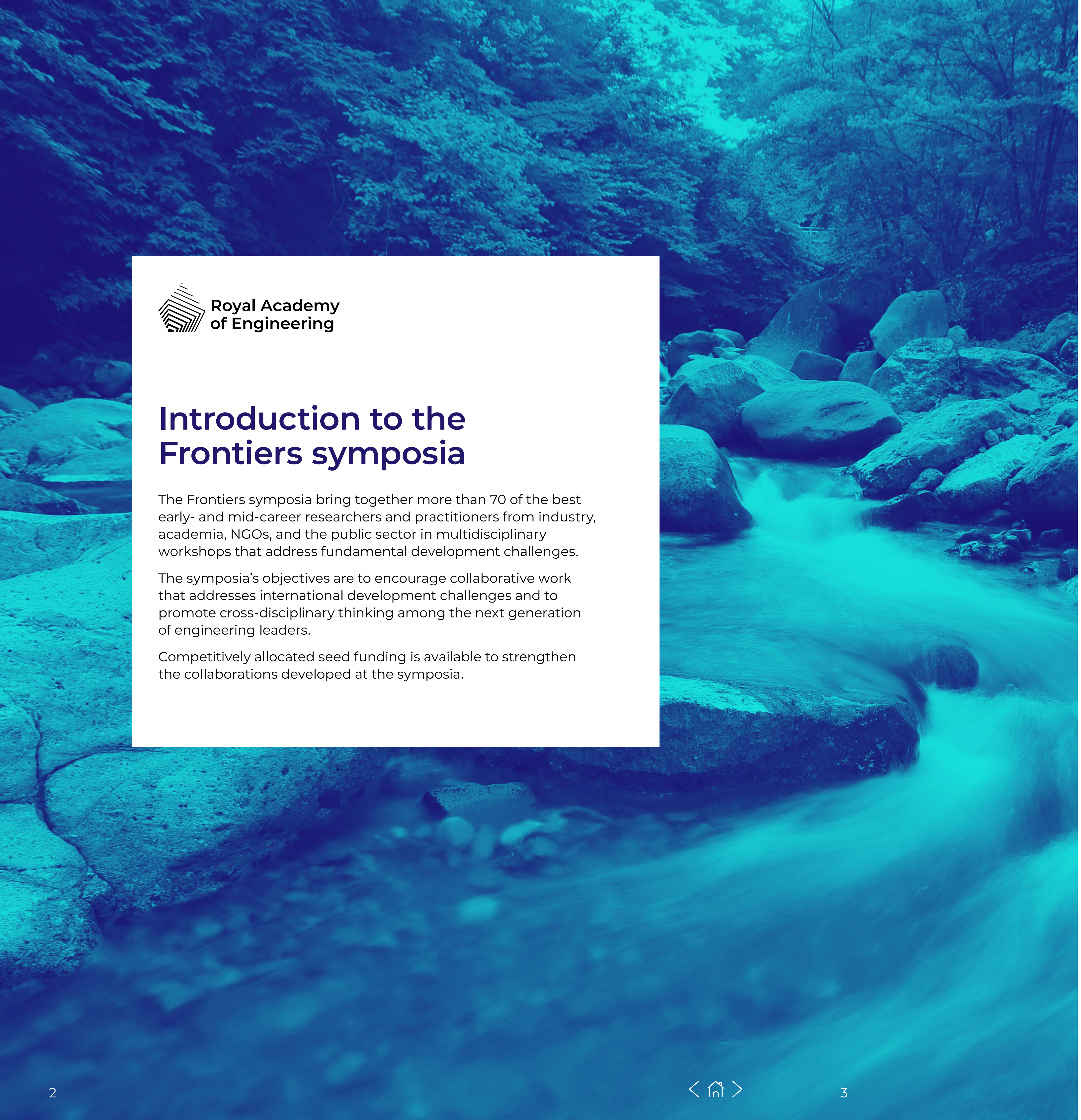
Royal Academy of Engineering

Symposium report

Frontiers symposium

From seeds to needs – regenerating ecosystems services to halt the biodiversity crisis

27 September to 4 November 2021



Royal Academy of Engineering

Introduction to the Frontiers symposia

The Frontiers symposia bring together more than 70 of the best early- and mid-career researchers and practitioners from industry, academia, NGOs, and the public sector in multidisciplinary workshops that address fundamental development challenges.

The symposia's objectives are to encourage collaborative work that addresses international development challenges and to promote cross-disciplinary thinking among the next generation of engineering leaders.

Competitively allocated seed funding is available to strengthen the collaborations developed at the symposia.

Contents

From seeds to needs

Regenerating ecosystems services to halt the biodiversity crisis

The Frontiers symposium event took place online between 27 September and 4 November 2021. Delegates from different disciplines, fields and countries came together to discuss how engineering solutions can make the largest impact on the global biodiversity crisis. The event was co-chaired by Professor Paul Kemp and Professor Oscar Link.

There is a global biodiversity crisis, with unprecedented and accelerating rates of species extinctions and degradation of habitats that will have grave impacts on humanity, especially those dependent on the ecosystem services they provide.

There is a need to simultaneously identify the major challenges to biodiversity conservation (like those in the Sustainable Development Goals) and the areas where interdisciplinary environmental engineering and science can have the greatest impact relative to cost.

The global biodiversity emergency hits lower- and middle-income countries (LMICs) the hardest. There are potential conflicts between conservation efforts and resource exploitation that often negatively impact the communities in LMICs and undermine development efforts. This symposium aimed to scope out those challenges and explore where interdisciplinary engineering solutions can make the largest impact.

This report summarises the key points from the discussions and activities that took place at the symposium. It captures the wide variety of expertise and insight that was present.

At the forefront of discussions was the halting and reversing of biodiversity loss. To do this, participants noted the necessity to take an inter- and multidisciplinary approach, from engineering to social science, anthropology, architecture, biology and more. Barriers to implementing solutions included a lack of policy drivers, lack of financial incentive, and difficulty in monitoring impact of new designs. A common perspective was the need for engineering solutions to integrate 'green' and 'grey' structures, focusing on natural structures such as forests, wetlands and soils (green) and built structures such as dams, seawalls, roads and pipes (grey).

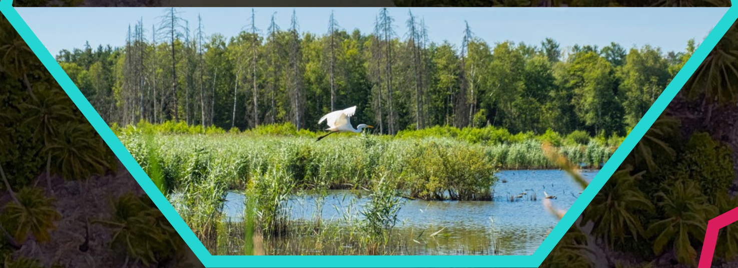
The Academy would like to thank everyone who made the symposium such a success, especially the event chairs, and the group of talented, experienced and engaged delegates who came together online to explore where engineering solutions can have a positive impact on the global biodiversity crisis.

Freshwater

Just **0.8%** of aquatic ecosystems, but vital for human life.

Includes streams, rivers and lakes, as well as wetlands.

