symposium

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TURNING THE TIDE ON MANGROVE LOSS

ABSTRACTS

Photos: ZSL

Organised by

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8.30 REGISTRATION OPENS

8.55 Welcome

9.00 Keynote: Mangrove conservation in a Chinese megalopolis

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The focus of the southern Chinese province of Guangdong is the Pearl River draining a vast area (~453,700 km^2) of China. The river is >100 km wide at its mouth, with Macau and Hong Kong flanking western and eastern banks, respectively. The Pearl is the second largest river in China, with an estimated flow of ~10,000 m^3 second.

Guangdong's population of >110 million is 7.8% of China's total. Its capital, Guangzhou, is the third largest Chinese city. The modern Guangdong city of Shenzhen has become the 10th most populous city and is China's economic powerhouse. The population of the Pearl River Delta Economic Zone, the world's first Mega City, or megalopolis, has an urban population of >150 million. This does not, however, include Macau and Hong Kong, with resident populations of 0.5 and 7.2 million, respectively, but with transient populations of >130 million. With a land area of only 1,104 km^2, the Alpha+ City of Hong Kong has, in Kowloon, a population density of ~44,000 km^{-2}, making it the most dense human conurbation ever known. The Pearl's delta is, therefore, home to >160 million people, but regional goals for 2020 include three new cities, the expansion of road, rail, seaport and airport infrastructures and the construction of the 50 km long Hong Kong–Zhuhai–Macau Bridge – across the Pearl.

Since the end of the last ice age, sea levels have risen in southern China by >10 metres and, because of the vast amounts of silt deposited by the river (~86 million tonnes each year), the Pearl's estuarine flanks are, or were, bordered everywhere by mangroves – these here close to the northern limits of the species' ranges and representing the most populous and diverse community within China. These tall plants, in stabilising the river's banks, accumulate up to 5 cm of silt annually, protecting shorelines from typhoons but also facilitating natural coastal reclamation. Only two areas of such mangroves are protected in the Pearl's estuary: Mai Po in Hong Kong and opposite it, at Shenzhen, in China.

The eastern, Mirs Bay, waters of Hong Kong, away from the Pearl, however, support another mangrove community of conspecific species but of '*bonsai*' proportions. Mountain streams draining into the bay are part of Hong Kong's East and West Sai Kung Country Parks and home to two marine parks at Li Chi Wo and Hoi Ha. Hitherto protected by sparse, village-based, communities, these eastern mangroves are now too under development threats.

9.30 Keynote: Understanding and quantifying the many values of mangroves, globally and locally

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Mangroves are "Olympians" in terms of their ecosystem services values, leading the field in terms of their importance for carbon storage and sequestration, for fisheries enhancement, and for coastal protection services. Mangroves are also among the best protected of all ecosystems, with 36% now within protected areas. But this is not enough – mangroves are still being degraded and lost, and these losses are coming along with impacts on coastal communities world-wide. To change attitudes and “move the needle” we need to greatly improve understanding of the value of mangroves. This requires more targeted science and better communications. Global summary values have raised attention, but often lack the substance to back up the sweeping claims. Following a simple approach of “review-model-map” a new initiative is pulling together information from disparate sources to understand, then to model and ideally to map critical ecosystem services at different scales. New global maps of carbon storage and the nearshore fisheries value of mangroves highlight the considerable spatial variability in mangrove values. Such maps may be more compelling to decision-makers than previous global averages which lacked much in the way of practical utility. At different scales improved understanding and models of the role of mangroves in coastal protection are already helping in the development and use of mangroves in coastal engineering. Accurate and reliable valuation of mangroves has the potential to open new doors in terms of conservation, wise management and restoration.

10.00 POSTER SESSION (TEA/COFFEE)

SESSION I: HOW MANY MANGROVES ARE THERE AND WHERE ARE THEY?

10.30 Exploring mangrove diversity with technical innovations for science and community partnerships

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Who amongst us has funding support to collect and collate information on mangrove plants? However, we all know such studies are fundamental to turning the tide on their loss.

And, there are further stumbling blocks holding up progress. The world list remains undecided, even the definition of a mangrove itself. As well, new mangrove plants are still being described. These problems of definition are coupled with unprecedented threats from climate change and growing human pressures.

However, we have the perfect study tool for at least collating information on plants. Smart new electronic gadgets can capture geo-referenced data and digital images. Shouldn’t we be making greater use of such tools? These popular mobile devices present cogent opportunities in offering solutions to the pressing challenges in protecting mangroves.

These devices can fundamentally assist our collation of information. But, importantly also, they provide the means to harness a wider group of volunteer observers. This will greatly expand the knowledge base for embattled mangrove habitat worldwide.

SESSION II: LIFE WITHIN THE MANGROVES: LIVELY OR LIFELESS?

11.00 Ecological and evolutionary significance of invertebrate behaviour for mangrove ecosystems

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Mangrove forests cover a considerable part of the world’s tropical and subtropical coasts. They are among the most productive ecosystems, providing substantial goods and services for local populations and the entire planet. The last 20 years have witnessed a real paradigm shift concerning the impact of biotic factors on their ecosystem functions. Prior to this kind of scientific revolution, structural and functional aspects of mangroves were viewed as the result of abiotic processes acting from the bottom up. A number of recent studies, however, leave no doubt about the paramount role of behavioural traits of the mangrove macrofauna in the functioning of such forests. Feeding behaviour, digging activity, and terrestrial adaptations of crabs strongly influence the C and N cycles and their fluxes in mangrove forests as well as their carbon-stock potential. Recent data also show that the physiological and behavioural adaptations of crabs to terrestrial life have in fact a major impact on the oxygen flux and dynamics of the soil, ultimately contributing to the overall outstanding, and puzzling, primary productivity of these forests.

These forests are nevertheless also considered amongst the most vulnerable and endangered ecosystems in the world, with no information available on the vulnerability of keystone macrofauna to climate change. Mangrove trees are definitely threatened by sea-level rise and by human land reclamation, but the global exposure of these systems to other factors related to climate change, such as temperature rise and ocean acidification, is still a challenging dilemma. I demonstrate how a mechanistic approach, involving the integration of data from behavioural and physiological traits of keystone invertebrates, conveniently integrated with environmental data, can resolve the above scientific challenge and help draw realistic scenarios of mangrove vulnerability to climate change.

11.30 **Scaling up integrated shrimp-mangrove aquaculture: a call for area-based management and certification**

Simon Bush, Wageningen University, The Netherlands
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Mangrove-integrated farming has been promoted in the Mekong Delta of Vietnam as a means of ensuring both livelihood and conservation goals are achieved. The Vietnamese government has sought to expand the scale of Naturland certified organic production in integrated shrimp-mangrove farming systems across the coast of Ca Mau province. But in doing so a series of challenges have been faced – some of which indicate clear limits to conserving landscapes by limiting regulation to the farm level. Building on earlier research, I revisit the government’s goal by examining the regulatory challenges of using organic certification as a means of linking farm-level management to the sustainability of coastal (mangrove) landscapes. The results show the importance of farmer perceptions of sustainable farm and landscape management, fair benefit sharing mechanisms in the certified value chain, and legitimate private sector-led auditing. The conclusions point to a new way of thinking about how to meet both livelihood and conservation goals, through greater recognition of the positive role provincial and local level government can play. They also show that while certification is one tool for promoting integrated farming, new models of area-based management need to be developed deliver outcomes that reach beyond the scale of the farm.

12.00 **Mangrove and climate: lifeless wood and lively ranges**

Nico Koedam, Vrije Universiteit Brussels & Farid Dahdouh-Guebas, Université Libre de Bruxelles, Belgium
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Adaptation of species and populations to environmental change on a shorter than evolutionary time scale must be a balance between range shifts and biological exploitation of a species’ or an individual’s flexibility. We here introduce several specific research approaches of our team which deal with (potential) range shifts and adaptation separately. The approaches start with reductionist straightforward expectations, which must eventually be understood in coherence. First, in the approach regarding range shifts the most immediate impact is local appearance and disappearance of potential or actual habitat because of sea level rise. Mangrove forests prominently occupy an intertidal boundary position where the effects of sea level rise will be fast and well visible. A study in East Africa (Gazi Bay, Kenya) addresses the question whether or not mangroves can be resilient to a rise in sea level by focusing on their potential to migrate towards landward areas. The combinatory analysis between remote sensing, DGPS-based ground truth and digital terrain models (DTM) unveils how real vegetation assemblages could shift under different projected scenarios of sea level rise (SLR). On the one hand, the increase in most species in moderate scenarios, including the socio-economically most important species in this area, *Rhizophora mucronata* and *C. tagal* on the seaward side, strongly depends on the colonisation rate of these species. On the other hand, under the maximum SLR scenario the area flooded by equinoctial tides only strongly decreases due to the topographical settings at the edge of the inhabited area. Thus the landward *Avicennia*-dominated assemblages are squeezed if they fail to adapt to a more frequent inundation and compete against other mangrove species.

