Carbon Storage During Upslope Marsh Transgression in Chesapeake Bay, USA

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Salt marsh, mangrove swamp, and seagrass bed ecosystems comprise a global carbon stock known as "blue carbon." While these ecosystems have a small global areal extent, their total carbon burial rates are comparable to global marine carbon burial rates, giving them an important and outsize role in the global carbon cycle that is just beginning to be fully understood. Under various scenarios of environmental change, including climate warming, sea-level rise, and vegetation change, the role of these systems in the global carbon cycle could change significantly, potentially becoming a source of carbon to the atmosphere. It is therefore important to understand the factors controlling carbon storage in coastal wetland systems in order to better predict their future behavior. Here, we will present data from a study marsh in the Blackwater National Wildlife Refuge in Chesapeake Bay, Maryland, USA, where a marsh is transgressing inland with sea level rise into an upland forest environment. Surface carbon accumulation rates range from 0.022 g C cm-2 yr-1 in the lower-elevation, oldest reaches of the marsh to 0.061 g C cm-2 yr-1 at the middle elevations of the marsh. Stable carbon isotope analysis of marsh soils gives evidence for a transition from C3 upland-sourced organic matter to C4-dominated marsh vegetation over time. Stable isotope and lignin chemistry results illustrate that landward encroachment of marsh grasses results in deposition of herbaceous tissues that exhibit relatively little decay. This presents a possible mechanism for organic matter stabilization in marsh soils as marshes migrate inland.

Coastal wetland carbon storage is controlled by accommodation space and influenced by sea-level rise

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The urgent need to mitigate climate change has focussed attention on the capacity of coastal wetlands, primarily mangroves and saltmarshes, to sequester and store carbon. Substrate carbon storage is related to vegetative capacity to add organic matter to substrates, and physical processes that enhance organic matter preservation and/or limit decomposition. Inundation by saline tidal waters is crucial for vegetative additions, and processes favouring preservation over decomposition. Global scale analyses have variably highlighted the role of temperature and precipitation on wetland carbon storage, but have ignored the fundamental influence of sea level on tidal inundation. By conceptualising the accommodation space available for carbon storage as being bounded by sea level, the influence of global variation in relative sea level over the past few millennia on soil organic matter and carbon storage within substrates of coastal wetlands is demonstrated. Using a unique study site exposed to rapid relative sea-level rise that resulted in a substantial increase in accommodation space, the relationship between carbon sequestration and sea-level rise is validated over short time scales. This confirms the capacity of coastal wetlands to adjust to sea-level rise by storing soil organic matter. The space available for carbon storage within mangrove and saltmarsh has become increasingly limited for many coastal wetlands where sea level has been stable for the past few millennia, particularly in the southern hemisphere. This paper verifies that sea-level rise will enhance carbon sequestration providing sediment supply is sufficient and space for lateral expansion does not become limited by coastal squeeze.

Mangrove extent and carbon burial during the closing stages of the postglacial marine transgression

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Evidence is presented of pan-tropical mangrove expansion co-incident with the closing stages of the post-glacial marine transgression from ~9000BP-7000BP. In situ mangrove vertical substrate development was analysed across 78 locations and occurred as rates of sea-level rise fell below 7mm per year. These forests represented a significant carbon sink and coincided with 5 ppmv lower global atmospheric CO2 concentrations. Ongoing vertical accretion led to the replacement of mangrove by freshwater wetland and terrestrial vegetation in many geomorphic settings, possibly contributing to mid- late-Holocene increases in atmospheric methane concentrations.

Quantifying nutrient addition impacts on pristine wetlands & methods to calculate change from baseline

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Increased nutrients in wetlands can lead to a decline in species richness, and compositional turnover. While the whole-community foliar N:P is a useful indicator of N or P limitation, in long-lived, sensitive ecosystems, it is not practicable to remove the biomass of an entire plot to ascertain the foliar N:P ratio. Fertilisation experiments were conducted at four wetlands around New Zealand to examine the vulnerability of pristine wetlands to increased nutrients and the utility of sampling only the foliage of dominant vegetation. Vegetation composition and foliar nutrients were assessed before and after nutrient addition, which lasted four years. Biomass was sampled after four years. We discuss (a) the ecological effects of nutrient (nitrogen) addition at a rate that simulates realistic agricultural run-off on pristine wetlands; (b) the utility of sampling a small amount of foliage from several dominant species to generate an N:P ratio and whether this predicts community nutrient limitation; and (c) how to incorporate natural variability in baseline condition when testing for impacts of nutrients and other disturbances. Although little compositional turnover was seen from realistic N addition, the New Zealand biota (including species found on our plots) is known for its longevity. Longevity is one factor contributing to ecological lags, and we suggest that longer periods of monitoring are required to understand long-term effects (i.e. delayed invasion by species adapted to higher nutrients).

