Inaugural lecture

Aquatic ecosystems in hotter water

INAUGURAL LECTURE BY PROF. DR. SARIAN KOSTEN

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Inaugural lecture prof. dr. Sarian Kosten

We depend on surface waters, like lakes and rivers, for irrigation and drinking water provisions, transportation and recreation. “Healthy” surface waters also teem with life. Unfortunately, many aquatic ecosystems are in hot water; they are “in trouble”. They are often subject to very high nutrient loadings and are warming due to climate change.

Sarian Kosten is interested in understanding how these pressures and others affect lakes, rivers, ponds and ditches. She also researches how we can minimise the negative effects.

Moreover, she is intrigued by the role surface waters play in regulating our planets climate as they store large amounts of carbon in their sediment and emit considerable quantities of greenhouse gasses into the atmosphere. Recent findings indicate that human impacts have considerably increased aquatic greenhouse gas emissions. Understanding which processes play a role and how we can mitigate these anthropogenic emissions forms the core of her research.

Sarian Kosten is an aquatic ecologist working at the interface of ecology and biogeochemistry. She did her Bachelor’s at the Hogeschool Zeeland, her Master’s and PhD at Wageningen University. She works at the Radboud Institute for Biological and Environmental Sciences since 2013 and is currently head of the Department of Ecology.

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Inaugural lecture given at the Faculty of Science on Friday, February 23, 2024.

Professor Sarian Kosten
Professor of Aquatic Ecology

Layout and production: Radboud University
Cover photo: Theo Hafmans

Thank you all for being here, either in this auditorium or online. *Dank jullie wel voor jullie aanwezigheid hier in de aula of online. Ik zal mijn rede in het Engels houden met de Nederlandse vertaling op de slides.*

In 2010, I defended my PhD thesis, entitled “Aquatic ecosystems in hot water” in which I focused on the impact of climate change on plants and animals in shallow lakes. Of course, the title referred to our waters getting warmer. Our waters are warming more rapidly than the air, and in many lakes, ponds and rivers surface, water temperatures are already 3°C higher than they were 100 years ago. This surpasses the Paris Agreement’s central aim to keep global temperature increases well below 2°C. The rapid warming of our waters has strong impacts on the plants, animals and microorganisms that live in our waters. “Being in hot water” also means being in trouble, which was certainly the case back then.

The share of European surface waters that – according to the Water Framework Directive - were in bad ecological condition ten years ago was extremely high. Clearly, Europe, and particularly the Netherlands and the surrounding countries were not doing a good job at restoring and protecting their surface waters. In many cases, this was related to excessive nutrient concentrations, which led to the disappearance of sensitive species and the bloom of others. The latest surface water status update shows that the situation of European waters has not improved much, if at all. This inspired the title “Aquatic ecosystems in (even) hotter water”. The problems are multi-fold: chemicals, including pesticides and medicine residues, end up in our waters; the same is true of nutrient pollution from our agroindustry. These factors are combined with drought, floodings and warming have significantly negative affect on the organisms that live in our waters.

I am interested in understanding how these pressures affect lakes, rivers, ponds and ditches, and how we can minimise them. I am also intrigued by the role that surface waters play in regulating our planets climate.

Life under water: what does it look like? Of course, it depends on where you are. Let’s take a deep breath and dive under water. We will start comfortably by diving into a healthy and transparent lake. What can we see? Fish, plants and if it is not very deep, we can even see the bottom. Now let’s make it a bit less pleasant: we’ll dive into a pea green pond. As we go down, we can see very little. It is dark due to the high density of algae. Plants have a hard time growing here because of a lack of light. Lastly, we will dive into a nutrient-rich sheltered place. Floating plants can thrive here. Floating plants, which grow on the water’s surface, are the first to profit from higher temperatures. This is why you often see floating plants in tropical countries. However, we also find them in our own ditches. They benefit from the warming climate and thrive in waters polluted with phosphorus and nitrogen. When we open our eyes, we see darkness; little light penetrates here, impeding most plants’ growth. No oxygen is produced here, nor can it diffuse in from the atmosphere because the plants block aeration. When we disturb the bottom. Bubbles rise. They can smell like rotten eggs, but there are also gasses that do not smell: particularly CO_2 and CH_4 – two important greenhouse gases.

Hence, pollution and climate affect lakes, ponds, rivers, reservoirs and ditches. This generally benefits algae or floating plants at the expense of the plants that live under water –so-called “submerged plants”. Inversely, surface waters are also important greenhouse gas emitters, especially of methane. The bubbles you often see rising to the surface of all kinds of waters consist largely of methane. Methane is responsible for roughly 30% of current global warming.

