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GREEN COASTAL INFRASTRUCTURE

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GREEN COASTAL INFRASTRUCTURE

EDITORIAL BY TOMOHIRO KUWAE & ANGELOS N. FINDIKAKIS

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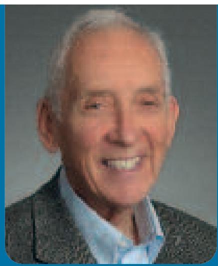
Guest Editor



Angelos N. Findikakis
Hydrolink Editor

Many coastal areas have always been vulnerable to catastrophic flooding caused by extreme events such as high waves, storm surges and tsunamis. Their vulnerability is now increasing as climate change causes rising sea levels, more frequent storms and more intense cyclones. The conventional approach to the protection of population centers and commercial and industrial facilities from such hazards has been to construct levees, groins, seawalls and other structures, often made of concrete and referred to as grey infrastructure. Such systems require a significant investment and are not always adequate or effective. The response of different natural systems during some major coastal flooding events over the last few decades has drawn attention to the use of non-structural approaches and nature-based solutions to the problems of coastal protection. For example, during the 2004 Indian Ocean tsunami villages behind mangrove forests in India, Sri Lanka and Thailand experienced less damage than other regions without such natural barriers. In the United States during hurricane Katrina in 2005 parts of southeastern Louisiana and southern Mississippi were protected by coastal wetlands which reduced the storm surge impact inland. During hurricane Sandy in 2012, oyster reefs absorbed part of the wave forces decreasing erosion along the North Carolina coast. In Japan during 2011 Tohoku earthquake and tsunami, coastal pine forests provided protection to parts of the coast by reducing the tsunami wave as it moved inland and by trapping the debris that it was carrying. Understanding systems such as wetlands, mangroves, coral reefs, and coastal forests, which are often referred to as green coastal infrastructure, has drawn the interest of many researchers working to contribute to the enhancement of coastal resilience.

Green coastal infrastructure represents an alternative approach to natural disaster protection and in some cases is more efficient and more economic. The economic argument in favor of this approach applies not only to developing countries that do not have the financial resources to undertake large grey infrastructure projects, but also to developed countries. For example, in Japan the combination of the current economic and social conditions, such as the declining birthrate, an aging population, low economic growth, and the reluctance to raise taxes, make it difficult to finance new conventional projects and to replace existing coastal protection structures that have either have degraded over time or must be upgraded in response to more severe conditions due to climate change.

This issue of Hydrolink brings together four articles that look at different aspects of green coastal infrastructure, ranging from assessing its economic value and ecosystem services, to advances in research aiming at understanding how it functions and finding ways to enhance its role in support of sustainable development along the coasts where hundreds of millions people live around the world.

The article by Lucy Emerton, Naoya Furuta, Tsuyoshi Inoue and Ryo Oyama discusses the valuation of ecosystem services of green coastal infrastructure by focusing on a multi-year mangrove planting project in South and Southeast Asia. The article assesses several ecosystem services of this project with significant socio-economic importance, concluding that their economic benefits were much greater than the required investment in the project, and that more than half of the project's benefits come from disaster risk reduction and other coastal protection services.

A discussion of how lessons from observations on the role of mangroves in providing coastal protection motivated research in this subject is presented in the article by Che-Wei Chang and Nobuhito Mori. The article reviews recent research in both numerical modeling and laboratory studies aimed at advancing the understanding of the physical processes and the mechanics of wave attenuation by mangrove forests.

The article by Erik van Eekelen, Arjen Luijendijk, Sonja Ouwerkerk, Henk Steetzel and Ellis Penning describes three coastal flooding defense projects in the Netherlands based on sandy strategies. These nature-based solutions not only counter coastal erosion, but they also provide additional benefits by creating new habitats, supporting biodiversity and providing new recreational areas through ecosystem development ranging from new dunes to foreshores.

An interesting perspective on the potential for the "greening" of grey infrastructure, which would enhance its resilience, is offered in the article by Yuichiro Kawabata and Larissa Naylor. The article discusses the possibility of bioprotection of concrete and rock materials in coastal structures by using organisms to help reduce their deterioration in the marine environment. It also explains how recent studies suggest that bioprotective species, such as barnacles, appear to enhance the durability of structures.

The articles in this issue touch only on some of the aspects of green coastal infrastructure. There are many more possibilities offered by nature-based solutions for the protection of coastal areas that must be explored and understood, so they can be used for the benefit of the millions who live and work near the oceans.

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Aerial overview of the Hondsbossche Dunes, The Netherlands

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IN THIS ISSUE

GREEN COASTAL INFRASTRUCTURE

VALUING MANGROVES AS AN ECONOMIC PART OF COASTAL INFRASTRUCTURE

BY LUCY EMERTON, NAOYA FURUTA, TSUYOSHI INOUE & RYO OYAMA

A general lack of evidence about environmental costs and benefits means that it is often difficult to make a strong business case for investing in green infrastructure. In an effort to overcome these information gaps, one of Japan's largest insurance companies has been piloting an innovative system of corporate ecosystem valuation. The aim is to account for and report to the company's customers, shareholders and other stakeholders on the economic impacts of its investments in mangrove restoration and rehabilitation.

Why ecosystem undervaluation is a problem

Even though the concept of 'green infrastructure' has gained currency over recent years, it still tends to be accorded a low priority as compared to more conventional 'grey' measures. One important reason is the lack of demonstrable evidence as to how and why ecosystems offer an economically worthwhile investment choice. For the most part, calculations of the relative returns to different land, resource and investment choices simply do not factor in ecosystem costs and benefits. Given these informational and methodological gaps, it is perhaps hardly surprising that both public and private sector planners often remain unconvinced — or even unaware — about the potential to harness the natural environment to deliver key infrastructure and development services.

Intensifying competition over scarce public and private investment funds, coupled with increasing demands from shareholders and taxpayers for information about how their money has been spent, means that the need to demonstrate cost effectiveness and value for money is becoming an ever-more pressing concern. Yet, while figures are readily available on the benefits of hard engineering options, and are routinely used to measure assets, inform investment planning and report on financial performance, much less information is on hand about the gains and economic opportunities from investing in nature-based solutions.

Ecosystem valuation can provide a powerful tool for placing green infrastructure on the agenda of investors, planners and policy-makers[1]. Yet, although it has increasingly started to enter the lexicon of public sector decision-makers, as yet there remain far fewer examples of ecosystem

A community mangrove nursery in Tar Ton Son village, Thailand

Mangrove planting site in Bedono Village, Indonesia. The sign reads "one mangrove = saves 5 lives in the coastal area"

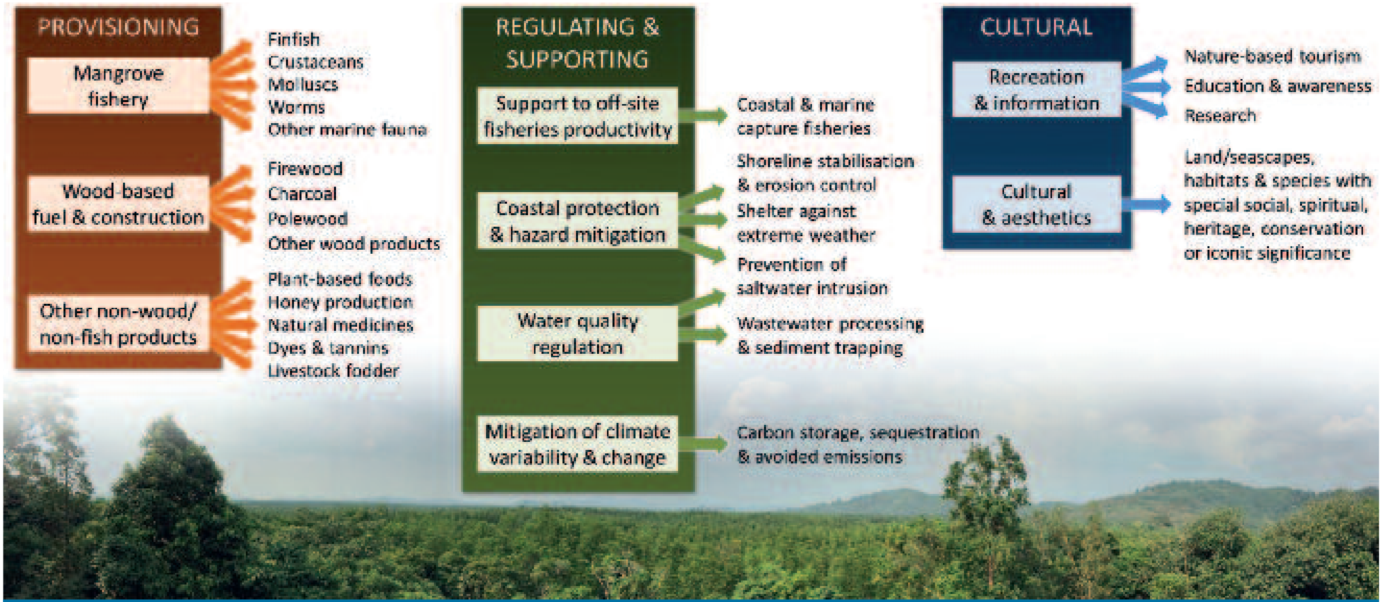


Figure 1. Mangroves provide a wide range of economically-valuable ecosystem services

valuation being used in a corporate context. It is against this backdrop that Tokio Marine & Nichido Fire Insurance Co., Ltd.(TMNF), one of Japan's largest insurance companies, initiated an innovative study to look at the economic value of mangrove ecosystem services – one of the most productive, and valuable, components of the 'natural' infrastructure base in coastal zones.

The Mangrove Planting Project

As part of its commitment to a safe, secure and sustainable future, TMNF has a long-standing corporate environmental and social responsibility programme. One of the core components is a Mangrove Planting Project. Between 1999 and March 2019, TMNF has worked with a network of non-governmental organisations and local partners to plant 10,930 hectares of mangroves in nine countries in the Asia-Pacific region: Bangladesh, Fiji, India, Indonesia, Malaysia, Myanmar, Philippines, Thailand and Viet Nam.

As well as contributing to corporate responsibility and reputational goals, the Mangrove Planting Project helps to secure important ecosystem services – 'the benefits people obtain from ecosystems'[2]. The intention is to support local community development, strengthen climate change mitigation and adaptation, assist in disaster risk reduction, and contribute towards biodiversity preservation. Yet many people – both within and outside the company – remain unaware of the wide-ranging benefits that the company's investments in mangrove planting have had on local livelihoods, national development, and even the global economy. This poses a real risk of undermining the support and funding that is required to sustain TMNF's mangrove planting activities into the future.

With a view to overcoming these information gaps, in 2015 TMNF commissioned an initial study to value the ecosystem services generated by its Mangrove Planting Project[3]. The intention was to account for and report to the company's customers, shareholders and other stakeholders on the economic returns from mangrove restoration and rehabilitation. Four years later, just after the project had come to the end of its fourth phase and twentieth year, the study was repeated and updated[4].

Valuing mangrove ecosystem services

The question of how to ascribe values to ecosystem services has long posed something of a challenge to economists. The easiest and most straightforward way, and the method used conventionally, is to look at their market price: what they cost to buy or are worth to sell. However, as ecosystem services very often have no market price (or are subject to prices which are highly distorted), these techniques obviously only have very limited application. However, over the last two decades or so, a suite of methods has emerged with which to value goods and services that cannot be calculated accurately via the use of market prices[5,6,7]. These have now come into wide acceptance and common usage among environmental economists.

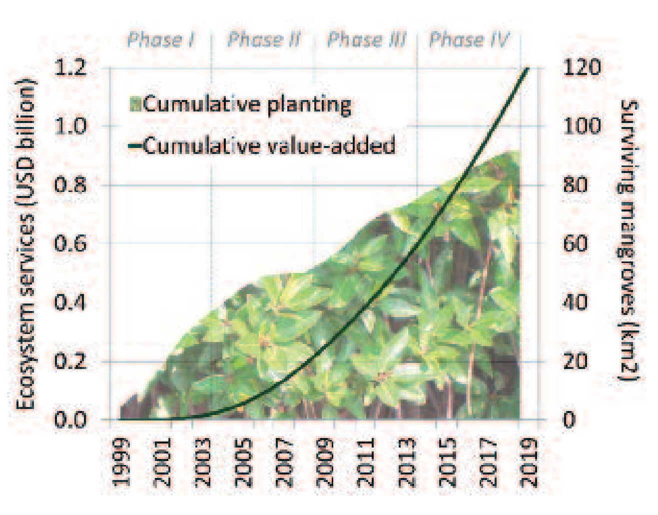
The TMNF study drew on this 'toolbox' of market and non-market ecosystem valuation techniques. It followed three interrelated steps: first identifying mangrove ecosystem services and their stakeholders at the project sites, going on to assess baseline economic values, and then modelling the changes in ecosystem service benefits resulting from mangrove restoration and rehabilitation. As well conducting a macro-level analysis of the economic impacts of mangrove planting across all nine countries, micro-level case studies of specific mangrove ecosystem service values and beneficiary groups were carried out at three planting sites: Bedono Village in Indonesia, Đồng Rui Commune in Viet Nam and Mueang Ranong District in Thailand.