Rare ecosystems – recovery of Sporadanthus raised bog

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Peatland extent and condition in New Zealand have declined significantly over the last 180 years, coinciding with the main period of European settlement. Many remaining peatlands continue to degrade from the impacts of drainage, invasive species, fires and peat mining. A comparison of historic and current wetlands was used to determine priorities for restoration according to extent, type and distribution in northern New Zealand. This identified the widespread loss of an endemic and rare ecosystem type, restiad (family Restionaceae) raised bog dominated by the threatened species, Sporadanthus ferrugineus and Empodisma robustum. Experimental trials following peat mining in this bog type were based on species and environmental conditions typical of both early and late succession, and showed vegetation recovery was most successful when it emulated bog development. Upscaling to whole project restoration involved a patch approach, whereby small 'islands' of the desired peatland vegetation are established, and which provide habitat and seed sources for spreading into bare mined surrounding areas. Patch development restoration techniques have also been successful in restoring degraded peatlands elsewhere, such as alpine Sphagnum bogs. In these cases, the key steps focus on 1) reinstating hydrological function, e.g., by raising water tables, 2) re-establishment of a suitable microclimate, e.g., by creating tall nursery vegetation, 3) reintroduction of invertebrates, and ultimately 4) recovery of ecosystem processes such as peat formation. Restoration of natural function (step 4) involves much longer timescales and remains a real challenge for peatland conservation, particularly under projected climate change scenarios.

Respecting our tuākana: Using eDNA and mātauranga Māori to restore healthy tuna (eel) populations

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Lake Moawhitu, situated at Rangitoto ki te Tonga (d'Urville Island), has been a culturally important site for mahinga kai (food gathering) for Ngāti Koata manawhenua. Of great cultural significance is tuna (short- and long-finned eel). Tuna is a taonga species (gift from the gods) with its own mauri (life force). Tuna have a unique relationship with Māori: they are upheld as our tuākana (elder brother) and as kaitiaki (guardians) of our waterways. Yet their populations and health are increasingly endangered, largely due to declining water quality, habitat destruction and the pressures of commercial takes. Ngāti Koata, among others, acknowledge that tuna have sustained human life over centuries, but now it's our turn to reciprocate by taking responsibility to ensure our tuākana are healthy and live in safe, healthy environments.

This presentation draws on an academic study of tuna at Lake Moawhitu, using both contemporary methods and environmental DNA analysis from sediment cores extracted as part of the Lakes380 project. It also draws from mātauranga Māori shared by Ngāti Koata kaumātua during wānanga and interviews. Both knowledge sources use records from the past to offer insights about tuna populations at Lake Moawhitu. Interweaving these knowledges is both challenging and rewarding, and it signifies an exciting time for kairangahau and kaitiaki who are connected by a mutual desire to enrich our understanding of tuna to improve sustainable restorative strategies. Another motivation for Ngāti Koata is retaining cultural practises, including allowing sustainable cultural harvesting of tuna to once again be practised by manawhenua.

Restoring Aotearoa New Zealand’s wetlands: threats, management challenges and the development of restoration tools

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Greater than 90% of Aotearoa New Zealand’s wetlands have been lost since the arrival of humans, and in some regions, loss is >98%. Those wetlands that remain are frequently fragmented and degraded. A wide range of threats that limit our ability to restore wetlands have been identified, but our understanding of their relative importance is variable. The Department of Conservation’s Arawai Kākāriki Wetland Restoration Programme is developing restoration techniques across representative wetland types at a landscape (7,000-20,000 ha) scale. Arawai Kākāriki is using conceptual models to plan restoration targets and identify threats and management requirements. Critical threats include significant ecosystem modifying weeds, invasive aquatic and terrestrial predators, declining habitat quality and human impacts. The programme also focuses on developing new restoration tools and robust monitoring techniques for measuring effectiveness of management. For example, a recent focus has been on describing and understanding the importance of wetland networks using examples from the programme’s threatened wetland bird research. Real-time GPS tracking of matuku/Australasian bittern is revealing use of complex national networks that will require restoration in their entirety if populations of mobile threatened species are to recover.

