanied by a short film as part of a 2050 water literacy toolkit. Water stewards will be able to analyze changes in water health by comparing the stored eDNA capsule with extracted samples in the future and use the terms in the short film to understand critical matters of water care.

Julien Masson

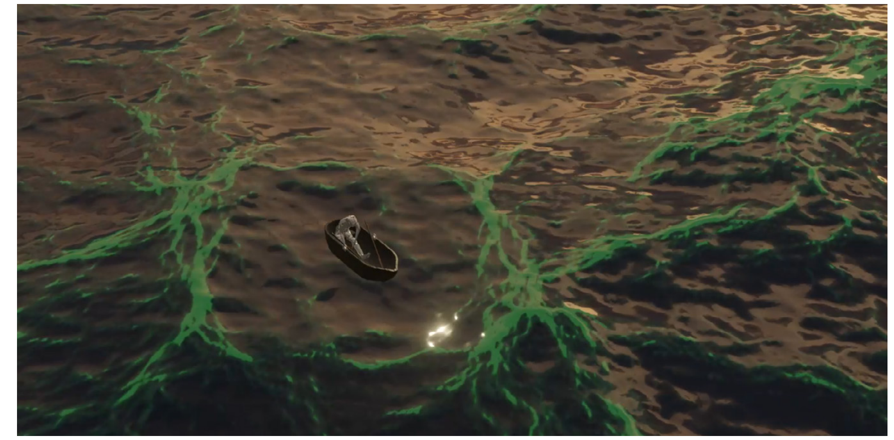
Blooms

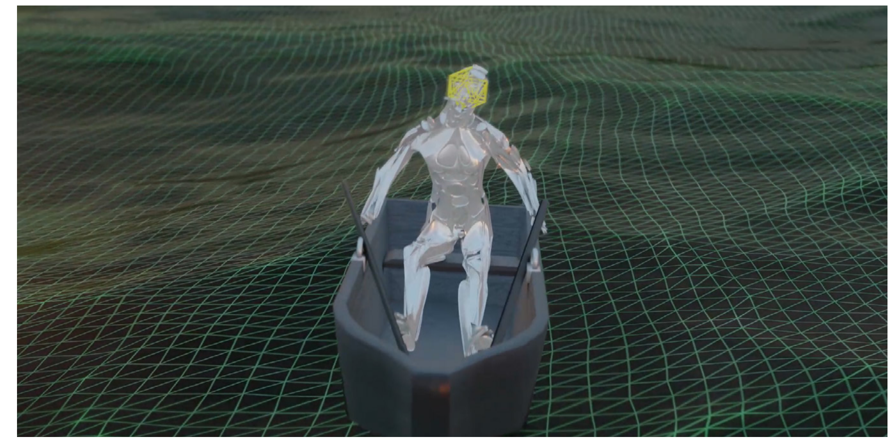
Julien Masson is a multimedia artist with a background in fine art and 3D computer visualisation. Experimentation and innovation are very important in his science- and technology-informed practice. His work aims to highlight the issues of our time and help the debate along. With ecosystems being under increasing strain it is important for Julien to remind the public of the current situation and the risks for the future.

***Blooms* is a reflection on the place and role of humankind in our environment to counterbalance the extreme changes caused by human activities and the ongoing exploitation of natural resources.**

An experimental approach with different techniques and glitches emerging from 3D animation programs generates strange and novel aesthetics, discovering new languages whilst at the same time reminding us of the challenges we are facing in our society.

“Blooms” of microscopic algae occur in a seemingly uncontrollable expansion in the environment. These Algae tides result from large concentrations of aquatic microorganisms dominated by toxic dino-flagellates and diatoms and can severely affect marine habitats. The effects of the so-called bloom events range from shading, to irritating delicate organs of cultured organisms, to producing toxins that may have severe effects on cultivated organisms and human consumers.



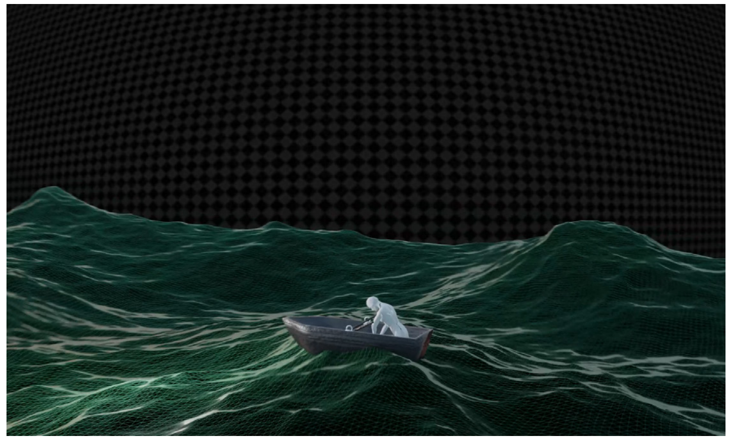


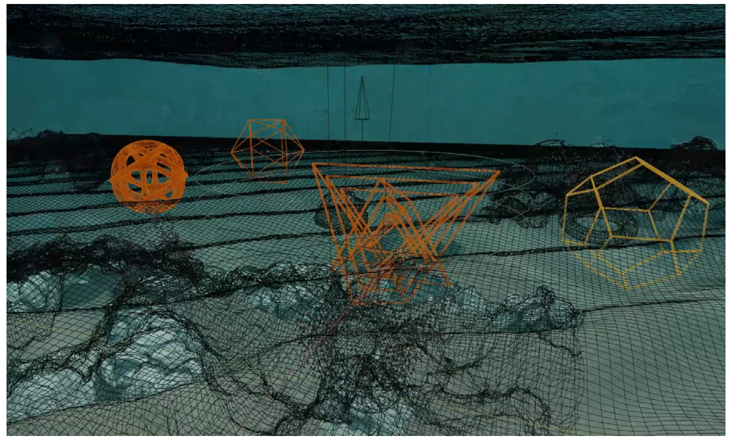
Algal Blooms are mainly found in inshore waters and estuaries and result in subsequent population crashes. Bacterial decomposition may reduce the oxygen in the water. Algae tides are often accompanied by a release of toxins which may poison higher echelons of the food chain. The retention of toxins produced in phytoplankton blooms can have a range of harmful effects on fish, shellfish and humans. Whereas some toxins disappear from shellfish soon after the bloom has subsided, other toxins can remain in the environment for months. The toxins are a health hazard but also the source of severe economic loss.

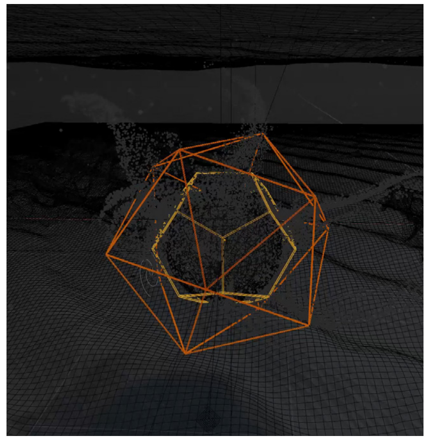
Some diatoms have spines that irritate the gills of fish and shellfish. They may cause lesions and encourage infections in fish raised in pens. The Chrysophyte alga's bloom events, also known as brown tides, have a direct toxic effect on shellfish, while also blocking the sunlight and causing harm to other phyto-plankton.

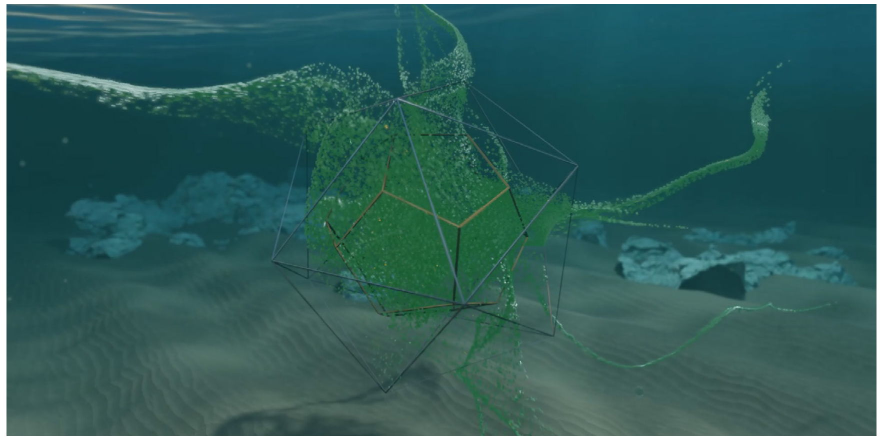
Toxic algal blooms are on the rise all around the world and the frequency and number of localities have increased considerably over the past few decades. The possible reasons for this change can be caused by an increase in coastal nutrient or general water pollution (be it for domestic, industrial, or agricultural resasons or for an increase in mariculture). This often results in local release of large quantities of nutrients and may cause distur-bance to local habitats and thus stimulating harmful algal bloom growth.