The warmer the water, the more methane is being produced and emitted. Based on laboratory experiments and with an analysis of field data, we have shown that methane emissions increase by 6–20% for each degree of warming. It is a lot of methane! And it is bad news, especially because methane is a very strong greenhouse gas. The good thing is that it breaks down quickly. Hence, reducing CH_4 emissions leads to a reduction of the greenhouse gas effect even in the short term.

CH_4 is formed by microorganisms, mostly when there is a lot of organic matter present and little oxygen. This makes the bottom of all kinds of surface waters ideal for CH_4 production. Dead algae, plants and material from the shore like branches and leaves end up there. The rotting process, which is the breakdown of organic matter, consumes oxygen. Accordingly, oxygen is depleted very quickly, and methane production increases. As CH_4 does not dissolve well, it forms bubbles. There are also microorganisms that can consume CH_4. They can form a methane filter on top of the sediment, especially when oxygen is present. As I mentioned earlier, if the water is covered by floating plants, oxygen availability is low. Under these circumstances, methane filters are less effective and methane production increases. The methane filter can be boosted when oxygen is “pumped” into the sediment. Some submerged water plants are able to do that. The presence of oxygen also impedes CH4 production. Hence, plants strongly affect CH_4 production and consumption. Plants affect GHG emissions in other ways too: they absorb CO_2 and transport CH_4 from the sediment to the atmosphere. Especially plants that emerge from the water – like reeds – act as CH_4 chimneys, which can increase – not decrease – CH_4 emissions. Hence, whether plants increase or decrease greenhouse gas emissions depends on the plant species and growth form.

From various experiments, we can clearly see that waters with submerged plants emit less methane emissions compared to systems with algae or floating plants. Overall, the picture is emerging that warmer waters increase CH_4 emissions. However, in systems with a lot of submerged plants, this effect is modest. Unfortunately, nutrient pollution and climate change tend to be detrimental for submerged plants and beneficial for floating plants and algae. These systems have very high emissions, but with climate change, their effects will increase significantly. The point I want to make here is that measures that aim to conserve or restore submerged vegetation are beneficial from both a water quality, biodiversity and climate perspective (Figure 1).

We conduct all kinds of field measurements and experiments, in the laboratory, in the greenhouse and outdoors. We want to further unravel how organisms in the water are affected by pollution and climate change here in the Netherlands and in other regions. We also focus on how water quality, climate change, plants, macrofauna and fish affect greenhouse gas emissions.

Our future waters will not only be hotter but also more saline in many parts of the world. The combination of rising seawater levels, changes in rainfall and the increase in water extraction for human use mean that the salinity of a lot of surface waters are going up. This strongly affects water quality, as well as plants, animals and microorganisms. How this will affect greenhouse gas emissions is an open question. Several long and short-term experiments suggest that methane emissions may go down if salinity goes up. It is, however, unclear if this is also the case in very nutrient-rich waters. Nutrient pollution and salinisation may interact in thus far unknown ways with yet-undetermined effects on global waters. This is one of the research lines I will explore further in the near future.

Our research is curiosity driven and has direct societal relevance. The societal relevance is most obvious through the inclusion of our findings in our education and through student collaborations in our projects. In the courses Applied Ecology and Management of Ecosystems and our basic ecology courses, we combine the newest insights in aquatic ecology and biogeochemistry. I really like my work because of this and feel our mission is achieved when, at the end, students are enthusiastic about protecting and improving our natural environment and have developed the necessary skills to do so. The societal relevance is apparent in other ways too. For instance, based on our measurements, we estimate that 7–16% of our national methane emissions originate from ditches alone. If we manage to reduce these emissions, we could have a considerable impact. As many of these ditches are constructed to drain land in order to facilitate dairy production, this implies that reduction of ditch emissions would also reduce the greenhouse gas footprint of milk and cheese.

This brings me to my other line of research. While I really enjoy working in pristine environments enjoying the beauty of nature, we aquatic ecologists also have a role to play in aquaculture, for instance in managing ponds used to cultivate fish. Globally, there are a lot of these ponds, and their number is growing due to the rising demand for proteins. This is related to the increasing world population and the decrease in wild fish stocks. The carbon footprint of cultured fish is currently unknown. Until three to four years ago, it was calculated principally based on the emissions related to the production of fish feed, the energy use on fish farms and the transportation of the fish products. The direct emissions from the fishponds were not considered. This is what we started measuring them in several fish farms in Brazil. We aim to quantify all emission pathways: we measure diffusive emissions, emissions from bubbles and measure emissions after the ponds are drained after the fish harvest. We also measured emissions from dredged material, focusing on carbon dioxide, methane and nitrous oxide, which is an even stronger greenhouse gas than methane.