The threat of invasive non-native plants to New Zealand wetlands and management to protect and restore them

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Around 50% of New Zealand's plant species growing outside of cultivation are not indigenous. It is a similar picture in New Zealand wetlands. Impacts of introduced species range from establishment into indigenous vegetation with little perceivable impact or at the other extreme, the competitive exclusion of indigenous vegetation and the fauna this supports, alteration of hydrology, nutrient cycling and/or susceptibility to fire damage (known as 'transformer species').
Human related activities including modified hydrology, eutrophication and grazing by livestock all contribute to increased invasibility. The establishment of many non-native plants in wetlands may reflect the change in wetland ecology rather than the plant being a driver of change. Unmodified wetlands, especially nutrient-poor systems, contain relatively few transformer species.
This talk discusses the management of invasive non-native plants in the Whangamarino Wetland and across New Zealand more broadly. Critical barriers to wetland protection from non-native invasive plants are the initiation of effective proactive, rather than reactive, biosecurity. This involves identification of transformer species (species risk assessment), knowledge of the their current and potential distribution (database), the risks the species poses to the conservation values of different wetland types (habitat risk assessment), management interventions to reduce the likelihood of introduction (pathway management) and the early detection, delimitation and rapid response to new non-native invasions (surveillance and incursion response).

Understanding predator-prey interactions in New Zealand freshwater wetlands

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The impact of introduced predators on indigenous threatened birds is of international concern, particularly in relation to island populations. A recent review of the impacts of introduced mammalian predators in New Zealand found that mustelids, feral cats and rats are common predators of wetland birds, and as such, are likely to be causing significant impacts to populations of threatened wetland bird species. Despite this, predator control is rarely a focus for most wetland restoration projects.

Here I present response rates of Australasian bittern (Botaurus poiciloptilus), spotless crake (Porzana tabuensis) and fernbird (Bowdleria punctata) populations in relation to experimental predator control at Whangamarino and Awarua wetlands. Results show crakes and fernbird populations are slowly increasing at treatment sites, whereas bittern populations continue to decline. Reasons for this are complex, but an adjacent study investigating the relative impacts of avian and terrestrial predators on artificial crake/bittern nests, shows nest predation rates remain high despite predator control (> 90 % nests failed). This trial, conducted across five New Zealand wetlands, showed that although artificial nests were visited by a suite of predators, collectively > 70 % of predation events were caused by a single native avian species - the Australasian harrier (Circus approximans). This suggests predation pressures switch from mammalian to avian once the former is removed, further hampering the recovery of wetland bird populations.

Results highlight the importance of including predator control as part of wetland restoration efforts, as well as understanding the effect of that predator control on existing predator-prey interactions.

A snap-shot of microbial populations at the Lake Areare floating wetland

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Microbial populations drive nutrient cycling and the ability of floating wetlands to provide water treatment ecosystem services. We identified the microbial community composition in water, fresh humus (FH) and soil compartments of Carex virgata on the floating wetland using phospholipid fatty acid analysis (PLFA) to obtain a deeper understanding of nutrient cycling. The floating wetland (60 m2) was constructed in a watercourse, which flows into Lake Areare, between dairy grazed pasture and the Waikato Expressway and was completed in December 2015. PLFA determined total microbial biomass, and biomarkers were used to allocate microbes into bacteria, fungi, gram-positive and gram-negative bacteria, and actinomycetes groups. The water compartment contained the least microbial biomass but relative abundances of the various microbial groups were more consistent between the compartments. Water contained a greater relative abundance of bacteria, but less fungi, and also had less gram-positive, gram-negative and actinomycetes compared to FH and soil. Absolute abundance of all the microbial groups, in all compartments, were positively correlated with total C, N, and P, with sigmoidal relationships indicating a tipping point where microbial biomass no longer increased with increasing nutrient concentrations. The tipping point was reached for all bacteria groups but not for fungi indicating greater nutrient demand/tolerance for these organisms. This snap-shot assessment indicated that microbial communities differed in their abundance and composition across floating wetland compartments. More information on the effect of plant species and season, as well as linking to microbial function, would be valuable in enhancing treatment efficiency of floating wetlands.