The returns to investing in mangrove restoration and rehabilitation

The study found that the vast majority of the coastal population in the project planting sites depend in some way on mangroves for their livelihoods and economic wellbeing. Nine ecosystem services were found to be of particular socio-economic importance (Figure 1): mangrove fishery, wood-based fuel and construction, other non-wood/non-fish mangrove products, support to off-site fisheries productivity, coastal protection and hazard mitigation, water quality regulation, mitigation of climate variability and change, recreation and information, and cultural and aesthetics.

It follows that a large number of local communities have benefited directly from the Mangrove Planting Project. These include more than 1.4 million people or almost 350,000 families, many of whom face high rates of poverty, live in extremely precarious economic

Figure 1. Mangroves provide a wide range of economically-valuable ecosystem services



Ecosystem services	Total value (USD million)	Average annual value (USD/ha)	Benefits per unit of investment (USD)
Mangrove fishery & other product harvests	144.97	752	11
Support to off-site fisheries productivity	360.95	1,872	26
Shoreline stabilisation & erosion control	258.13	1,924	19
Shelter against extreme weather	128.20	956	9
Wastewater treatment & sediment trap	168.17	872	12
Prevention of saline intrusion	134.06	695	10
Carbon sequestration	11.55	60	1
TOTAL	1,206.0	6,256	87

Table 1. The economic value and return on investment from mangrove planting 1999-2019

conditions, and are subject to recurrent shocks, stresses and pressures. In addition, many towns and industries further afield depend on the disaster risk reduction services provided by mangroves, and even global stakeholders benefit from the climate change mitigation offered by the 1.25 million tCO_2e stored in mangrove forests and soils in the project planting sites.

The economic impact is substantial. The study calculated that mangrove ecosystem services worth USD 125 million* are being generated in the year 2019 alone. This figure will continue to increase into the future – in another 20 years, by 2038, the annual value of mangroves planted is projected to reach almost USD 150 million. In total, the project is estimated to have added ecosystem services with a value of USD 1.2 billion over its first 20 years of operation – an average of USD 6,256/ha/year (Figure 2, Table 1). It is worth noting that a large proportion of this value – more than half – is accounted for by disaster risk reduction and other coastal protection services.

By the end of 2018, TMNF had invested around JPY 1.23 billion in the Mangrove Planting Project (equivalent to almost USD 14 million at current price levels). Comparing this figure with the value of ecosystem services added over the course of the first four phases of the project suggests that, to date, each USD (or JPY) of TMNF's investment has generated 87 Dollars (or Yen) of economic benefits for coastal communities, surrounding areas and the global community. This figure has risen steadily over time, in line with the growth in planted area, and as mangroves have increased in maturity and thus in the level of ecosystem service benefits they are able to generate. The return on investment is impressive: over its first four phases, the Mangrove Planting Project displays an economic internal rate of return (EIRR) of 157%.

Acknowledgements

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** All values in the study were expressed at constant 2019 price levels, in international USD. This accounts for the effects of inflation, and also adjusts for differences in real prices and values between the countries in which the Mangrove Planting Project was carried out. I thus allows for costs and benefits generated in different years and places to be directly compared, combined and aggregated.*

Lucy Emerton is an environmental economist specialising in ecosystem valuation, finance and incentives. Over the last 30 years she has worked as an adviser to a wide variety of governments, non-governmental organisations, United Nations agencies, research institutes and private sector companies, across more than 70 countries worldwide. Lucy is currently Conservation Economics and Finance Director of the Environment Management Group, a consultancy group and think-tank providing policy and planning advice and technical support in environmental sustainability.

Naoya Furuta is a coordinator at IUCN Japan Liaison Office and a professor at the Institute of Regional Development, Taisho University, Tokyo, Japan. Since the Great East Japan Earthquake in 2011, he involves in various projects and publishes many articles on Eco-DRR and green infrastructure to advance national and global policy and to provide technical support for governments, NGO and the private sector.

Tsuyoshi Inoue is a consultant with experiences in disaster risk reduction and climate change adaptation. Over the past decade, he has worked with customers in public and private sectors in risk analysis and modelling projects. He is currently employed by a Mitsubishi Research Institute, Inc. as a senior consultant.

Ryo Oyama is a consultant working for Mitsubishi Research Institute, Inc. Through over 100 projects for governmental organisations and private sector companies, he has worked as a researcher in the fields of energy and the environment and economic evaluation.

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GREENING FOR IMPROVING THE RESILIENCE OF GREY INFRASTRUCTURE ASSETS

BY YUICHIRO KAWABATA & LARISSA A. NAYLOR

Coastal, estuarine and marine environments (hereafter, marine environments) are harsh for grey infrastructure, especially concrete and mortar-joint based infrastructure assets like seawalls, bridges, ports and harbours. Chloride-induced corrosion of reinforced concrete structures is one of the most severe asset deterioration problems, which leads to loss of structural capacity of the asset. This is caused by repeated exposure to intense marine environmental conditions that negatively affect the durability and maintenance of concrete engineering structures. These effects are found worldwide, are very expensive to manage and are expected to increase as our climate continues to change [1].

As such, extensive efforts have been paid by grey engineers to understand and manage these risks of deterioration. Deteriorated structures also require burdensome repair process including erection of temporary scaffolds, removal of deteriorated concrete, restoration of removed cross-section and application of cathodic protection in some cases. These offshore works are frequently impeded by tidal conditions and wave action. Therefore, highly-durable materials such as anti-corrosive steel, highly-durable concrete using chemical and/or mineral admixtures, and coatings are typically recommended, although these traditional approaches to reduce the risk of asset deterioration are expensive. Moreover, experimental studies comparing the ability of different admixtures and coatings on improving the durability of concrete from chloride ion penetration [2] have shown that these additives lose their effectiveness in zones XS2 (intertidal) and XS3 (supratidal) within 10 years of deployment in the harsh intertidal conditions. Therefore, there is a pressing need to identify alternative methods of improving the durability of marine concrete to harsh environmental conditions.

Bioprotection to improve the resilience of grey infrastructure assets

In the past decade, engineering and biogeomorphology researchers in Japan, Italy and the United Kingdom have explored the possibility of

Figure 1. Barnacles on concrete superstructure of open-type pier

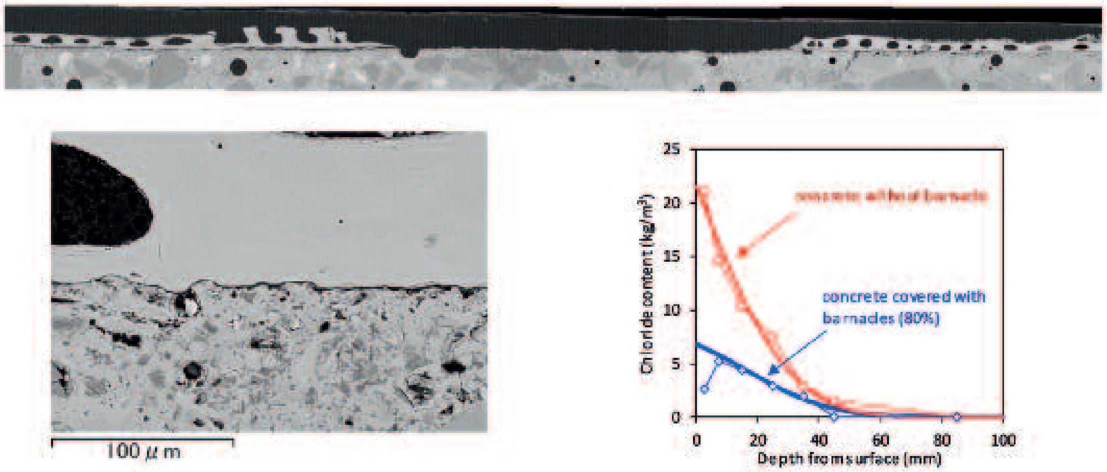

Figure 2. Basal membrane of barnacles attached on concrete surface and chloride ion profile in concrete. Top shows basal membrane of barnacles attached on concrete surface and bottomkawak left is interface between concrete and basal membrane. Bottom right is chloride ion profile in concretes w/ and w/o barnacles exposed to marine tidal zone for approximately 10 years, showing significant prevention of barnacles against chloride ion penetration

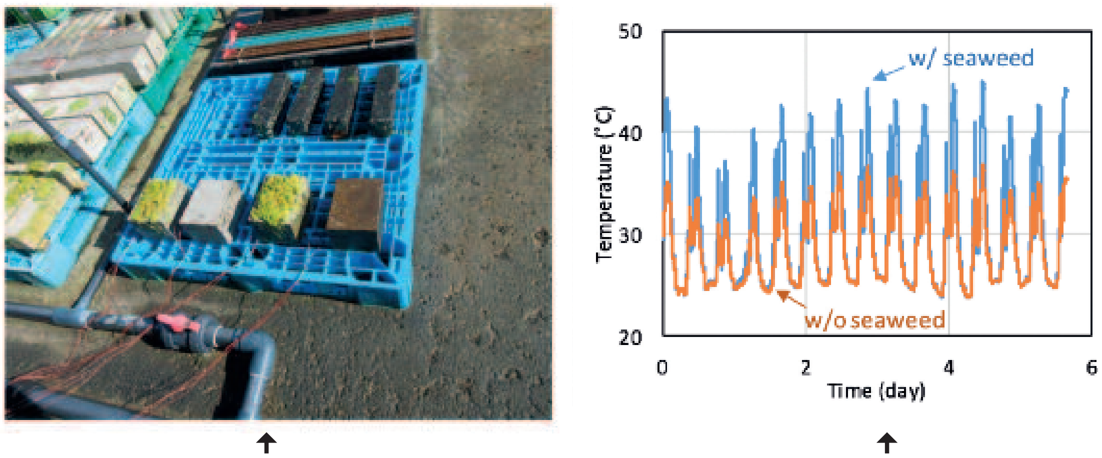

Figure 3. Influence of seaweed on temperature variation (measurement: the end of July 2019)

(a) Field-exposure test with and without seaweed on concrete surfacesurface

(b) Temperature of concrete (5mm from the surface)

using ecology to help reduce the risk and/or impacts of weathering-related deterioration of marine concrete and rock materials [3-7]; this is known as bioprotection. Other researchers have also explored the effects of cyanobacteria and algae on the durability of marine concrete [8]. Recent studies interestingly conclude that bioprotective species appear to enhance the durability of assets [3]. One example is barnacles – a species which is commonly found on hard marine engineering structures worldwide. Barnacles are frequently found colonizing concrete surfaces in the intertidal (XS2) zone (Figure 1). Figure 2 shows the interface between concrete and basal membrane of barnacles. The basal membrane of many barnacle species is significantly denser than concrete, and adheres very well to concrete. Also, even when the barnacles are detached from the concrete surface, they produce a secondary cement secretion, which is denser than concrete. Consequently, the basal membrane and secondary-cementing substances play a role as an inorganic surface coating. The previous study revealed that the basal membrane of a barnacle has a potential to prohibit chloride ion from penetration [4]. The possibility of durability enhancement with marine growth raises the next question: how long can this enhancement be maintained? The life span of grey infrastructure is generally 50-100 years whilst that of marine organisms is 1-10 years, with species like barnacles reproducing and settling on marine infrastructure annually. Therefore, it is questioned whether bioproctetive species like barnacles can influence the long-term durability of marine concrete structures. In order to answer this question, the Port and Airport Research Institute, Japan, conducted a field-exposure test of a large-scale reinforced concrete beam (200 × 300 × 2400 mm) for approximately 10 years. Following exposure, concrete cores were sampled from the beam and the profile of chloride ions in the concrete was measured. Figure 2 shows distinct reduction in chloride ion penetration into concrete covered with barnacles (blue plots), suggesting that the beneficial effect of barnacles is maintained for at least 10 years. Also, the rapid electrical migration test on concrete cores of real field structure and scanning electron microscopy image analysis of the barnacle-concrete interface, all supported this result [9].