At a biogeographical scale we investigated the potential dynamics of mangrove latitudinal limits in South Africa, which shows that both expansion and retraction could take place under climate change scenarios. Second, regarding flexibility, we conjectured whether species will dynamically adapt as individuals and populations to local climatic and environmental change through comparison of actual patterns of vascular traits and behaviour of water transport tissues (as key to their ecological success) upon such changes both in their natural environment and experimentally. Vascular traits, shrinkage and swelling patterns (because of water status) through automatic point dendrometers on the trunks of adult *Avicennia marina* trees *in situ* and on seedling leaves and stems of *Bruguiera gymnorrhiza* and *Rhizophora mucronata ex situ* are used to understand a tree's behaviour. Our findings suggest vascular flexibility (possibly within boundaries for each species), both on the time scale of the development of an individual tree and on the time scale of immediate responses. Such findings are indicative of rapid changes in mangrove individuals in the highly dynamic environment that mangrove forests are, but demand integration in order to understand eventual success or failure to survive. As yet, the several approaches which indicate both loss of mangrove as well as flexibility and survival, cannot yet be integrated into a comprehensive understanding of mangrove species responses to a changing environment. This is mostly because extrapolation of data is not yet sufficiently justified.

Presented by Nico Koedam[1] & Farid Dahdouh-Guebas[2]

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Based on research by Nico Koedam, Diana Di Nitto, Elisabeth M.R. Robert, Silvia Lechthaler, Griet Neukermans, Helen Defever, Frank Pattyn, James G. Kairo & Farid Dahdouh-Guebas

12.30 **Mangrove-fisheries relationships: the knowns, unknowns and current challenges**

Ivan Nagelkerken, University of Adelaide, Australia
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Mangroves are globally valued for the important ecosystem services they provide to mankind.One of these services is their fisheries production, which includes a wide variety of finfish and shellfish species (e.g. shrimp). Mangrove estuaries can be highly productive areas, but mangroves also support offshore fisheries through their nursery function. In many parts of the world, mangroves – often in conjunction with other habitats such as seagrass beds – act as juvenile habitats for fishes and crustaceans which move offshore to deeper waters, where they replenish adult populations and contribute to fisheries production. Mangroves can also enhance populations of other important species, such as endangered and iconic species, and species that perform important roles in maintaining ecosystem health, such as parrotfishes and top predators like sharks. Some species show such high reliance on mangrove/seagrasses ecosystems to complete their life cycle that their adult abundances are greatly reduced where these ecosystems are absent or lost. The existence of such strong cross-habitat linkages implies that ongoing global loss and fragmentation of coastal ecosystems will have serious implications for their functioning, health, and productivity; appropriate management is therefore urgently needed. In this presentation, the ecological role of mangroves as nurseries for marine species will be evaluated as well as their economic value in supporting related fisheries. The strong cross-ecosystem linkages that are present between mangroves and other habitats through animal movements will be evaluated as this has important implications for ecosystem functioning, management of fish stocks, and marine reserve design. Current challenges in valuing, understanding, and studying mangrove–fisheries linkages will be discussed.

13.00 LUNCH

SESSION III: CAN MANGROVES DROWN? HIGHLIGHTING THE THREATS TO MANGROVES

14.00 Mangroves as land builders: paradigm revisited

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The term "land builder" refers to the idea that mangroves act as geomorphic agents by accreting inorganic sediments or by autogenic peat formation. The idea that mangroves actively accumulate sediments and promote seaward expansion of landforms captured the imagination of early researchers who collected evidence of the "geologic role of mangroves" as well as its relationship to vegetation succession. This land-building role is contrasted with a different view of mangroves as mere stabilizers of land, a perspective that was vigorously promoted by another group of researchers. In this talk, we will review the colorful history of the land-building concept and re-examine the evidence, including more recent work on vertical accretion processes. Modern studies have revealed how mangroves can influence trapping and vertical accretion of inorganic sediment as well as contribute directly to vertical land development through peat formation. Several lines of evidence indicate that accumulation of mangrove organic matter contributes to soil volume and upward expansion of the soil surface. In contrast, there is little empirical evidence for mangrove influence on lateral land expansion, especially as envisioned by early workers. Along muddy coasts, for example, land progradation may be driven mainly by physical processes, and mangroves passively follow the developing landform. Even in such cases, however, there may be as yet unrecognized biophysical feedbacks promoting shoreline progradation. What emerges from the literature is a more global view of mangroves as biotic agents interacting with physical processes of sedimentation and sea-level change to influence land formation. The direct contribution of mangroves to land development varies, however, with geomorphic and sedimentary setting. Also, work showing mangrove contributions to vertical accretion is limited in scope and needs to be repeated in a range of geomorphic settings to define the broader role of mangroves in land development. A better understanding of geographic differences in mangrove contribution to soil accretion is important to conservation and restoration of mangrove forests. If mangroves are seen as passive players in coastal dynamics, then arguments for their protection may be weakened. More importantly, such a narrow viewpoint may lead to faulty management plans. For example, peat-forming mangroves may be more vulnerable to activities affecting organic matter accumulation, whereas those along muddy coastlines may be more affected by changes in sediment supply. Recognition of such differences will be critical to manage mangroves effectively, especially in the face of rising sea level and climate change

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14.30 **An expanding network to monitor mangrove vulnerability to sea level rise in Southeast Asia and the wider Indo-Pacific**

Dan Friess, University of Singapore, Singapore
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Accelerated Sea Level Rise (SLR) threatens human populations and coastal habitats around the world. Large parts of the Indo-Pacific – and in particular Southeast Asia – are vulnerable due to high anticipated (but variable) SLR in the future. SLR is a particular threat to wetlands such as mangroves, as species have adapted to tolerate particular hydroperiods; an increase in inundation regime beyond a species-specific threshold could cause a reversion to less-biodiverse mangrove pioneer communities, or unvegetated mudflat. However, mangroves may be able to keep pace with rising seas in many instances by increasing their surface elevation through the creation of belowground biomass and sediment trapping.
Rod Surface Elevation Tables (RSET) are able to measure the annual millimetre changes in wetland surface elevation, though have been primarily installed in the US and Europe. Preliminary data synthesis from an expanding Indo-Pacific network of RSET instruments located at 27 sites across 45 degrees of latitude found that sediment availability (linked to accretion on the soil surface) was fundamental to maintaining rates of surface elevation gain that matched or exceeded SLR. 55% of our study sites had rates of surface elevation gain less than SLR (over variable time periods), and may be vulnerable to submergence. These data highlight the importance of maintaining sediment supply for minerogenic mangroves in the face of human modification of river flows, for example in the Mekong River. Mangroves at sites with large tidal ranges and high rates of sediment supply could survive for thousands years even with predicted accelerated rates of SLR, however those with low tidal range and reduced sediment supply could be submerged much sooner.

These data highlight the importance of a standardized method that can give a broad regional overview. The Indo-Pacific RSET network is rapidly expanding, with RSETs recently installed with the Centre for International Forestry Research (CIFOR) in Indonesia, Ateneo de Manila University in the Philippines, and Universiti Kembangsaan Malaysia in Malaysia, though several geographical and geomorphological settings still remain unrepresented.

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15.00 **Shelter from the storm: coastal greenbelts and Typhoon Haiyan**

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The toll of Super Typhoon Haiyan, the strongest storm on record to make landfall, was ~10,000 dead and missing, and US$12-15 billion total damage. Based on the storm's path, around 28,000 ha mangroves (12% of total) were expected to be damaged, hence millions of pesos were spent or allocated by government agencies, nongovernment organizations, and international aid/development agencies for mangrove planting. Nevertheless, a survey of 14 sites in the hardest hit provinces of Leyte and Eastern Samar found that although mangroves sustained damage, they later showed recovery visible as sprouts on bare trees and seedlings on the ground. Natural stands (of *Sonneratia alba* and *Avicennia marina*) generally showed less damage and greater recovery compared to plantations (of *Rhizophora* spp.), so priority should be given to protecting the former. Moreover, science-based protocols of planting the right species (*S. alba* and *A. marina*) in the right sites (middle to upper intertidal) should be followed in rehabilitating the few devastated areas. The default mode of government and NGOs alike of planting *Rhizophora* on seagrass beds – more for convenience than ecology – should be stopped. With increasing storm frequency and intensity associated with climate change, there is need to maximize protection by coastal vegetation. Energy reduction of wind and swell waves by 13-60% and 50-99% will require greenbelts 100 m and 500 m wide, respectively (McIvor et al, 2012). Coincidentally, a 1986 government regulation requires the expansion of mangrove greenbelts from 50 m to 100 m along shorelines in storm surge areas. A mangrove band of only 20-50 m can be rehabilitated in most seafront areas due to a steep intertidal slope caused by continuing erosion. Therefore the required 100-m band can be completed by restoring supratidal beach forests which can tolerate salt spray, strong winds, low nutrients, and grow up to 200 masl, making them suitable for lowland reforestation as well.

15.30 POSTER SESSION (TEA/COFFEE)

16.00 Costa Rica Térraba-Sierpe Ramsar site: successes and challenges of mangrove conservation through ecotourism

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Privileged by its geographic position, CR is home to 5% of the world's biodiversity within its 51.000km^2. This treasure is protected by the National System of Conservation Areas, and represents 26% of the total land area. Thanks to its extensive mangroves, Térraba-Sierpe was recognized as a National Wetland in 1994 and a Ramsar site in 1995. Located in the Southern Pacific it safeguards two major areas bordered by the Sierpe, and Térraba rivers, and has characteristic tropical plants and animals. The Southeastern wetland (9723.5 ha) comprises a unique lacustrine palustrine vegetation, while the Northwestern area (14637 ha.) is mostly composed of the largest mangrove in the country (6 species and 4 families). The South Pacific area is also a socioeconomically depressed area with the fewest job opportunities in the country. Most economic activities include extensive agriculture activities (oil palm, banana, rice and extensive livestock), tourism, fishing, and occasional work. Among fishers, there are three groups that belong to different counties and represent more than one hundred men and women (with families: approx. 4000 people); these groups fish and collect bivalves of commercial value.