Aerated Floating Treatment Wetlands for enhanced wastewater treatment

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Floating Treatment Wetlands (FTWs) are an alternative approach for treatment of contaminated water involving emergent macrophytes growing on buoyant mats or rafts. Water is treated in the submerged root-mass suspended beneath the mats. The extensive root mass and attached microbial biofilms create a large respiratory biomass, commonly resulting in anaerobic zones beneath the mats. Organic sediments accumulating in the quiescent water beneath the FTWs can exert further oxygen demand, exacerbated by shading of algal photosynthesis and restricted gaseous exchange through the floating mat. These anaerobic conditions processes such as denitrification and sequestration of metals, but they inhibit the aerobic processes necessary for efficient treatment of organic and ammonium-rich wastewaters. This one-year pilot-scale study evaluates the treatment benefits of aerating the initial stages of single-pass and recirculating FTW systems treating primary domestic wastewaters. The recirculating system achieved >95% of TSS and >85% removal of cBOD5. The single-pass system showed slightly better removal with >97% of both TSS and cBOD5, maintaining the final effluent TSS and cBOD5 concentrations at below 2.5 and 2 mg/L respectively. The recirculating and single-pass FTW systems achieved 66 and 75% overall TN removal respectively. While the single-pass system had lower levels of nitrification than the recirculating system (NH4-N removal 76.9%), it achieved higher denitrification (NOx-N removal 81.3%), thus resulting in ~10% higher overall TN mass removal. This one-year mesocosm-scale FTW study showed that FTWs supplemented with mechanical aeration of~15% of the total FTW area can provide enhanced levels of wastewater treatment and nitrogen removal.

Floating wetlands and stream enhancement in an urban stream

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Many waterways that flow through Christchurch have historically been channelised and artificially lined, to drain the swamp areas around the district and improve drainage function. Today, timber and concrete lined channels are still common. No.1 Drain, a waterway in east Christchurch, suffered extensive damage to its concrete lined channel from the 2010-2011 Christchurch Earthquake sequence. As part of Christchurch City Council's waterway renewal programme, and a growing focus on stormwater treatment and ecological enhancement, a multi-faceted restoration approach was undertaken to improve water quality and ecology, and improve flood attenuation. In 2016, the vertical concrete banks were replaced with more natural banks with native riparian planting, instream habitat features were installed, and an online stormwater pond system was created. Floating treatment wetlands were then installed in 2019. An ecological monitoring programme was instigated prior to works to establish the baseline condition and monitor the success of restoration over the long-term. The results from the first round of post construction monitoring show that overall the project has successfully enhanced aquatic habitat, and improved the diversity of invertebrate and fish communities. However, there are some aspects that still require improvement. A monitoring programme has recently been instigated to assess the effectiveness of the stormwater ponds and floating wetlands in improving water quality. Monitoring will continue in the future to further assess restoration success, guide further improvements at the site, and to determine the effectiveness of using floating wetlands at this site and elsewhere in Christchurch.

Nutrient removal and hydraulic performance of a floating wetland treating agricultural pollutants in the Lake Areare catchment

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Diffuse pollution from agricultural catchments has led to widespread degradation of lakes, wetlands, rivers and estuaries in New Zealand and worldwide. More recently, the expansion and intensification of dairy farming to meet growing global demand for milk solids has accelerated water quality decline due to increased nutrient and sediment loads. Numerous and varied mitigation measures have been developed in attempts to alleviate the negative impacts of intensive agriculture on aquatic environments, including constructed wetlands.

Floating treatment wetlands (FTWs) are being trialed as tools to improve peat lake ecosystems in the Waikato region, New Zealand. This study investigates FTW efficacy, evaluating nutrient and sediment attenuation, and exploring biological and environmental variables influencing treatment performance. Three FTWs were placed in a watercourse flowing through intensive dairy land use into Lake Areare, a shallow peat lake managed by for protection and enhancement of wetland flora and fauna and recreational values. The FTW rafts were placed in series and planted with one of three species of indigenous sedge. Surface water concentrations of nitrogen, phosphorus and suspended solids were evaluated as well as biomass accumulation in the leaf and root systems of the three different sedges. The monitoring of the FTWs began in April 2019 and will be completed in May 2020. The results of this study will be presented in due course.

FTWs in agricultural watercourses have the potential to provide inexpensive and effective water quality treatment whilst fitting practically within the productive farming landscape, requiring little maintenance and no loss of productive land.