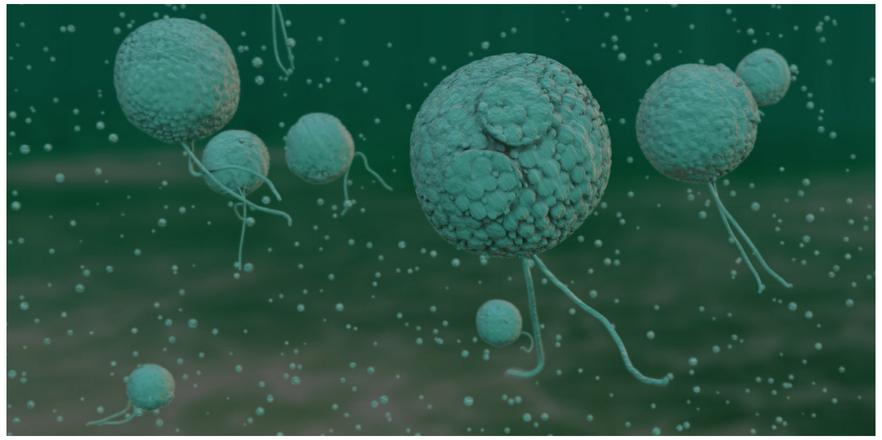
Interestingly Oceanographic processes can be an important factor in causing harmful blooms. And some Dinoflagellates have resting states that can survive in sediment for many years. Given the problematic effects of algae blooms, there is urgent need for rethinking water systems globally.

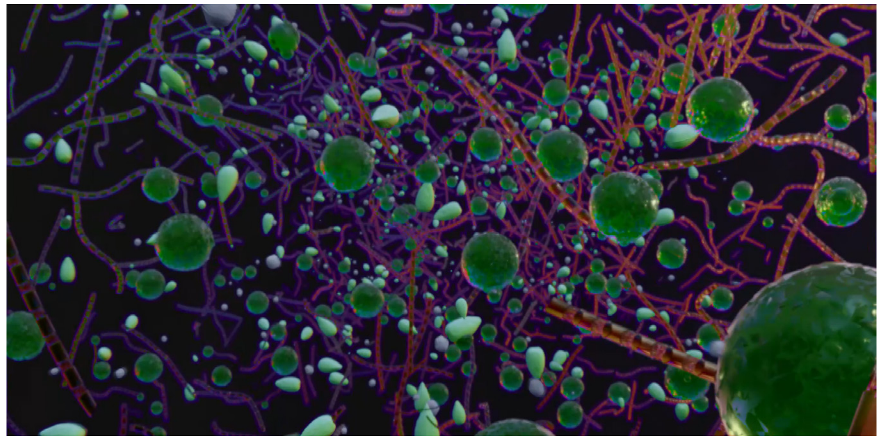












Barbara Neumann, Lina Röschel,
Ben Boteler & Sebastian Unger

Beyond curbing emissions – Possible approaches from the ocean to support attainment of global climate goals

Barbara Neumann is a senior research associate in the Ocean Governance Research Group at the Institute for Advanced Sustainability Studies (IASS) in Potsdam, Germany. Trained as geographer, she loves all things "geography" between mountain tops and the deep ocean. As a researcher, she aims to better understand the complicated relationship between people, planet and ocean, and to identify pathways towards a more sustainable future.

Lina Röschel is a research associate at IASS, a budding expert on governance of the ocean-climate-nexus and works with Barbara on the critical topic of "negative emission technologies". Ben Boteler spends his days thinking about how to protect and conserve high seas biodiversity and is a scientific project leader at IASS. Sebastian Unger leads the Ocean Governance Research Group at IASS and works to gain insights and advance governance processes for the conservation and sustainable use of the ocean.

Experts have warned that cutting emissions alone may not be sufficient to address the impacts of climate change and further action may be necessary if global climate goals are to be met. An essential part of the Earth's climate system, the ocean could offer a range of options for climate mitigation, amongst others through its ability to sink carbon dioxide from the atmosphere. This paper discusses the benefits, risks and governance challenges of two different groups of approaches that aim to enhance the ocean's carbon sink function: So-called 'blue carbon' approaches that come with a range of co-benefits for environment and human well- being but require rapid onset and long-term strategies to be effective; and more technological approaches such as ocean alkalinization which promise rapid responses, but potential risks for the marine environment are still unclear and appropriate governance is lacking.

Achieving the goals of the Paris Agreement will not be easy – but the ocean offers opportunities

The IPCC 2019 Special Report on the Ocean and Cryosphere in a Changing Climate [N.L Bindoff et al., 2019] is a call to action to global policy makers and the public to urgently address the devastating effects of climate change on the ocean. And in 2021 there is reason to hope that at least some are listening: with the Biden Administration taking office, there is encouraging new leadership and commitments from the United States to the Paris Agreement [M. McGrath, 2021]; the EU is now aiming to be climate-neutral by 2050 and create an economy with net-zero greenhouse gas emissions as part of its Green Deal and in line with its commitments to the Paris Agreement [European Commission, 2018; European Commission, 2019]; China, the world's biggest source of carbon dioxide and responsible for around 28% of global emissions has declared that it aims to hit peak emissions before 2030 and achieve carbon neutrality by 2060 [D. Normile, 2020]; and after a ruling of the federal constitutional court in Germany declared in 2021 that the government had failed to set out how it would bring carbon emissions down beyond 2030, officials announced the country would aim for a 65% cut in carbon emissions by 2030 and 88% by 2040 – and nearly net zero emissions by 2045 [Reuters, 2021].

But these goals will not be easily met without innovative approaches – and ambitious but prudent leadership. First and foremost, climate change must be tackled at its root and global emissions must be cut. But science suggests that the goals of the Paris Agreement [UNFCCC, 2015], particularly the 1.5°C goal, can only be achieved if further action is taken in addition to cutting emissions, including through approaches to actively remove carbon dioxide from the atmosphere [M.G. Lawrence et al., 2018; J.C. Minx et al., 2018; J. Rockstrom et al., 2017; J. Rockstrom et al., 2016]. The ocean offers a range of possible opportunities for climate mitigation, but these come with challenges and risks that must be considered from different perspectives [J.-P. Gattuso et al., 2021; O. Hoegh-Guldberg et al., 2019].

Ocean approaches to tackling climate change – opportunities with challenges

Representing an inextricable component of the Earth's climate system, the ocean is a global climate regulator – but it is also highly vulnerable to changes in the climate system [M. Visbeck and S. Keiser, 2021; IPCC, 2019]. As a result of unabated global warming and increasing levels of human-induced greenhouse gases, researchers note ocean warming and increasing frequency and intensity of marine heat waves, acidification as well as deoxygenation of ocean waters, melting of sea ice, rising sea-levels, and shifts in ocean currents [IPCC, 2019; N.L Bindoff et al., 2019]. These ongoing changes will likely result in losses to biodiversity across the globe and have far-reaching effects for human well-being [G.G. Singh et al., 2019; B.S. Halpern et al., 2019; N.L Bindoff et al., 2019], but the close linkage between ocean and climate can also provide valuable opportunities. One of the most important is possibly the ocean's ability to capture carbon dioxide from the atmosphere and store it in seawater, biomass and sediments [C. Zhang et al., 2018]. It is estimated that between 25% and 30% of all human-induced carbon emissions are absorbed by the ocean today [IPCC, 2019; N. Gruber et al., 2019; A.J. Watson et al., 2020].

The ocean's carbon sink could be a key piece in the puzzle towards combatting climate change. The restoration and long-term upkeep of 'blue carbon ecosystems', i.e., ecosystems that store carbon in their biomass and sediments such as mangroves or seagrasses, provides opportunities to effectively reduce global warming [C.M. Duarte et al., 2013; Y. Zeng et al., 2021]. In addition to their role in mitigating climate change, these natural ecosystems provide a plethora of further benefits to local communities and beyond [D.A. Friess, 2016]. They can enhance biodiversity and ecosystem functions, e.g., by improving water quality or providing nursing habitats for important species that can spill over into fishing grounds. Furthermore, blue carbon ecosystems increase resilience to climate change impacts both of the marine environment and of coastal communities, e.g., by offering protection against storm surges [I. Möller et al., 2014; N. Leonardi et al., 2018]. These multiple benefits could also make their implementation and upkeep attractive for stakeholders and funding mechanisms beyond those related to climate mitigation efforts, including biodiversity conservation, development cooperation, and financial investment mechanisms [L. Wylie et al., 2016]. Another approach to secure the global carbon sink of the ocean is to conserve carbon rich sediments in the open ocean. This could be done by identifying areas with especially carbon rich sediments and restricting activities that potentially harm the seafloor and disrupt and release stored carbon such as bottom-trawling [E. Sala et al., 2021].

But the implementation of policies and measures aimed at the restoration and/or preservation of blue carbon ecosystems will require step changes in ocean management, as marine and coastal ecosystems that store carbon, such as coral reefs or mangroves, will only maintain their function if not lost over mismanagement, economic exploitation and other human pressures [M. Waycott et al., 2009; C.E. Lovelock and R. Reef, 2020; M.A. Vanderklift et al., 2019; L. Wylie et al., 2016]. But the consistent upkeep of these ecosystems is crucial as the full delivery of the benefits at their maximum global capacity will require years to decades to be achieved. To be effective, the strategic establishment of blue carbon habitats for climate mitigation must not only be built on long-term commitment but also start as early as now [C.A.J. Girardin et al., 2021; L.K. Reynolds et al., 2016].

Restoring marine nature for the benefit of humankind as is the case for blue carbon approaches is largely associated with clear benefits and comparably few risks – or, in the words of Gattuso et al. [J.-P. Gattuso et al., 2021], a 'low regret' option. Another group of approaches aims to mitigate the effects of climate change through technological enhancement of the ocean's natural carbon sink. These more technical ocean-based 'negative emissions technologies' range from theoretical ideas to mesocosm experiments and pilot studies and include concepts such as artificial upwelling of carbon-unsaturated ocean water of the deep sea, dumping of carbon-rich biomass to the seafloor for long-term storage, or electro-chemical alterations to the seawater to enhance carbon uptake such as through ocean alkalinity enhancement [P. Boyd et al., 2019; J. McGee et al., 2018]. Ocean alkalinization, in its most basic description, is an approach that involves adding alkaline substances to seawater to increase the pH of the seawater and by that enhance the ocean's capacity to take up carbon dioxide from the atmosphere [A. Lenton et al., 2018; S. Gore et al., 2018]. These substances could include minerals, such as olivine, or artificial substances, such as lime or some industrial by-products [P. Boyd et al., 2019; P.A. Davies et al., 2018].