Seaweed and other algae (also often referred to as fouling organisms of marine infrastructure) have an ability to regulate microclimatic variability, such as temperature and humidity fluxes. In the intertidal zone, the temperature of concrete surfaces can increase to over 50 °C due to ambient temperature and solar radiation during the low tide phase and decreases by 10-20 °C due to seawater supply during high tide [10]. Such temperature variability may accelerate mechanical weathering and induce micro-cracking of concrete surface, which reduces the resistance of concrete against mass transfer and strength [11,12]. Coombes et al., via an exposure experiment at three sites in South West England, UK, reported a statistically significant, positive effect of microclimatic buffering by seaweed, where the variability of temperature and humidity was significantly reduced [8]. This effect was confirmed in Japan as shown in Figure 3, where seaweed growth reduces the temperature of concrete surface by approximately 15 °C. Barnacles were also found to play a similar role in regulating temperature variability of marine concrete and rocks (limestone and granite) in laboratory trials [5]. Cyclic thermal history is known to induce micro-cracks on concrete surface [10, 11]; a stable microclimate is thus beneficial for concrete durability.

There is also some evidence worldwide showing that deterioration of grey marine concrete infrastructure can also be caused by biology, where algae (mainly caused by organic acids), found within the concrete mix, or growing on the surface of marine concrete and rocks, can cause deterioration at the micron/mineral scale [13]. Therefore, recent research shows that some biology can have positive benefits for asset resilience (as well as negative effects); these potential benefits and/or risks should be considered in the design and construction of green-grey and traditional engineering structures [14].

Enhancing the design of concrete engineering structures to encourage bioprotective species

Recent research has also demonstrated that ecological growth on marine concrete structures can be improved by changing surface texture of traditionally smooth grey assets [15-17]. Altering the texture of marine concrete can occur at a range of spatial scales from mm-scale for target early-coloniser species such as barnacles (e.g. [15]), to creating pits and crevices suitable for mobile species (e.g. [18]). Creating simple and inexpensive textures at the mm-scale has been shown to statistically increase the rate of barnacle settlement in the UK [15, 19] and higher covers of barnacles were found to reduce thermal fluxes on marine concrete (and limestone and granites used in coastal engineering assets) [5], thus reducing the risk of thermal-related deterioration. This means that it is simple and inexpensive to alter the surface texture of marine concrete to improve the rate at which barnacles settle – which when coupled with the reduced chloride ingress and improved microclimate regulation discussed earlier, has the potential to increase the bioprotective ability of barnacles by achieving fuller cover of concrete surfaces, more quickly. Recent research, from the largest known experimental concrete tile experiment in the UK, has shown that designing surface textures from the mm to dm scale will have the best ecological outcomes in northern latitudes. It is thus recommended that designs are created to optimize for bioprotective as well as wider ecological benefits that a more structurally heterogeneous surface marine concrete design provides; this will better mimic the natural geomorphic diversity on rocky shores.

In addition to manipulating the surface texture, the chemical composition of marine concrete can also be altered to improve ecological suitability. For example, in Japan, "Environmentally Active Concrete (EAC)" was developed by adding amino acid to concrete, which chemically promotes the growth of algae significantly by releasing amino acid from the concrete [20]. EAC was implemented in the Port of Wajima and this project was awarded a "Working with Nature" Prize by PIANC in 2018 [21]. Such approaches are quite beneficial to enhance not only the ecological value of coastal and marine engineering assets to 'green the grey' [14], but can also potentially improve the durability of grey marine infrastructure.

Yuichiro Kawabata is a senior researcher of Port and Airport Research Institute, Japan. He has worked on the design and maintenance of coastal structures. His research interest is mainly a microstructural characterization of cement-based materials, including concrete deterioration. Also, he is currently working on bioprotection research including green-grey hybrid coastal structure at the Port and Airport Research Institute, Japan.

Dr. Larissa Naylor is a reader here in the School of Geographical and Earth Sciences at the University of Glasgow. She specialises in interdisciplinary and applied biogeomorphology, focused in coastal and urban settings. She has made substantive local and globally recognised contributions to ecological enhancement, biogeomorphology and rock coast geomorphology communities working in collaboration with academics and practitioners worldwide. Her significant contribution to geomorphology was recognized by being awarded the 2018 mid-career award from the British Society of Geomorphology.

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Concluding remarks

This article discusses the possibility of enhanced resilience of grey infrastructure assets by greening the grey. Although further work is still necessary, especially engineering-scale field trials combining material composition, material texture and the effects on both ecological (i.e. greening) value and marine infrastructure durability and resilience (i.e. grey), the results to date seem promising that green-grey infrastructure has the potential to build a win-win relationship for both ecosystems and society. ■

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SANDY STRATEGIES FOR RESILIENCE – LESSONS LEARNED FROM BWN

BY ERIK VAN EEKELEN, ARJEN LUIJENDIJK, SONJA OUWERKERK, HENK STEETZEL & ELLIS PENNING

Amongst the various Nature-Based Solutions (NBS) for flood defenses, sandy strategies are well-known and applied regularly in sandy coastline systems to counter or compensate erosion. However, this is only part of the possibilities that sandy strategies offer as they provide additional benefits by bringing new habitats and supporting biodiversity and recreational areas through the active development of ecosystems ranging from new dunes to foreshores. Several sandy strategies have been piloted in the Netherlands by the EcoShape consortium, a Dutch consortium on NBS knowledge development termed Building with Nature, in order to establish a knowledge base regarding the full palette of opportunities for sandy strategies. It was found that although the studied cases operate very differently and have inherent differences in supplying and using (ecosystem) functions, and that their feasibility is strengthened by the availability of sand and an appreciation for the strategy's long term flexibility and contribution to (coastal) resilience.

Introduction of sandy solutions and pilots

A substantial part of the world's coastlines consists of sandy beaches and dunes that form a natural water defense protecting the hinterland from flooding while at the same time providing valuable space for recreational activities and nature development. More than 75,000 km of sandy shorelines are experiencing persistent sand losses which on the longer term results in a setback of the coastline, negatively influencing the functions and values of these areas[1]. To mitigate these effects, coastal managers implement mitigating measures, which can either be hard constructions (i.e. sea walls or revetments) or soft (sandy) strategies.

Sandy strategies are based on the availability of sand in the system and, when necessary, on the supply of additional sand via sand nourishments (soft solutions) instead of altering the system (hard solutions).

Sandy strategies are widely applied on working coastal systems such as beaches and dunes, with various potential mechanisms to conduct the nourishments. The construction of new sandy solutions is however less common, but also seems a logical response in light of the valuable functions that these solutions offer in terms of provision of habitats and supporting biodiversity and providing space for valuable landscape and recreational functions. Within this article three projects are described: a localized mega-nourishment, the Delfland Sand Motor, a newly created dune landscape, the Hondsbossche Dunes and a sandy foreshore in front of a dike in a lake environment, the Houtribdijk. All three of them comprise sandy solutions, but they work in different systems based on different principles. Still, their lessons learned are applicable to sandy solutions and NBS in wider context.

Figure 1. Execution of sand nourishments

Sand Motor

The Sand Motor is a large sandy peninsula, constructed in 2011 on the Dutch North Sea coast near The Hague. This unprecedented pilot project involved placing 21.5 million m^3 of sand on and in front of the beach with the aim that it would spread along the coast. The Sand Motor is a unique beach nourishment due to its size (about five times that of an average nourishment), the design philosophy behind it, and its multifunctionality. The Sand Motor is intended to feed the adjacent coasts by using the natural forces of tides, waves and wind; in a way, it is built to "disappear". Another unique aspect of the Sand Motor is that it combines the primary function of coastal protection with the creation of a new natural landscape that also provides new leisure opportunities. From the outset, "learning by doing" has been a crucial part of the project.

A key question was how the morphological behavior would influence the various functions in space and time. For example, measurements show that the model simulations upfront overpredicted growth of the dune area by 500% after four years[2]. Furthermore, the observed erosion volume in the first years is significantly higher than predicted upfront[2] (reference). The high resolution and frequency of the measurements facilitated a unique 'numerical living lab', where the relevance of a range of environmental forcing and processes have been analyzed in detail. This has resulted in greatly improved interdisciplinary knowledge on the behavior of such sandy solutions [3]. Extended model capabilities for predicting its decadal behavior now allow for landscape designing of sandy solutions elsewhere in the world.

Hondsbossche dunes

The Hondsbossche and Pettemer sea dike no longer met current safety standards. Therefore, the dike was reinforced in 2015 with a soft, natural barrier of 30 million m^3 of sand on the seaside of the dike. It was renamed 'Hondsbossche Dunes'.

The design consists of a soft shallow foreshore (the beach) and a varied artificial dune landscape that has the potential to develop in valuable Natura 2000 habitats. Together, these connected systems make up the primary flood defense and provide the desired spatial quality. In order to get more insight in how the design of such a new dune can influence landscape forming processes, an innovation project was started, including the following themes:

- Optimizing design and morphological evolution
- Predictability in the development of engineered habitats
- Perception of local community and visitors

Monitoring showed us that the morphological development of the dunes was relatively well predicted [4]. The development of the engineered habitats is more difficult: it is a slow process and it takes (more) time to be able to conclude whether valuable Natura2000 habitats are created [4]. The perception of local community and visitors is merely positive: the amount of hinder by sand being transported over the dike (one of the biggest fears before construction started) is limited [4].
Furthermore, the Hondsbossche Dunes combine water safety, recreational value and nature value.[4] In several occasions one has to choose which function prevails.

Different coastal solutions

Although at first glance the large-scale sandy interventions of the Hondsbossche dunes and the Sand Motor seem much alike, their concept and their design are very different. Whereas the Hondsbossche dunes created a new beach-dune system that is designed and created to stay in place and protect the hinterland, the design of the Sand Motor has been such that it disappears. Morphological long-shore transport is part of the working of the Sand Motor, as long as the sand is brought to other parts of the beach or foreshore of the Dutch coast, but this transport was to be minimized for the goals of the Hondsbossche dunes. Despite their differences, the similarities regarding the additional values created by both projects are also striking; both areas are now renown landscape features that have an enormous ecological and natural value, but also attract recreation. Aeolian development of young dunes and associated habitats is taking place at both sites.

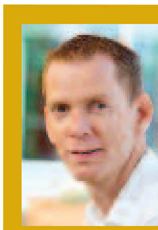

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Figure 2. Aerial view on the Sand Motor

Figure 3. Aerial overview of the Hondsbossche Dunes

Figure 4. Execution of sand nourishments

Figure 5. Planted section of the sandy foreshore

Houtribdijk

A conventional dike reinforcement is usually the first option to be considered when an existing dike does not meet the required safety standards. An alternative solution is to construct a foreshore which consists of a large quantity of sand that is capable to dissipate the incoming waves, thereby reducing or even eliminating the wave loads on the dike. For the strengthening of the Houtribdijk the latter was considered, but required further insights in the behavior of such foreshore in its lake environment.

In order to gather such insight, a research project was established with the objective to demonstrate the feasibility and the limitations of this approach, and answer research questions on, for example, the effect of waves on the foreshore and beach and the influence of vegetation growth on the stability of the sand body. Results have been used to support decision making and enable the design of future foreshores for other locations and environments [5].

As part of the project, a large-scale pilot study was carried out. The research plot was located along the Houtribdijk between the cities Enkhuizen and Lelystad in a large shallow lake called Markermeer in the Netherlands. The foreshore test section was monitored intensively during four years, from 2014 to 2018. This monitoring included water levels, as well as wave measurements, morphological changes in the sandy profile and vegetation development. All the data gathered has been analysed to answer a series of pre-defined research questions, such as how a secure, stable and cost efficient sandy foreshore can be designed in a lake system. Finding a balance between security and cost-efficiency requires insight in the physical processes driving the morphological change and the wave damping capacity, as well as quantification of the related uncertainties. The results have been applied to design a sandy reinforcement of a large section of the Houtribdijk as shown in Figure 4 [5].
The application of a sandy foreshore in a lake environment, demonstrates that sandy solutions are not only applicable in coastal settings.