We are currently doing this in a wide range of ponds in different regions across Brazil, where different species are cultured and different management practices are used. The ultimate goal is to understand what drives the emissions and how we can minimise them. In this way, we can advise fish farmers how to best manage their fishponds. We focus on environmental sustainability particularly on greenhouse gas emission and downstream pollution. We also collaborate with animal physiologists, veterinarians and social scientists, with the objective to find ways we can improve environmental conditions and the livelihoods of farmers. These issues are deeply interconnected. Current overviews of “food footprints” suggest that cultured fish has a relatively low carbon footprint compared to other sources of meat. This said, a predominantly vegetarian diet remains the best option for reducing the footprint of your daily meal. Considering the thus far ignored emissions from the ponds changes this picture. From our first findings, it is clear that there is a diversity in GHG footprints between farms. The next step is to relate these footprints to management practices because there is clearly room for reducing the footprint of many farms. Better feed management and better management of the sludge that accumulates at the bottom of the ponds seem particularly promising methods for reducing greenhouse gas footprints.

To round off, it is clear that our surface waters are in hot water. Excessive nutrient loading, warming, flooding and drought diminish our water quality. Our research, however, indicates that there is enough momentum to turn the tide. This momentum for climate-smart-water management comes from an ecological and a sustainability perspective. From the ecological perspective, we show that reducing the excessive nutrient loading to our surface waters will lead not only to an increase in water quality, but it will also reduce greenhouse gas emissions. This is a win-win situation, which should double the incentive to work on improving the ecological status of our waters. From a sustainability perspective, we show that there are potentially large steps that we can take to reduce greenhouse gas emissions related to the landscape and our food production.

During my talk, you have heard me say “we” 34 times versus “I” nine times. This is because what I presented here is based on team-work. Without our technicians at the department, the general instrumentation and the techno-centrum, my fellow researchers and I would not be able to do the research we do. We are at the forefront of greenhouse gas research in waters and wetlands because of the development of new measurement techniques. We can quantify emissions of greenhouse gases and other gases in innovative ways, for instance with a high tech laser that can measure all gases between two points. This laser was developed in-house at the Trace Detection Lab. These collaborations and the collaborative and fun atmosphere first at the Aquatic Ecology and Environmental Biology Department and, as of 1 January 2024, at the Department of Ecology mean that I cycle to work whistling. I would like to thank all colleagues, PhD candidates – current and former – as well as the students. This brings me to the acknowledgements.

I would like to thank Dean Sijbrand de Jong, RIBES director Mark Huijbregts and former head of department Leon Lamers for encouraging me to take the step to become a full professor and to make this moment possible. Leon, Jan Roelofs and Fons Smolders, thank you for your support and the confidence you gave from the moment I started in Nijmegen.

To come to Nijmegen, I had to leave the warm nest of Wageningen. The time at the Aquatic Ecology and Water Quality Management Group was very special for me. This is not least because we had the shared goal of sampling 100 South American lakes in Brazil, Uruguay and Argentina. This took me and my PhD sister Gige Lacerot about two years. I do not know where to begin expressing my gratitude for my mentors Marten Scheffer, Eric Jeppesen, Egbert van Nes and my scientific mother, Vera Huszar. Their doors and inboxes were always open, and I learned so much from you. There are many other special colleagues and students. I have fantastic memories of that expedition, and it led to many new friendships and long standing collaborations in Uruguay and Brazil.

Quisiera agradacer mucho a mis companeros Uruguayos e meus colaboradores e amigos brasileiros. Sem seus conhecimentos, sabedoria de vida, humor, musica, comida e bebidas, meu currículo e minha vida seriam muito diferentes. As realidades em que vivemos e os desafios que temos de enfrentar diferem até certo ponto, mas trabalhamos para melhorar o mesmo planeta. Isso me faz sentir que nosso trabalho vale a pena. Obrigada.

I could easily fill my 45 minutes only talking about all my precious colleagues, national and international collaborators of current and past projects. Please know that I thought about you all when preparing this talk. Special thanks to my colleagues at our spinoff company, B-Ware, who have truly enriched my view on nature management in the Netherlands.

Graag ga ik nog iets verder terug in mijn dankwoord en wil ik ook de docenten aan de Hogeschool Zeeland en van mijn middelbare school - Scheldemond in Vlissingen - bedanken. Daar heb ik een goede basis kunnen leggen. Ik wens alle kinderen dezelfde gedreven onderwijzers als ik heb gehad. Met de enorme lesuitval en docententekorten is dat helaas zeker geen gegeven meer.