The economic feasibility of mining such substances on the global scale would be tied to process integration into e.g., the cement industry, while the shipping sector might develop interests in deployment through their fleet of bulk carriers [M. Butenschön et al., 2021; S. Caserini et al., 2021]. Ocean alkalinity enhancement may potentially deliver additional wanted effects such as countering ocean acidification and its effects on calcifiers (such as corals), enhancement of the ocean's biological pump and the option for co-producing hydrogen for energy [R. Albright et al., 2016; E.Y. Feng et al., 2017].

The benefits many of these technologies offer, however, are countered by uncertainties and unknowns that come with risks to alterations to the natural ocean system, especially on the global scale. Ocean alkalinity enhancement, for example, has been linked to diverse risks such as contamination through toxic trace elements in alkalinizing minerals, complex unknowns in terms of altered food-web interactions and uncertainties of transboundary ecologic, economic, and socio-political effects [P. Köhler et al., 2013; S. Fuss et al., 2016; S Fuss et al., 2018; L.T. Bach et al., 2019]. Also, these technologies for removing carbon dioxide from the atmosphere have emerged conceptually rather recently, meaning they have not been adequately tested or tested at scale and therefore their effects are not fully understood by researchers as well as policy makers [J. McGee et al., 2018; P. Boyd et al., 2019; G.F. Nemet et al., 2018; S. Fuss et al., 2016]. This also means that regulations and rules for such technologies, even in the testing phase, lag behind the technologies themselves. This lack of scientific understanding and policy framework to govern exploration of such technologies require severe caution before proceeding. Policy making needs to be proactive because without appropriate governance arrangements, research and deployment of these technologies might take place in a political and legal grey area. This is especially the case because the economic interest of private companies in these technologies may increase as their potential for carbon offsetting is realised.

Ocean approaches to support climate goals – stay optimistic, proceed with caution

While some experts include both blue carbon and technical approaches as 'negative emission technologies', others make a clear distinction between the two and describe blue carbon as a 'nature-based solution' [C. Albert et al., 2017]. The latter recognises an important aspect that must not be forgotten when aiming to take action against climate change: Different ocean-based approaches offer varying effectiveness, benefits and trade- offs, and risks and uncertainties. This determines their relevance for climate policy as well as their governability, i.e. "… the potential capability of the international community (both nation states and international non-state actors) to implement them …" [J.-P. Gattuso et al., 2021]. Nature-based solutions such as blue carbon also pose complex governance issues, but these are more tied to questions of actual management and finance, integration of sectors or involvement of relevant stakeholders at the local to regional scale [J.-P. Gattuso et al., 2021]. They even have the potential to deliver synergies for complex nexus issues across different regulatory frameworks, e.g. for the climate, biodiversity and ocean [UNFCCC SBSTA, 2021]. Where trade-offs or disservices occur with blue carbon approaches, they will likely happen at a smaller scale and come with less risks and uncertainties for the marine or coastal environment than with negative emission technologies. Often critiqued as fragmented and not fit for purpose [W. Watson-Wright and V.J. Luis, 2019], the legal and institutional framework in place to regulate and govern human activities in the ocean will be further challenged by approaches that entail unclear risks or management requirements, that could potentially counteract other policy goals such as biodiversity conservation.

Although described with a relatively low effectiveness in terms of carbon uptake [J.-P. Gattuso et al., 2021; N.L Bindoff et al., 2019], restoration and conservation of carbon rich marine ecosystems has the potential to create synergies for climate and biodiversity action, and a range of benefits for humanity. Such approaches could even be described as a no-regret option as their implementation, to the current understanding, will not have detrimental effects even if employed at larger scale. However, to reach their full potential, these approaches require careful long-term management, clear mitigation goals, capacities and cost-effective financing mechanisms [L. Wylie et al., 2016]. In future, more technologically oriented approaches such alkalinization may provide additional potential for sinking carbon in the ocean. But since most of these negative emission technologies are far from being sufficiently understood and regulating frameworks are for the most part not yet in place. And the unknowns and complexities associated with these technologies entail considerable risks.

There is much to learn and understand before informed decision-making is possible on whether a possible future and larger-scale implementation of approaches like ocean alkalinization is advisable and feasible. If done properly, these approaches could support progress towards carbon neutrality and net-zero goals. Nonetheless, if the deployment of such technologies is to be part of a future reality to reach the global climate targets set by the Paris Agreement, there needs to be an integrative strategy in place that brings together climate and biodiversity conservation goals – as well as other global policy goals put forward by the 2030 Agenda for Sustainable Development [United Nations, 2015]. Climate change is, in fact, one of several planetary boundaries that define the 'safe operating space' for humanity – and they are all interconnected [K.L. Nash et al., 2017; S.J. Lade et al., 2020; W. Steffen et al., 2015]. Thus, when embracing ocean-based approaches to tackle climate change, the ocean must not only play a central role in climate policy and governance. Policymakers and governments must be proactive about these new technologies and their implications to ensure that any future deployment is in line with agreed goals and accepted principles and norms of good governance.

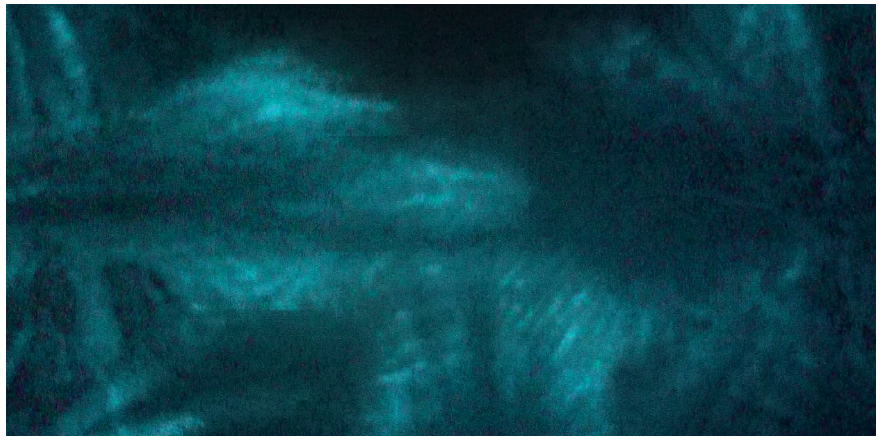
Pauline Hegaret

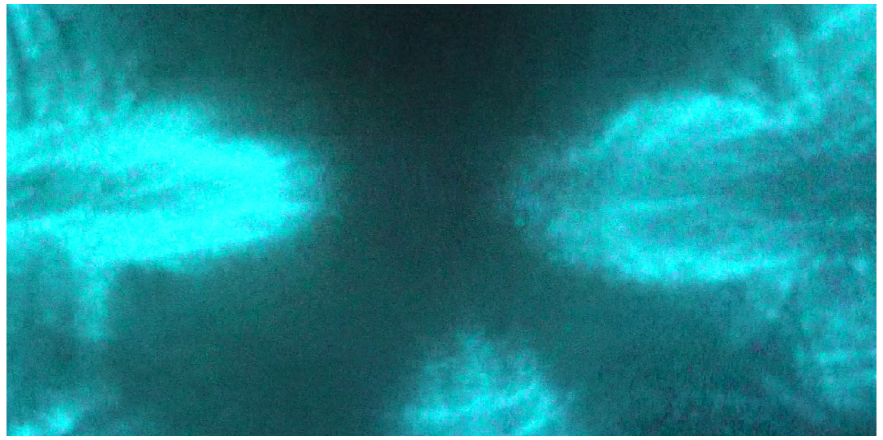
Solar Bloom

Pauline Hegaret is a digital and visual artist. She creates devices that question our relationship to the world through the prism of cultural, cognitive and sensory anthropology.

The project is a scientific collaboration with Hélène Hégaret, CNRS Researcher at the Laboratory of Sciences of the Sea Environnement LEMAR. She is specialized in Physiology, bivalve interactions, toxic microalgae.

These months of March and April 2021 massive bloom episodes take place in Chile and California. In Chile the purple water causes the death of millions of animals by hypoxia, while in California the red water produces bio-luminescent waves at night. These phenomena are caused by climate change, as well as other parameters and variables: water warming, sediments, upwelling, currents, nitrogenous discharges (nitrate, ammonia, nitrogen) related to human activities. In 2016, a global bloom phenomenon appeared: human nitrogenous discharges and the El Niño climatic phenomenon were blamed. In 2021, it is the La Niña phenomenon that causes the phenomenon of upwelling (rising nutrients to the surface) that allows the emergence of these blooms with dizzying dimensions.





Marie-Julie Bourgeois

Toxic Algal Bloom

Marie-Julie Bourgeois is a digital artist. Her research focuses on physical and perceptual human activities. She questions our relationship to technology and natural rhythms.

In an aquarium the micro-organisms are subjected to external stimuli produced by sound waves.

During the day the red cluster is powered by sunlight, it moves around the aquarium and reflects the luminous and architectural forms induced by human action. In the night phase, sound variables cause bioluminescence. Luminous geometrical forms appear on the surface of the tank and reveal a poetic of plankton, based on what is supposed to be its defense mechanism against other animal species.

Animal sound recordings are broadcast in real time at the bloom. While other recordings from machine/industrial productions are alternatively broadcasted. Luminous and diversified reactions are drawn and observed. These captures and compositions reveal the current issues related to the study of underwater acoustics and human intervention in the marine space.