To achieve social and ecologically sustainable conservation objectives, our project TC-581 offers environmental education to school children, youths and organized groups, and promotes alternative economic activities. A multidisciplinary group facilitates community characterization, organization and management through home surveys, workshops and activities. Subsequently with the project ED-3025, ecotourism training started in 2013 with two of the groups. All sessions with fishers were undertaken in their local meeting places and the methods included active and participatory teaching strategies considering their low education level. The topics were: tourism legislation, concepts and types of tourism, types of tourists and guides, heritage tourism, attitudes and conflict management with visitors, processing and components of a tour, a map and a tour, environmental interpretation, assertive communication, leadership, technical guidance and customer service, mainly.

To date, a total of 18 workshops and three field practices have been developed in Ajuntaderas, and 14 workshops and one practice in Coronado, with an average of 16 participants per group. Many benefits have been obtained: fishers are much more aware of the importance of conservation and the sustainable use of resources; they have strengthened their knowledge, skills to use the available resources in an appropriate way through conservation and wetland protection and reforestation; they have improved their communication skills and contributed in the rescue of traditions, and they now report practices not allowed in the wetland. They have also recognized the advantages of teamwork, and improved tourism research and sustainability issues. They have also provided folk knowledge useful for the creation of new materials for mangrove tours. There is a positive empowerment of the groups and their training should continue in coordinated support from governmental/non governmental organizations. Ecotourism practices have formed a valuable path to reach sustainable integrated conservation of the wetland.

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16.30 PANEL DISCUSSION

17.30 POSTER SESSION with cash bar. Symposium end of day one (18.45)

19.00 SYMPOSIUM DINNER – tickets to be booked in advance

SESSION IV: STANDING OR FELLED: WHICH IS MORE VALUABLE TO US?

9.00 Climate change implications of mangrove conversion to shrimp ponds: the jumbo carbon footprint of a small prawn

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Mangroves provide a number of ecosystem services including habitats for many species of fish and shellfish, storm protection, influences on water quality, wood, aesthetics, and a source of nutrients and energy for adjacent marine ecosystems. C stocks of mangroves are among the highest of any forest type on Earth. We have measured the ecosystem carbon stocks in mangroves across the world and found them to range from 250 to >2000 Mg C/ha which is a CO_2 equivalence of 917 to 7340 Mg/ha.

Because the numerous values of mangroves are well known, it is ironic that rates of deforestation largely relating to land use/land cover change are among the highest of any forest type on earth exceeding that of tropical rain forests. Dominant causes of deforestation include conversion to aquaculture (shrimp), agricultural conversion, and coastal development. The "Land Use Carbon Footprint" is the carbon emissions that arise from the conversion of an ecosystem to another land cover type in order to provide some commodity. As the carbon emissions arising from conversion of mangroves to other uses is exceptionally high it is informative to calculate land use carbon footprints from conversion to shrimp ponds. High emissions arise because of losses of both aboveground and soil carbon stocks with conversion. Emissions from conversion of mangroves to shrimp ponds from studies in 4 countries range from about 800 to over 3000 Mg CO_2e/ha. In low input shrimp ponds over a ton of CO_2 is emitted for every kg of shrimp produced. This places the carbon footprint of shrimp arising from such ponds as among the highest of any food product available.

Conversion results in the loss of centuries of soil carbon accumulation in mangroves. Of great interest is the potential value of mangroves in carbon marketing strategies and other financial incentives that are derived from the conservation of these wetlands. This is because of the combination of high carbon stocks in intact mangroves, the high greenhouse gas emissions arising from their conversion, and the conservation of other valuable ecosystem services provided by mangroves.

9.30 Quantifying habitat structural complexity of mangroves and its implications for ecosystem services

Joe S.Y. Lee, Griffith University, Australia
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Most of the key ecosystem functions and services offered by mangrove ecosystem are related to the lower aboveground structural complexity of the forests. The types of aboveground root and shoot structures, their relative and absolute abundances as well as their spatial arrangement determine how mangrove forests may offer protection to juvenile nekton, ameliorate wave action, and trap sediment and carbon. Structural complexity of mangrove forests has, however, not been quantified due to the lack of suitable practical methods and tools. We developed a simple and low-cost method for accurately capturing the three-dimensional complexity of mangrove root structure using a RGB-D sensor and readily available computer software. The realistic 3-D computer model can then be analysed to quantify habitat structural complexity using metrics such as fractal dimensions. I will illustrate potential applications of this method by the example of how the same mangrove root structures may appear differently to juvenile fish and their predators, and thus, influence the nursery value of the habitat.

10.00 Mangrove Action Project (MAP) - standing at the roots of the sea

Alfredo Quarto, Mangrove Action Project, USA
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Today there is a growing urgency to recognize the importance of conserving and restoring protective mangrove greenbelts to lessen the dangers from future natural catastrophe. As sea levels rise, so will the frequency and intensity of hurricanes and storm surges. Mangroves can buffer against the fury of such destructive natural events, potentially protecting those settlements, livelihoods and lives located behind a healthy mangrove fringe. Mangroves are also vital to curb climate change and to help restore our threatened marine biodiversity.

Though there are good reasons aplenty to conserve and restore mangroves, why are we still losing around 150,000 ha of mangroves a year, and what can we do to halt this trend? More than that, why are we not taking more effective actions?

Over the last two decades, Mangrove Action Project has set off on a unique course to combat mangrove loss. MAP's "roadmap" for the future of our planet's mangroves interweaves a multi-faceted approach where all "roads" lead to a common solution.

This five-pronged approach to long-term mangrove conservation involves: education, advocacy, networking & collaboration, conservation & restoration, and sustainable community-based development.

In this presentation, I will better define the major routes that MAP takes and how these connect to MAP's overall mission:

"Partnering with mangrove forest communities, grassroots NGOs, researchers and local governments to conserve and restore mangrove forests and related coastal ecosystems, while promoting community-based, sustainable management of coastal resources."

10.30 Ponds, parks and protected areas: strategies for mangrove conservation in the central Philippines

Heather Koldewey, Zoological Society of London
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With over 50% of mangroves lost, 7,700 islands, a population of 100 million people and increasingly severe storms and typhoons, successful approaches to mangrove conservation in the Philippines are urgently required. Although there is a huge enthusiasm for mangrove replanting programmes supported by government, NGO and the private sector, many of these efforts are wasted due to poor selection of species and sites and a lack of monitoring and capacity.

ZSL initiated its mangrove conservation efforts in 2007, focused on Panay Island, Western Visayas, on a ground-breaking project to revert brackishwater ponds (fish and shrimp) to mangrove forest and to protect remaining mangrove forests. The Community-based Mangrove Rehabilitation Project established and/or built the capacity of local community organisations to gain tenure of their forests through 25-year community-based forest management agreements. In addition, we have carried out some innovative work on the practicalities and process of fishpond reversion. Using science-based methods we have been able to develop simple approaches to mangrove conservation that can be readily implemented by communities. At the same time, we have initiated mangrove associated livelihoods, including mangrove nurseries and eco-parks, that benefit local communities and encourage mangrove conservation.

Over the last two years, we have explored how we can better integrate mangroves into coastal management plans of local government. On the fringes, mangroves fall between forest and marine resource management. MPAs in the Philippines are currently focused on coral reefs and the area of protection falls well short of international and national targets. We have therefore developed a strategy to increase the diversity of marine habitat protection with particular focus on mangrove forests. To date, we have implemented and expanded six MPAs in the Visayas, resulting in 2,087.46 ha of protection. Particularly notable is that by adopting a strategy of combining mangroves to reef-based MPAs and protecting the entire ecosystems, the average size of these MPAs is 435.34 ha, compared to average size of MPAs in the Philippines of between 10 to 30 ha.

This presentation will outline these projects, sharing our practical experiences of mangrove conservation in the Philippines.

11.00 POSTER SESSION (TEA/COFFEE)

SESSION V: HOW TO REBUILD OUR LOST FORESTS

11.30 Lessons learned from 40 years of successful Ecological Mangrove Restoration (EMR) in the subtropical and tropical Americas

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Given the historical losses of mangrove forests in the tropical and subtropical Americas, attempts to restore lost mangroves have accelerated over the last four decades. Unfortunately, many of these well intentioned efforts have failed to establish persistent mangrove cover over time. Similar failed efforts have occurred around the world. Attempts to determine the reasons for these failures are hampered by typical funding restrictions for restoration attempts which support community-based nurseries, and physical plantings of seeds or seedlings, but do not support pre-restoration investigations, nor post-restoration monitoring and reporting for meaningful periods, typically at least five years. Thus investigations of the causes of failures are largely limited to anecdotal observations and post-restoration site visits.