Vegetation development

In all the above examples it is clear that vegetation and its development play a major role in sandy solutions. Dune and shoreline vegetation such as marrow grass, reeds and willows have a strong impact on morphodynamic processes in sandy foreshores. The presence of vegetation helps to stabilize the sediments and limits aeolian transport. Also, when vegetation develops along the shoreline and in shallow waters it reduces wave impact on the shore. Especially in newly created sandy foreshores, vegetation needs several years to establish itself and mature. Therefore, it can be beneficial to stimulate the presence of vegetation to reduce sand drift inland immediately after construction. The success, speed and type of vegetation development depends strongly on the abiotic conditions at the site, such as soil type, average groundwater table and fluctuations in water levels along the shore. Additionally, the available seed bank and grazing of the vegetation by birds and mammals affect the final result. Planting the desired vegetation speeds up the process, as does the application of more nutrient rich silty sediments or clay supplied to the top-layer of the sandy foreshore. The additional nutrients stimulate growth and the enriched soil retains water better during dry periods. Planting should be done in the correct season depending on the plant species, generally in early spring and if necessary, a temporary irrigation system (e.g. using sprinklers) could be used to aid the solid rooting of the planted vegetation. As vegetation develops over time, attention must be payed to its management over the life time of the sandy foreshore. A proper long-time vegetation management plan must be made that addresses potential measures to counter undesirable developments, such as the sudden collapse of the vegetation due to illness or heavy grazing and the occurrence of undesirable species. Creating such management plans during the design phase of a new sandy foreshore also help in the acceptance of concept.

Conclusive remarks

Despite the distinct features of the various sandy solutions studied by EcoShape, it is clear that as a palette of solutions, the sandy strategies have demonstrated their feasibility, both from a technical perspective as well as from the perspective of created value. For further upscaling it is important to recognize key components that have contributed in this feasibility being a) the availability of sand (at relatively limited costs), b) an appreciation for the flexibility that the sandy strategy inherently offers and c) the landscape values created and their opportunities for recreation. ■

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ENGINEERING FUNCTIONAL EVALUATION OF MANGROVE FORESTS FOR COASTAL DISASTER REDUCTION

BY CHE-WEI CHANG & NOBUHITO MORI

Mangrove forests are widely considered as the major type of green infrastructures or Ecosystem-based solutions to Disaster Risk Reduction (Eco-DRR) in Southeast Asia, South Asia and the Pacific Islands. Historical records show clearly the capability of mangrove forests as a natural barrier, but their mechanism in reducing energy of tsunamis, storm surges and waves is still not well understood. Recent studies have contributed to progress in quantifying the engineering effects of mangrove forests against coastal hazards, and have identified future research needs.

Introduction

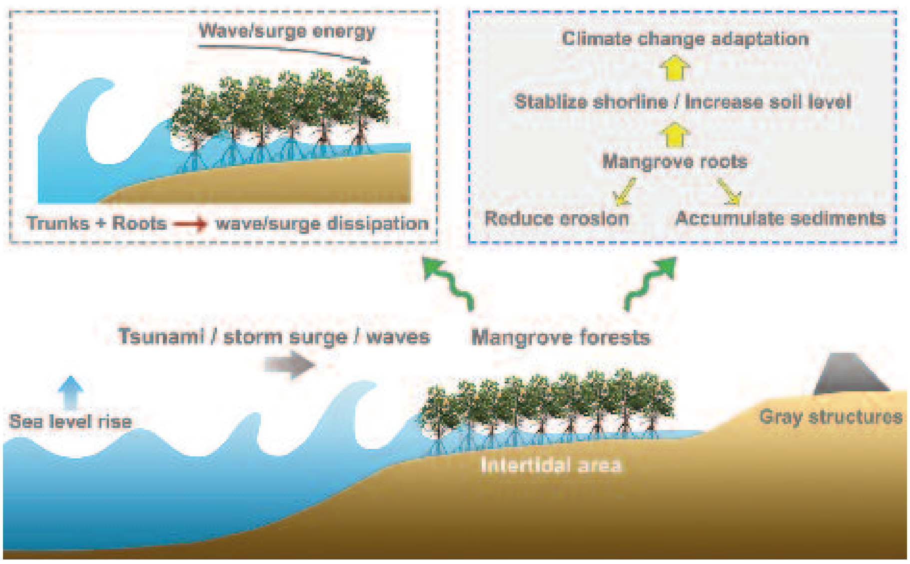
Green infrastructure, or Ecosystem-based Disaster Risk Reduction (Eco-DRR) has become popular after the *Sendai Framework for Disaster Risk Reduction 2015-2030*[1]. Likewise, the *Intergovernmental Panel on Climate Change Fifth Assessment Report*[2] pointed out the importance of green infrastructure for coastal flooding mitigation. The cost efficiency of this approach and its capability of adapting to the changing climate have drawn a lot of attentions around the world[3], [4].

The green infrastructures that function as natural protective barriers for coastal hazards mainly include coastal dunes, sandy beaches, coastal forests, mangroves, coral reefs and salt marshes. Dunes and sandy beaches are popular due to their ease of maintenance by nourishment or restoration. Coastal forests and mangroves are widely recognized for their protective function through wave or hydrodynamic energy reduction, e.g. storm waves, surges and tsunamis. Coral reefs and salt marshes are also capable of attenuating wave energy, but they are both difficult to install or maintain.

Coastal pine trees have been used in East Asia for coastal protection for decades. As reported after the 2011 Tohoku Earthquake Tsunami[5], coastal pine forests played a critical role in reducing the tsunami energy and in trapping debris. Their engineering function has also been well studied due to the simple structure of their trunks and branches. Another major coastal tree species, mangroves have been identified as natural buffers in tropics and subtropics since the 2004 Indian Ocean

Figure 1. Planted mangrove afforestation in South Tarawa, Kiribati

Figure 2. Protective/Eco-DRR function of mangroves against coastal waves and climate change



Earthquake Tsunami[6], [7]. Additionally, with large capacity for carbon storage, mangroves are valuable to climate change mitigation. In fact, the plantation of mangroves is becoming prioritized in Southeast Asia and the Pacific Islands to combat extreme disasters and mitigate the effects of climate change. Figure 1 shows a planted mangrove afforestation in South Tarawa, Kiribati. Furthermore, by dissipating the energy of incoming waves/flows, mangroves can stabilize shorelines by reducing erosion and accumulating sediments, which can counteract sea level rise. A sketch of the protective function of mangroves against coastal waves and climate change is in Figure 2.

Current scientific studies of these aspects of coastal protection are relatively limited. Because the structural complexity, physical properties and botanical characteristics of mangroves are not sufficiently addressed, the engineering function of mangrove forests for coastal protection has not been well investigated and requires further study. In the following, some of the representative works on mangroves and coastal vegetation for Eco-DRR are reviewed. The unsolved challenges and potential future research directions are also presented.

A lesson from nature

In the 2004 Indian Ocean tsunami, reduced mortality and loss of property were observed in regions with dense mangrove forests, unveiling the potential of mangroves as protective infrastructure against extreme coastal disasters. Similar findings after Typhoon Haiyan in 2013 further proved the buffering function of mangroves. In the aftermath of these events, abundant field studies identified the effects of mangroves on disaster mitigation, and therefore drew increasing attention from both the public and researchers.

Some of the very first reports after the Indian Ocean Earthquake Tsunami pointed out the critical role of coastal vegetation in reducing tsunami damage[6]. According to these reports, the villages behind mangrove forests experienced less damage than other regions without natural barriers. Kathiresan and Rajendran[8] conducted a field survey in several coastal hamlets along the southeastern coast of India and suggested planting mangroves and other species for future tsunami hazard protection. Similarly, a field survey along the coast of Sri Lanka and Thailand showed that mangrove-type vegetation was one of the most effective species in tsunami wave dissipation

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due to their complex root structures[7]. The role of mangroves in reducing tsunami damage has also been identified in other tsunami events, e.g. the Indonesia Sulawesi Earthquake Tsunami[9].

The effects of mangroves on reducing storm waves and surges were relatively well recognized in the past. Das and Vincent[10] presented a correlation of mangrove shields with the reduction of deaths during a super cyclone in 1999. More recently, several villages were saved by mangrove shields during the super typhoon Haiyan in 2013 while the destruction of mangroves also triggered a heated discussion on the effectiveness of different mangrove species, the assessment of mangrove forests recovery and future planting of mangroves[11].

Despite general agreement in their capability of reducing wave energy, the effectiveness of mangrove forests during extreme events like tsunamis or storm surges is still unclear quantitatively. As it is unlikely that they can stop the destructive power of extreme waves, "what is the protection level that mangrove forests can provide?" becomes a must-answer question to scientists.

Scientific research progress

Historical events and field studies demonstrated the protective function of mangrove forests against extreme tsunamis, storm waves and storm surges. An improved understanding of wave-mangroves interaction will benefit coastal protection design and management. To better quantify the effectiveness of mangrove forests, enormous efforts have been made via numerical and physical modeling to address different aspects of the issue, e.g. physical processes in wave-vegetation interactions and wave attenuation by vegetation. Some of the representative studies and research progress are discussed next.

Numerical modeling

Numerical or mathematical modeling has long been conducted to study the interaction between waves and vegetation since the 1980s. In the early stage of this work, several macro-scale models were introduced, which used an additional drag term to account for the dissipation by vegetation[12], [13], [14]. These pioneering studies provided a conceptual methodology to address vegetation effects, while the prescription of wave profiles and the calibration of empirical coefficients restrained their application. Detailed flow fields were not available using these models.

With growing requests for a better understanding of vegetation-induced dissipation, another type of numerical models based on the Navier-Stokes (N-S) equations were developed in recent years. These models simulate the flow in detail using appropriate numerical approaches and turbulence closure schemes. By resolving each individual tree in numerical discretization, N-S models detail the flow features and turbulent interactions among vegetation, providing more insight into the energy dissipation process. Representative studies of this type can be found in the work of several investigators[15], [16], who developed models based on the Reynolds-averaged Navier-Stokes (RANS) equations. In addition, Large eddy simulation (LES), another type of N-S models, has also been applied to study flow/wave-cylinder interaction problems, where detailed information of wave forces on cylinder arrays can be obtained[17]. Despite detailed flow fields and physical mechanisms provided in these direct numerical approaches, both RANS and LES models demand considerable computational resources for a large forest region including complex tree shapes, which may limit their engineering application.

Another type of intermediate semi-analytical model was developed recently based on the multi-scale homogenization theory in which the linearized RANS equations were applied[18]. This model was later extended numerically to three-dimensional problems for multiple forest patches of arbitrary shapes[19], [20]. This type of models simulates micro-scale flow motions surrounding trees which are then used to solve macro-scale wave dynamics. However, the use of linearized governing equations and the requirements of simplified vegetation conditions limit the application of this model in mangrove environments.

Depth-integrated wave models, based on nonlinear shallow water equations or Boussinesq-type equations, have become popular due to the balance between physical approximations and computational efficiency, which makes possible their application to larger areas. Similar to the macro-scale approach, the vegetation effects are modeled as an additional dissipation term in the momentum equations, which relies on precise prescription or calibration of empirical coefficients. In some of these models[21], [22], the vegetation effects were integrated as enhanced bottom friction which cannot well represent vegetation-induced resistances. On the other hand, the Morison-type formula[23] has been considered more appropriate for parameterizing vegetation effects and has been widely used[24]. In addition to depth-integrated models, a nearshore spectral wave model has been developed[25] by employing a layer approach to account for vertical variation for mangrove-type vegetation. Similarly, calibrations of certain empirical coefficients were required.

Despite the remarkable progress of computational models, it should be noted that simplified vegetation conditions have been mostly applied in these models. The structural complexity of mangrove trees has not been well addressed and needs to be taken into account in future model development.

Physical modeling

In addition to the development of numerical tools, physical tests have been conducted for years to better assess the energy dissipation capacity of vegetation and complement numerical simulations in accounting for different interaction processes. Using simplified tree models, such as uniformly-distributed cylinders, wave propagation through coastal forests were investigated in some studies[21], [26]. Similarly, vertical cylinders were used to study the impact of an open gap in coastal forests on tsunami runup[27]. These simplified tree models have been well applied to study coastal trees without complicated structures, e.g. pine trees.

On the other hand, as a particular feature of mangroves, their complex root system has been widely considered effective in reducing wave energy. Simplified tree models may underestimate mangrove effects on wave attenuation and limit their application to mangrove environments without considering the effects of the root system. Thus, in the past decade, several studies started to address the complex structures of mangroves using artificial tree models. Some investigators proposed a parameterized tree model[28], which consisted of a group of cylinders with different heights, to represent prop roots on the basis of identical hydraulic resistance. In these studies, mangroves were represented by simplified structures based on certain equivalent physical characteristics of tree models and prototype mangroves. Thereafter, several studies made an improvement by reconstructing artificial mangrove models with prop roots based on field measurements[29], [30].