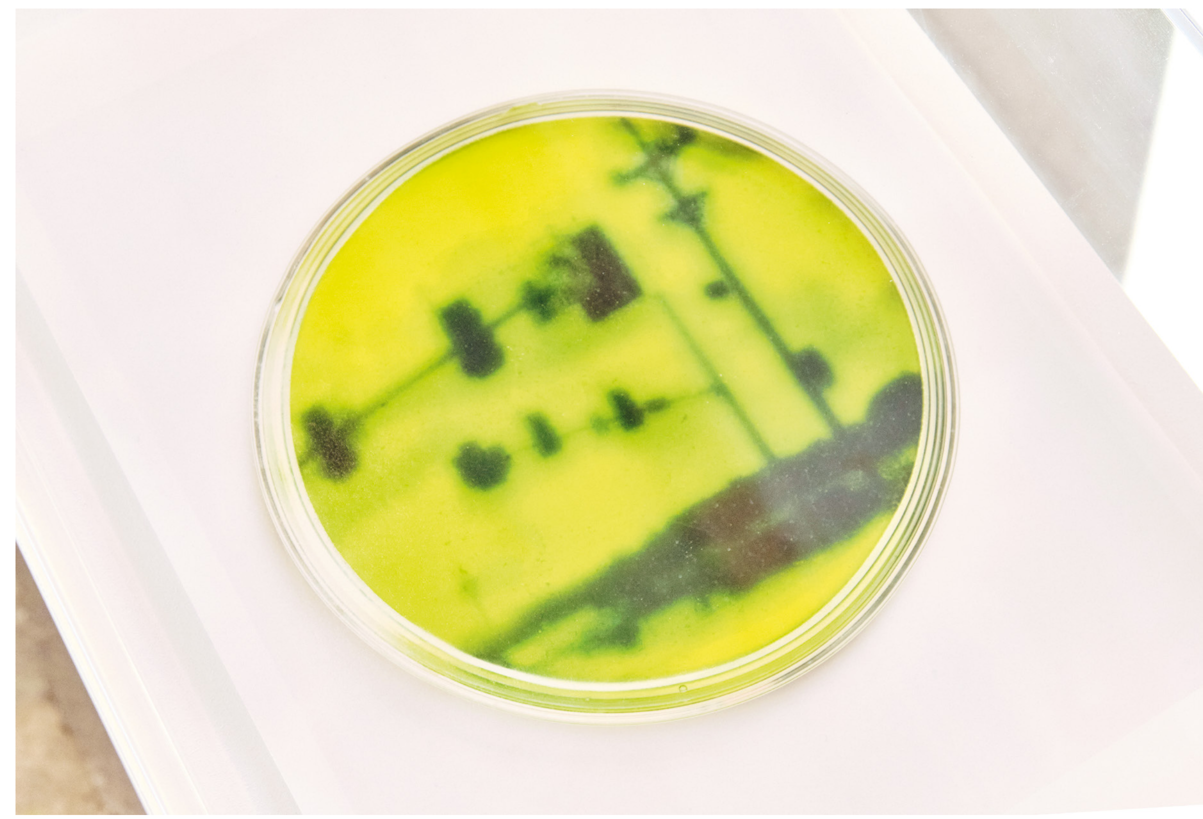
Kari Varner

Monett & Sedalia

Kari Varner explores representations of the landscape through the photographic image. Her current practice focuses on the role that industrialized agriculture and the channelization of our waterways have in profoundly altering our land and water. The ongoing series "Monett & Sedalia" uses Algae to generate images that explore the negative impacts of intensive animal farming and their contributions to annual algal blooms in the Gulf of Mexico.

In the series Monett & Sedalia photographs depicting two Tyson chicken plants and the surrounding waterways have been grown in the microalgae Chlorella Vulgaris. Tyson is one of the largest contributors to the dead zone that forms annually in Gulf of Mexico. These images grown in algae explore the fragility of nature and ongoing impact that industrialized agriculture has on our waterways.

"My practice, form and content are inextricably linked. The use of algae as photographic material acknowledges the mutability and vulnerability of nature. The images are ephermeral and rely on nitrogen rich environment to grow. The overabundance of these same nutriets nitrogen is one of the main drivers of dead zones around the world. This series of photographs is implicated in this delicate and continuous cycle of unsustainable growth and death perpetuated by the practices of industrialized agriculture and factory farming."



Cinzia Corinaldesi,
Sara Canensi, Antonio Dell'Anno,
Michael Tangherlini, Iole di Capua,
Stefano Varrella, Trevor J. Willis,
Carlo Cerrano & Roberto Danovaro

Microplastics in the oceans: the many ways they can harm coral life

Cinzia Corinaldesi is professor of Marine Biology and Applied Marine Ecology at the Polytechnic University of Marche (Italy). She investigates the effects of climate change and other human impacts on marine life trying to identify eco-compatible solutions. She has published > 110 articles in international journals (including Nature, PNAS, Science Adv, Nature Ecol & Evol). Recently included by Expertscape in the 50 top world scientists for Oceans and Seas' Science.

Sara Canensi, Antonio Dell'Anno, Michael Tangherlini, Iole di Capua, Stefano Varrella, Trevor J. Willis, Carlo Cerrano and Roberto Danovaro are scientists working to ensure a sustainable and healthy future for our oceans.

Microplastics are one of the main threats to marine ecosystems, but the mechanisms determining their impact on marine life are still largely unknown. We investigated the impact of microplastics on the red coral, an emblematic and threated species belonging to the Corallium genus, which is distributed at almost all latitudes and depths. We report here that microplastics are ingested and accumulated by corals (preferentially polypropylene and polystyrene), either directly (as microplastics are confounded with the plankton, which is the coral prey) or through the ingestion of zooplankton containing microplastic particles. Once ingested, microplastics cause multiple biological effects, spanning from feeding impairment and mucus release. Microplastics also cause DNA damage and a shift in the coral microbiome that together with their tissue abrasions, favour the proliferation of opportunistic/pathogenic bacteria. Since microplastic contamination is expected to double in all oceans from 2030-2060, we anticipate that their impact will likely increase in the future, with the potential of causing coral death. The effects reported on the red coral could be similar on many other habitat-forming species and may act in synergy with other stressors, potentially exacerbating the impacts of heat waves and other climate-driven events.

Microplastics in the oceans: real threat to marine life?

Microplastics (i.e., particles <1 mm) [N.B. Hartmann et al., 2019; M.A. Browne et al., 2015] are recognised as a potential global threat to marine life and ecosystems. These particles can be similar in size to the prey of various marine organisms [S.L. Wright et al., 2013], so that they are mistaken for their natural food and ingested, with negative effects on different forms of marine life, from the tiny zooplankton to the large fish and sharks, at all latitudes and depths down to the life inhabiting the seafloor [C.M. Rochman et al., 2016;

K.L. Law, 2017; T. Kögel et al., 2019; H. Ma et al., 2020]. The huge plastic contamination of the oceans can also alter the whole ecosystem functioning. However, so far the biological mechanisms through which microplastics affect marine life remain largely unknown. Microplastic concentrations are not homogeneous in all seawaters, and can vary widely in marine ecosystems. Thousands of particles per m3 of seawater have been found in some coastal marine areas [N.N. Phuong et al., 2016; H.S. Auta et al., 2017; I. Paul-Pont et al., 2018] and current estimates indicate that these concentrations can be several orders of magnitude higher [J.A. Brandon et al., 2020] and are predicted to double by 2030 [A. Isobe et al., 2019]. In addition, the impact of microplastics over-imposes to many other direct and indirect impacts, including the impact of climate change.

The red coral (Corallium rubrum) is one of the most known, emblematic and threated species of the world. The genus Corallium is an ecosystem engineer, distributed at almost all latitudes and depths, from Antarctica to the equatorial latitudes and is widespread in the Mediterranean Sea [A.W. Bruckner, 2009; A.W. Bruckner, 2014; N.E. Ardila et al., 2012].

These characteristics and the very long life span (more than 200 years) make C. rubrum an ideal model to investigate the effects of microplastics on marine life and habitat forming species.

How did we investigate the impacts of microplastics?

We exposed red corals to different levels of microplastic contamination, spanning from those present in some contaminated coastal areas to those predicted for some seas and oceans in the next decades (2030-2060; [A. Isobe et al., 2019]). We used the same microplastic polymer composition reported from the marine environment, including polypropylene and polystyrene, which are used to produce disposable plastics (i.e., containers, bottles, cups, pipes; [I. Paul-Pont et al., 2018]) in order to simulate the natural conditions.

We conducted a wide array of analyses to investigate the microplastic impact on coral feeding, defence against stress, tissue integrity (due to the physical contact with these particles), molecular response (i.e., gene expression and DNA damage), and the effects on the coral-associated microbiome (i.e., bacteria living in symbiosis with coral epidermia). We also investigated the accumulation of microplastics by the red corals, and the microplastic transfer from the preys to the predators (i.e., small crustacean larvae falling in the same size range of microplastics).

The sneaky taste of the plastics: stimulating hunger while short-circuiting all biological mechanisms

While corals unexposed to microplastics continued to feed without any sign of stress, the feeding activity of the corals exposed to microplastics decreased significantly with increasing microplastic concentration. After an initial stimulation of coral feeding activity, since microplastics contain phagostimulants (i.e. substances enhancing appetite), feeding activity declined and almost completely ceased at high microplastic concentrations. This response was the result of a sort of food congestion due to microplastic particles ingested [M. de Oliveira Soares et al., 2020]. At the end of the experiment, hundreds of microplastic particles (particularly the polypropylene) accumulated within each branch of red corals exposed to high microplastic concentrations. The ingestion of microplastics (particularly polystyrene) was also observed for crustacean larvae which are preyed by red corals, and by many other consumers/predators of the oceans.