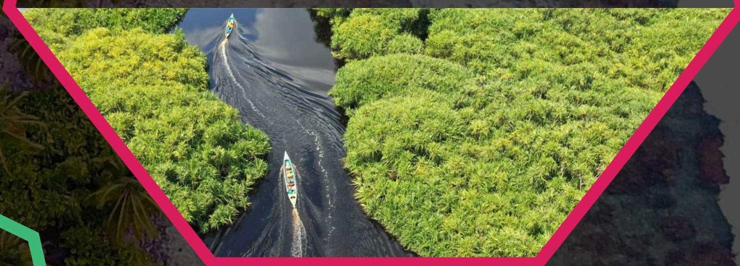
More than **100,000** species live in freshwater. Many are highly adapted and endemic.



Terrestrial

Includes deserts, rainforests and deciduous forests, taiga, grasslands, and tundra.

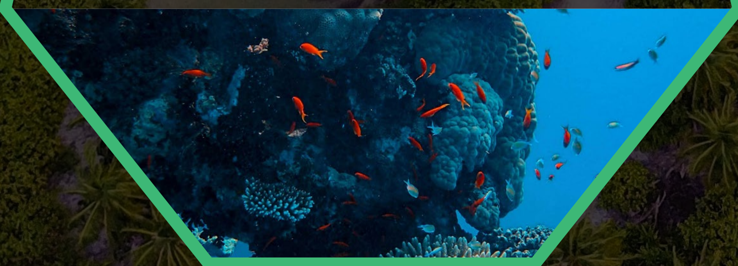
Economic and social importance including for human settlements, food systems and industry.



Marine

70% of the surface of the globe and **97%** of all water.

Includes ecosystems like open oceanic areas, coral reefs, deep water, salt marshes, and hydrothermal vents.



72 delegates from different disciplines, fields, and countries came together to discuss how engineering solutions can make the largest impact on the global biodiversity crisis.

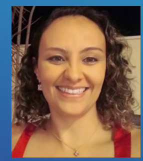
Paul Kemp is a professor of ecological engineering, Director of the International Centre for Ecohydraulics Research at the University of Southampton and founding Editor-in-Chief of the *IAHR Journal of Ecohydraulics.* As a result of his interest in sustainable infrastructure and the built environment, he is also Director of the University of Southampton Future Towns Innovation Hub, the EPSRC-funded Centre for Doctoral Training (CDT) in Sustainable Infrastructure Systems, and the UKCRIC CDT in Sustainable Infrastructure for Cities.

Paul's interests relate to the development of more environmentally friendly water, energy and food systems, in particular sustainable fisheries management.

Oscar Link is a professor of civil engineering at the Universidad de Concepción in Chile. His interest is in river engineering. In recent years, his work has focused on the development of practical solutions to complex problems such as the fish passage through the hydropower dams for native fish species conservation, the sedimentation of high mountain reservoirs, and the bridge pier scour. He aims to achieve engineering solutions for sustainable development of water and energy resources. He is also Associate Editor of the Hydrological Sciences Journal and Director of the PhD programme in energies of the University of Concepción.

Freshwater

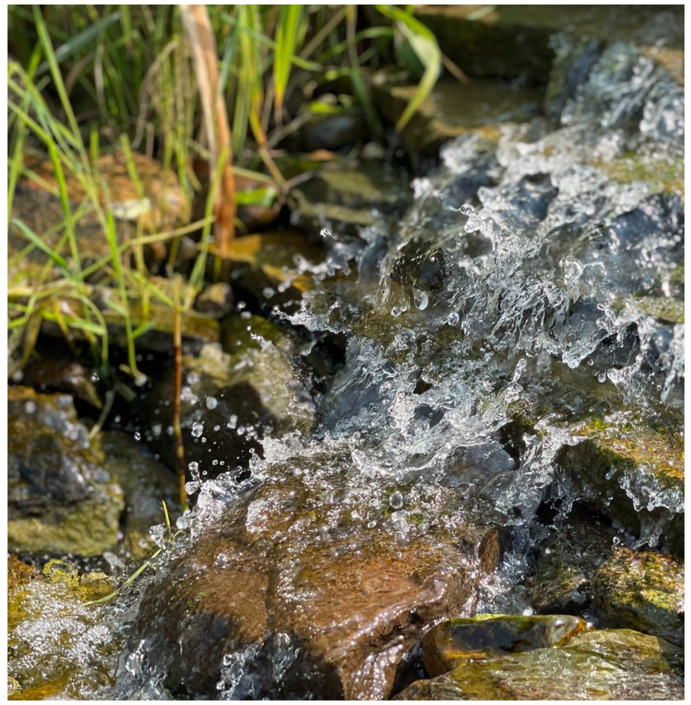
Freshwater session chairs



Raquel Loures
Environmental Analyst, Cemig

Luiz G.M. Silva
Senior Scientist, ETH-Zurich

Hector Vera-Alcaraz
Head of Zoology, Ministerio del Ambiente y Desarrollo Sostenible (MADES)



Key takeaways

- Any sustainable solution must involve multiple stakeholders from different perspectives, especially the communities most impacted.
- It should be considered whether engineering solutions are scalable and, if so, to what extent (eg regional or international).
- Any conversation on engineering solutions to freshwater biodiversity must engage with industry voices to develop more biodiverse-friendly solutions.