All the physical models discussed above proved the importance of vegetation on reducing wave energy. The different experimental findings in simplified tree models and artificial mangrove models necessitated the inclusion of the prop roots in both numerical and physical modeling. The recent artificial mangrove model studies greatly improved the understanding of the root system in dissipation processes. The roots can reduce flow speed, increase friction, and enhance wave dissipation by means of turbulent interactions. The vertical variation of porosity due to the root system enables mangroves to have higher potential for wave attenuation.


Figure 3. The 3D image of a mangrove

Until today, however, there is still a lack of a consensus on the effectiveness of mangrove forests on disaster mitigation, quantitatively. Field studies have demonstrated the complexity of mangrove structures and their large regional variation depending on the environments, which cannot be represented by the artificial/idealized tree models. Therefore, a proper representation of realistic mangrove characteristics should be a priority in future modeling.

Recent advances in laboratory experiments

Wave force measurements

As mentioned above, the Morison-type formula has been widely applied to simulate wave forces and parameterize vegetation-induced dissipation in most macro-scale or depth-integrated numerical models. Calibration is usually required to determine the force (drag and inertia) coefficients based on wave amplitude measurements in laboratory experiments. Thus, the determination of force coefficients and the resulting wave dissipation depends on the accuracy and reliability of experimental data. The proposed drag/inertia formulas became unique for each study and cannot be generalized. On the other hand, direct measurements of wave forces on tree models were applied to several recent studies, in which the force coefficients were computed by the Morison-type equation with the measured velocity and forces[31], [32]. Without calibrations of force coefficients with wave measurements, their proposed formulas in terms of flow parameters (Reynolds /Keulegan-Carpenter numbers) are applicable to a certain range of wave/flow conditions.

A new 3D real tree model

As presented in field studies, real mangrove structures are more complicated than artificial/idealized tree models. A recent step forward is a set of model-scale experiments using 3D-printed mangrove models[32]. Based on 3D scanned images from the field, the detailed structure of prop roots was scaled down and was reproduced at a scale of 1/7 as shown in Figure 3. Wave-induced forces on tree models were directly measured such that the force coefficients in the Morison-type formula were obtained based on the experimental data. Comparing with previous work using rigid cylinders with the same trunk diameter[31], it was observed that force coefficients become more scattered but within the same range due to the impacts of prop roots. The fluctuating velocity profiles, which were different from those

A mangrove forest on the edge of a remote island in Raja Ampat, Indonesia (gettyimages)

in cylinder experiments, also indicated the non-negligible effects of prop roots, which should be taken into account for more precise parameterization of mangrove effects in numerical models. Such 3D scanned tree data can be used potentially in the direct numerical approach as well. Another set of laboratory experiments was also conducted by using real trees, which allowed further investigation of the flexibility and breaking conditions of real mangroves. Some of the experimental analyses are ongoing and will be discussed in future publications.

Conclusions and future directions

Mangrove forests, as one of the most well-known Eco-DRR in the tropics and subtropics, have been seen as one option against coastal hazards and climate change in the near future. To maximize the potential of mangroves in coastal protection, better quantification of the effectiveness of mangrove forests will be required. The first priority of the future studies should well address the incorporation of complex mangrove structures in both numerical and physical modeling. A latest technology, 3D laser scanner, can be useful to capture the detailed structures of mangrove roots in fields, which make it possible to rebuild more realistic tree models in laboratory experiments. The anticipated advantages include a precise determination of parameters based on experimental findings, which will be desirable for depth-integrated models. The scanned data can also be used in numerical computations to resolve detailed flow fields by using RANS/LES model. Furthermore, a comprehensive dataset, combing botanical and physical characteristics of mangroves such as age, size, root structure and rate of growth, will be required for integrated assessment of afforestation. This will make a breakthrough in quantitative evaluation of mangrove effects against extreme waves (short-term) and climate change (long-term). ■

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RESERVOIR SEDIMENTATION – NEED FOR ACTION AT GLOBAL, REGIONAL, CATCHMENT AND LOCAL SCALES

BY HELMUT HABERSACK & CHRISTOPH HAUER

Sediment surpluses and deficits following the interruption of sediment flow continuity through the river system by the construction of dams are growing in almost all river basins. Land use changes and climate change intensify this tendency. Consequences are reservoir sedimentation and river bed erosion in the free flowing river sections, leading ultimately to significant coastal erosion. Examples of international activities at global, European, regional and catchment scales demonstrate the increasing importance of reservoir sedimentation and associated research and management challenges.

According to Syvitski *et al*.[1] the pre-development (*i.e*. prior to any anthropogenic influence) sediment flux delivery of all rivers around the world was estimated to be 14 Gt/year. According to Walling[2], due to human activities the total flux in the absence of reservoir trapping would be 36.6 Gt/year, of which 24 Gt/year are trapped in reservoirs. This is approximately a 160 % increase in the sediment flux delivery compared to the undisturbed system (*i.e*. 14 Gt/year) and approximately a 66 % reduction due to reservoir sedimentation. The management of these quantities without working “with the rivers” would not be technically, economically, and ecologically possible[3].

World’s Large Rivers Initiative and Selected Projects

Climate and land use changes affect soil erosion and sediment transport. It is therefore important to start studying rivers in a joint effort between nations to develop a global assessment of the present status of the world’s large rivers. Sediment transport is an integral part of the UNESCO IHP World’s Large Rivers Initiative (WLRI) (http://worldslargerivers.boku.ac.at/wlr/), coordinated by the Austrian UNESCO Chair on Integrated River Research and Management (http://unesco-chair.boku.ac.at/). The WLRI aims at analysing the status of up to 300 rivers considering different issues (from hydraulics to hydropower) and including sediment transport and reservoir sedimentation. A close cooperation with the UNESCO International Sediment Initiative (ISI) has been established. The International Conference on the Status and Future of the World s Large Rivers is organised every three years and is co-sponsored by IAHR (2011 in Vienna, Austria, 2014 in Manaus, Amazonas, Brazil, 2017 in New Delhi, India and the next will take place in 2020 in Moscow, Russia). So far, ten special issues in top Science Citation Index (SCI) journals have been published as the result of the efforts of the WLRI, which include a total of 143 articles by 554 authors.

In general reservoir sedimentation is a key topic for integrated, sustainable river management, which is affected by climate and intensive land use changes (*e.g*. glacier retreat, deforestation, intensification of agriculture) increasing soil erosion and therefore sediment delivery, nutrients and contaminants into reservoirs[4, 5]. In this context the European Sediment Network (SedNet: https://sednet.org/) aims at integrating sediment transport issues in European Strategies to meet the goals of the EU Water Framework Directive and the EU Floods Directive. This includes the development of new tools and strategies to support and guide reservoir sedimentation management[6].

At regional scale, the EU Alpine Space projects SedAlp and HyMoCARES can be mentioned. The SedAlp project (www.sedalp.eu) made recommendations for sediment management in Alpine basins with a focus on integrating sediment continuum, risk mitigation and hydropower production. Methodologies, tools and field monitoring techniques are recommended for effective reduction of sediment related risks, while improving the aquatic ecosystem and reducing the impact of hydropower plants on sediment continuity. The HyMoCARES project (www.alpine-space.eu/

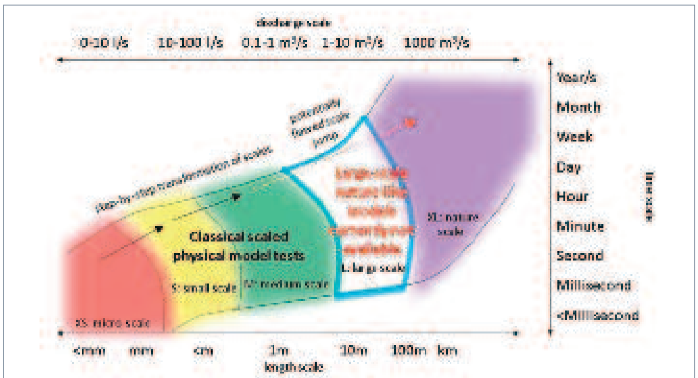

Figure 1. Time and length scales in physical models and real-world situations (nature scale); potentially flawed scale jump from small and medium scale models to nature scale

Figure 2. Experimental research channel at BOKU University, Vienna, being used for 1:1 scale sediment transport tests

projects/hymocares/en/home) deals with hydromorphological assessment and management at basin scale for the conservation of Alpine rivers and related ecosystem services over which hydropower and reservoir sedimentation exert a significant influence.

Examples for catchment sediment related activities are the EUSDR PA7 Flagship Project Danube River REseArch and Management (DREAM), the INTERREG Danube Transnational Programme (DTP) Project DanubeSediment and several bilateral INTERREG projects on the Danube basin. The project DREAM aims at fostering cooperation between research organisations working on the Danube basin. Besides flow and morphodynamic numerical models and field monitoring, research vessel infrastructure is of central importance.

Sediment transport scaling issues limit, however; the applicability of empirical formulas[7] which yield sediment transport rates that are often off by orders of magnitudes from field measurements[7, 8]. Thus, there is great need for collecting field data to improve the theoretical concepts forming the basis of numerical models. However, boundary conditions (discharge, water level, turbidity, bedload, biofilms) cannot be controlled during field measurements and deploying instruments under flood conditions is dangerous. Therefore experiments form the basis for understanding complex phenomena. To avoid or minimize scaling errors large-scale experimental facilities have been designed in several hydraulic laboratories[9] (Figure 1). As an example, a research open channel (5 m wide, up to 3 m water depth) with a 10 m^3/s free flowing discharge (using the water level difference between the Danube and the Danube canal) was constructed at the University of Natural Resources and Life Sciences (Universität für BOdenKUltur, or BOKU), Institute of Hydraulic Engineering and River Research, where no scaling of sediment was anymore needed (Figure 2). There are plans to construct a new Hydraulic Engineering Laboratory at BOKU, where it will be possible to use a discharge of 10 m^3/s inside the laboratory.

Another example is the EU DTP Project DanubeSediment – Danube Sediment Management - Restoration of the Sediment Balance in the Danube River. Between 1950 and 1980 a total of 69 large reservoirs were constructed. In 1998 the Freudenau reservoir was constructed in Vienna. Depending on the

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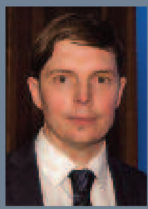

Dr. Christoph Hauer is the Head of the Christian-Doppler-Laboratory for Sediment research and management at the Institute of Hydraulic Engineering and River Research at the University of Natural Resources and Life Sciences in Vienna (BOKU), Austria. He has experienced over 15 years in interdisciplinary research linking hydraulics and sediment transport to aquatic and semiaquatic biota with focus on hydropower plant management.

type, size and location of the run-off-river hydropower plants significant sedimentation has occurred in these reservoirs. Today only less than half of the former annually transported suspended sediment in the Danube reaches the Black Sea, where significant coastal erosion with a maximum of 20 to 25 m/year is observed[10]. During floods significant remobilisation of sediments from reservoirs of run-of-the-river dams can occur, leading to sedimentation in the floodplains downstream. Similar problems can be found in the Rhine (https://www.iksr.org/de/) and the Elbe (https://www.ikse-mkol.org/) rivers, where sediment transport is as well crucial for the functioning of the river systems.

Christian Doppler Laboratory "Sediment Research and Management"

The ongoing reservoir sedimentation related problems suggest that there is a need for further research activities to improve understanding of physical processes at various scales and to develop robust tools for sediment transport management. The Christian Doppler (CD)-Laboratory at BOKU University has a seven-year program (from 2017 to 2024) to address these needs. This program has been motivated by the fact that 60% of all new energy investments over the next 20 years will be in renewable energy systems and that new hydropower production will represent 25% of all new renewables, mainly due to high hydro potential in China, Africa, Latin America and South-East Asia. In the European Union, the growth of hydropower production aims to support achieving the set emission reduction targets by 2050. Some of the key economic, technical and ecological challenges in this context are the deposition, the treatment, and the dynamics of disturbed sediment in river catchments, which can reduce significantly the future market potential of hydropower due to reservoir sedimentation[11] (Figure 3).