After 40 years of attempts to successfully restore mangroves, mostly in Florida, but including similar efforts in 22 foreign countries, we have developed and teach a method called Ecological Mangrove Restoration (EMR) (Lewis 2005, 2009). It basically emphasizes careful advanced characterization of the ecohydrology of whatever mangrove species are the target of the restoration effort, and topographic and hydrologic examination of control mangrove sites with comparisons to proposed restoration sites. Restored or created tidal creeks are also an essential part of any ecologically functional mangrove restoration project.

A thorough understanding of both primary and secondary succession in mangroves of a particular locality are also important. Planting of mangroves is rarely needed as mangroves seasonally produce large quantities of floating propagules that quickly colonize appropriately prepared sites. Planting of appropriate nurse plant species such as smooth cordgrass (*Spartina*) or saltwort (*Batis*) in the Americas, or mangrove grass (*Porteresia*) in Southeast Asia, may be essential in higher wave energy or erosion prone sites.

Case studies of several successful mangrove restoration sites as large as 500 ha will be shown to emphasize these points. The emphasis for successful restoration is pre-restoration investigations of conditions that prevent natural recovery of a given site. Hydrologic restoration is the preferred method of restoration for routine success and ecosystem restoration at minimum cost. “Strategic Breaching” of impounded mangroves including abandoned aquaculture ponds is introduced.
www.mangroverestoration.com

12.00 Applying resilience thinking to mangrove conservation, sustainable utilization and rehabilitation across Indonesia

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Indonesia historically maintained 4.2 million ha of mangroves exhibiting the highest levels of floristic mangrove diversity on earth. That total has been reduced by more than half over the past three decades, attributed at least 60% due to shrimp and milkfish aquaculture development in addition to unsustainable logging, port, road and settlement development and most recently intrusion including filling due to oil palm plantation. Mangrove planting efforts, undertaken routinely as a gesture of management by a variety of government agencies, have a near total failure rate, with numerous sites being planted repeatedly over decades without honest monitoring or reporting.

The mangroves of Indonesian Papua provide an antithesis to the story of degradation; historically covering 1.3 million hectares, down to perhaps 1,150,000 representing a loss of only 12%. Papuan mangroves currently comprise an estimated half of the Indonesian total. They are of critical local importance to a wide variety of ethnic groups, and are also of global importance as a major world carbon sink. These enormous forests are inextricably linked to even larger expanses of lowland freshwater swamp forests, especially along the southern coast which together with mangroves carbon storage figures ranging from 587 – 1378 tonnes/ha with average values hovering around 1000 tonnes/ha.

Although Indonesia exhibits large heterogeneity of mangrove types (both geomorphological and in terms of community associations) as well as a variety socio-economic coastal conditions, for the purposes of management we recognize three major social ecological system (SES) types; varying by degree in terms of resilience and threat.

i. In tact Systems
    1. Immediate/direct threat
    2. Future/indirect threat
ii. Nominal to Significant Degradation
    1. Opportunities for rehabilitation
    2. Stable
    3. Trend/threat of continuing degradation
iii. Wholesale Degradation
    1. Repair feasible current techniques and stakeholder support
    2. Repair potentially feasible – requires research & development
    3. Repair infeasible

This paper looks at examples of the above mentioned SES types as they move through the four stages of an adaptive cycle (conservation, release, reorganization and re-growth). Next, thresholds of mangrove-aquaculture agroecosystems systems are discussed in order to understand how human activity has interrupted the natural adaptive cycle, leading to reorganization of an alternate stable state of lower value. This leads to a brief discussion of the importance of identifying key variables which underscore change in mangrove systems, understanding feedback mechanisms and managing mangrove systems to stay away from thresholds, rather than attempt to achieve an optimal state of production of a specific suite of goods and services. The subsidence of mangrove-aquaculture agroecosystems is used to illustrate this shift in regimes.

Seven principles for building resilience in social-ecological systems are next introduced, originally posited by members of the Resilience Alliance. Examples of management approaches are drawn upon to illustrate these seven principles, including a variety of sustainable development activities ranging from education and livelihood programs, gender equity, ecological mangrove rehabilitation and the linkage of resilience thinking with collective learning systems. The talk closes by underscoring the importance of building the capacities of a variety of stakeholders to participate actively in multi-stakeholder mangrove management working groups, tasked with developing and testing hypothesis as a key element of long-term adaptive collaborative management.

12.30 Ecosystem-based mangrove rehabilitation and management along mud-coasts of the Mekong Delta, Vietnam

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Along the mangrove-mud coasts of the Mekong Delta erosion is affecting the life of many thousands, often poor farmers and fishermen. The traditional response of building dykes and seawalls often does not work because the subsoil of these mud-coasts is too soft. In such situations an area coastal protection strategy which combines floodplains (foreshore), mangrove forests and, where necessary, an earth dyke is the most effective solution. However, in sites where the foreshore and the mangrove forests have been destroyed by erosion, such a strategy can only be implemented after restoration of the eroded floodplains. The most effective way to restore eroded foreshores is to use permeable T-fences which do not inhibit sediment input and create calm water conditions for sediment deposition. T-fences reduce erosion and lead to the immediate solution of an acute threat in areas where the foreshore erosion has progressed all the way to the dyke. Such an approach requires numeric modelling (based on data recorded on site) to determine boundary conditions and to ensure that down-drift erosion can be minimised as much as possible. It uses bamboo poles which is cost-effective and avoids the problems associated with building heavy concrete structures on soft mud. After successful restoration of the foreshore, natural regeneration of mangroves will occur providing the area is protected from human impacts. If natural regeneration is not sufficient, planting of mangroves may be necessary. Appropriate species need to be planted in the right site at the correct time. This is best done by learning from nature – by mimicking the way nature plants and the way nature creates a species zonation. An ecosystem-based coastal protection strategy must also contain long-term mangrove protection and management; otherwise the investments will be wasted if the mangroves on the restored floodplains will be destroyed (again) by anthropogenic impacts and after that the floodplains will erode again. Co-management, or shared governance, is an effective approach for sustainable mangrove protection and management.

13.00 LUNCH

SESSION VI: ALIGNING RESEARCH TO CONSERVATION NEEDS

14.00 Developing good practice for blue carbon projects: status and information needs

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The importance and value of coastal wetland ecosystem services for climate change mitigation and adaptation provides a basis for the development of interventions that conserve and restore these ecosystems. Such interventions may take the form of policy actions, adjusted management actions or project-based investments that leads to improvements in coastal wetland conditions.

While blue carbon is a new concept, planning successful conservation and restoration of coastal ecosystems is an established practice with a learning curve of experience spanning over 40 years. Experience has developed at different rates and with different foci around the world but each brings lessons that can be shared as examples of common good practice. This learning encompasses phases of increasing complexity: (1) building wetland conservation and restoration experience and capacity; (2) scaling up to establish multi-use functional landscapes integrating community activities in balance with sustaining environmental conditions; and (3) inclusion of climate change adaptation and mitigation in land-use planning. The technical ability to successfully restore coastal wetland ecosystems today is available on a global level, even if it is not always applied.

To achieve a successful intervention, coastal wetland conservation or restoration should be planned with a landscape response to climate change in mind. Connecting climate change mitigation with adaptation planning will greatly increase the likelihood that blue carbon interventions will be successful. Geomorphic and engineering tools exist to aid in the understanding of how blue carbon ecosystems will respond to sea-level rise, thus supporting project planning and design. Project success is greatly increased if local community engagement and capacity building predates or accompanies the intervention. Examples of good practice exist.

Our challenge at this stage is to assist communities and countries advance along the learning curve. Pilot demonstration of policy and practice implementation is needed. Key is the question of how coastal communities adjust to rising sea level and can they do this while incorporating management of coastal ecosystems along with wider concerns of achieving sustainable livelihoods, maintaining food security, and reducing vulnerability to environmental change.

14.30 The value of mangroves in Madagascar – carbon and communities

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Madagascar's west coast hosts the fourth largest extent of mangrove forests in Africa - nearly 2,800 km^2. These mangrove forests and coastal wetlands are a vital support system for critical biodiversity, traditional livelihoods and the local fishing economy. As such, they are essential to the survival of thousands of coastal communities in Madagascar, who are among the poorest and most vulnerable to climate change in the world. However, these 'blue forests' are being lost an alarming rate. From 1990-2010, Madagascar lost approximately 21% of its mangroves. Much of this loss was anthropogenic; driven by deforestation for timber and derivative products (such as charcoal) and conversion for agriculture. As well as being one of the primary agents of mangrove degradation in Madagascar, the island's coastal people also have the most to lose from the destruction of these habitats and their associated ecosystem goods and services. Coastal communities are therefore key to tackling mangrove deforestation.

It is well established that mangroves are amongst the most carbon dense ecosystems in the world. This carbon sequestration capacity opens up the possibility for projects that prevent further deforestation to access money from the voluntary carbon market, by applying REDD+ methodologies more commonly associated with terrestrial forest projects. Since 2011, through its Blue Forest project, Blue Ventures has been assessing the feasibility of this 'blue carbon' as a means to both catalyse and fund community-led mangrove management in Madagascar. In this presentation we highlight the potential of blue carbon, when integrated with suitably robust livelihood protection schemes, to act as a long-term incentive for sustainable, locally-led marine management.