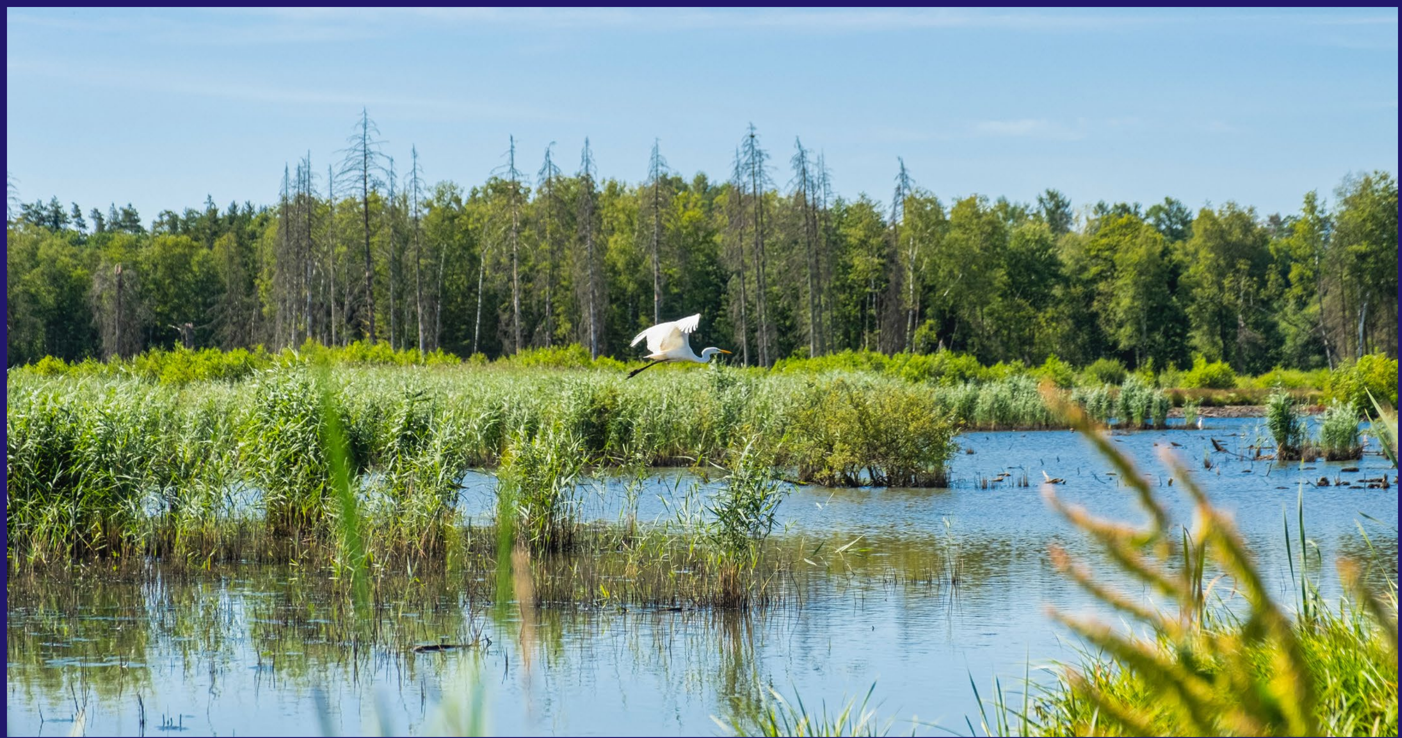
Freshwater facts

- Many countries are involved in freshwater boundaries.
- Freshwater comprises diverse types of environments such as rivers, streams, waterfalls, wetlands, karsts, caves, lakes, seasonal ponds, and mud.
- Freshwaters have transversal interactions with terrestrial ecosystems, responsible for many ecosystem services or goods.
- Freshwater represents only 0.01% of the world's water and covers only 0.8% of the Earth's surface.
- There is a rapid decline in the world's freshwater species and habitats.

Biodiversity crisis in freshwater environments

- Over 100,000 different species live in freshwater.
- Freshwater species are of economic and medical importance.
- Freshwater species are of ecological importance, indicating freshwater quality.
- In freshwater ecosystems, animals tend to be specially adapted to their environment and found nowhere else on earth. This makes them vulnerable to changes in the environment, potentially leading to extinction.

Over
100,000
different species live in freshwater



The first session of the 'From seeds to needs' symposium, focused on freshwater biodiversity, specifically on reversing river fragmentation to halt freshwater biodiversity loss. Speakers emphasised the importance of interdisciplinary approaches throughout the symposium. In the freshwater session, speakers examined the interrelated aspects of biology, engineering and industry as solutions to biodiversity loss.

Reversing river fragmentation to halt freshwater biodiversity loss: the biology perspective

Hector Vera-Alcaraz of MADES used his extensive experience in biology to focus on the biological aspects of the biodiversity crisis in freshwater environments. He began by outlining the extent to which freshwater environments are suffering from rapid loss and deterioration. Freshwater environments are risky and problematic because they are receivers from the reservoir environment – anything that happens on land will eventually impact freshwater. He outlined five major contributors threatening freshwater biodiversity loss: overexploitation; water pollution; flow modification; degradation or loss of habitat; and invasion by exotic species.

To illustrate this, Hector presented an example from Asia, showing that large and migratory species from rivers are particularly susceptible to human impacts – especially overfishing. These species are economically important and are facing rapid loss and near extinction.

In the breakout room on biology, participants were encouraged to offer their thoughts on freshwater from a biological perspective. They made the point that biodiversity refers to more than the number of species in an environment. It manifests in the functioning and structure of species, such as how fish behave in ecosystems.

Participants discussed the over-exploitation of fishing from a social science perspective, highlighting the impact on livelihoods and employment opportunities. As temperatures in rivers rise, they become uninhabitable for certain species. In South America and the Niger Delta, rising temperatures and pollution have pushed fish migration to the sea. This has forced local communities to shift their fishing to other areas, leading to conflicts between communities.

"Ecosystem-based solutions can deliver multiple benefits. But in the long-term adapting to climate change, nature-based solutions will be key."

Any solution to the biodiversity crisis in freshwater systems needs to be inclusive and consider local community needs, especially of those most vulnerable to biodiversity loss.

On the issue of pollution in freshwater, participants raised the idea of improving the use of fertilisers that affect freshwater, with the caveat that farmers need to be incentivised to adopt best practices and subsidised for any incurring costs.

Participants emphasised that everything that occurs on land affects rivers and the sea. Historically, cities have been built in an estuarine environment. Greening the grey (biodiversity enhancement of hard infrastructure) from a coastal perspective implies that any infrastructure will have multifunctional structures – such as constructed blocks in a city with a river – which will have huge implications on biodiversity. In this case, all new infrastructure must be considered beyond its engineering function.

Integrating grey and green tactics – constructed and natural – is driving the way we think about solutions, especially concerning city sustainability. While local solutions are critical, participants acknowledged that scalability of these solutions is key, and scaling will require input from the private sector, governments and local communities.

Reversing river fragmentation to halt freshwater biodiversity loss: the engineering perspective

Technology will play an increasingly important role in engineering solutions to biodiversity issues. Sensors, such as those through drones and satellite imagery, can help us better understand ecosystems. In addition, robotic research can examine how to introduce microbiomes into machines and artificial agents. These engineering solutions are becoming part of the ecosystem and helping researchers think about nature and ecosystem compatible structures of the future.

Luiz G. M. Silva, a senior scientist working on ecohydraulics at ETU Zurich in Switzerland, posed the question: if we think about technologies and technological approaches to help biodiversity loss, what will be the challenges in the coming decades? Continuing with an interdisciplinary perspective, Luiz explained how his approach to hydraulic engineering considers both ecological and biological aspects. Current examples of interdisciplinary collaborations to halt biodiversity loss include the FIThydro project and AMBER projects in Europe, and the HydroPASSAGE project in the US.

Luiz cautioned that there are several challenges to bringing different fields together, specifically:

- Adaptive technologies – how well can we design new and adaptive technologies?
- Scalability – how scalable are new solutions and technologies?
- Policies vs environmental needs – how much should mitigation technologies be bounded by policies (eg fish passage)?
- Integration with decision-making processes – how well can mitigation solutions and new technologies be integrated with decision-making processes (eg cost-benefit analysis, initial project design, built-in costs)?

In terms of adaptability, participants noted that solutions to common problems such as water loss in distribution networks happen worldwide yet often insights are not shared. This is frequently because of a lack of capacity and access for developing countries.
Attendees widely held the view that solutions to common problems need to be shared more, and this will require greater engagement with both local and global stakeholders. Several participants noted a disconnect between disciplines – “sometimes fish experts forget that fish live in water”. For those working on freshwater and other habitats, interconnectivity is vital to find lasting solutions.

> “Not every solution is scalable, even small changes can have a negative impact on biodiversity.”

Scalability and adaptability, while essential, face many roadblocks for habitat connectivity in freshwaters. Mitigation technology or solutions that reconnect habitats could be done opportunistically, without considering the complete catchment.
For example, a single barrier can affect the whole system. It is therefore important to acknowledge that any mitigation or improvements done on a small scale might not always be beneficial across larger spaces. Furthermore, participants cautioned that while dam design adaptivity is imperative, dams are inflexible once implemented.

To determine how well new technologies can be scaled and transferred to meet different needs, regional dynamics must be considered. This can be seen in freshwater sustainability at national borders, where impacts often overflow and cause an unsustainable problem abroad.

Policies must also integrate environmental needs. Luiz brought up the example of the Igarapava Dam in Brazil, whereby monitoring the migration of fish moving upstream showed that a high percentage of fish were passing through turbines, and as much as 70 to 80% of fish were killed. This proved that while the technology and policy requirements for the dam were met, the environmental needs were not.