These findings indicate that microplastics can be accumulated either as a results of the direct (through direct feeding) and indirect (through predation on plankton) ingestion processes, which increase the risk of microplastic accumulation and contamination to the highest trophic levels.

The dangerous touch of the microplastics

After 1 week of experiment, more than 20% of the coral tissue was damaged, and more than 50% of coral tissue was furrowed after two weeks, with profound lacerations which reached also the coral skeleton (figure 1). These abrasions can cause tissue necrosis [J. Reichert et al., 2018]. Regeneration mechanisms can rapidly repair small lesions of coral tissue, but healing time increases proportionately to the extent of the lesions [R. van Woesik, 1998]. In mass mortality events, tissue necrosis (with large portions of naked skeleton) have been documented in red corals and other species [C. Cerrano et al., 2000; J. Garrabou et al., 2001; J. Garrabou et al., 2009]. The mechanical abrasions observed in our study could contribute to the start of necrosis.

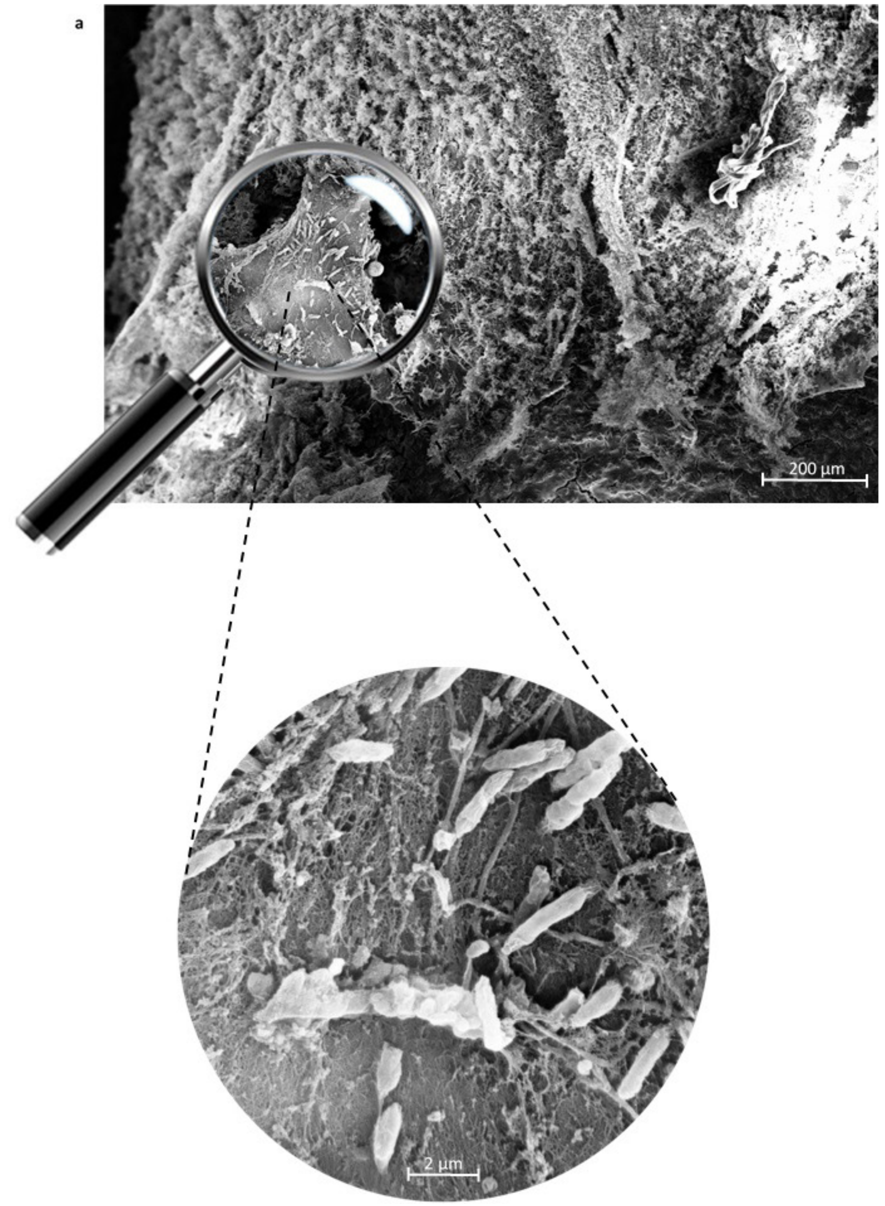


Figure 1. Damage of the red coral tissue caused by microplastic contamination. a) Tissue lacerations observed by Scanning Microscopy Analysis (SEM), and b) close-up of the coral tissue with lesions densely colonized by bacteria.

From a simple "flu" to the coral DNA damage

The first visible negative effects of microplastics on Carallium rubrum was the release of huge amounts of mucus, just like our flu, which is used by corals to create a protective barrier against adverse environmental conditions [B. Glasl et al., 2016; J. Reichert et al., 2018; C. Martin et al., 2019; J.A. van de Water et al., 2018]. Mucus produced by the red corals entrapped the microplastic particles along with bacteria, with amounts increasing with the increase of particle concentrations (figure 2). As a result, in a few days, the health status of the red corals worsened as demonstrated by the oxidative DNA damage and alteration of the expression levels of genes crucial to guarantee the coral defence system against stress and toxic compounds [Y.D. Louis et al., 2017; A.M. Tarrant et al., 2014].

Figure 2. Red coral (Corallium rubrum) exposed to the highest microplastic concentration enwrapped in mucus.

Photograph © Ettore Moretti

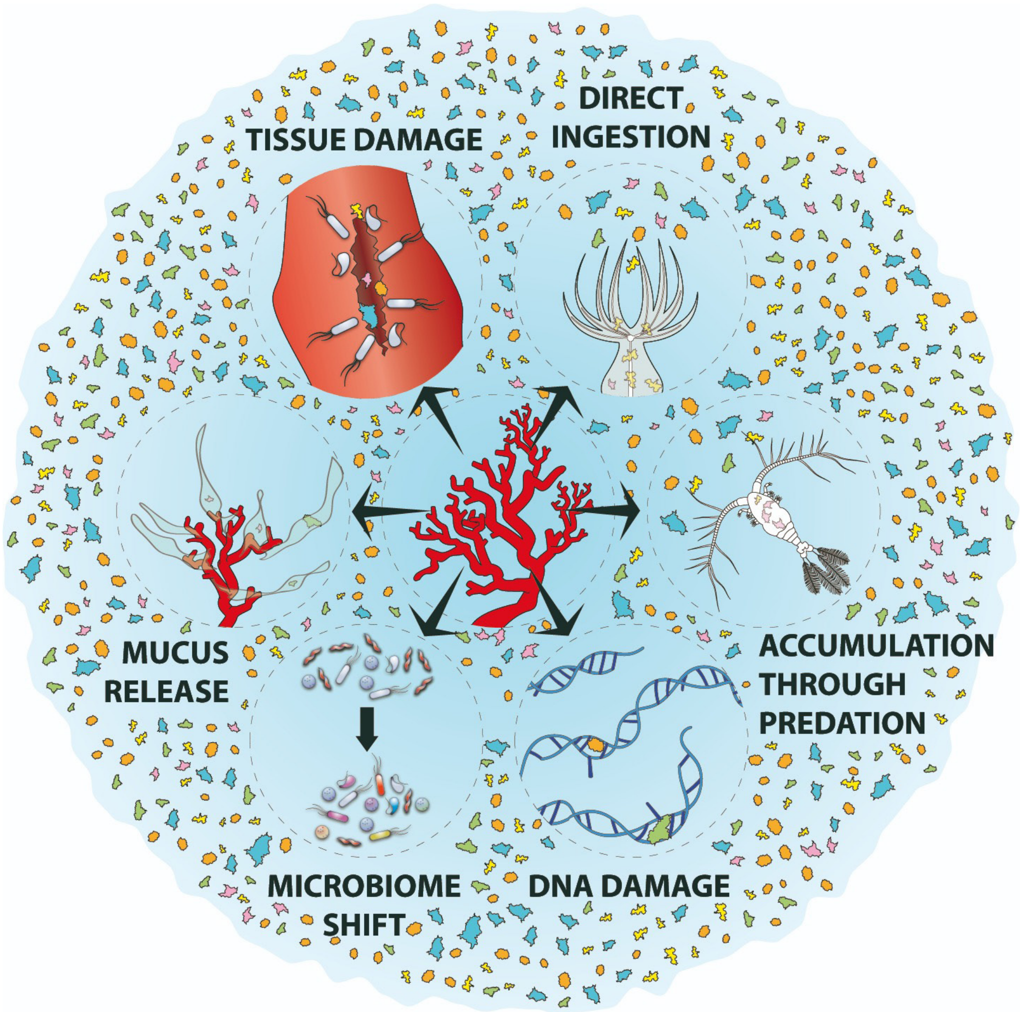


Figure 3. Conceptual model of the multiple biological and physical impacts of microplastics on the red coral. Microplastics can: accumulate within corals through direct ingestion or indirectly through predation, physically damage coral tissue, cause stress as demonstrated by the enormous release of mucus, affect DNA integrity, and cause displacement of the natural microbiome of the coral epidermis. The combination of all of these processes can ultimately cause coral mortality.