15.00 **Science as a foundation for effective mangrove management: perspectives from the western Indian Ocean region**

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The Western Indian Ocean (WIO) Region covering 10 countries has about 1 million ha of mangroves, which is about 5% of the global coverage of mangroves. Most of the mangroves are found in Mozambique, Madagascar, Tanzania and Kenya. Other regional mangrove countries include Mauritius, Seychelles, Comoros, Somalia and South Africa. These ecosystems provide a wide array of ecosystem goods and services, thus making them critical to local communities and national economies as well. Current data indicate that mangrove losses in the WIO range from 20 to 33% over the last 25 years with the major cause being over-exploitation for wood products and conversion of mangrove areas to other land uses, particularly aquaculture and rice paddies. However, mangrove losses in some locations have far exceeded the global mean of 1 – 2% pa. For instance, mangroves of the Zambezi Delta in Mozambique and peri-urban mangroves in Mombasa, Kenya have reported cover losses of between 2.7 – 5.1% pa. Mangroves in regional countries are faced by similar management challenges albeit at varying intensities and extents. Research activities have concentrated on resource assessments, vegetation structure, provision of diverse ecosystem goods and services (e.g. fisheries, biodiversity, biogeochemistry, coastal protection), restoration ecology, climate change impacts and more recently carbon storage. However, the link between research and management has been elusive and there is a lot of scientific data, which could otherwise inform sound management of this spatially limited and very critical ecosystems. Recent partnerships between scientists and managers in management planning, mangrove restoration, carbon stock assessments and exploration of opportunities for carbon financing are great efforts in strengthening this hitherto weak link. The formation of the Western Indian Ocean Mangrove Network may also provide a forum for managers and scientists to work together for improved management of regional mangroves.

15.30 **POSTER SESSION (TEA/COFFEE)**

16.00 **Linking research and conservation needs of mangroves: current status, challenges and prospects in west-central Africa**

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About 14% of world mangroves with six major species cover most of the coastal regions of Western Africa in 19 countries stretching from the coasts of Mauritania to Angola in the Gulf of Guinea. There is a great structural peculiarity of mangrove stands in Central African coast stretching from Cameroon to Angola in being the most giant in Africa reaching over 100cm in diameter and 60m in height especially around the Wouri estuary in Cameroon. Mangroves have been playing significant ecological, economical and socio-cultural roles in the lives of coastal communities of over 100 million people living within Western Africa. Mangroves in Western Africa are in moderate decline, with average estimates reducing by a quarter between

1980 and 2006. Four key drivers have been identified as the principal factors influencing mangrove change: population growth, economic and political trends, climate change and changes in upstream habitat. Most threats (over exploitation of mangrove resources for different uses, unplanned urban and economic development projects and programmes, hydrocarbon pollution, invasive species) are well known but not properly quantified and documented for management applications. Long-term values of intact and functioning mangrove ecosystems are not being recognized in the coordination and application of current policy strategies and decisions, where short-term gains resulting in loss of the ecosystem are being pursued at the expense of long-term sustainability.

The few ongoing efforts geared towards addressing threats through conservation (20% in protected areas with often non-mangrove defined objectives), various restoration programmes and projects of governmental and nongovernmental organizations are largely isolated and uncoordinated with little private sector participation. Current mangrove isolated research initiatives with weak technical, material and operational capacities are hardly integrated into projects; and mangrove issues are largely descriptive with hardly any quantitative data or information on stocks, regeneration dynamics, flows of ecosystem services and threats for any meaningful actions at various levels to sustainable mangrove management and livelihood support. However, fewer projects have monitoring components that integrate mangroves (sustainable livelihoods and biodiversity project in the Niger Delta, water bird census by Wetlands International, large marine projects, among others) but these monitoring programmes had not been capitalized for research endeavors leading to decision making at the regional levels. Future challenges and perspectives include: mainstreaming mangrove research activities into regional forestry projects as a core component (especially in REDD+ projects); taking on board quantitative aspects of ecosystem services and threats in research; and building the capacity of regional expertise including material and operational capacities in mangrove management and research. This could happen via postgraduate training, sharing of cross border skills and the use of existing networks (like the African Mangrove Network, institutions and regional universities) with adequate research equipment and infrastructure; strengthening communication between science and policy; and incorporating indigenous knowledge into mangrove management at regional levels with more involvement of the private sector as potential investors and funders of research.

16.30 Supporting mangrove ecosystem conservation needs in Southeast Asia through research – experiences from the MFF initiative and other international mangrove projects

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Mangroves for the Future (MFF) is a regional initiative supporting 11 countries across the Indo-Pacific region, including the Southeast Asian countries of Cambodia, Indonesia, Myanmar, Thailand and Viet Nam. In addition, Cambodia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam were involved in a related regional project on Transboundary Diagnostic Analysis (TDA) of Indo-China Mangrove Ecosystems, which ended in 2013. Based on MFF's extensive experience of implementing mangrove rehabilitation projects, and a comprehensive assessment of policy development and research needs undertaken by the TDA Project, the following research areas were identified help governments to better integrate environmental conservation and sustainable use needs into coastal development planning.

Research to fill knowledge gaps:

- Phenotypic and genetic differences between mangrove species populations and how species interconnectivity can support ecosystem resilience;
- Migration and coastal habitat dependency of endangered species (dolphins, dugongs, turtles);
- Techniques to achieve long-term, cost-effective mangrove rehabilitation;
- Sustainable mangrove-polyculture models and “crab banks”;

- Implications of sea-level rise and global warming/climate change on mangrove structure and function; and on the corresponding capacity of mangrove ecosystems to provide climate change adaptation and mitigation benefits.

Research to bridge science-to-policy gaps:

- Valuation of mangrove goods and services at national to transboundary scales;
- Mangrove-fisheries ecological linkages and their economic value;
- Payment for mangrove ecosystem services (PES);
- Assessment of using mangroves as part of integrated solutions for coastal erosion control.

Research based on monitoring:

- Improved estimates of the areas of mangroves, species composition and vulnerability assessments, using standardized, regionally consistent methodologies;
- Qualitative assessment of ecosystem integrity (health), based on regionally agreed criteria;
- Simple, within country mangrove monitoring methods and programs that coastal communities can fully participate in.

17.00 **PANEL DISCUSSION (Chair – Dan Alongi)**

CONCLUSIONS AND SUMMING UP

Jurgenne Primavera, Zoological Society of London, Philippines & Joe S.Y. Lee, Griffith University, Australia: Co-chairs of the IUCN SSC Mangrove Specialist Group

END OF SYMPOSIUM

POSTER PRESENTATIONS

A smelly playground: mangroves as nursery sites for the commercial mud crab Scylla serrata

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While mangroves are claimed to serve as nursery sites for a variety of fish and invertebrate species, the association of early life-history stages of many estuarine species with mangrove forests remains unclear.

The mud crab Scylla serrata is a highly exploited species in the Indo-West-Pacific, but despite efforts to study the early benthic stages (EBS) in the wild, the exact habitats of these life stages are unknown.

We studied the microhabitat of EBS juveniles at two mangrove sites in eastern Australia with regards to the character of sediment (sand vs. muddy) and the location (within mangrove fringe vs. unvegetated tidal flats). We were able to locate juvenile mud crabs between 3 and 30 mm carapace width (CW). The majority of EBS crabs (92%) were detected in muddy areas and of these, 87% were found in intertidal areas within the mangrove fringe, few (13%) were on unvegetated mud flats seawards to the mangroves. EBS from the mud flat (including first instars of 3-4 mm CW) were significantly smaller ($p<0.001$) than those from the mangrove fringe. This indicates an active migration from the mud flat towards the mangroves as the crabs grow, linking mangroves with the adjacent mud flat. By identifying the microhabitat of the critical early benthic stages of S. serrata in eastern Australia, our findings may contribute to the development of appropriate management strategies for this commercially important species.

Co-authors: Shing Yip Lee, Karen Diele, Matthias Wolff and Inga Nordhaus

Caribbean-wide patterns of reef fish abundance in relation to mangrove forest area

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Research conducted at the island scale suggests that mangroves habitats serve to enhance fish abundances on Caribbean coral reefs by providing nursery grounds for several ontogenetically-migrating species. Evidence of such enhancement at the Caribbean regional scale, however, has not been reported and recently researchers have questioned the mangrove-reef subsidy effect. In the present study, we compiled and analyzed data from an ongoing citizen scientist fish monitoring program, human population censuses, and several wetland forest information sources. Specifically, we tested for a Caribbean-wide mangrove forest area effect on the abundances of 12 reef fish species that have been previously characterized as mangrove dependent. After accounting for human (fishing and habitat degradation) and latitudinal influences, we found reef densities of six of the 12 fishes examined were positively correlated with mangrove forest size. Therefore, consistent with smaller-scale studies, our results are consistent with the notion that greater mangrove habitat area increases certain reef fish densities across the entire Caribbean region. Recent work questioning the mangrove–reef fish subsidy effect likely reflect a failure to focus analyses on mangrove-dependent species and/or to account for human impacts, especially fishing pressure. With this study, we provide a scientific rationale to not only protect mangrove habitat against degradation and loss at a local scale but also stress mangrove conservation at the transboundary level.