In addition to environmental needs, local legal procedures need to be considered. An example of an environmental agency ‘punishing’ an industry with fines was brought up to show how the penalty was counterproductive to progress. In this case, the industry subsequently stopped reporting fish mortality numbers to avoid fines. Any biodiversity solution needs to consider industry voices.

Reversing river fragmentation to halt freshwater biodiversity loss: the industry perspective

To engage industry voices, the biodiversity crisis must also be viewed as a business crisis. In her presentation, Raquel Loures, a biologist working with Cemig, cautioned that biodiversity is vital when doing business because we all depend on ecosystem services and raw materials for necessities like food and energy. As ecosystems decline, businesses face significant risks, including higher raw material costs and a potential backlash from consumers and investors.

By investing and developing solutions to reverse freshwater impacts, businesses can:

- help to mitigate and prevent ecological impacts
- avoid conflicts with local communities
- prevent image problems with stakeholders
- gain trust from environmental agencies
- avoid fines or penalties
- help provide and inform benchmarks for investors and governments on food, environmental and social practices (eg. The Dow Jones Sustainability Index).

These incentives to halt biodiversity loss can also be opportunities for companies. However, challenges remain, such as high freshwater fish diversity, high hydropower civil structure diversity, watershed specificities, varying policy and regulatory frameworks, and the balancing act between financial penalties and the costs of finding and implementing solutions.

Raquel made the case that companies need to understand the dynamics between these aspects and develop strategies tailored to addressing challenges at the local ecosystem level.

> "Understanding and highlighting the social impacts of fish biodiversity loss can help generate public support for solutions."

For that to happen, there needs to be integration between biology, engineering and industry fields to mitigate and prevent biodiversity loss in freshwater.

In the breakout room, participants discussed ideas for mitigating environmental impacts of river infrastructure on fish and ecosystem services. It was noted that any new fish-friendly dam will require public support and engagement. This will require collaboration between biologists and engineers to call for improved sustainability and communication of the impacts on fish biodiversity.

Issues of scale were brought to the forefront, such as the cost-benefit of larger dams versus smaller dams to generate electricity and how best to reduce biodiversity loss. Nets can prevent fish from going into turbines, upstream dams can be beneficial in terms of fish migration, and biologists can help implementers understand where sensitive species may exist to avoid building in these areas.

As in the biology and engineering breakout rooms, the industry discussion returned to the idea that all industry, biology and technology perspectives are interconnected and therefore an interdisciplinary approach is required to find solutions to halt biodiversity loss in freshwater.

Terrestrial ecosystems

Terrestrial session chairs

Dr Rachel Carmenta
Lecturer, Climate Change and International Development, University of East Anglia

Natalia Estrada-Carmona
Associate Scientist, The Alliance of Biodiversity and CIAT

Sarobidy Rakotonarivo
Research Fellow, Universite d'Antananarivo

Key takeaways

- There is not one single engineering solution that can manage land or biodiversity loss; multiple parts, actors and activities will be involved.
- Technology can bridge knowledge gaps by providing up-to-date information on changes in biodiversity, and therefore help inform best strategies.
- People need to be at the centre of any technological or engineered solution. For this to happen there may need to be trade-offs between environmental management and local needs.
- Preserving global biodiversity will require involvement from the agriculture sector.
- The humanitarian aspects of biodiversity loss must be communicated to generate support and impact.
- Monitoring impacts requires indicators that are sensitive to dynamics across scales, and can capture different values and metrics.

Terrestrial ecosystem facts:

- A terrestrial ecosystem is a land-based community of organisms and the interactions between biotic (living – plants and animals) and abiotic (non-living) components.
- Different terrestrial ecosystems vary a lot. Examples include tropical rainforests, temperate forests, frozen tundra, grasslands, and deserts.
- The type of land-based environment depends on many factors including soil type, rain, temperature, amount of light, and human interaction with the area.

Biodiversity crisis in terrestrial environments

- 75% of land-based environments have been significantly altered by human actions. This trend is less severe, or avoided, when land is held or managed by indigenous peoples and local communities.
- If global warming exceeds 2°C 20 to 30% of terrestrial species are at risk of extinction, including species that are critical to food systems (like crops and pollinators).
- Only 10% of land is projected to be near-natural by 2050, and over 20% of land will be degraded.

75%

of land-based environments have been significantly altered by human actions

The session on terrestrial biodiversity sought to stimulate ideas and connections between the different disciplinary expertise of the attendees. The discussions centred around biodiversity loss in the anthropogenic scene and how engineering solutions can contribute.

A cross-cutting theme was that since biodiversity loss is driven by actions happening across scales, solutions to the crisis need to operate across scales too. When designing conservation interventions, it is essential that solutions must involve different disciplines, scales and technologies.

In this session, attendees gave agriculture much attention. While agricultural transition and regenerative approaches have been discussed for decades, uptake among smallholder farmers has not made an impact. The lack of success is in part due to the exclusion of local people in decision-making processes. For any engineered solutions to be effective, inclusive and equitable, local needs must be integrated in design and implementation. Despite this, it was cautioned that communities are not homogenous and a solution for one community may not necessarily benefit another.

Integrating local voices in the design and implementation of regenerative lands

In her presentation, Sarobidy Rakotonarivo provided some context on involving local voices in terrestrial biodiversity. Forest conversion to agriculture for staple crops or cash crops is the biggest cause of deforestation in the tropics, especially in Africa. As tropical economies develop, hard choices between conservation and development goals must be made to balance trade-offs. A key issue is that the interests of farmers and wider communities are often misaligned. While land management decision-making takes place at the farm scale, many impacts of these local decisions are felt across the landscape, even on national and global scales.

An integrated approach to resolving trade-offs in environmental management requires a good understanding of farmers' land-use decision-making and how they respond to alternative management policies. Gaming can play a role here. Local farmers can use engaging and interactive games around land-use decisions to help extrapolate attitudes and socio-economic characteristics. This information can be used to better integrate local needs and preferences in the design of interventions or management approaches.

In the breakout session, Dr Marco Haenssgen, who came to the discussion from a social science perspective, made the case that integrating local voices will involve rethinking processes rather than technologies. In Southeast Asia, forest communities have been adversely affected by the use of national GPS mapping to impose changes. Traditionally, forest communities have managed the ecosystem through traditional knowledge developed and shared over generations, yet now they feel the government has imposed a 'new reality' on their land.

"local people, rural communities and smallholder farmers should be part of the solution, that way solutions are most effective and equitable."

Revising how the processes of new technologies are developed, rather than imposing them from above, will help build best strategies going forward.

Traditional ecological knowledge about the land or sea is invaluable because local communities are authorities on their environment. Technology can be used to enhance local knowledge. For example, gaming processes using participatory mapping to allow local fishermen and farmers to collect data (for example, to monitor the rift or find areas that require restoration processes) will benefit local people.

Dr Rania Aburamadan, an architect from Jordan who specialises in refugee studies in sustainable development, praised the use of gamification to help understand and track local voices. She gave the example of MindHouse, a game that lets refugee communities enter an augmented reality to build their imagined home. Similarly in agriculture, the use of virtual reality allows people to experience how they will live once restoration or technological solutions are implemented. Virtual reality can also increase empathy between humans by exposing them to alternative perspectives and encouraging healthy conversations. Bearing this in mind, uses of virtual reality in gaming should consider who, where and at which level (scale) change should be targeted.

Engineering approaches can be part of the solution to the biodiversity crisis with careful planning that considers possible unintended consequences and aligns local needs.