Microplastics affect the coral microbiomes and skin

Microplastic contamination caused the increase of bacterial contamination and coral tissues were densely colonized by large microbial cells, which surrounded the lesions and induced a shift of the coral skin microbiome [J.A. van de Water et al., 2018]. The bacteria of the family Spirochaetaceae and Endozoicomonadaceae, which are typically associated with healthy red corals [J.A.J.M. van de Water et al., 2016; J.A. van de Water et al., 2018], strongly decreased or even disappeared in the corals impacted by microplastic contamination [J.A.J.M. van de Water et al., 2016; M.J. Neave et al., 2016]. Conversely, opportunistic bacterial of the families Rhodobacteraceae, Alteromanadaceae and Oceanospirillaceae increased, colonized mucus and compromised coral tissues [J.A. van de Water et al., 2018; D. Meron et al., 2011; R.L. Maher et al., 2019; M. La Riviere et al., 2013]. Some of the bacteria colonizing corals exposed to microplastics grow on these particles [E.R. Zettler et al., 2013] and contribute to degrade plastic polymers [T. Morohoshi et al., 2018]. Thus microplastics can favour the growth and/or transmission of opportunistic bacteria, which can affect the corals under physiological stress.

Re-building the multiple biological effects on the red coral's health

The impairment of the feeding activity caused by microplastics, combined with the tissue abrasion caused by the contact with microplastics, increased the stress of C. rubrum, also at molecular level, causing the collapse of the cell defence, resulting in the proliferation of opportunistic bacteria and, consequently, triggering coral diseases (figure 3). Based on our findings we anticipate that all these factors combined can have cascading effects on red corals, thus causing their mortality at the concentration present in highly contaminated marine areas [Elifantz et al. 2013; Meron et al. 2011] and predicted for 2030-2060 in the oceans [A. Isobe et al., 2019].

Since microplastic concentrations can be high at all depths and accumulate on the deep seafloor [K. Pabortsava and R.S. Lampitt, 2020; R. de la Fuente et al., 2021], we cannot exclude that microplastics are already causing negative biological effects on deep-water corals, similar to those reported here for the red corals and can apply to a wide range of marine life forms that share similar characteristics (e.g., filter feeders, predators and plankton feeders [H.S. Auta et al., 2017; M. de Oliveira Soares et al., 2020; M.E. Miller et al., 2020]).

Microplastic contamination need to be stopped as it has the potential to threaten red corals and other species, and such an impact could act synergistically with climate change, exacerbating the effects and frequency of the mass mortality events reported in several marine ecosystems [C. Cerrano et al., 2000].

Yu Lin Humm

Alchemy of Emotions

Yu Lin Humm is a visual artist, composer and musician born and raised in Milan, Italy. Her works elicits an immersive stimulation of the senses, where one can enter a state of contemplation and reflection. Along music and fine art, her work is now mainly focused on creating immersive experiences merging sound, science and visual art to open the senses to the natural organism we belong to.

Alchemy of Emotions is a selection of photographs taken by Yu Lin Humm. The series portrays human vulnerability immersed in rising temperature waters.

Earth is mostly a water planet, our bodies are mostly made of water. We all come from the same water. Water knows no borders. Water knows no skin color.

A call to face our relationship with our inner waters, with our emotions and with the environment.

Chris Wilmott & Robert Fred

Fish & the hermitage, St. Petersburg - Diptych

Chris Wilmott paints frolicking fish in the UK. Connecting climate science, art and heritage. Fred of Geneva, inspired by life, writes poems about Chris's painting. Used as visual art, on a decal, poems accompany the painting. Amplifying the painting's story: the impact of rising sea levels on private life and heritage, climate change consequences, disrupting our certitudes. For which there are no vaccines.

Meier et al. (2004) claim, flooding is not uncommon in St Petersburg's past; rising sea levels threaten the Baltic. On the shores of which sits St Petersburg, home to the Hermitage Museum, a building on the UNESCO World Heritage List. Rising sea level science intersects with heritage, in art, which submerges the Hermitage, a surreal scene. The surreal is embedded in climate scientist visions.

ARTWORK

INCLINE

In the tide's balancing act
when sea enters land
and the coast capsizes its salt water treasures,
from this dance, this coming and going
is born breadth united with sand creating life.

The evolution in these unspeakable swirls
carries its apocalypse under the stars,
a monument of clay deposited in the wind
thought in the hands of time, a passage,
a crackling spark in the fire of the universe.

Helen F. Yan

Overfishing and habitat loss in a warming ocean

Helen Yan received her Bachelor of Science with Honours from Simon Fraser University in Biological Sciences with a concentration in Ecology, Evolution, and Conservation. She then worked as a research assistant and programme officer for the International Union for Conservation of Nature (IUCN) Species Survival Commission Shark Specialist Group. Now, she is a PhD candidate in the Research Hub for Coral Reef Ecosystem Functions at James Cook University.

Our destructive actions are threatening global biodiversity. In the marine realm, overfishing is driving many species towards extinction, but is this further exacerbated by climate change? Unlike animals on land, fishes are experiencing a two-tiered impact on their habitats from climate change:

1. **the water that surrounds them is changing in temperature and chemical composition and**

2. **the structure and food availability of their habitats are changing. Ocean warming is directly affecting the physiology of fishes, whereby fishes growing under warming scenarios will grow to smaller maximum sizes. Increasing ocean temperatures is also threatening critical fish habitats, like coral reefs. A haven for fish biodiversity, coral reefs are disappearing with increased water temperatures. Because many fishes rely on coral reefs for food and shelter, the loss of corals could have cascading impacts on fish communities. A large proportion of the world is reliant on fisheries, where coral reefs alone support the livelihoods of nearly 500 million people. Understanding the intrinsic relationships between climate change and habitat loss for fishes will provide a holistic understanding to the general impacts of climate change in fisheries.**

Biodiversity loss in the ocean

We are losing biodiversity at an alarming rate. Although we have been able to track many of the mass declines of animals on land, it seems that we are decades behind for species in the ocean. Due to technological constraints and a lack of adequate monitoring in the past, we are now realizing that many of the world's marine species have been declining drastically [D. Ricard et al., 2012]. Although unsustainable fishing (i.e., overfishing) is undeniably the dominant threat to marine species globally, habitat loss is further driving these species towards extinction [H.F. Yan et al., 2021].

Typically, when we think about habitat loss, we think about very conspicuous events like clear cutting entire forests or large oil spills in the ocean. Of course, an oil spill can have devastating effects, but the less-conspicuous impacts of climate change can also have huge, negative effects on biodiversity in the ocean.

A warming ocean

Increases in greenhouse gas emissions in the atmosphere are causing various changes in the oceans. Not only are ocean temperatures increasing as well, the increased carbon dioxide ($CO2$) in the air is mixing with the water to form carbonic acid, thus making the oceans more acidic (also known as ocean acidification). The increased temperature also decreases the concentration of dissolved oxygen, while also contributing to increased sea ice melting, changing the salinity (i.e., salt concentration) of the water as well. In other words, both the temperature and the chemical composition of the oceans are changing.

As you can imagine, the effects of climate change manifest differently on land than in the ocean. On land, animals can move to find shelter from the sun or soak in watering holes when the temperature becomes too hot. In the ocean, fishes are surrounded by the warming waters with very little escape. Although some species are capable of moving deeper while others can migrate towards to poles to search for cooler waters, these are rather large movements that smaller fish species are not capable of doing.

Most fishes are unable to escape the warming waters; thus, ocean warming is having a two-tiered impact on the fishes' habitats. Firstly, because fishes are ectothermic animals and rely on the temperature of the water to regulate their internal body temperatures, the changes in ambient temperature and chemical composition of the surrounding water can directly cause physical changes to their bodies. Secondly, the increases in water temperature can also impact the habitat structures that fishes prefer to live on or around. Consequently, the effects of climate change on fishes could work synergistically to negatively affect fish populations both directly and indirectly.

Direct impacts of climate change: shrinking fishes

The direct impacts of climate change on fishes is linked to the deep relationship between metabolic rate and temperature [J.F. Gillooly et al., 2001]. Simply put, metabolic rate is the conversion of food into energy to maintain bodily functions. Even as you sit there reading this article, your body is using the energy you have acquired over the last few meals you have had to flex and relax your diaphragm to breath, to allow your eyes to focus on the words that you are reading, to remove metabolic by-products from your cells (which will eventually be removed through your pee), and everything else that your body needs to do to function.

Although there is a huge amount of variation in metabolic rates across animals (and even amongst people), metabolic rates all react similarly to different factors. Specifically, metabolic rate increases as temperature increases: as temperatures become warmer, there is more energy for the chemical reactions in the body, which causes them to react faster.

Just as sugar dissolves faster in hot coffee than in iced coffee, oxygen will diffuse faster into the blood when it is warm than when it is cold. Because fishes are ectothermic, increasing ocean temperatures results in increases in their metabolic rates.

The changes in chemical composition of the water also impacts the metabolic rates of fishes. As waters increase in temperature, the dissolved oxygen concentration decreases. Fishes have to breath harder and heavier to acquire an adequate amount of oxygen, which means that they have to work harder and thus, elevate their metabolic rates. So, fishes are experiencing higher metabolic rates due to (1) the direct relationship between temperature and metabolic rate, and (2) the decrease of dissolved oxygen in the water.

So, what does an elevated metabolic rate mean for fishes? Well, despite an extensive network of gill tissue (i.e., the site of oxygen uptake in fishes), fishes will have to work even harder to grow to a larger size. As a result, the maximum body size of fishes under warming temperatures are predicted to decrease substantially. A study led by Dr. William Cheung from the University of British Columbia used models to find that high greenhouse gas emissions will result in a 14-24% decrease in maximum body size across more than 600 fish species by 2050 [W.W.L. Cheung et al., 2013]. Because, typically, the largest fishes are targeted by fisheries, shrinking fishes would have large ramifications for global fisheries production.