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The Global Mangrove Watch

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This study has developed a method of mapping and monitoring the change in mangrove extent across the (pan-) tropics over the period 1996-2010. A mangrove baseline is being developed for the year 2010 and changes in forest extent are being mapped back to 1996. The primary datasets that will be used to achieve a baseline classification include Japanese Aerospace Exploration Agency (JAXA) spaceborne radar imagery and the global optical Landsat mosaic of Hansen et al, 2013. Additional datasets include elevation (SRTM) and the existing mangrove baseline (Giri et al, 2011). The methodology is built using a Bayesian maximum likelihood approach to utilize the context that characterizes the mangrove environment. As mangroves are located within close proximity to saline/brackish water at low elevations, these characteristics are being used to refine the classification, alongside reference to the existing mangrove baseline. For the detection of change the classification of mangroves is overlain on the earlier radar (JERS-1) scenes and regions which no longer fit the statistical pattern of the class they were originally assigned are identified to be re-classified identifying the change regions. It is intended that this study will highlight mangrove forests that have suffered the greatest degradation over the past 14-years and will be utilized within decision and policy making for the protection and preservation of these important ecosystems. The intention is that, once produced, the data products from this study will be made freely available through the Global Wetlands Observing System (GWOS), a repository for a plethora of datatypes and information on global wetlands.

Co-authors: Nathan Thomas and Dr Andrew Hardy

SNV Ghana's "Mangrove Restoration in Action" Project

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From 2005 to 2010, Ghana lost on average 2.19% of its forests annually, the highest globally after Togo and Nigeria. The mangrove forest cover reduced from 12,400 ha in 2005 to 9,500 ha in 2010; a staggering annual loss of 5.8%, more than double the national average deforestation rate. At this rate there will be no mangrove forests in Ghana by 2025.

The identified causes of mangrove deforestation are urbanisation and fuel wood harvesting. In Ghana, mangroves are mainly used as fuelwood for fish smoking, which is a dominant economic activity in Ghana. Ghana produces an estimated 560,000 tonnes of smoked fish per year (Bank of Ghana, 2008). This is done on an estimated 120,000 fish smoking stoves, consuming 7.4 million tonnes of fuel wood per year; most of which, is mangrove wood.

Reversing this trend calls for integrated solutions targeting both demand and supply side factors. Demand side solutions include the introduction of efficient fish smoking stoves that reduce fuel wood consumption by at least 40%. Supply side interventions, involves sustainable mangrove and alternative woodlot cultivation, conservation and rehabilitation.

SNV Ghana, under its Renewable Energy Program, is implementing the 'Mangrove Restoration in Action' Project under which a 5 hectare community-led mangrove and 3 hectare alternative woodlot plantation have been developed and 100 improved fish smoking stoves have been installed thus far. The project aims to create an enabling environment to scale up both demand and supply options to make a measurable impact and restore the mangrove forests in Ghana.

Co-author: Benedicta Samey

The Panama Bight Mangroves: conservation issues, challenges and opportunities

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The Panama Bight mangroves are one of eight mangrove eco-regions in the world prioritized for its outstanding biodiversity. Located in North Western South America and encompassing the (Pacific) coasts of Panama, Colombia, Ecuador and northern Peru, this region harbors one of the most structurally-developed and intact mangrove ecosystems in the Neotropics. Differing levels of anthropogenic intervention have led to severe losses in Ecuador but also to relative unaltered mangrove systems in southern Colombia. In the latter area, several initiatives to protect these ecosystems during the last 15 years have taken place. Empowering locals, supporting the establishment of protected areas, accompanying regional environmental agencies and local organizations in producing sustainable (fisheries) management plans, assessing mangrove vulnerability to climate change and initiating bi-national conservation strategies (e.g. with Ecuador) have allowed increasing awareness from local to international levels on the importance of preserving mangroves and the ecosystem services that it provides to humans in this region. Pressing problems facing mangroves in this region include increased pollution from mining activities in the upper watershed of rivers, over-exploitation of fisheries resources (e.g. mangrove cockles) and land reclamation near the largest towns. Better coordination between local communities, regional and national environmental agencies, fisheries authorities, academic institutions and NGOs will help facing these threats in an effective way. A regional vision that acknowledges the different social and cultural contexts where local communities develop in this region is urgently needed to better allocate conservation efforts aimed at maintaining the pivotal ecosystem services provided by mangroves.

Co-authors: LA Zapata, O Guevara, LF Gomez and C Candelo

An international assessment of mangrove management: incorporation in integrated coastal zone management

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Due to increasing recognition that mangrove habitats provide substantial benefits to mankind, protection policies have emerged under wetland and forestry programs. However, there remains little consistency among these programs and inadequate coordination between sectors of government. With approximately 123 countries containing mangroves along their shorelines, the need for global management of these ecosystems is crucial to sustain the fisheries, timber and tourism industries, and coastal communities supported by mangrove forests. In order to determine the most effective form of mangrove management, this study presents a review of mangrove management guidelines, particularly those associated with Integrated Coastal Zone Management (ICZM). The key elements of mangrove management defined in this review are based on the guidelines developed by international organizations such as the Food and Agricultural Organization's Forestry Department, Ramsar Convention, International Tropical Timber Organization, and International Society for Mangrove Ecosystems. To further explore the fundamentals of mangrove management and how it is implemented worldwide, four case studies were reviewed. The management methodologies of two developed nations (United States and Australia) as well as two developing nations (Belize and Bangladesh) were assessed to encompass all factors that influence mangrove management such as socioeconomics, politics, and land-use regulations. Based on this review, it appears that successful mangrove management will require a blend of forestry, wetland, and ICZM programs in addition to the cooperation of all levels of government. Legally binding policies will be essential to the implementation of effective mangrove management, including the preservation of existing mangrove habitat and restoration of damaged mangroves.

Co-authors: Dr Steffen Schmidt and Dr Amy Hirons

Wood degradation and carbon cycling by teredinid bivalves in mangrove forests

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In this study the breakdown of organic carbon from large woody detritus in mangrove ecosystems was found to be caused by consortia of biodegrading organisms from terrestrial and marine habitats, within mangrove forests in Southeast Sulawesi, Indonesia. Within the high intertidal regions of the mangrove forests, basidiomycetes on woody debris were common. Coleopteran larvae and termites were also found in decaying wood, but only down to the mid-intertidal areas. Marine bivalves belonging to the family Teredinidae are the dominant biodegraders of woody debris in the low-intertidal areas of the forests and their boring activity greatly reduces the volume of woody debris. Teredinids where found in areas with at least 11 hours per day immersion, which was the greatest environmental variable that explained the distribution of the biodegrading organisms, spanning from the supra-tidal down to the low-intertidal. The various biodegrading organisms share the same LWD environment but they occupy a different niche, in this case areas of different tidal immersion. Changes of biodegrading consortia in LWD on the mangrove forest floor between the terrestrial and marine organisms was distinct, creating a biodegradation boundary - in a distance as narrow as 1 meter. Further study is envisaged, to characterise and quantify the role of teredinids in driving flows of carbon in mangrove ecosystems. The combination of lab and field observations gives insights into the mechanism whereby mangrove ecosystems mobilise organic carbon which is subsequently sequestered or exported.

Co-author Simon Cragg

Building an expert-judgement based model of mangrove fishery catches

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This poster will discuss the development, results and implications of an expert-judgement based model of benefits to fisheries from mangroves. Mangroves are a crucial habitat for fisheries, supporting resident populations of commercially important fish, crustaceans and molluscs, as well as providing a nursery ground for target species of offshore fisheries. However, the spatial variation in these benefits that mangroves provide to fisheries is poorly understood.

We have developed a preliminary model of the spatial distribution of these benefits. Based on an extensive literature review, we developed a set of environmental factors that influence the biomass of fish produced by mangrove areas, and a set of socio-economic variables that determine the level of fishing and the proportion of this biomass that is caught. We then used the knowledge of a panel of mangrove and fisheries experts to select which of these variables to use in the model and the relative importance of each.

The model predicts that fish production by mangroves will be highest where there is high freshwater and nutrient input to mangroves, such as in large estuaries. Total mangrove area is also a key driver. Fishing effort is predicted to be highest close to human populations, which provide both the fishers and the markets for their catch. The model is qualitative and has not been calibrated with field data, but nonetheless provides a useful insight into the drivers and spatial distribution of fishery benefits from mangroves, and can help prioritise areas for mangrove conservation and restoration.

Co-authors: Mark Spalding and Philine zu Ermgassen

Status of the genetic diversity of major component plant species of mangroves

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We have established a research network for conservation genetics of mangroves since 2009, obtaining grant supports from JSPS (Japanese Society for Promotion of Sciences) and Chiba University, Japan. The main purpose of the network is to document the present genetic diversity of major component plant species of mangroves, as fundamental information for future conservation. We have targeted some representative groups of plant taxa, performed extensive field works to collect population samples over their wide distribution ranges, and employed molecular markers to assess genetic diversities and understand their genetic structures. In the poster presentation, we will introduce our progress in studying the genetic diversity of Bruguiera gymnorhiza, Xylocarpus granatum, Rhizophora mucronata, Sonneratia alba and Acrostichum aureum, and their closely related taxa. We will show the maps of genetic diversity for the taxa studied, and show the spatial pattern and genetic structure over their geographic distribution range. We will also compare the patterns of genetic diversity and genetic structures among species, and try to elucidate the common processes that caused the differences and commonness among species.