Connecting scales across causal chains to address global environmental change

Dr Rachel Carmenta of the University of East Anglia drew on examples from her own work, showing that while biodiversity and carbon losses are accruing from global environmental change, there is also a significant and important human dimension. Vulnerable communities and those who are outside mainstream development, not least those living in rural areas and not operating in cash economies (such as forest dependent people), are impacted massively by forest flammability and biodiversity loss. Yet, their story is often missing. If the discourse can shift to engage the humanitarian component of biodiversity loss, it can be more powerful than biodiversity loss narratives alone. Combining narratives could result in better outcomes for both people and nature.

In the breakout session that followed, the discussion was organised around the drivers of biodiversity loss, the different impacts that stem from biodiversity loss, and the kinds of interventions that may be required.

There are many different manifestations of biodiversity loss, for example habitat loss or fragmentation, fires, pollination decline, insect decline, and disease. Participants agreed that different approaches targeting different stakeholders are required to have impact. Local-level interventions such as supporting indigenous land rights, empowering indigenous communities, and appreciating indigenous or local knowledge, will need to be manifest in any intervention operating at site level. At the same time, it must not be forgotten that large-scale farms and agro-industry, plus government interventions, all have a huge imprint on biodiversity.

The question then arose as to how to decide on which interventions to carry out: interventions that can address the biggest drivers of biodiversity loss such as agro-industry (which may be difficult to adapt and modify because of power dynamics), or alternatively, interventions that are smaller in scale and support local needs, where there is less likelihood of resistance? Participants recognised the benefits and drawbacks of both.

> "How can multiple scales be addressed? Is it better to focus on the biggest drivers where you could have potentially the most impact, or the lower hanging fruits that could be easier to implement?"

Consumers of agricultural produce also have a role to play. Technology can help increase the transparency of actors in distant landscapes, like different price labelling or 'eco-labelling' on foods in supermarkets. While several participants supported the need to change people's consumption habits, other participants expressed reluctance to put the onus on the consumer, and instead argued that retailers should take responsibility for the products they offer.

Neil Auchterlonie mentioned that one way to get industry on board is with independent certification schemes. For this to happen, there must be incentives, such as charging a premium rate to consumers and paying more to the producer. However, certification schemes are often costly thus favouring big business over local small-scale suppliers.

The participants gave ample attention to the connections between environmental, human and planetary health. Rachel noted that indicators can be used to show the relationship between environmental health and wellbeing, and this could be another means to communicate the need for biodiversity conservation. Natalia Estrada-Carmona agreed that how you communicate the biodiversity crisis is important, as people are more likely to respond to emotive calls for action. What is considered important to people's wellbeing – nutritious food, good relationships, peace, tranquillity, happiness, trust – needs to be part of the conversation on engineering solutions to the biodiversity crisis.

Engineering solutions with interdisciplinary collaborations for biodiversity

If we want to halt the biodiversity crisis, the whole ecosystem must be considered not just "charismatic species", said Natalia Estrada-Carmona of The Alliance of Biodiversity and CIAT, in her presentation. A good example of this is insects, which are not inherently "charismatic species", yet they are the engineers of many ecosystem processes and services including the food system. Yet, insect populations are declining rapidly.

Natalia asked how we can put agrobiodiversity back onto plates, into the fields and into the gene banks to be safeguarded. Engineered solutions will need to change behaviour and perceptions, increase empathy, and improve value systems to increase collective action across sectors and countries.

In the breakout session, one of the most popular ideas to halt biodiversity loss via agricultural land management was the use of environmentally resilient native plant species.

> "Use native plant species that are resilient to environmental change."

Dr Charlotte Seal of the Royal Botanic Gardens, Kew, put forward this idea, adding that wild plants that are native and are related to crops can help increase biodiversity.

They can also stabilise soils and may have lower water requirements. Dr Andrew Vowles of the University of Southampton agreed with this point, adding that one of the biggest reasons for water withdrawal from freshwater ecosystems is for agricultural purposes. Using crop species that are more native to an area would help lower input requirements for survival. With reference to coastal areas, Dr Louise Firth said native, salt-tolerant plants should be more widely used and this would also link to the broader issue of environmental change.

Dr Odirilwe Selomane of the Centre for Sustainability Transitions made the point that all interventions should consider social and ecological dimensions. To ensure this, any proposed engineering solution should be modelled before implementation.

Biodiversity is in constant flux and considering that agriculture is the largest terrestrial managed biome, engineered solutions will need to consider how to make agriculture more sustainable and part of the solution to halt the biodiversity crisis. These solutions may include monitoring agricultural biodiversity-friendly practices, providing tools to compensate farmers for good practices, and improving communication to consumers about agricultural products with biodiversity-friendly practices.

Marine

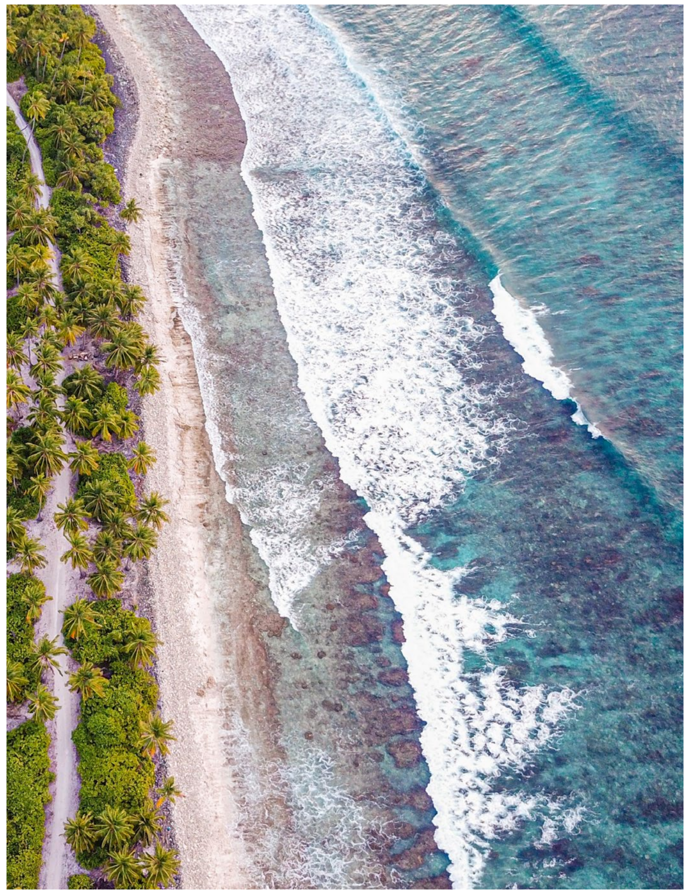
Marine session chairs

Neil Auchterlonie
Independent consultant

Dr Louise Firth
Lecturer Marine Ecology, University of Plymouth

Nikita Gopal
Principal Scientist, ICAR

Dr Bindi Shah
Assistant Professor, University of Southampton



Key takeaways

- Policy and financial incentives are two major barriers to implementing engineered solutions to halt biodiversity loss.
- Grey and green infrastructure must be integrated in engineered solutions.
- The concept of social capital can be used to think about adaptive capacities and resilience among small-scale fishing communities.
- Urbanisation of coastal cities is one of the biggest contributors to the global biodiversity crisis.

Marine facts

- It is unlikely that the SDG targets for oceans and coasts can be met, as marine and coastal ecosystems are declining too quickly.
- The risk of irreversible loss of marine and coastal ecosystems increases with climate change. Corals are particularly vulnerable, projected to decline to 10 to 30% of their former cover at 1.5°C of warming and to less than 1% at 2°C of warming.