Treatment of organic compounds in floating plant root mat

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Floating plant root mat (FPRM) is hybrid of soil matrix-free pond systems and conventional soil matrix based constructed wetlands (CWs) containing macrophytes, growing as a floating mat on the water surface or touching to the bottom of the water body where it function as a plant root mat filter (PRMF) for the contaminated water. Recently, floating treatment wetland were used for different types of wastewater. However, investigation on FPRM for the treatment of wastewater contaminated by organic compounds such as volatile organic compounds (VOCs) and herbicides are missing. In this study, a FPRM and PRMF (polit scale) were investigated for the treatment of water contaminated by benzene and methyl tert-butyl ether (MTBE), and a FPRM and four conventional CWs were investigated for the treatment of water contaminated by herbicides. Results show that both systems have the similar removal behavior for benzene and MTBE removal during the two years operation. However, better removal for both pollutants during the summer was found in the first year. The emission rates of benzene and MTBE were less than 16 and 12 mg/m/d, respectively. This means less than 7% benzene was removed through volatilization. But the volatilization of MTBE reached up to 60% of the total removal. The metabolites (OA and ESA) of herbicides peaked at 9 days in the FPRM, while the detected metabolites account for 20% ~ 25% of the mother compounds. In conclusion, FPRM is the most cost-efficient alternatives for VOCs and herbicides removal due to the absent of substrate.

Lagniappe for the working coast: reducing flood risk and protecting sacred sites and tribal communities' resilience by strengthening Louisiana's marshes

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Three Tribes in coastal Louisiana initiated this project – Grand Bayou, Grand Caillou/Dulac, and Pointe-au-Chien – to provide a lagniappe, the extra value gained from simultaneously restoring marshes, reducing land loss, and protecting sacred sites. This will be done by filling in the canals dredged in Louisiana's wetlands, whose dredged materials create continuous levees, or spoil banks, that are aligned perpendicular to the canal. Filling in canals with the spoil bank is called 'backfilling' and is intended to restore marsh on the spoil bank and in the canal and prevent further marsh loss. The team is identifying the many abandoned canals threatening sacred places, discerning places that can be restored or conserved, and recognize those that have passed their survival tipping points. The team is using expert knowledge, including Indigenous Knowledge and Local Knowledge, and modeling to co-produce a decision matrix to determine the optimal places for canal restoration, and then restore them. This project tests innovative and replicable strategies to increase cultural heritage and community resilience and develop a resilient cultural heritage safe-haven prototype, and guide(s) documenting the necessary steps other communities can adopt. This project fills a critical role in shaping cumulative best practices for integrating coastal resilience activities and cultural heritage across coastal Louisiana and in all at-risk regions of the United States.

Mai te rangi ki te whenua, mai te whenua ki te rangi: kaupapa Māori literature review identifying land-based values and actions to benefit freshwater systems

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Land, water, climate, and communities in Aotearoa New Zealand are part of a large web of interconnected systems undergoing significant change due to numerous events of natural and anthropogenic origins. With increasing frequency of disruption to these systems the adverse impacts to the physical and spiritual wellbeing of the environment are felt by the indigenous Māori people. This literature review was funded by Our Land and Water National Science Challenge to support the development of a free online tool that will record efforts to improve water quality. By applying kaupapa Māori methodology, this literature review identified 5 actions, as shown below, that support the wellbeing of land, water, and indigenous people from a uniquely Māori perspective.

- Engage with tāngata whenua to incorporate their values into policies, plans, and decisions that affect land and water
- Conserve and restore wāhi tapu (culturally significant sites)
- Support opportunities to enhance kaitiakitanga
- Strengthen the practice of traditional and contemporary tikanga (holistic methods) on the whenua
- Revitalise the use of traditional Māori place names

The resulting actions should be implemented by all parties – from large entities to individual landowners. The actions that have emerged from the literature are centred in improving empathy and communication with tāngata whenua (local indigenous Māori tribes). If the identified actions are explored further with genuinely good intent, they are expected to benefit the land, water, and people of Aotearoa New Zealand.

Optimal riparian buffer design – lessons learned from 24 NZ streams

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Riparian planting is one of the most-commonly practiced mitigation interventions to buffer streams from surrounding land use and restore stream health in New Zealand. However, very few riparian planting projects have been adequately assessed after implementation, limiting both our knowledge of their efficacy and our ability to predict the ecological outcomes of riparian restoration.

We conducted a space-for-time study to investigate relationships between riparian buffer characteristics, stream morphology, water quality, and biota at 24 sites across the Waikato, Taranaki, and Canterbury regions. All sites contained at least 500 m of continuous planted riparian vegetation on both banks, planted 5-20+ years prior to sampling.