Co-authors: Koji Takayama, Alison K.S. Wee, Junya Ono, Nazre Saleh, Yuki Tomizawa, Yoshimi Shinmura, Takeru Yamakawa, Takeshi Asakawa, Yusuyuki Watano, Edward L Webb and Shigeyuki Baba

Mangroves in coastal defence

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Mangroves can reduce risk from natural hazards such as cyclones and tsunamis and can reduce erosion rates. The level of reduction will depend both on site characteristics and the local hazard context. Wind and swell waves are reduced over tens to hundreds of metres of mangrove vegetation, potentially lessening wave damage during storms. However, wide mangrove belts, ideally thousands of metres across, are needed to reduce the peak water levels of storm surges created by tropical cyclones, hurricanes and typhoons. Narrower mangrove belts, hundreds of metres wide, may nevertheless reduce flood extent in low lying areas behind mangroves, and can also reduce local wind speeds and the impact of wind waves on top of the storm surge. Wide areas of mangroves can reduce tsunami flood depths, helping to reduce loss of life and damage to property in areas behind mangroves. Mangroves can also reduce erosion, and over time they can actively build up soils through sediment deposition at the surface and growth of subsurface roots. The resultant rise in the level of the soil surface can help to counteract the effects of sea level rise on mangroves. With sufficient sediment input, this can enable them to survive in areas that would otherwise be drowned by the sea. Therefore mangroves can provide coastal risk reduction services into the future. They are best used in combination with other risk reduction measures to reduce coastal risk to the lowest level possible.

Co-authors: Tom Spencer, Iris Möller and Mark Spalding

Are anthropogenic influences increasing biodiversity in an Indonesian mangrove?

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Mangrove forests are one of the worlds most threatened ecosystems. Currently anthropogenic influence poses the greatest threat to mangrove forests and their habitats. For one population of fiddler crabs in the Wakatobi Marine National Park, Southeast Sulawesi, anthropogenic influence seems to be increasing the biodiversity rather than the normal effect of decline. Fiddler crabs have been identified as a keystone species, which can be used as an indicator of ecosystem health. Studies have linked the activities of *Uca* to nutrient cycling and primary productivity within mangrove habitats.

In this area the highest level of sympatry in fiddler crabs has been recorded, with eleven species coexisting in a 50m² area on the fringe of the mangrove. Quantitative sampling reveals that although all species may occur on the same shore, populations of each species remain discrete, with species occupying micro-niches. The high levels of alpha diversity seen at this research site are likely to be driven by factors specific to the habitat. Anthropogenic factors seem to be directly altering the ecosystem, allowing crabs to dwell in places which would otherwise be unsuitable for the particular species'; such as unnatural shading provided by man-made structures. These changes increase the site heterogeneity, therefore contributing to a greater range of niches.

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Mangrove habitats in Ghana are fast degrading and need remedial management action

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Many mangrove habitats in Ghana are in a state of degradation therefore reducing its capacity to fully serve as an ecological and nursery habitat for many faunal species. The threats contributing to this state of affairs are numerous and related to poverty and poor social infrastructure in coastal communities. This study utilised laboratory, remote sensing field visits and interviews with residents and managers to determine the location, state of mangrove habitat, fauna and flora, uses, issues and threats to the mangrove habitats of Ghana. It revealed that the coastal area is endowed with mangroves of small, medium and large expanses. The current mangrove cover is estimated as 72.4 km2 with total tree numbers estimated as over 18 million, distributed in all four regions along Ghana's coast. The Volta Region has the highest abundance of mangrove in terms of area of coverage followed by the Western, Greater Accra and Central Regions. Mangroves are the habitats for a number of animals including significant numbers of birds, mollusc, fishes, reptiles and mammals. The absence of a mangrove reserve in Ghana underlies the low importance attached to mangroves in the country. The fragmentary nature of the existing environmental laws coupled with lack of their enforcement renders the national laws less effective in protecting mangroves. The current state of mangroves in Ghana requires some interventions to restore the ecological integrity of these vital ecosystems.

Co-authors: Andrews K Agyekumhene, Emmanuel Aziebor & Benedicta Samey

Biogeochemical cycling in mangrove systems: a stable isotope approach to quantify carbon and silicon sequestration

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There is an intimate relationship between silicon and carbon cycling, with silicon (the second most abundant element in the Earth's crust[1]) inherently controlling the global inventory of CO_2 in the atmosphere[2]. Estimates of silicon and carbon cycling in coastal regions (including mangroves) are poorly constrained and human alteration of these regions is leading to a reduction in CO_2 sinks[3]. The aim of this project is to provide the first detailed joint estimate of silicon and carbon budgets in coastal mangrove systems in Malaysia. This will quantify (through a stable isotope approach) silicon and carbon sources, sinks and fluxes in these environments, thereby feeding into global budgets. Comprehensive sampling from one pristine and one human impacted site, of vegetation (land and aquatic), soils, suspended particulate matter and geology, as well as hydrology (including soil porewater, fresh- and sea-waters) will be conducted in order to ascertain silicon (and carbon) concentrations and isotopic signatures ($\delta^{30}Si$, $\delta^{13}C$, C/N). Stable isotope techniques will be adopted in order to trace the flux of silicon and carbon through mangrove systems (along a downstream transect), as well as to investigate sources and sinks of nutrients and variations in these biogeochemical cycles over temporal and spatial scales. This project proposes to place at the forefront the importance of silicon cycling in coastal regions (in particular mangroves where estimates to date have been neglected) thereby highlighting its value to the carbon community in order to develop more robust estimates under future GHG emission scenarios.

Co-authors: McGowan S, Horstwood M, Zakaria R M and Chong V C

[1]Epstein, E., 1999. Silicon. *Annu. Rev. Plant Physiol. Plant Mol. Biol*.50, 641– 664; [2]Pondaven P, et al. 2000. *Nature* 405:168–72; [3]Duarte, C.M., et al, 2013, *Nature Climate Change*, 3, 961-968.

IWP mangrove forests and watershed management: restoring and maintaining ecological connections

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Mangrove management in the Indo-west Pacific region has been dramatically unsuccessful. This outcome has been mainly due to the different management priorities of local stakeholders, who rarely value biodiversity, ecotourism and conservation, and mostly consider mangrove forests either as a source of potential revenue for silviculture and aquaculture, or simply wastelands to be reclaimed and converted. This trend however, has also been caused by the lack of understanding by conservation biologists of the network of ecological and evolutionary connections between mangrove forests and many other ecosystems, traditionally conceived as distinct, both at the landscape (e.g. peat swamps, freshwater swamps, riverine systems and uplands) and at the seascape (e.g. seagrass beds, coral reefs) levels. At the landscape level, it is proposed that the only sustainably manageable ecosystemic unit is the watershed, since all ecological subsystems within the watershed (however defined) evolved in highly interconnected networks of fluxes of matter and energy. In a cybernetic perspective, the theory of complex systems predicts that once inputs are changed and internal connections are disrupted, systems become less resilient, and prone to more frequent and drastic structural and functional fluctuations. The practical consequence of such theoretical models is that any attempt to preserve mangrove forests or other tropical wetlands when disconnected from other adjacent ecosystems, will inevitably result in drastic changes of the structure, functions and therefore ecological services. This prompts for actions which could restore ecological connections (mostly represented by ecotones) between pristine or degraded natural or semi-natural systems (e.g. through sound water management plans), thus rehabilitating whole watersheds.

Enabling more equitable resilience in mangrove social-ecological systems

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Mangroves play a key role in ensuring the surrounding environment is able to provide water, energy and food (WEF) for coastal communities and beyond. Drivers of mangrove degradation include the development of aquaculture, infrastructure, urbanisation, tourism, agriculture and charcoal making. Many of these drivers are influenced by policy decisions and processes, including formal government policies (informed by scientific knowledge) and local customs and norms, as well as being influenced by markets. These policies, institutions and knowledges (PIK) interact within and across international, national and local levels. Their impacts combine to affect mangroves' extent, condition and their ability to provide WEF, as well as shaping the overall resilience of the mangrove social-ecological system and determining who wins and who loses out.
This research aims to inform more just and equitable resilience in mangrove social-ecological systems, identifying who wins and who loses under specific conditions. It does this by combining and extending resilience thinking (which considers the system's ability to manage change) and nexus thinking (which focuses on the connections between different system components), and is guided by an innovative WEF-PIK resilience framework. The research investigates mangrove social-ecological systems in three countries from three different continents, each of which places substantial reliance upon mangroves in the provision of local coastal livelihoods: Vietnam, Brazil and Zanzibar. The findings will provide important insights for the more equitable and just management and resilience of mangrove social-ecological systems.

Co-authors: Lindsay Stringer, Rachel Berman, Thi van Hue, Flower Msuya, Juarez Pezzuti, and Steven Orchard

The effect of mangrove restoration on fish diversity and biomass in estuarine systems in the SE Gulf of California

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Mangrove forests play an important role in the life histories of many fish species, many of them with commercial importance. Coastal lagoon systems in the south-eastern Gulf of California support a large number of small scale fisheries, and several families depend on these areas for their income and as a source of protein. However, these systems experience increased stress due to habitat alteration. In order to better understand and protect them, it is important to examine the communities they support and understand the factors that are influencing the distribution and abundance of certain fish species. Previous works state the importance of mangroves as a key habitat for sustainable fisheries, but environmental conditions in some mangrove areas can be extremely difficult for the survival of fishes, crustaceans and mollusks (i.e. due to oxygen depletion). Thus, it seems that the role of mangroves is more related to the support of fisheries in surrounding habitats such as tidal channels, intertidal sand banks, seasonal flood plains, coastal lagoons and adjacent marine areas than "in situ" mangroves. Riverine, fringe and overwash mangrove forests are more beneficial to fisheries than basin and dwarf mangroves that play different ecological functions other than supporting fisheries. In order to test this hypothesis, the ichthyofauna at the estuarine system of Las Cabras will be assessed before and after a restoration process that consists in the construction of a series of channels through the mangroves. It is expected that the appearance of the channels will increase the fish biomass and diversity.