The CD-Laboratory "Sediment Research and Management" aims at establishing and preserving the long-term use of reservoir storage capacity, and ensuring a long technical lifespan of various hydropower plant components, such as the intake channels, pumps and turbines. The CD-Laboratory is organized into three Modules. Module 1 aims at improving the economical, technical and ecological standards for hydropower use. Module 2 focuses on the improvement of sediment management for industrialised rivers, and Module 3 targets ways to achieve a long technical lifespan of hydropower plant components. All these issues will be addressed within the framework of the overall aim of minimising costs in the future by improving sediment management in river catchments.

Based on the state-of-the-art of engineering practice, basic research activities will be conducted on erosion, sedimentation and remobilisation of bedload and suspended load. A combination of laboratory (*e.g.* flume experiments, physical models) and field studies (*e.g.* monitoring of reservoir sediment flushing) at different scales (from mm to catchment) is expected to improve understanding of the relevant physical processes. Moreover, based on the development or adaptation of hydrodynamic-numerical models and monitoring techniques (*e.g.* seismic profiling), advanced tools will be developed for use by hydropower companies.

The CD-Laboratory is based at the Institute of Hydraulic Engineering and River Research, Department of Water – Atmosphere – Environment, BOKU University of Natural Resources and Life Sciences, Vienna. The laboratory was established in 2017 with four industrial partners (VOEU, viadonau, Andritz AG and Voith GmbH): VOEU (Verein für Ökologie und Umweltforschung) for studies on hydropower technologies and management (Module 1), viadonau participating in studies on sediment management in large rivers (Module 2), and the companies Andritz AG and Voith GmbH as contributors to Module 3 (sediment turbine research). One additional

Figure 3. Sedimentation in an Austrian reservoir after a controlled reservoir level drawdown (courtesy: Gökler)

module (abrasion studies) is scheduled to be launched at a later stage of the CD-Laboratory. The CD-Laboratory will provide new standards for technological, ecological and economical optimisation of hydropower management and novel aspects for sustainable sediment management in rivers based on (i) advanced understanding of physical processes, (ii) environmental impact assessments, and (iii) development of new monitoring and modelling technologies. The implementation of the results in strategy plans, guidelines, manuals, natural water safety plan and into laws is expected. A significant contribution to a consistent Austrian strategy concerning the future sediment management in surface waters is planned, in cooperation with all federal groups working in the field of mountain and hydraulic engineering.

The first phase of the CD-laboratory research activities focuses on small-scale experiments. For instance, Lichtneger *et al*.[12] investigated locally velocities, turbulence and shear stresses over a fixed non-porous rough bed to characterise the hydraulic conditions for the initiation of motion of natural sediment. In the work of Schobesberger *et al*.[13] the 3D coherent flow structures during incipient particle entrainment under 2D flow conditions and behind vertical cylinders (3D flow) with different diameters were investigated. Time-resolved 4D Tomographic - Particle Tracking Velocimetry (4D-PTV) and Shake the Box (STB) algorithm were applied for measuring the 3D velocities. The 4D-PTV method is well suited to shed light on the interaction between coherent structures and incipient conditions for sediment motion.

The goal of the CD-Laboratory is to improve the description of sediment transport mechanisms in numerical models. Tritthart *et al*.[15] presented a small-scale model reproducing turbulent flow structures and the associated pressure field using the high-resolution Large-Eddy Simulation (LES) method and describing their effect on a single spherical grain. This model contributes substantially to the future development of more advanced bedload transport models. The need for an integrated ecological impact assessment of specific sediment management measures, such as sluicing and flushing, has to be addressed. High-suspended sediment concentrations are known to be harmful to biota in downstream river reaches. It is common to set legal sediment concentration limits for reservoir management operations. However, there is considerable spatiotemporal variability of suspended sediment concentrations along both the longitudinal and cross-sectional profiles of rivers. To consider this variability in reservoir management operations, a 3D modelling approach based on the BOKU iSed-Model was developed[15].

Assessing whether the concentration of fine sediments in the aquatic environment is excessive is important because they can have an adverse effect on the habitat of both macroinvertebrates and fish, especially on their spawning sites. Research work has been undertaken at the CD-Laboratory to quantify the vertical distribution of fine sediments in river systems during hydropeaking flow regimes[16]. A repeated survey of fine sediments infiltrating a gravel matrix revealed the general importance of de-clogging caused by flooding and the role of fine sediment infiltration in the aquatic environment, especially during the initial stages of riparian vegetation establishment. Based on these findings it is clear that both coarse and fine sediments are ecologically relevant, and turn-overs reflected in the morphodynamics are targets for future sediment management in river systems.

Conclusions

The socio-economic, technical and ecological problems caused by mismanagement of sedimentation issues or by the lack of understanding of the underlying processes are a call for better management based on science. As stated in the World Congress of Hydropower in Kyoto 2003, the last century was the time of building (large) dams, while in the 21st century hydropower reservoirs will be focusing on sediment management. Research and engineering activities must be coordinated adequately at both local and global scale. Sediment is a resource which is fundamental for ecosystem services and has to be considered in a development framework considering changes in natural systems during the Anthropocene, as well as the future challenges arising from climate and land use changes.

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XXIX Congreso Latinoamericano de Hidráulica (LAD2020)
October 05-09, 2020 | Acapulco, Mexico
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2nd International Symposium on Water System Operations (ISWSO2020)
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December 16-18, 2020 | Nanjing, China
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9th Gerhard Jirka Summer School on Environmental Fluid Mechanics (GJSSEFM2021)
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THE NEW IAHR MEDIA LIBRARY: THE REASONS WHY MOVIES AND PHOTOS INCREASE RESEARCH IMPACT

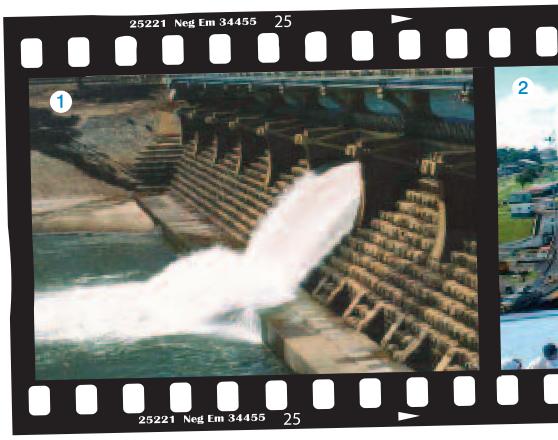
BY MICHELE MOSSA

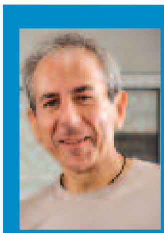
The IAHR Media Library (web site: www.iahrmedialibrary.net/) was officially launched on November 15, 2004 and the first files were inserted on February 10, 2005. Many years have passed since the birth of the site and the total number of visitors is now very high. An initiative regarding films of interest to Fluid Mechanics was undertaken in 1976 by the *American Society of Mechanical Engineers-ASME*[1]. Of course, not having a website in 1976, the *Fluid Mechanics Committee* of the ASME compiled a film catalogue, realizing, however, that many of these films were not widely distributed amongst researchers. To help put these films into the hands of researchers, the creation of an *Engineering Societies Library* (ESL) was proposed in order to obtain, store and distribute these videos. The 1976 ASME paper states that: "*Many fluid flow systems involve complex, time dependent, phenomena that are most readily recorded by motion pictures. Over the years a considerable body of such motion pictures has been accumulated by research workers. However, no organized channel for dissemination or location of these often-important data existed prior to 1960. […] To supplement the catalog and provide greater access to the film list via an archive journal, the titles currently in the catalog, along with authors, locations, and film type and running time are published here. We hope that additional use of the library might be stimulated, and more films submitted for possible inclusion.*" [1]

The IAHR Media Library represents the evolution of that idea using new systems and social media. Furthermore, a second area of the IAHR Media Library has been devoted to teaching tools in hydraulics (slides of class lectures and seminars, didactic computational software, documentation of appropriate field cases, e-learning tools, e-books and bibliographies).

More recently Khoury et al. observed that "*Graphics are becoming increasingly important for scientists to effectively communicate their findings to broad audiences, but most researchers lack expertise in visual media. We suggest collaboration between scientists and graphic designers as a way forward and discuss the results of a pilot project to test this type of collaboration. When we think of ground-breaking scientific advances, it is often in visual terms – the first depictions of the structure of DNA; Darwin's sketches of the tree of life; even Da Vinci's Vitruvian Man. The power of these pictures to speak to people, especially those outside our specialized research communities, is worth far more than a thousand words. Scientists' need for visual art has never been greater. More sophisticated graphics are required to communicate the results of ever more complex and transdisciplinary research. Well-constructed graphics can widen the impact of research articles striving to be noticed in an ever-increasing flood of published work, and supplementary visuals, for instance graphical abstracts, are often now requested by journals, if not required. Funders are also increasingly emphasizing the value of graphics in grant proposals. Online, where viewers decide whether to engage with material within a matter of seconds, compelling visuals are pivotal, especially as research organizations incorporate social media attention in their impact metrics.*
While many researchers are rising to the challenge of communicating their work via social media and other formats beyond their traditional channels, very few scientists have expertise in visual media communications, and even fewer in design tailored for online platforms. Learning the specialized skills needed to create graphics for the changing array of conventional and new science media is a very big ask.

But scientists do not need to go it alone. Collaborations between researchers, graphic designers, and other visual communications professionals offer great potential."[2]





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The main topics of his research group are relevant with the Environmental and Maritime Hydraulics. He is authors of many papers and books and he is actively involved in international and Italian research projects. For further details, visit the web site: http://www.michelemossa.it/en/

Even though the paper cited above mainly refers to visual art and graphics, we can surely extend the authors' conclusions also to movies and pictures. In other words, as the presentation of science moves beyond the traditional static journal article, there is every reason to think that movies and pictures will become even more critical.

It is necessary to recognize the value of movies and pictures in improving the communication of research and the accessibility of results relevant to society. Research societies and journals should support the creation and diffusion of scientific movies.
The benefits of collaborations between the authors of papers and the editors and the IAHR Media Library could be fundamental in terms of public outreach and increasing the impact of research.

These are the main reasons why the IAHR Media Library was created. It was launched by the Polytechnic University of Bari (Italy) with the initial support of Fondazione Caripuglia, Bari, Italy, with the Research Project LIC-MON of 2003 and, then, the Project IMCA (Integrated Monitoring of Coastal Areas) financed by the Italian Ministry of University and Research. Later, the initiative was supported with other Professor Michele Mossa's funds, most recently provided by the RITMARE Project and other research projects. Particularly, the RITMARE flagship project (Italian Research for the Sea) is one of the leading national marine research projects for the period 2012-2016; the overall project budget amounts to 250 million euros, co-funded by public and private resources.

Now a new and more appealing web site of the IAHR Media Library has been launched. Apart from the graphic design, the new website technologies are:

- Proprietary PHP code
- PHP with MySQL database
- Powerful internal search engine
- Home page with items listed by categories
- Fully responsive HTML/CSS
- Mobile and tablet compatible
- Registration form to create accounts
- Protected area with password to insert materials

The IAHR Media Library has many innovative characteristics, which the user can explore in detail when using it. Furthermore, now all the videos are both on a server and on the IAHR Media Library YouTube channel. Therefore, the new solution avoids the access problems to YouTube experienced in the past by users in some countries.
Nevertheless, the real success of technical and scientific products depends on its use by our community.
Examples of the pictures available in the IAHR Media Library are shown in Figures 1 through 4. I would be very glad to boost the activity of the media library. As written, I am sure that many scientific works could be better appreciated inserting movies and photos describing the phenomena that researchers have reported in their scientific papers. We should raise awareness for the library among our members, hoping that more and more people could contribute to it.

Many thanks to the entire editorial board of the IAHR Media Library and those who have contributed to its success, demonstrated by the impressive statistics of users, also through their uploads.