Biodiversity crisis in marine ecosystems:

- One-third of marine fish stocks were overharvested in 2015, a portion that has increased from 10% in 1974.
- Fertilisers entering coastal ecosystems have produced more than 400 'dead zones' totalling more than 245,000 km2 – an area bigger than the UK.
- Marine plastics pollution has increased tenfold since 1980, constituting 60 to 80% of marine debris. Plastic is found in all oceans at all depths and concentrates in the ocean currents.
- 33% of reef-forming corals and marine mammals are under threat of extinction.

1/3

of marine fish stocks were overharvested in 2015, a portion that has increased from 10% in 1974.

As with the previous sessions, there was wide agreement that social scientists are an important element of any engineered solution to marine eco-engineering as they can better consider the impact of any new technology or solution on livelihoods. With the focus on future marine structures, combining both grey and green infrastructures – incorporating natural solutions into engineering solutions – was a popular proposal. Any future solution to protect marine ecosystems must be durable and multi-functional, yet policy and financial costs were continuously emphasised as the main barriers to effective implementation.

> "It's important that when we look at solutions, we look at the social, economic and environmental perspectives."

Fisheries, aquaculture and seafood development

Neil Auchterlonie, an independent consultant working in the seafood sector, noted that aquaculture is the fastest-growing food production sector. He caveated this by saying that this development needs to be sustainable, as both fishers and aquaculture industries have impacts on biodiversity.

The seafood sector is relatively conservative in its uptake of innovation, and while marine fisheries have plateaued in recent years in terms of what is produced, aquaculture demand continues to grow globally. Neil outlined several engineering-based solutions for fisheries and aquaculture such as improved vessel technologies and remote monitoring systems. While there are similar engineering-based solutions to both fishers and aquaculture, there is more potential for innovation in aquaculture such as the use of artificial intelligence, robotics, and precision farming.

In his closing remarks, Neil made four points on fisheries, aquaculture and seafood development:

1. Science, innovation and technology are key components of seafood sector sustainability.
2. Scope for innovation is extensive and where that innovation occurs there are varying degrees of potential impact (including biodiversity, greenhouse gas emissions, water use).
3. Innovation supports seafood industry sustainability as well as marine (and wider) environment quality.
4. Often what is good for business is also good for the environment (provides continuity of supply, high value products, market recognition).

A breakout room session followed, where Dr Yves Plancherel highlighted the relationship between pollution and the future of aquaculture, noting that engineering solutions were helpful in mitigating pollution from fish farms in India.

Dr Amare Alamrew shared examples from the aquaculture business in Ethiopia, where the costs of feed are high. Neil pointed out that different species of fish have different nutritional requirements, and that the recent interest in seaweed farming in Europe is in part due to seaweed having fewer feed requirements. Yet, seaweed farming systems may be having an adverse impact on waves, which could potentially have an effect on coastal erosion. Clearly any changes in marine life will have an impact on territorial biodiversity too.

Neil reflected that with over 30,000 different species of fish, it takes a long time to find where gains can be made with interventions. Nonetheless, marine life is a fascinating topic given the potential to learn more. Dr Deepayan Bhowmik corroborated this by sharing examples of using underwater cameras to study fish behaviour. His research documented gill health and showed that changes in fish behaviour can often indicate there is a poor health issue. Early warning systems and monitoring of fish health is beneficial to the industry, as well as the environment and biodiversity.

Aquaculture offers an efficient way of producing protein and is more environmentally friendly compared to terrestrial animals, with the possible exception of chickens. There is a role here for national governments to bolster the sector by enforcing regulations and certification in terms of sustainability. The topic of certification schemes was considered. Despite the costs involved, these schemes can provide market access allowing farmers to potentially get more profit for their produce and ensure higher welfare standards in the sector. One way for smallholder farmers or fishers to become part of a scheme is to form a cooperative.

Climate change and COVID – through the gender lens in marine fisheries

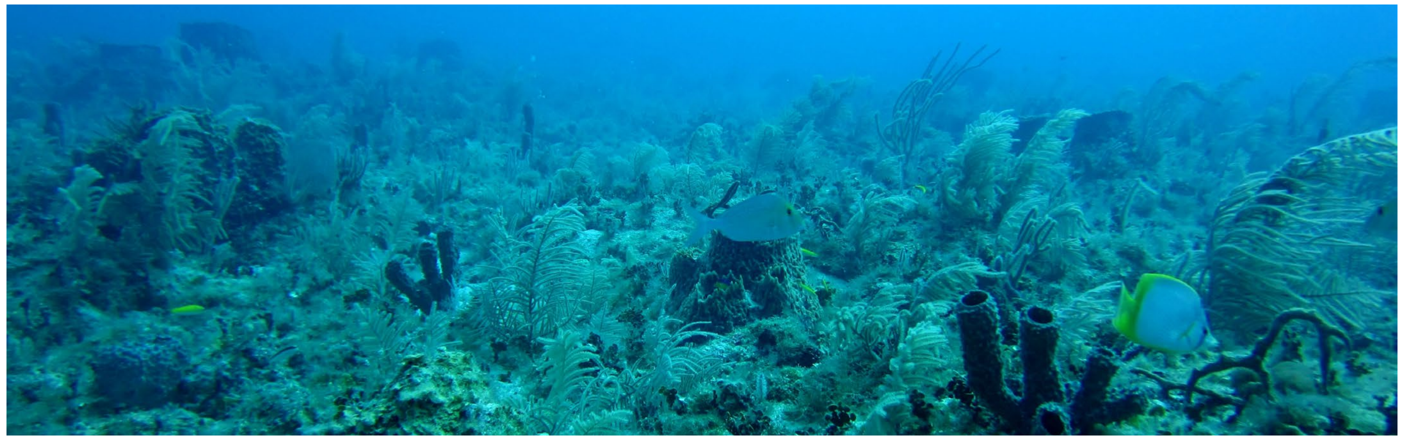
> "Community engagement is key to any solution."

In their presentation, Dr Nikita Gopal and Dr Bindi Shah considered the impact of the climate change-induced biodiversity crisis and the COVID-19 pandemic on women in marine fisheries. As in many parts of the world, fishing communities live with increasing uncertainty due to sharp increases in catches, environmental degradation, vulnerabilities to sea-level rise, reduced incomes, and labour precarity. These trends have been exacerbated by the COVID-19 pandemic.

Women contribute significantly to fish value chains – the United Nations Food and Agriculture Organisation (FAO) estimates that women make up 50% of people in capture fisheries, and women make up 60% of all fish sellers in Asia and Africa. However, their work continues to lack visibility, and is not given the economic importance it deserves. In situations that have long-term impacts, like climate change or the recent pandemic, women are often the hardest affected.

Nikita introduced the concept of social capital to think about how researchers, policymakers and non-governmental organisations can work with small-scale fishing communities and particularly women to develop engineering solutions to halt the biodiversity crisis and help countries meet the Sustainable Development Goals. When there is greater gender equality and inclusiveness, there is all around gain.In the corresponding breakout session, Rukevwe Siakpere discussed how local women in Nigeria use mangrove trees to smoke fish. Although it helps them meet household nutrition needs and provides a source of income, it can also damage the ecosystem. One solution is to introduce a different type of drying with solar power or other wood.