Indirect impacts of climate change: the coral reef crisis

The indirect impacts of climate change on fishes relates mainly to critical fish habitats, like coral reefs or kelp forests. Coral reefs are arguably the most productive marine ecosystems in the world: they support more than 6,000 species of reef fishes and are globally distributed throughout the tropics. Unfortunately, climate change is threatening the persistence of the world's coral reefs.

Although people typically think of corals as plants, they are actually animals that are closely related to jellyfish and anemones. Imagine an entire colony of tiny anemones that have surrounded themselves with a hard, calcium carbonate shell. The coral themselves are transparent; they receive their stunning colours from tiny algae that live inside the coral tissues. These tiny algae, called zooxanthellae, provide food for the corals during the day via photosynthesis and the corals provide protection for the algae. Unfortunately, this balanced, symbiotic relationship is threatened by ocean warming.

As ocean temperatures increase, the activity of the algae becomes toxic for the corals, so the corals expel the algae out of their bodies. Despite the short-term benefit for the corals, they lose their colour and turn white, thus coining the term "coral bleaching".

Although some corals can recover from bleaching, most eventually die because they lose a critical food source. The aftermath of mass-bleaching events is an entire flattened area of broken coral skeletons, overgrown with algae.

Mass bleaching events are increasing in frequency and have been observed throughout much of the world's tropical coral reefs [T.P. Hughes et al., 2017]. As many different species of fish rely on corals for both food and shelter, climate change-induced coral loss will undoubtedly reshape coral reef biodiversity as we know it.

Climate change and fisheries

More than three billion people in the world depend on fisheries as a means of food security, financial opportunity, and/or cultural value. Overfishing is already the dominant threat to most of the world's fish populations; however, the hidden effects of habitat loss due to climate change could further drive these populations to collapse. Shrinking fishes could put more pressure on fisheries to increase yields to subsidize the loss in biomass, thus putting more pressure on fish populations. The loss of critical habitats like coral reefs and kelp forests, which frequently serve as nurseries for juvenile fishes, could have cascading negative impacts on adult fish populations. Although addressing both overfishing and climate change are huge endeavours that require global attention and action, the two need to be considered simultaneously to reverse the biodiversity loss in our oceans.

Jane Stewart

Dead Seas Scroll: How long is long enough?

Born in Essex, with a BA (Hons) Degree in Fine Art from Colchester School of Art, multimedia artist Jane Stewart has been an environmental activist and diving instructor for nearly 30 years, her passion is conservation of the oceans. She uses her work as a vehicle to raise awareness, as a call to action and activism and start a dialogue about our relationship with the environment in a global consumerist society.

With the sea, tide and tideline as an active participant, this giant scroll also has a 2300 word biographical essay, handwritten with the 'plastic pen' about my own experiences of the plastic pandemic, it is a comment on the death of marine life by 2050.

"The issues of overfishing, the plastic pandemic, climate change and global warming are not new problems for the world, we have had many years to make the change, to find solutions, but still, we continue to destroy this fragile ecosystem.

How long is long enough?"

My first experience of plastic pollution was in 1992/1993. I had just arrived in Hong Kong and was living on one of the outlying islands. The local beach was a narrow strip of sand with a view of mountains rising up from the sea with a small pagoda in the distance, at the other end of the beach was a huge coal fired power station. At night it looked like a funfair with all the lights, but during the day, the three chimneys, buildings, pipes and conduits were a total eyesore.

My first visit to this beach was with a few friends one afternoon, I was shocked by the amount of rubbish on the tideline, not just the tideline, but up in the bushes behind the beach and strewn across the cable road that fed into the power station from across the island. Mostly Styrofoam and polystyrene boxes, but bottles, cans, and general plastic detritus that had floated in on the incoming tides.

We humans have a great way of blocking out what we don't to see. I was amazed by my friend's attitude to this amount of rubbish, comments like 'Oh, it's always like this'. We become inured to things we see every day. Even now I watch people at the beach, when a food wrapper tumbles past them, caught in the breeze, they look through it, don't even notice that it's there. They stub out their cigarettes in the sand, leaving the butts behind, oblivious to the damage they are causing by that simple act.

From this visit to the beach in Hong Kong, the Hong Kong Beautification Society was born, after meeting with a German guy called Dirk and his girlfriend Kim, who took the idea and ran with it. I was not an active part of the running of the group but helped

with organising beach clean-up events around the island on which we all lived. One such beach was Mo Tat Wan, in

Figure 1 Me & Kim creating a painted banner from old sheets, for the Hong Kong Beautification Society

Figure 2 Kim (left), Me (right) and an unknown volunteer attaching the banner to the junk

the North of the island, very hard to reach on foot at the time, it faced the South of Hong Kong Island and was basically a small community of a few houses with not a lot else there.

We hired an old wooden junk to take all the volunteers round to the bay, so we could have access easily, there was a small jetty, once stepping off the boat, floating beside this jetty was a dead dog, one of the islands street dogs no doubt, but bloated and floating like a balloon.

This has got to be one of the most depressing beach cleans I have ever been on. There was the usual bits of Styrofoam and polystyrene lidded box from the local fishermen, who use them to store live fish to transport to local markets and restaurants.

There were several really disturbing finds that we made that weekend, the first being the amount of used syringes, bottles of pills, drip bags and catheters that had washed up on the beach. This was medical waste, not waste from drug abuse, but actually dumped into the sea by the Hospital in Aberdeen across the water. By researching into the names of the doctors names on some of the bottles, the Hong Kong Beautification Society was able to prosecute the hospital for dumping toxic waste. All of this should have been incinerated very carefully as it was medical waste. We had no idea what the pills and potions were in the bottles and vials, but if these had leaked, as some had, into the water, the effects could have been disastrous for marine life. There is no information available to show how long this practice had been continuing.

That is the problem with a huge population in a tiny place, there are just not the facilities to deal with all the rubbish. I remember seeing from the ferry, dustcarts driving into the side of a large rock hill to unload their waste inside a huge cave hollowed out from the mountainside. This was nearly thirty years ago, I wonder if that mountain has been sealed up now, what will happen to that waste inside? It's the same thing as landfill, nothing ever goes 'away'.

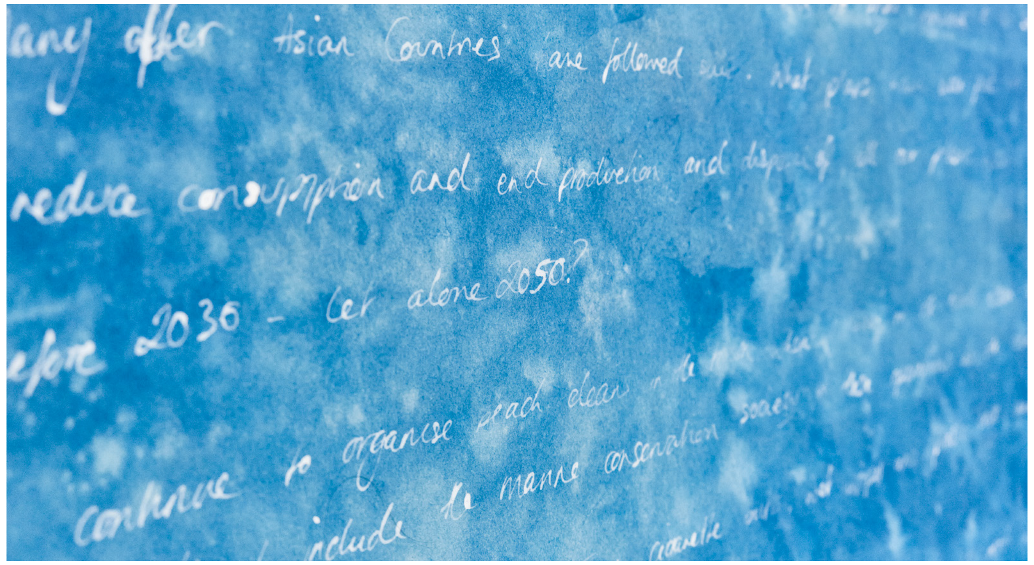
The second disturbing finding was the amount of plastic sand. Tiny particles of plastic that were effectively the same as sand granules. We dug a pit about 6 feet deep, just to see if we could work out a timescale for this, but at six feet down, we called it a day. The plastic sand was just as bad at six-eight feet as it was on the surface, so the granules must have been breaking down form the surface plastic for a great many years. Remember this was in 1992/3, so how bad is it now?

According to the Natural History Museum in 2015 a team of scientists on Henderson Island, one of the most isolated places in the world, discovered more than four billion plastic particles in the top five centimetres of sand.

I would love to say that as Mo Tat has become more of a tourist destination with more houses and a larger community, that things have changed for the better, but during my research I found a Facebook page entitled 'Clean Up Mo Tat Wan', some of the pictures show a disturbing amount of plastic still washing up on the beach and creating more plastic sand thirty years later. At least there are people in the community who are trying to do something about it.

Plastic pollution is not down to just you or me to solve, this issue has to be tackled at a grass roots level, it simply has to stop being created.

Every piece of plastic you have ever used still exists in one form or another, and more is created every day in larger and



larger quantities. This plastic has to go somewhere, and unfortunately South East Asia, being the manufacturer of the planet, with limited resources to dispose of waste, just brush it under the carpet by dumping in the sea or hiding it inside a mountain. At least it's gone 'AWAY' right?

If you think we in the West are any better, we are not, we have been shipping our waste to developing world countries for years. Since 1992 China has been importing forty fiver percent of the world's plastic waste,2 but from 2030 will no longer continue to do so. Many other Asian countries have followed suit. What plans have been put in place to dispose of all our plastic waste before 2030, let alone 2050?