We will present an analysis of relationships between riparian buffer characteristics and stream ecological values. Riparian characteristics measured included buffer age, length, width, canopy cover (shade), and planting density. Stream responses included a range of water quality (nutrients, temperature, clarity), physical habitat (substrate, sediment cover, bank conditions) and ecological (aquatic plant cover, macroinvertebrate community diversity and composition) variables. By identifying which buffer characteristics are most strongly linked to desired outcomes, we aim to provide updated guidance on riparian buffer design for landowners, community groups, iwi, regional councils, and other resource managers. This guidance will also support more efficient implementation of national and regional legislation, including new NPS requirements for development of management action plans for degraded waterways.

Advancing Wetland Restoration at Ramsar Sites and Beyond

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In 2021 the wetland community will celebrate the 50th anniversary of the Ramsar Convention on Wetlands. The Convention was a response to increasing concerns about global wetland losses and the participants agreed to “stem the loss and degradation of wetlands now and in the future.” Among other things, they committed to the designation and management of Wetlands of International Importance, a.k.a “Ramsar Sites.” The Convention now has 171 national government members that have designated over 2,000 sites covering over 2 million km2. While this scale of interest in wetlands and the ecosystem services they provide is impressive, the designation and management of these sites is not the endpoint. Most Ramsar Sites and other wetlands around the globe have been degraded by various anthropogenic activities and would benefit from targeted wetland restoration efforts (and many have). Although the Convention has published documents on the principles and importance of wetland restoration, some Ramsar Site managers and their restoration practitioners may lack guidance on the applied techniques they need to effectively restore sustainable wetland systems. In this presentation, I will use Ramsar Site case studies and other projects to illustrate the aspects of wetland restoration planning, design, and implementation essential to restoring the ecological processes needed to sustain healthy wetlands. I will provide specific guidance that can be used by managers and practitioners to improve restoration outcomes at Ramsar Sites and other important wetlands.

Climate-Change Driven Conservation in a North American Coastal Landscape Shared by Whooping Cranes and People

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Endangered Whooping Cranes migrate 4,000 km annually from breeding grounds in Northern Territories, Canada, to wintering grounds in Texas, United States, and require vast expanses of fresh, brackish and saline wetlands. After reaching a record low of <16 individuals in 1941, the Whooping Crane population has grown to about 500 individuals through international species protection, habitat conservation, and public awareness efforts. However, wetland habitat loss and degradation on coastal wintering grounds remains the primary limiting factor for continued Whooping Crane recovery. Sea-level rise (SLR) along the Texas coast in United States is ~4 mm/yr, twice the global SLR rate due to regional land subsidence. Land change projections indicate a 50% loss of coastal marsh from 1-m SLR in next 75 years. These changes exacerbate current wetland habitat loss due to urban and industrial expansion and increasing water offtake in river basins, further reducing coastal habitat quality. Heritage ranching families comprise a large proportion of the 95% privately owned lands and are striving to continue their land legacy while providing wildlife habitat. We introduce diverse opportunities to offset the cost of maintaining these working landscapes through conservation easement purchases, wetland/grassland restoration, improved water availability, and promoting ecotourism and carbon exchange programs. To mitigate for climate change, particularly SLR, we aim to conserve 51,000 ha of coastal marsh and 152,000 ha of coastal prairie, now and in the future, that will ensure the recovery of the Whooping Crane as well as maintain the preferred livelihoods in an agricultural environment.

Estimation of Blue Carbon Storage in Indonesia's Coastal Wetlands: Problems and Perspectives

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Coastal wetlands, i.e., mangroves and seagrass meadows, are important carbon sinks that play a key role in the mitigation of global climate change. The inventory of blue carbon in these ecosystems is a pertinent issue in Indonesia because coastal areas continue to be degraded and threatened by anthropogenic activity, while the ecosystem services they provide become increasingly more important. It has been estimated that Indonesia's mangroves and seagrass meadows store 3.4 Pg (petagrams) of carbon, or approximately 17% of the world's blue carbon (Alongi et al., 2016). However, there is much uncertainty around reported data, partly due to variation and inconsistency in assessment methods which may potentially overestimate or underestimate measurements. Proper quantification of blue carbon is a prerequisite to the implementation of policy initiatives related to climate change mitigation. In this paper we discuss the issue of blue carbon estimation in mangroves and seagrass meadows based on a review of the current literature and results from our own studies in various field sites across Indonesia. We will present the variability of data and identify main problems and perspectives, particularly with relevance to Indonesia. Certain aspects of carbon science and measurement practices still need to be formalized and standardized. Issues that contribute to the problem may be broadly categorized as: (1) technical issues (e.g., how we collect field data); (2) conceptual issues (e.g., the theoretical and scientific basis of the methodology we use); and (3) analytical issues (e.g., how we analyse our data and draw conclusions).