Projects first need to understand this gender difference. In what part of the system are the women involved in and what are the techniques that can be challenged for each context? For example, what are the consequences of banning fishing to prevent biodiversity loss while there is a famine happening at the same time? The concept of social capital is important here in considering how to think about adaptive capacities and resilience among small-scale fishing communities, and particularly for the women in these communities.



Designer ecosystems: making space for nature in urban spaces

Dr Louise Firth opened her presentation by discussing 'designer ecosystems'. This is where ecologists, engineers, social scientists, landscape designers, and artists can all work together to help make space for nature in urban environments.

Urbanisation is undoubtedly one of the biggest contributors to the global biodiversity crisis. In coastal marine environments, valuable coral reefs, mangroves, beaches, and rocky shores are being converted into reclaimed land and artificial islands. These artificial structures are proliferating globally, and they typically make for very poor habitats for marine and terrestrial life.

Any negative impacts on biodiversity will ultimately have a negative impact on the functions that are carried out by these species and the services that are provided to humans. For example, prior to the building of a sea wall, mussels or oysters may have been present. Mussels and oysters are very important bio-filters and can provide important services to humans in terms of clean water and sanitation.

Louise provided the example of engineering a sea wall to make space for nature. This is an intertidal environment, and marine life cannot survive if it is too dry. Engineered features like rock pools onto sea walls can create wet environments, ensuring marine life can survive.

Participants noted that mitigating and reducing the impact on biodiversity will require engineers and the construction industry to have a better understanding of their impact on ecosystems. Often cost is given as a reason to circumvent more sustainable materials and structures within designer ecosystems. Yet, there are multiple beneficial reasons to have marine life on new structures, such as the potential of marine life to prevent cracks in concrete.

> "We need to think big about how we can create space for nature through urban design."

Husam HajAli made the point that dynamic modelling is key to designing marine structures, this way engineers can avoid adverse impacts on marine life. Professor Ramzy Kahhat added that lifecycle assessments are important when it comes to infrastructure, design and development. Professor Ioannis Ieropoulos gave examples from their research in robotics, which considers how to mimic biodiversity and nature to better inform design solutions.

Dr Peter Wangai, a social ecologist involved in working in urban ecosystems, made the point that urbanisation is occurring in coastal areas. The 2021 IPCC report claims that 90% of urban areas can be found along coastlines, and thereby the impact of urbanisation is critical when discussing marine ecosystems. Rising sea levels compound this challenge. Dr Charlotte Seal shared her interest in plant biodiversity and the natural generation of plants, considering the role of plants in resilience to sea level rise. These engineered solutions are critical, yet the lack of political will to drive legislation around marine protection is a major barrier to change.

With such a wide potential scope to provide a range of benefits to humans and the environment, this session made a strong case for different fields and disciplines to collaborate to halt global biodiversity loss: ecologists need to talk to engineers, landscape designers, artists, and social scientists.

Richard James MacCowan

Biomimicry Innovation Lab

Though not an engineer by trade, Richard James MacCowan's experiences as a designer have allowed him to work across a variety of fields – all relating to urbanisation and its relationship with the environment. Richard underlined the role of ecosystem services as a pathway to connect our cities to the natural world.

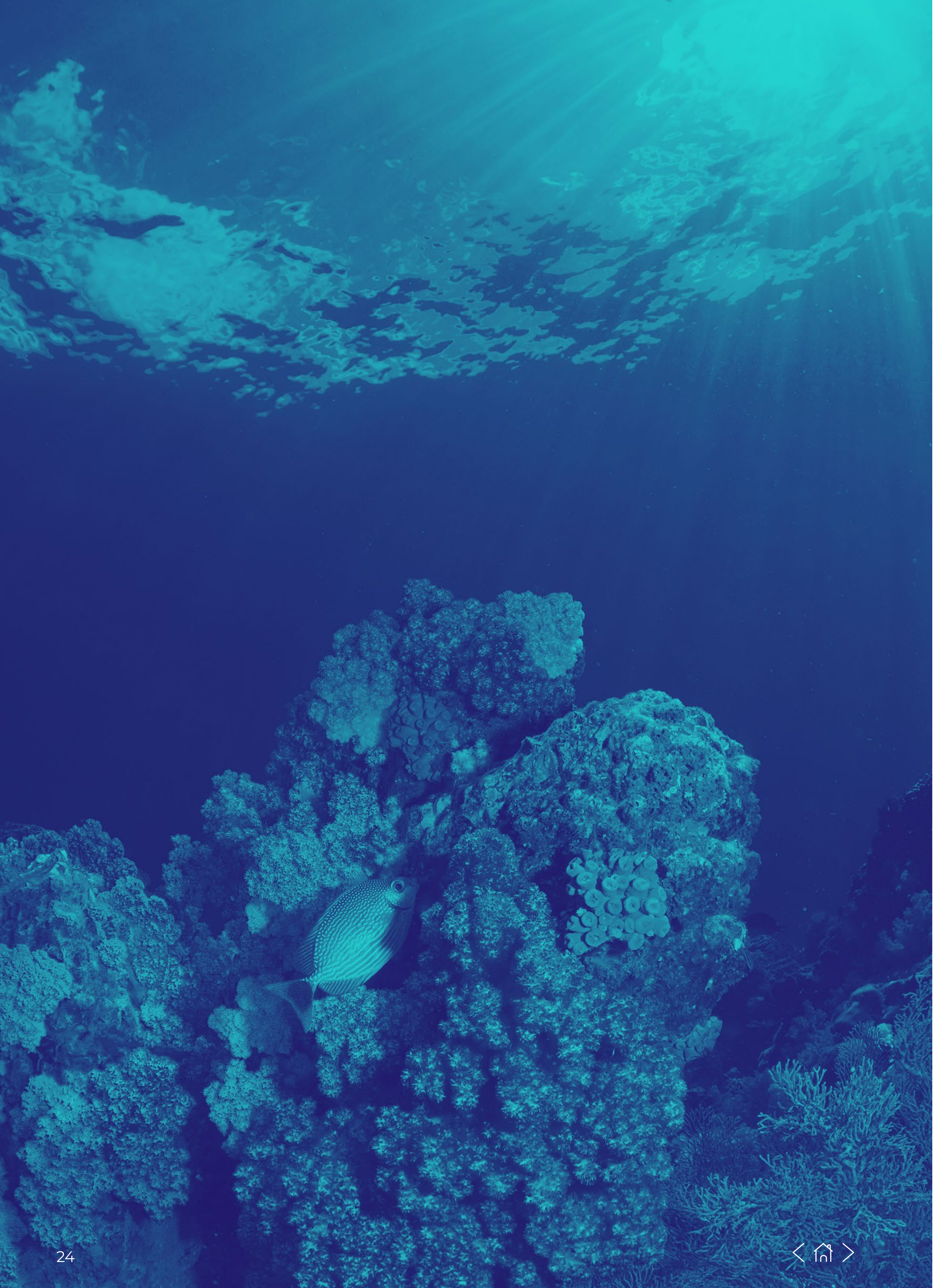
Work in this field can bring together the technical, biological and urban development spheres to create environments that are better for the planet and people. Richard provided some examples. Urban cooling from planting trees strategically can have a larger impact than technological solutions. Lifecycle analysis can look at product elements and examine where they overlap along the supply chain to minimise environmental effects. However, he warned of companies who commit 'greenwashing', incorporating ecosystem services in one part of their production line but damaging environments in another part of the world.