I continue to organise beach cleans in the town where I live on the North East Coast of Essex, I include the Marine conservation society in these clean up operations as they count and make records of everything they find, especially things like cigarette butts and wet wipes, plastic bags and, more recently, surgical masks.

The beach near my house is supposedly a blue flag beach with good water quality, however on the beach and between the beach huts there are so many cigarette butts that it gets too many to count. Each cigarette manages to pollute a litre of water and the soil surrounding it.

I cycle a lot, and on my cycle rides I try to stop along the beach path and collect the plastic rubbish I find, enough to fill the basket on the front of my bike. The things I find most are plastic bottle tops, pieces of rope, lighters and tampon applicators. These are the things that annoy me the most. These applicators used to be paper, or, the ones I used, just nothing, just use a finger. If you can't put in a tampon without the need for a plastic applicator, how are you supposed to know your own body well enough to give yourself pleasure? I called Proctor and Gamble who make these applicators. They say they are just responding to demand, but if they never made the things in the first place, there would be no demand.

But that's capitalism all over isn't it, create a need and fill that need. About eighteen years ago I started using a menstrual cup, one piece of plastic. I have been using it ever since, never paid a single penny on sanitary products ever since. For eighteen years. Never. Not Once! Fucking capitalism up one little piece at a time.

A couple of years ago I did a project that focussed on the Pacific garbage Patch. I huge swirling gyre of varyingly degrading plastic in the middle of the Pacific, there is one in the Atlantic too, in fact, there are small plastic gyres all over the planet. at the estuaries of rivers where river water meets coastal water and creates a swirling movement, plastic is trapped to move around and around in a vortex for as long as the plastic exists. A local fisherman told me about a patch near to the mouth of the river I live beside.

Boats drop their rubbish in the sea, rather than paying to dispose of it on Land in the UK, it is then unregulated and it just keeps swirling round, getting caught in old nets that eventually sink, due to the weight of the detritus, this rope then deteriorates and starts to float back up to the surface, collecting more debris it sinks again and the circle continues, while all this plastic soup swirls round in it's everlasting vortex

So my findings over the years when it comes to plastic pollution, or as I call it, the plastic Pandemic, the concept that there will be more plastic than fish by 2050 is just a ridiculous notion. There are probably more tiny, microscopic pieces of plastic on one beach in South East Asia than there are fish in all the oceans and it has probably been like that for a very long time.

So what are we going to do about it?

It's not about you and I stopping the use of plastic bottles, straws, cotton buds etc. Though that helps a tiny bit, what really needs to happen is for industry to stop making this shit, stop creating pointless items and components from plastic and start looking at making alternatives cheaper. Hempcrete, plant based plastics and compostables.

We all know the name of Elon Musk, or Jeff Bezos, Richard Branson and Bill Gates, but how many people have heard of Boyan Slat?

Who is Boyan Slat?

He was the young Dutch guy who, at eighteen years old, devised a way of collecting the plastic waste in the gyres around the globe. 'The Ocean Cleanup' has been collecting plastic waste from the ocean since 2013, they are now collecting waste from rivers, the capillaries that feed the oceans in South East Asia too. 3 There are also many small start-up businesses that are starting to utilise marine plastic as a material, although it is still plastic, at least it is being removed from the sea and actually used.

So while Steve Bezos is trying to find ways of getting to space, because he wants to escape a fucked planet, Boyan Slat is trying to save us all from the plastic shit that Steve Bezos delivered to us in the first place.

Boyan Slat, remember that name and use it often!

'Mediated Matter' is a group, the brainchild of Neri Oxman at MIT who have developed and created an experimental biopolymer, a bioplastic, made entirely of materials that will naturally decay at the end of their useful life. Cellulose, Pectin, Calcium Carbonate and chitosan (made from insect and shrimp exoskeletons) which can be 3D printed into any shape, but designed to decompose naturally at the end of its natural life.

In 2016 at a Japanese waste dump, scientists discovered an enzyme that breaks down plastic, and in 2018 researchers from the University of Portsmouth managed to recreate this in a lab and which started breaking down the plastic on just a few days. In 2020 a French company claimed they had also created a similar enzyme that degrades up to ninety percent of all plastics within hours. Other researchers are currently working towards a bug that can break down polyurethane, a widely used but rarely recycled plastic.5 So there is hope for the future, but we need to change the way we think.

CAPITALISM IS NOT WORKING, GREED WILL NEVER CRETE A SOLUTION. THE GLOBAL COMMUNITY HAS TO ACT NOW. WE CANNOT WAIT, WE ARE IN THE FINAL MINUTES OF THE 11TH HOUR.

ACT NOW!

PROTEST!

ARTWORK

Neonature

Future Playground – Coastal Ecotone

a futuristic vision of a floating, mangrove-inspired city that adapted to the rise of sea levels.

Neonature is a creative partnership between illustrator Johannes Fuchs and biodesigner Kassandra Huynh. Together as "future tastemakers", they create speculative design and proactive art for a "neonatural" planet: a world in which people and nature live in balance with each other. Their mission is to fabricate immersive stories, beautiful objects and interactive experiences; centered around sustainable and social transformation, desirable and inclusive future design, as well as science communication.

Future Playground – Coastal Ecotone is an immersive story which imagines a hopeful outlook for coastal cities threatened by oceans rising. The artwork illustrates a city scene which draws from the adaptive and resilient strategies of mangroves. The narrative speculates that by looking to nature, we can solve problems of flooding, soil erosion, water pollution, habitat and biodiversity loss.

TEILNEHMENDE

Yona Silvy Renuka Ramanujam Levke Caesar
Sebastian Unger Aindreas Scholz Laura Donkers
Timo Herbst Martine van Lubeek Dylan Gomes
Gordon Axel Cinzia Corinaldesi Julien Masson
Pauline Hegaret Stefano Varrella Chris Wilmott
Jane Stewart Lisa Crozier Michael Tangherlini
Anita Yan Wong Antonio Dell'Anno Sara Canensi
Iole di Capua Roberto Danovaro Helen F. Yan
Buket Yenidoğan Catherine Euale Neonature
Selma Kozak Marie-Julie Bourgeois Lina Röschel
Barbara Neumann Robert Fred Carlo Cerrano
Mitra Tashakori Ben Boteler Trevor J. Willis
Jessica Giannotti Yu Lin Humm Kari Varner

Directory of works

Selma Kozak, Speaking of the oceans, 2021, Turkey, video, 15:05 min, postcards, on recycled paper, 14.8 x 10.5 cm

Anita Yan Wong, Nature's poem, 2021, USA, Sumi-e ink on Xuan paper on silk roll, Dance of the ink creature, 160 x 40 cm, The plastic predator, 160 x 40 cm, Whisper of the winter branch, 139 x 55 cm

Mitra Tashakori, Restless Earth, 2021, Iran, art print on canvas,20 x 20 cm

Aindreas Philip Scholz, Seasick, 2022, United Kingdom, cyanotype on Hahnemühle paper, variable size

Jessica Giannotti, Renuka Ramanujam und Taynuilt Primary (P6/P7 Students), Plastic Futures, 2021, Scotland, Digital textile print and embroidery from recycled fishing nets on organic silk satin, 140 x 112 cm

Martine van Lubeek, the mountain that got stuck in the delta works, 2021, Netherlands, installation made of sand, paper, beach grass, natural ink, driftwood, wooden stage, asphalt, charcoal, variable size

Laura Donkers, Land Radius / 2, 2021, New Zealand, video, 60:00 min

Timo Herbst, Nor'easter, 2021, Germany, pencil on paper on acrylic glass 140 x 100 cm, 30 x 21 cm

Buket Yenidoğan, Ritual of rejoin, 2021, Turkey & United Kingdom, video, 17:08min

Catherine Euale, Water Warriors: DNA Capsule, 2021, Spain & Canada, video, 04:22 min, sterling silver pendant

Julien Masson, Blooms, 2021, France, Video, 03:22 min

Pauline Hegaret , Solar Bloom, 2021, France, Video, 09:05 min

Marie-Julie Bourgeois, Toxic Algal Bloom, 2021, France, Video, 01:44 min

Kari Varner, Monett & Sedalia, 2021, Italy, Pigment print, grown in the, microalgae Chlorella Vulgaris, 30 x 40 cm

Yu Lin Humm, Alchemy Of Emotions, 2022, Portugal, Digital print on paper, 60 x 80 x 2 cm

Chris Wilmott & Robert Fred, Fish & The Hermitage, St. Petersburg – Diptych, 2021, United Kingdom, Oil on canvas, sticker, 50 x 60 cm

Jane Stewart, Dead Seas Scroll: How long is long enough?, 2021, United Kingdom, Cyanotype on Linen paper, with seaweed, sand and other beach finds, 600 x 56 cm

Neonature, Future Playground – Coastal Ecotone, 2021, Germany, 360° Video, 05:17 min

Imprint

www.climanosco.org | www.dear2050.org

This catalogue is published on the occasion of the exhibition *Dear2050: Oceans on the rise.*

Michel Bourqui, Director

Bettina Rohr, Curator Art & Science

Muriel Büttel, Communication

Caroline Glock, Events & Mediation

Sophia Schaub, Events & Mediation

Swati Prasad, Graphic designer

*The scientific manuscripts are in the process of peer review process and will be published on climanosco.org.

Our heartfelt thanks go to all the artists and scientists involved, without whom this project would not be possible!

70% of the earth's surface consists of oceans. They contain 97% of all the water on earth. *Dear2050: Oceans on the Rise* is an exhibition of art and research about the oceans in climate change. Dedicated climate scientists meet critical artists from all over the world and tell touching and exciting stories that show the oceans from a completely new perspective.

CLIMANOSCO