Soil seed banks and wetland restoration potential in Northeast of China

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Soil seed banks can be important components of ecological restoration, particularly if the species remain viable in the soil for long periods of time. A germination experiment was conducted in the greenhouse to determine seed bank viability based on length of time farmed. Soils from sedge meadows farmed between 0 and 50 years were collected in Sanjiang Plain, China. Most dominant sedges (e.g., Carex schmidtii, C. lasiocarpa) and grasses (e.g. Calamagrostis angustifolia) survived as seeds if farmed for less than 5 years, therefore fields farmed for short periods of time are the best candidates for wetland restoration. Certain important structural components (tussock-forming Carex spp.) are not retained in seed banks when farmed for 6-15 years, but the seed banks still contained viable seeds of other important sedge meadow species, which could contribute to the restoration of wetland communities. However, most sedge meadow species were missing in fields farmed for more than 16 years, which make these fields difficult to restore via natural recolonization. We conclude that the duration of farming can be used as a general indicator of the potential of natural restoration for sedge meadows. This information could be used to determine which wetlands might be targeted for restoration.

The effects of sea-level rise and watershed sediment supply on tidal freshwater wetlands

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The ecosystem structure and functions of tidal wetlands, and their persistence during climate change, are theorized to depend on rate of sea-level rise as well as sediment availability. Tidal freshwater forested wetlands occur close to the head-of-tide along rivers, where watershed loads of sediment are delivered, and thus are influenced by both coastal and estuarine processes as well as watershed inputs. We measure rates of tidal freshwater forested wetland surface elevation change using deep-rod surface elevation tables (SETs), and rates of sediment deposition using artificial marker horizons, at sites along tidal freshwater rivers in Virginia (since 2015), South Carolina, and Georgia, U.S. (both since 2009). In Virginia, non-tidal floodplain had the smallest surface elevation increases, tidal freshwater forested wetlands had intermediate increases, and salt-stressed and oligohaline marshes had the greatest elevation increases. Nearly all Virginia tidal wetlands were gaining elevation faster than relative sea-level rise, with the exception of higher elevation hummock surfaces. However, rates of surface elevation change were independent of sediment deposition rate in Virginia. In conclusion, most tidal freshwater forested wetlands are currently gaining elevation faster than relative sea-level rise rates, sometimes in association with greater sediment supply or other processes such as subsurface changes. Changes in sediment availability along tidal rivers and estuaries is likely to have an important influence on the resilience of tidal wetlands to sea-level rise.

Impacts of hydrologic management on soil surface elevation and carbon sequestration at Tomago Wetland, Australia

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Wetlands are threatened worldwide by land-use change and impacted by hydrological modifications. Tomago Wetland, a Ramsar listed wetland, has been impacted by ring-drains and levees that limited tidal exchange and promoted wetland drainage. Degradation of waterbird habitat prompted floodgate manipulation in 2015 that facilitated management of tidal exchange. To study the effect of tidal restoration on wetland vegetation structure and elevation, low (~0.02 m Australian Height Datum, AHD) and high (~0.2 m AHD) elevation sites in the impacted zone, and control (0.2 m AHD) sites were established to monitor changes over a five year period commencing prior to tidal reinstatement. Before tidal reinstatement, the low sites were dominated by Paspalum vaginatum and Bolboschoenus caldwellii, high sites by Sporobolus virginicus and P.vaginatum and control sites by Phragmites australis. Following reinstatement, observations of hydrological change indicated extended periods of standing water followed by periodic drainage. High and control sites transitioned to S.virginicus-dominated marsh, and vegetation cover was lost from low sites. High sites gained elevation, whilst high rates of vertical accretion, likely from the decomposition of dead vegetation, was observed at low sites, temporarily ameliorating subsurface elevation loss. This contrasted control sites, where substrate elevation declined after tidal reinstatement. Loss of vegetation, substrate elevation and C within substrates is concerning; substrate elevations at low sites already appear to be below the vertical range suitable for mangrove and saltmarsh establishment. These consequences of hydrologic manipulation were unintended and ongoing monitoring will provide information that will improve restoration science and inform future management activities.