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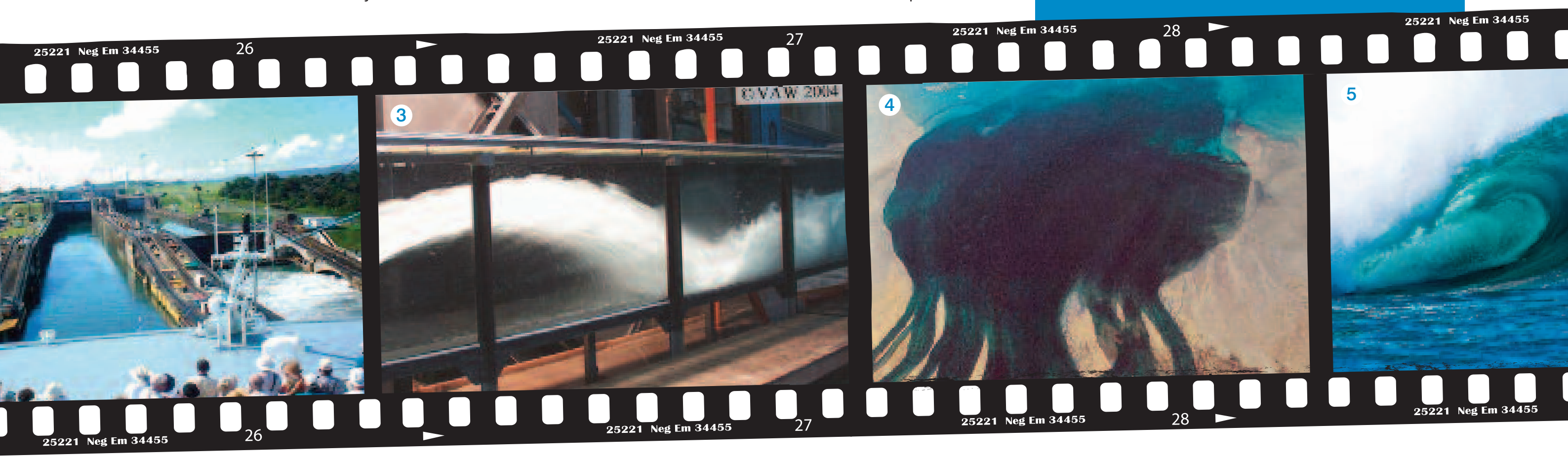
1 Goulburn weir (Australia) - View from left bank

2 Miraflores locks, Panama Canal

3 Ski jump investigation with circular-shaped flip buckets in a hydraulic model at VAW (Laboratory of Hydraulics, Hydrology and Glaciology (VAW), Swiss Federal Institute of Technology Zurich, Switzerland

4 Waste from a water desalination plant, Kuwait

5 Ocean waves in deep water (displayed in the home page of the web site)



REPORT FROM THE 38TH IAHR WORLD CONGRESS
PANAMA CITY, SEPTEMBER 1-6, 2019

BY LUCAS CALVO, CARLOS SENN & TOM SOO

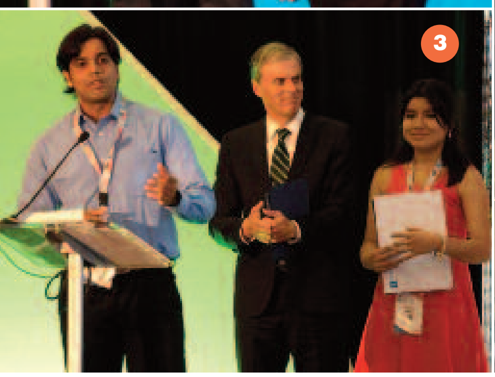
Following on from the success of past World Congress events held biennally, the IAHR community gathered together at the 38th edition from 1 to 6 September 2019 held at the Riu Plaza Panama Hotel in Panama City,where nearly 925 participants from 54 countries attended. Some 751 full papers were presented at the Congress. The congress covered six main themes, including:

- Hydraulic Structures
- Ports and Coastal Engineering
- Hydro-Environment
- Water Management and Hydro-Informatics
- River and Sediment Management
- Climate Change and Extreme Events

The Panama IAHR World Congress was opened on Monday 2nd September by the Congress Chairman: Ing. Carlos Vargas, Executive Vice President of the Water, Energy and Environment Chapter of the Panama Canal Authority. Ing. Jorge Quijano, the former CEO of the Panama Canal Authority, was the opening speaker from Panama and gave a fascinating introduction lecture about the Panama Canal performance and perspectives. The second opening keynote was presented by Marisa Escobar, the Water Program Director at Stockholm Environment Institute (SEI), about the topic of "Bridging Science and Policy: Creating a World with Equitable Water Access". Both Kennedy-YPN Award winners Siddharth Seshan (IAHR Baden-Wurttemberg YPN) and Rosa Camila Timana Mendoza (IAHR UTEC-Peru YPN) gave inspiring motivational speeches. The congress closed on Friday 6th with closing remarks from the former IAHR President Peter Goodwin and the introduction of the newly elected IAHR President Joseph Lee.

During the week there were a total of 8 keynotes involving leading specialist and professionals in the hydro environmental domain from around the world, as follows: Dr. Jing Peng, China (Hydraulic Structures), Prof. Hubert Chanson, Australia (Hydraulic Structures), Dr. Iñigo J. Losada, Spain (Ports and Coastal Engineering), Prof. Vladimir Nikora, UK (Hydro-Environment), Prof. Lin Chuxue, China (Water Management and Hydro Informatics), Prof. Marcelo García, USA (River and Sediment Management), Dr. Tosi Nakaegawa, Japan (Climate Change and Extreme Events), Dr. Felipe Arreguín, Mexico (Climate Change and Extreme Events).

Throughout the congress, a series of side events took place: pre-congress Workshops, Forums, Special Sessions and multiple meetings of the IAHR Technical Committees, Regional Divisions and Journals Editors. Highly successful Workshops on Water Security (Identifying Areas of



1. Arthur Mynett, Emeritus Professor in Hydraulic Engineering, IHE Delft Institute for Water Education, The Netherlands receiving his Honorary Membership Certificate from Peter Goodwin, IAHR President

2. 2019 Honorary Members, Young C. Kim, Angelos Findikakis and Arthur Mynett at the Opening Ceremony with Carlos Vargas and Peter Goodwin

3. Motivational Speeches given during the Opening Ceremony by the 2019 Kennedy-YPN Awardees Siddharth Seshan (IAHR Baden-Wurttemberg YPN) and Rosa Camila Timana Mendoza (IAHR UTEC-Peru YPN) Available in IAHR YouTube Channel!

4. 2019 Awardees together with IAHR Executive Committee Members and Willi Hager, founder of the Willi Hager Best Paper Award

Vulnerability and Enhancing Resilience) and Nature Based Solutions were held. A Global Forum consisting of a structured debate between leaders and experts from government agencies and research institutes took place seeking to exchange experiences and best practices in implementing landscape scale ecosystem management.

The congress hosted as much as 21 Special Sessions covering an extensive range of specific hydro-environment areas:

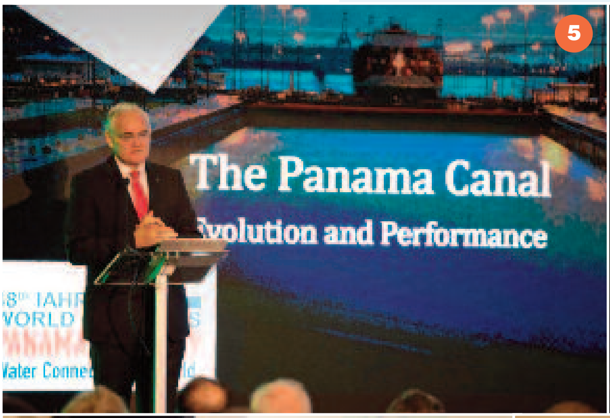
- Outfall Systems
- Nature Based Solutions in Water Management
- Large Scale Experimental Facilities for Ecohydraulic Research
- Recent Advances in Air-Water Flow Modeling Techniques
- Urban Drainage
- Transient in Pipes
- Robust, Climate-Change Sensitive and Adaptive Water Resources Management
- Coastal Reservoirs
- Low-Lying Coasts Under Climate Change and Anthropogenic Pressures
- Sustainable Water Storage to meet Water, Food, and Energy Development Goals
- Climate Change Impact Assessment on the Water Cycle
- Advances in Tools, Methods and Modeling of Water System Operation
- Advances on Tsunami Modelling and Characterization
- Riparian Vegetation Processes: Focused on Causes and Effects and Modeling
- Non-intrusive Measuring Techniques for Free-surface and Pressurized Flows
- Instrumentation and Modelling Tools to Mitigate Flood Risks Associated to Dam and Dike Failure
- Tribute to the Late Forrest Holly
- Flow-vegetation-sediment Interactions: Advances in Incorporating Natural Plant Features in Hydraulic Experimentation and Modeling
- Case Studies of Major Water Engineering Projects

Special activities took place at the exhibition area within the IAHR Stand such a the launch of the new White Paper Series, with a first issue published about Artificial Intelligence by Dragan Savic, and a debate on the history of IAHR World Congresses with the presence of the Honorary Members moderated by Willi Hager. Other exhibitors were Nortek, Macafferri, Flow 3D, Xylem, UTP, Cathalac, Panama Canal, SENACYT, CDS, UTP, USMA, Ulatina, Sequoi and Embassy of Israel and Embassy of the Netherlands.

The recently created Young Professionals network from Panama helped to coordinate a full programme of activities including a YP General Members Assembly, different talks, among them: “How to write good papers for JHR and other Scientific Journals” by Mohamed Ghidaoui and “Scientific innovations and novel technologies that turn arid basins into a productive land – the Israeli experience” by Eilon M. Adar, a technical tour, a YPN night to Panama Old City, and a YPN corner.

The congress was organized by the City of Knowledge Foundation (host), Panama Canal Authority (ACP), Technological University of Panama (UTP), Santa Maria la Antigua University (USMA), Universidad Latina de Panamá (ULATINA), Water Center for the Humid Tropics of Latin America and The Caribbean (CATHALAC) and National Secretariat of Science, Technology and Innovation (SENACYT).

The congress was sponsored by SENACYT and the Prince Sultan Bin Abdulaziz International Prize for Water (Platinum Sponsors), Maccaferri (Silver Sponsor) and the Embassy of the Kingdom of the Netherlands. The Chinese Hydraulic Engineering Society (CHES) was a Partner of the



5. Keynote Speaker Jorge Quijano, Panama Canal Administrator

6. Keynote Speaker Marisa Escobar, the Water Program Director at Stocklholm Environment Institute (SEI)

7. Farewell speech by Cristopher George at the General Member Assembly

8. IAHR Secretary Generals, Jing Peng - IWHR, China - and Ramon Gutierrez Serret – CEDEX, Ministry Ecologicall Transition, Spain. Both institutions were recognised by their continuing support

9. Tom Soo, New IAHR Executive Director

Congress. Special thanks to IAHR hosts Spain Water and IWHR, China. The Technical Visits were a central part of the Panama IAHR World Congress. Some participants had the opportunity to visit the new Panama Canal Locks at the Agua Clara Visitors Centre on the Atlantic Ocean side. The trip back to the city was provided via the Panama Canal Railway, bordering the Gatun Lake and through the tropical forest. Other participants had the privilege to make a Partial Transit on a ship through the locks of the old Panama Canal. Visits to impressive Miraflores Visitor Center, Frank Gehry Museum and the Panama Bay Sanitation Project were also conducted.

The IAHR Awards were announced during the Opening Ceremony and the Congress Gala Dinner, including : Honorary Members, M. Selim Yalin Lifetime Achievement Award, Arthur Thomas Ippen Award, Harold Jan Schoemaker Award, Willi H. Hager JHR Best Reviewer Award, the new Kennedy-YPN Award and the World Heritage and Industry Awards (to see the list of awardees please go to page XX). At the end of the Gala dinner all participants enjoyed a very nice local spectacle and dance time!

IAHR News: General Members Assembly

Opening

The IAHR Annual General Members Assembly (GMA) was chaired by the IAHR President Peter Goodwin on September 5th with around 90 people present which was a 25% increase compared to past GMA's.

Recognition of Christopher George

IAHR President recognised former IAHR Executive Director, Christopher George recently retired, for his 20 years of dedication to the Association since he was appointed the first Executive Director in 1999. Council Members, Past Presidents and close Members dedicated to him warm words, highlighting his charm and gentility.

Introduction of Tom Soo

A new Executive Director was introduced by Peter Goodwin. Tom Soo joined IAHR in April 2019 after being Executive Director of IWRA and the World Water Council. He has over 20 years of international leadership experience in the water sector and he is widely recognised as an ambassador for water and builder of networks.

Council Elections

The results of the 2019 Council Elections organised by the 2019 Election Nominating Committee chaired by Prof Roger Falconer were announced. A list of the complete council including the newly-elected members is provided in Hydrolink 3, 2010. Prof Arthur Mynett represented Prof Falconer, Chair of the NC in his absence. The results of the Elections show a higher gender balance compared with previous years: Members: 4 males / 4 females; Vice Presidents: 2 males / 1 female; Secretary Generals: 1 male / 1 female and Chairs of Regional Divisions: 4 males.