Richard emphasised the importance of ecosystem services as a part of a wider effort to mitigate the negative impact of increasing urbanisation on the planet. Through biomimicry, his team is working on understanding the complexity of urban environments. He highlighted his organisation's research into the increased frequency of zoonotic diseases with the growth of urbanisation. Richard also discussed different urban planning projects that his team works on to determine the value of different elements of a city such as parks, green infrastructure and waterways.

Ultimately, Richard's speech focused on the complexity of urban environments and how ecosystem services can help to break down those complexities and find solutions. While it would be difficult to create a fully circular city, there are methods to create low entropy cities that integrate green infrastructure and other innovations.

Biography:

Richard MacGowan is an award-winning multidisciplinary designer and works worldwide on urbanism, manufacturing and agricultural projects. He has a background in international real estate investment and development and sustainable design, combining this with behavioural science and bio-inspired design.



For more information about these projects, please visit **raeng.org.uk/frontiers**

Seed funding projects

Awarded in November 2021 as a result of the event

Fish for Peace: Advancing Sustainability of Hydropower in Developing Nations

- Andrew Vowles, University of Southampton
- Luz Jimenez-Segura, Universidad de Antioquia
- Peng Bun Ngor, Royal University of Agriculture, Khan Dongkor
- Frank Masese, University of Eldoret
- Amare Mezgebu Alamrew, Bahir Dar University
- Vinicius Menezes de Oliveira, Universidade Federal de Rio Grande
- Oscar Link, University of Concepcion

Food, gender, enterprise: leveraging interdisciplinarity for sustainable small-scale fisheries

- Bindi Shah, University of Southampton
- Nikita Gopal, ICAR-CIFT
- Bethan O'Leary, University of Exeter
- Deepayan Bhowmik, University of Stirling
- Madhu V R, ICAR
- Sandhya K M, ICAR
- Rejula K, ICAR
- Richard James MacCowan, Biomimcry Innovation Lab
- Paul Kemp, University of Southampton

Harnessing the Destructive Energy in Pine Leaf-litter for Biodiversity Regeneration

- Modupe Jimoh, University of Warwick
- Rajnish Jain, Avani Bio Energy
- Sarobidy Rakotonarivo, University of Antananarivo
- Atiyeh Ardakanian, University of West London
- Richard James MacCowan, Biomimcry Innovation Labs

Restoring Environments, Societies, Ecosystems and Trees (RESET)

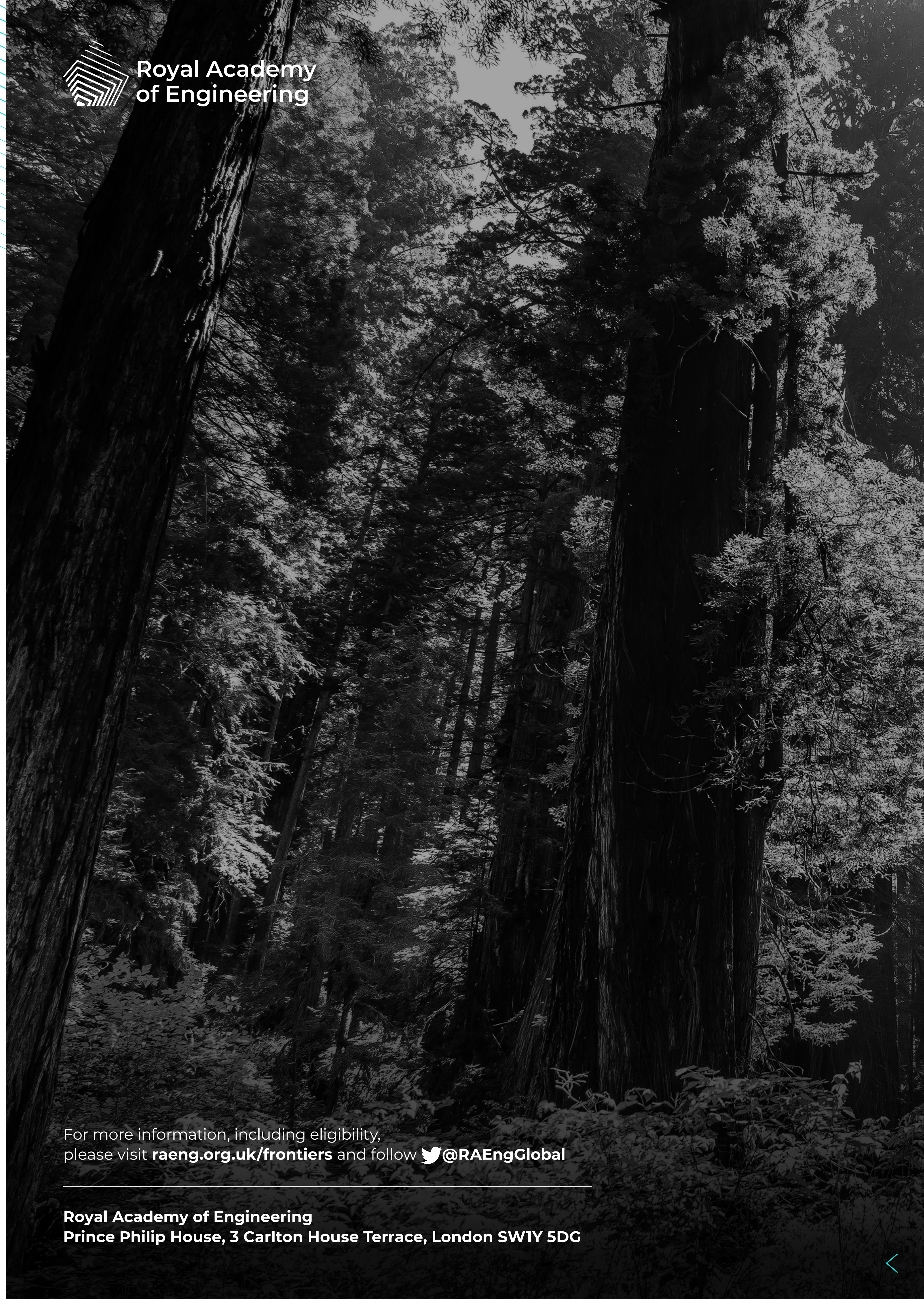
- Francesco Pomponi, Edinburgh Napier University
- Biniam Ashagre, Anglia Ruskin University
- Sarobidy Rakotonarivo, University of Antananarivo
- Ronald Twongyirwe, Mbarara University of Science and Technology

Safe Use of Wastewater in Agriculture; a Water-Food-Energy Nexus

- Atiyeh Ardakanian, University of West London
- Kourosh Behzadian, University of West London
- Ioannis Ieropoulos, University of West of England
- Modupe Jimoh, University of Warwick
- Mohammad Gheibi, Zist Pardazesh Aria Company
- Olfa Mahjoub, National Research Institute for Rural Engineering, Water and Forestry (INRGREF)
- Mazoor Qadir, United Nations University Institute for Integrated Management of Material Fluxes and Resources (UNU-FLORES)

Satellite-powered remote sensing approaches for more inclusive forest conservation policy

- Marco Haenssgen, University of Warwick
- Sarobidy Rakotonarivo, University of Antananarivo
- Alex Lechner, Monash University
- Prasit Leepreecha, Chiang Mai University
- Ta-Wei Chu, Chiang Mai University
- Ivo Vlaev, University of Warwick



Royal Academy of Engineering

For more information, including eligibility, please visit **raeng.org.uk/frontiers** and follow **@RAEngGlobal**

Royal Academy of Engineering
Prince Philip House, 3 Carlton House Terrace, London SW1Y 5DG