Leaf litter of riparian tree species has contrasting effects on nutrients leaching from soil during large rainfall events

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Restoring woody vegetation to riparian zones aims to reduce sediment and nutrient transfer from catchment land to freshwaters and there is ongoing substantial investment in riparian planting world-wide. However, release of dissolved nutrients and organic compounds from decaying leaf litter during rainfall may partially offset the benefits of this green infrastructure. This work aimed to understand how litter-derived nutrients and organics affect nutrient leaching from riparian soil, and how tree species affect these processes. We simulated large rainfall events through the leaf litter of two riparian woody tree species, with and without subsequent leaching through soil, as well as soil alone. Tree species were a Eucalyptus and a Casuarina, native to Australia but with international distributions as forestry or invasive species. We compared the forms and loads of nitrogen and phosphorus in leachate. Litter of both tree species stimulated additional nitrate release from soil (~100-200%) compared to bare soil. More ammonium and dissolved organic nitrogen also leached from soil with Eucalyptus litter, whereas less leached with Casuarina litter. More phosphate leached from soil with either species litter compared to bare soil. Increased nitrogen releases from soil with litter were greater than inputs from litter, suggesting they are driven by positive priming of soil microbial processes, whereas litter inputs increased phosphorus leaching. This information could be combined with rates of other riparian nutrient processes (e.g. plant uptake and denitrification) to quantify the net impact of trees on nutrient retention in riparian zones.

Restored river-floodplain connectivity promotes woody plant establishment

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Riparian forest ecosystems are declining globally, and remaining fragments often experience degradation. Many floodplains no longer flood and thus cease to satisfy the hydrologic requirements for riparian tree maintenance and regeneration, i.e. particular wetting and drying patterns. To promote woody riparian plant recruitment where flood regimes have been altered by flow regulation, effective approaches to restoration need to be developed. We implemented a landscape-scale experiment in a remnant, temperate floodplain forest. By constructing two weirs within channelized reaches of a stream, we redirected flows into networks of historic distributary channels, which facilitated widespread floodplain inundation. Using a control-reference-impact study design, we assessed the establishment and growth of planted seedlings of three woody species (Eucalyptus camphora, Leptospermum lanigerum and Melaleuca squarrosa) over 13 months in response to flooding achieved by floodplain reconnection. Planted seedlings had higher height and diameter growth rates at both induced (19–29 cm, 1 mm) and naturally flooded (34–44 cm, 3–5 mm) than at non-flooded (4–10 cm, -5–-3 mm) sites. However, survival rates and temporal growth patterns differed between species according to variation in surface water presence and soil moisture, illustrating the different hydrological requirements of the coexisting species. This highlights that surface water fluctuations are essential to create recruitment niches for different riparian plant species and shows the importance of river floodplain connectivity for providing adequate flooding regimes. Our study demonstrates the suitability of two complementary restoration approaches – restoring hydrology and active revegetation – for promoting the regeneration of riparian forests.

Warmer water temperatures exacerbate the negative impacts of inundation on herbaceous riparian plants

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In temperate climates with winter/spring dominated rainfall, river regulation often reduces natural flow peaks and increases warm season flows for irrigation, to the detriment of stream health. However, the effects of elevated flows in different seasons on herbaceous plants of riparian areas are not well understood.

Our study aimed to improve understanding of plant responses to inundation season to inform flow management in temperate regulated rivers, using water temperature as a proxy for season. Using a tank-based experiment, we tested the effect of inundation durations typical of environmental or managed flows (0 to 36 days) in both cool and artificially warmed water on eight herbaceous plant species selected across a range of expected inundation tolerances, growth forms and origins (locally exotic or native).

All species showed negative effects of inundation, and tolerance varied among species as expected, with greater reductions in growth and survival at longer inundation durations. Plants inundated in warm water died faster and/or in higher proportions than those inundated in cool water, for inundation intolerant to moderately tolerant species, with no differences in inundation tolerant species. Plant growth was largely unaffected by temperature.

Our study demonstrates clear negative effects of warm water inundation on a range of herbaceous plant species, suggesting that artificially elevated warm-season flows that inundate plants in riparian zones for nine or more days are likely to be detrimental to both intolerant and moderately tolerant species. This suggests that these warm-season flows should be short in duration to reduce the risk to riparian vegetation.