Co-authors: Felipe Amezcua and Francisco Flores

The effects of elevated CO_2 on mangrove performance, distribution and ecosystem services

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The persistent rise in atmospheric CO_2 concentrations over the past few centuries from a preindustrial level of ca. 280 ppm to more than 400 ppm is having a pronounced effect on the physiology of most plant species, generally stimulating photosynthesis and growth. Future CO_2 concentrations are predicted to be much higher and understanding how salt tolerant plants, such as mangroves will respond to this increase is key to predicting future global C cycling and ecosystem function. In a series of glasshouse studies as well as a study of herbarium specimens collected over the past two centuries, we characterise the response of mangroves to rising atmospheric CO_2 levels. We find that, especially under nutrient replete conditions, mangroves respond strongly to CO_2 fertilisation in terms of both growth and photosynthesis. We find that elevated CO_2 increases the temperature tolerance of mangroves and while elevated CO_2 does not alleviate the detrimental effects of hypersalinity, we did observe a significant shift in the salinity niche of mangroves within the mid-salinity range (0-50 ppt). Elevated CO_2 and nutrients also affect root properties, altering microbial decomposition rates of these tissues, which could affect both the carbon storage potential and the ability of mangroves to keep pace with sea level rise. The response of mangrove to elevated CO_2 was different among species. Future increases in CO_2 levels will thus likely have a significant effect on mangrove distribution, productivity, carbon storage, soil respiration, interspecific competition and the ability to keep pace with sea level rise.

Co-authors: Catherine E Lovelock, Klaus Winter

Assessing the impact of degradation on mangrove carbon stocks in NW Madagascar

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Mangroves are carbon-rich tropical ecosystems that provide essential services to coastal communities and support rich biodiversity. Rising anthropogenic pressures have caused substantial degradation and habitat loss through overharvesting and land-use change. Carbon finance mechanisms (e.g. REDD+) could help fund mangrove conservation, restoration and sustainable use, but require data on mangrove responses to degradation over space and time. Here, we combined field data with satellite imagery to quantify spatial variability in aboveground carbon stocks and degradation within ecologically distinct mangrove types in NW Madagascar, and explored the relationship of carbon with mangrove diversity. We found that carbon stocks are greater in more diverse, closed canopy mangroves, and stocks decrease nonlinearly with degradation. Yet, driven by within-class ecological variability, low-level degradation has no significant effect on carbon. Proximity to roads is an effective degradation predictor in these mangroves. We conclude that strategic conservation could enhance both diversity and carbon, feeding into an ongoing mangrove REDD+ feasibility assessment aiming to protect critical ecosystems and livelihoods. Our models will be extended to look at the effect of degradation on soil carbon storage, whilst including additional degradation predictors such as navigable river channels. Translated into a spatially explicit model this could help us locate current and future mangrove degradation hotspots.

Co-authors: Trevor Jones and Marion Pfeifer

A note about the unusual habitat distribution pattern and novel clonal growth exhibited by the globally critically endangered mangrove *Bruguiera hainesii* (Rhizophoraceae) and its implications for conservation

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The rare *Bruguiera hainesii* C. G. Rogers is known from fragmented locations in Asia and was reported to occur naturally on the landward side of the mangrove forest. However, recent surveys revealed that *Bruguiera* was able to grow in the other zones (sensu Watson) and including the seaward zone. Such an anomaly may be attributed to the unique adaptive characteristics exhibited by this species or simply due to anthropogenic disturbance experienced by *Bruguiera* and their concomitant longevity. We observed that *Bruguiera* trees were able to reproduce vegetatively, where young shoot(s) developed directly on the kneed pneumatophores. This is probably the first report of the formation of new mangrove trees of Rhizophoraceae directly from pneumatophores (1-6 shoots per kneed pneumatophore). There is usually one larger shoot per pneumatophore that dominate and it will eventually developed into a normal tree. The distance between such pneumatophore-derived young trees and the mother tree varied between 0.5 and 40 m, while most young trees were within a 10 m radius. When viewed from the top, this ramet-like mode of vegetative reproduction in *Bruguiera* is similar to a “fairy-ring” like outgrowth of young trees arising from a central mother tree. The unusual and direct formation of new shoots from the pneumatophores implies that the protection of *Bruguiera* trees and their adjacent “fairy-ring nursery” habitat for new shoot development requires special consideration in view of their novel mode of vegetative development. Efforts to multiply this endangered species by rooting the “ramet” shoots through various means have started.

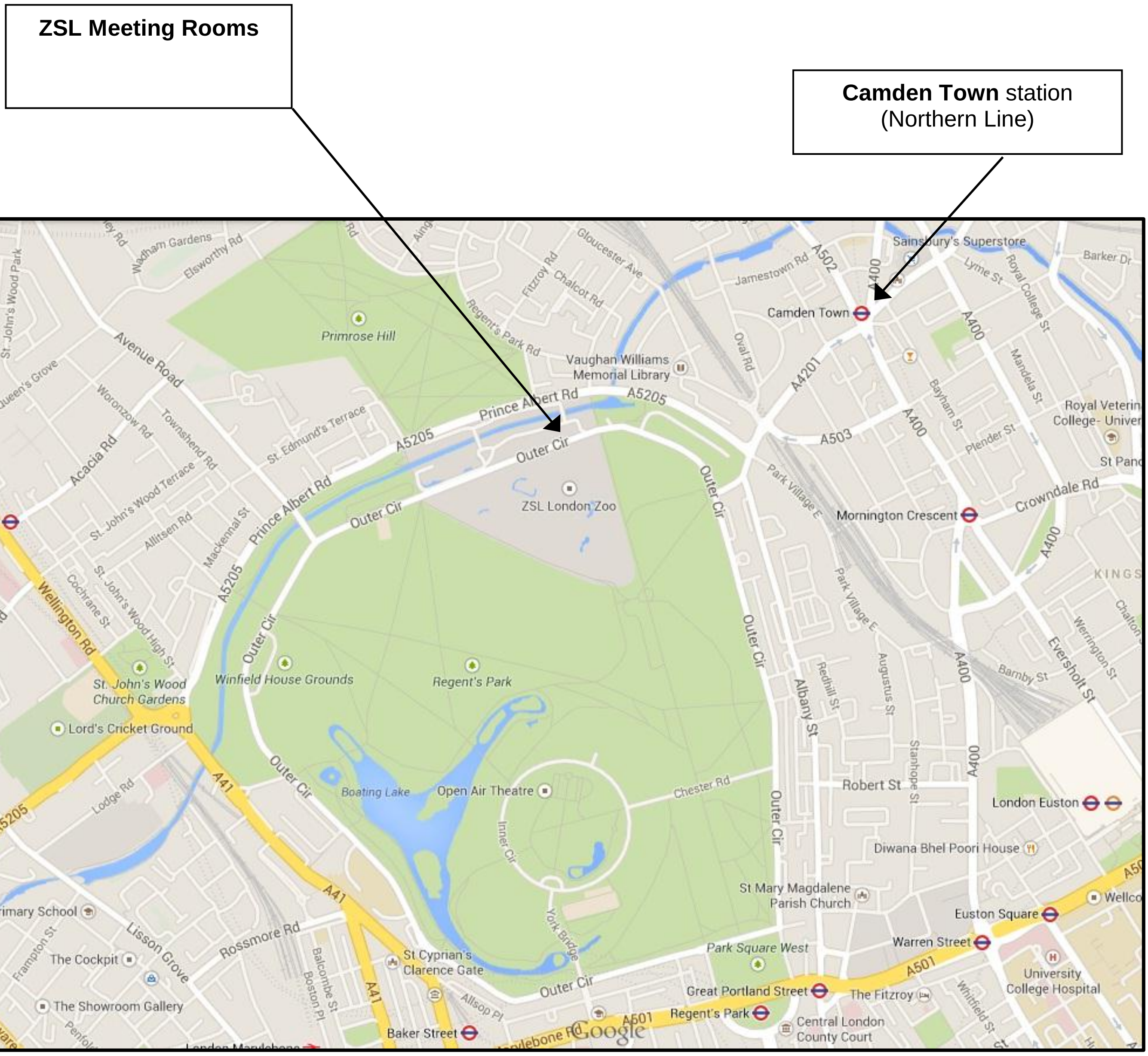
Remote sensing for conservation: uses, prospects and challenges symposium

Location of lunch (Thursday & Friday): Prince Albert Suite

Location of Thursday dinner (booking required) Prince Albert Suite

Venue for Thursday and Friday lunch and symposium dinner
Suggested route (through tunnel)

Entrance to Meeting Rooms from Outer Circle



To walk between ZSL London Zoo and Camden Town underground station takes around ten minutes.

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