Constitution and Bylaw Changes

After an online consultation to members about a proposed constitution and bylaws change, the results were 84% YES, 5% NO, 11% ABSTAIN. Changes will take effect in 2021. The main ones are that the President will serve one 2-year term and one 2-year term as past president (rather than the current 2 x 2-yr terms).

Technical Divisions will be eliminated whereas the Council will be expanded to include chairs of Technical Committees (TCs), chairs of

10 & 11. Technical visit at Agua Clara Visitors Centre on the Atlantic Ocean side

12. Trip back on train bordering the Gatun Lake

13. YPN Technical Visit to the Hydro-Electric Station. Activity organized by the Panama YPN

Working Groups and Journal Editors, together with a YPN member from each region with IAHR support to participate.

Highlights

President Peter Goodwin remarked the launch of the new White Paper Series, as well as the new Technical Committes and Working Groups created such as Climate Change Adaptation, Sustainable Development Goals, Drones and Dam Reservoir Sedimentation; the numerous technical and regional congresses successfully organised in the previous two years receiving around 6000 delegates in total; the increasing number of Young Professionals Networks which amounts to 58 from 49 different countries; the increasing portfolio of Journals as well as the relaunch of the new IAHR Media Library created by Michelle Mossa.

2018 Financial Report

The 2018 financial report was presented by Prof James Ball, Vice-President and Chair of the Finance Standing Committee. The results, which have been audited by Ernst & Young, show an operating surplus for the year of €35K.
Regarding membership fees, they will remain unchanged for 2020. There is a general reminder to members who have not renewed their fees to make an effort to pay.

2019 - 2023 Strategic Plan - Draft

(1) A Task Force composed by James Ball, Angelos Findikakis, Joseph Lee, Silke Wieprecht, Peter Goodwin and Tom Soo was created and has been working to draw the new 4-year strategic plan. The draft plan is based on the following four pilars and will be finalised soon: Provide a world class international networking platform and great member experience

(2) Inspire, disseminate and catalyse state-of-the-art knowledge and thinking

(3) Institute events that set agendas, harness and amplify the collective knowledge of the global Hydro-Environment community

(4) Act as a global voice on behalf of the Hydro-Environment engineering industry and research community

At the end of the GMA Siddharth Seshan President of the IAHR BW YPN (Germany) and 2019 Kennedy-YPN Award Winner shared the outcomes of the Global Forum. Ellis Penning from Deltares summarized the "Nature Based Solutions" Workshop.

Following the GMA the Ippen lecture was presented by Claudia Adduce on "Gravity Currents propagating over complex topography: implications for fluid entrainment and sediment transport".
The closing ceremony included some words from retiring President Peter Goodwin, an intrudtcion of the new President Joseph Lee, a Congress report from Lucas Calvo, Chair of the Local Organising Committee, and the presentations of the next Congress Venue in from Granada 2021 and Vienna 2023.

The retiring council was acknowledged for their extraordinary work and dedication during a difficult transition period.

The post congress survey gave a good satisfaction rate from delegates. We thank all delegates for their participation, and we hope to see you in the next edition of the IAHR World Congress in Granada in 2021! ■

14. IAHR Council Meeting held ahead of the World Congress in August 30-31st

15. IAHR stand

16 & 17. Gala Dinner

18. Lucas Calvo, Chair of the LOC, Silke Wieprecht, IAHR Vice-President and staff from the Panama University

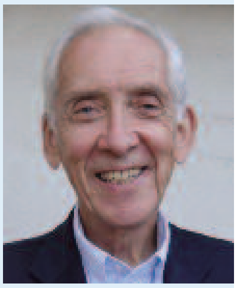
2019 AWARDS
AT THE 38TH IAHR WORLD CONGRESS IN PANAMA

Honorary Membership

Young C. Kim
Professor Emeritus of Civil Engineering
California State University, Los Angeles
USA

For his life-time contributions to the dissemination of science and technology through leadership in university education, short courses, conferences and in facilitating state-of-the-science contributions in coastal and ocean engineering through his role as editor. Further, this award is in recognition for exemplary service to IAHR and fostering links with other professional societies.

Angelos Findikakis
Bechtel
USA



For his life-time contributions to the field of groundwater hydraulics and environmental issues and in recognition of his leadership of IAHR contributions to the UN Sustainability Development Goals, his Editorship of Hydrolink, and outstanding service to IAHR Technical Committees, Council and as Vice-President.

Arthur Mynett
Emeritus Professor in Hydraulic Engineering
IHE Delft Institute for Water Education
The Netherlands

For his life-time contributions to the field of computational hydraulics and the application of emerging computational technologies to address complex environmental issues and in recognition of his mentorship of young professionals and his outstanding service to IAHR Technical Committees, Council and as Vice-President.

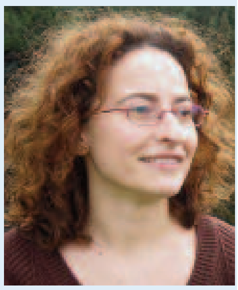
7th M. Selim Yalin Lifetime Achievement Award

Vladimir Nikora
University of Aberdeen
UK

For enduring theoretical, experimental and modeling contributions to the understanding of open channel turbulence and river hydrodynamics, development and application of the double-averaging methodology as well as excellence in graduate teaching and advancement of academic programs in hydraulic engineering.

21st Arthur Ippen Award

Claudia Aducce
Università Roma Tre
Italy



For outstanding contributions in the field of experimental and numerical modeling and innovation in experimental techniques with applications to stratified flows and sediment.

21st Harold Jan Schoemaker Award

Andrew Nichols
Senior Lecturer in Water Engineering
The University of Sheffield
UK

Simon J. Tait
Professor of Water Engineering
The University of Sheffield
UK

Kirill V. Horoshenkov
Professor of Acoustics
The University of Sheffield
UK

Simon J. Shepherd
Emeritus Professor
UK

For the most outstanding paper published in the Journal of Hydraulic Research during the period 2016-2018“A model of the free surface dynamics of shallow turbulent flows” Journal of Hydraulic Research, 2016, 54:5, 516-526

2019 Kennedy-YPN Award

Siddharth Seshan
IAHR Baden-Wurttemberg Young Professionals Network

Rosa Camila Timana Mendoza
IAHR UTEC-Peru Young Professionals Network

2019 Willi H. Hager JHR Best Reviewer Award

Michael Pfister
Haute École D'ingénierie Et D'architecture (HEIA-FR, HES-SO)
Switzerland

For outstanding reviews during the period 2017-2018

Ling Zhou
Hohai University
China

For outstanding reviews during the period 2017-2018

4th Hydro-Environment World Heritage Award

Panama Canal Authority

3rd Hydro-Environment Industry Innovation Award

City of Knowledge, Panama

IAHR CONFERENCES AND CLIMATE CHANGE

BY SANDRA SOARES-FRAZÃO

When I attended the 38th IAHR World Congress in Panama last September, it was striking to see the importance of climate change issues in the presented work. There is now a technical committee on climate change, climate change was one of the conference themes and it was the topic of some keynote lectures. Also, the number of presentations related to the consequences of climate change has been steadily increasing. Of course, climate change is often part of our business as hydraulic and environmental engineers and researchers. Engineers try to find the best technical solutions to mitigate the consequences of catastrophic events related to climate change, and each new such event seems to add to the justification for researchers to obtain funding for work in this area.

Meanwhile, at the United Nations climate change Conferences of Parties (COP), governments of the participating countries agree that more ambitious actions are urgently needed to achieve the goals of the Paris Agreement[1]. Facing the incredible inertia of public authorities to seriously tackle this problem, people all over the world start taking small-scale initiatives, or contribute to spread the message like the young Greta Thunberg[2] who initiated the school strikes for climate in Europe.

But what are we, as an association, doing to improve the climate situation? Are we only working in our laboratories on theoretical solutions, or designing flood defense structures? IAHR could certainly, and should, do much more. IAHR should be an example for all its members.

According to the IPCC, climate change is due to the increase in concentration of CO_2 in the atmosphere[3], and energy production is one of the most important sources of CO_2; energy that is used for transportation, heating, cooling, producing electricity. Let's think about the congresses and conferences.
Transportation is a difficult issue because if we want to meet, flying is often unavoidable. But still, isn't there something we could do? Regarding my own experience, I have now acquired a reflex. If I go to attend a conference in a luxurious hotel as it often happens, I have to take warm clothes with me. Not for outside, but for inside the buildings. Why is the air conditioning always set so low? Do we really need to have 18°C in a room to feel comfortable? Personally not. In some European countries, at least in Belgium where I live, we hear each winter the same advice: if you want to help the planet by reducing your energy consumption and your heating bill, just set the house temperature one degree lower, and put on a sweater. We could do the same, in the opposite direction of course, for air conditioning! If in each conference room the temperature was set few degrees higher, it would certainly still be bearable, even for those who absolutely want to keep on their jacket all the time.

Waste production is another great problem of our times. Have you ever seriously thought of the fate of all our plastic waste? Again, during our conferences, we have presentations about pollutants concentrations, pollutants propagation, micro-plastics in the oceans, etc.

However, we still all buy or receive pre-packed food, water or any other drinks in plastic bottles. Have you ever thought of the waste production during a congress? At the scale of a congress gathering more than one thousand people, the waste production quickly becomes impressive: lunch boxes, sandwiches packed in plastic, promotional material, etc. And on the top of that, often absolutely no waste sorting. Paper ends together with food leftovers and plastic in the same bin.

We cannot continue closing the eyes to our waste production. Many Southern countries that used to receive tons of waste produced in Northern countries now start to refuse accepting it. Just as an example, Indonesia refuses to take any more garbage from other countries[4] and has recently sent back contaminated waste to Australia[5].

The awareness of the consequences of this excessive waste production is increasing in many countries. We hear more and more examples of local and small-scale initiatives in that respect. In the US, Bea Johnson[6] has become the leader of a zero-waste movement with more than 400 thousands followers on social media, in France the emblematic "zero waste family" holds a blog[7] that has already more than 2.7 million visitors, in the UK, Penzance has become a plastic-free town[8], the European Union slowly steps into the movement too with initiatives such as the new law banning single-use plastic items such as plates, cutlery, straws and cotton buds sticks[9].

Sandra Soares-Frazão is professor of hydraulics and fluvial hydraulics at UCLouvain (Belgium). She is vice-chair of the IAHR Fluvial Hydraulics Committee that supports the River Flow Conferences. Most of her researches are devoted to numerical and experimental modelling of flow-sediment interactions. She is also active in developing countries, especially Haiti, where she is leading a project about floods and sediments

So, why not joining these initiatives and starting such a movement for scientific events, above all scientific events aimed at a community who cares about climate change? IAHR could become an example for us all by promoting a serious reduction in energy consumption and waste production during IAHR-sponsored events. Why not starting an IAHR "UN Momentum for change[10]" action for our international conferences and congresses, to make them more sustainable? We could in this way contribute more than by science to climate actions!

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39th IAHR WORLD CONGRESS
GRANADA, SPAIN 2021
From Snow to Sea

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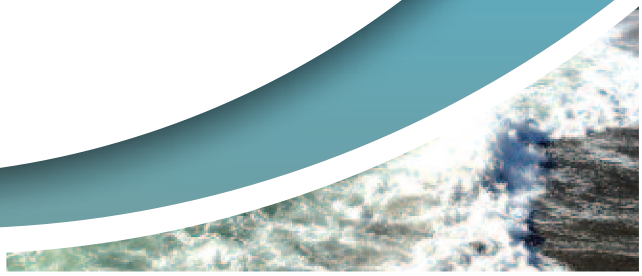
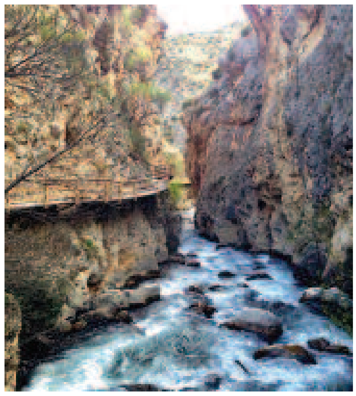
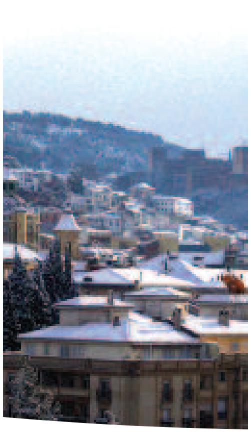
July 4-9, 2021

KEEP IN YOUR MIND: GRANADA 2021





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