Reizen heeft mijn leven verrijkt. Dat leven begon in Bresjes, een durp in Zeeland dat ik nooit dacht te verlaten. Veel familie op loopafstand. Beide opa's werkzaam in de watersector: een in het drinkwater de ander als visser. Maar vooral ook kleindochter van twee sterke oma's en veel tantes en een opoe op loopafstand. Thuis deden we al aan actief-biologisch beheer: watervlooien vangen voor helder water, stekelbaarsjes, kikkerdril, alle voedselwebben werden uitgeprobeerd *in de vijver; waarbij mijn vader en zus altijd meededen. Een heerlijke plek om op te groeien en zo dacht ik dus nooit weg te gaan. Heel fijn ma, dat jij mij stimuleerde om de wereld in te trekken. Wat een voorrecht om de wereld in te trekken met zo'n sterke thuisbasis waar je altijd weer naar terug kunt keren. Dat had jij al wat eerder door, Annabel.*

Ik heb de halve familie meegesleept op veldwerk. Rho, jij reisde ervoor naar Ecuador (oké, de Galapagos waren ook een hoogtepuntje). Pa en ma, jullie reisden ons overal achterna. Mij eerst naar Costa Rica, toen naar Ecuador, later naar Brazilië waar jij, ma, alle apparatuur grondig hebt schoongemaakt – ik weet nog dat Gige lachend zei dat ze met het verkeerde familielid aan de expeditie was begonnen – en pa jij hebt daar de gaten in onze visnetten dicht gebreid. Jeroen, toen kwam jij terug in mijn leven en trokken we er samen op uit. Na een poosje kwam Linde ons leven verrijken en vond je het geen probleem – vooraf dan – om me achterna te reizen samen met Linde. Samen de rimboe in, maar gelukkig vooral ook tijd om daar van het land te genieten.

Ewoud, met jou was ons gezin compleet. Jij en Linde hebben jullie eigen interesses, maar ik ben blij dat jullie je – soms na enige… stimulans – ook laten enthousiasmeren om mee te gaan op veldwerk. Eerst gingen we de Gelderse beekjes af. Afgelopen zomer nog gingen we samen met oma de Zeeuwse sloten af. Jeroen, jij staat altijd klaar aan het thuisfront. Altijd scherp om dingen kritisch en overwogen van een andere kant te bekijken. Zeker met al mijn nieuwe management-uitdagingen is dat super fijn. Mijn liefde en dank aan jou, de kinderen en aan jullie: pa, ma, Annabel en Jennifer, zijn verder niet in woorden uit te drukken.

Ik heb gezegd.

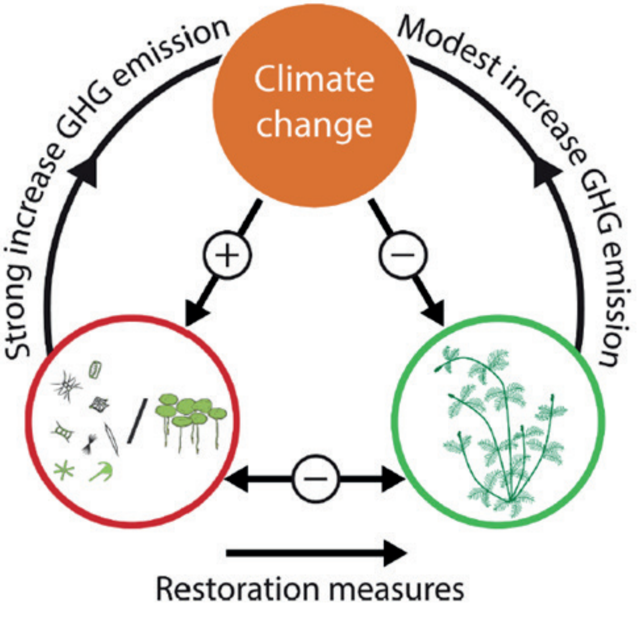

Figure 1 (previously published in (Aben et al., 2022)). Interactions between climate change, changes in plants types that dominate aquatic systems and greenhouse gas (GHG) emissions. Climate change favours dominance of algae and floating plants at the expense of submerged plants. Restoration measures establish dominance by submerged plants in shallow aquatic ecosystems can moderate the positive feedback loop between climate change and aquatic GHG emissions. The plus (+) and minus (-) symbols denote stimulating and inhibiting effects, respectively. Each dominant plant type self-stabilises its state through a variety of feedback mechanisms, thereby inhibiting shifts to dominance of other functions.

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