Proposal for a SCOR Working Group

Title: The dynamic ecogeomorphic evolution of mangrove and salt marsh coastlines

Acronym: DEMASCO

Summary/Abstract

The goal of this working group is to unravel the interdisciplinary feedbacks between physical and ecological processes, and to develop a robust framework to understand and manage the future of vegetated shorelines. The world's coastlines are highly dynamic regions subject to oceanic energy in the form of waves, tides and storm surge. Marine vegetation like tidal marshes and mangroves have been shown to provide defense against these often-destructive forces while simultaneously providing ecological co-benefits, such as providing critical habitat for economically-valuable flora and fauna and serving a vital role in the sequestration of blue carbon. All of these roles are threatened by the predicted hydrodynamic changes associated with a changing climate (such as sea level rise and increased storminess) and anthropogenic developments (such as reservoir and dam construction). However, the complex biophysical feedbacks between sediment, hydrodynamics and vegetation are still not well understood, and these gaps in knowledge limit our ability to successfully apply ecosystem-based management of these threatened and highly populated regions. This proposed working group includes members spanning the globe and encompassing the many different areas of expertise required to make significant jumps forward in this interdisciplinary space. The group aims to meet yearly for three years and produce two peer-reviewed scientific reviews (one focused on physical processes and one on management) and an applied report for managers and policy-makers, in addition to keeping the wider community involved through development of a website and the proposal to organize an AGU Chapman Conference.

Scientific Background and Rationale

Rationale

A growing amount of attention and research has focused on the roles that marsh or mangrove vegetation plays in estuaries. From an ecological perspective, coastal vegetation supports functions that are critical to numerous ecosystem services and the economic value of this natural capital is being increasingly recognized (Costanza *et al.*, 1997, Barbier et al., 2008). Furthermore, coastal wetlands have been shown to play a substantial role in blue carbon storage. Both tidal marshes and mangrove swamps posses the ability to sequester disproportionately large quantities of CO_2, with a burial capacity, which is estimated at six times that of the Amazonian rainforest and 180 times that of the open ocean (Nelleman et al., 2009; Donato et al., 2011; McLeod et al., 2011; Breithaupt et al., 2012). Lastly, in addition to providing ecosystem services, attention in recent years has focused on the ability of coastal wetlands to provide protection, buffering shorelines against damage (Arkema *et al.*, 2013; Temmerman *et al.*, 2013), even during extreme conditions such as large wave events (Möller *et al.*, 2014) or tsunamis (Wolanski, 2007).

The use of 'ecodefense', or protecting coastlines through nature offers a cost effective alternative to traditional hard structures, which often are accompanied by negative effects such as fragmenting habitats and reducing ecological connectivity (Peterson and Lowe, 2009). Conversely, 'soft' solutions can enhance resilience, improve water quality and provide habitat for biodiversity offsetting (Jones et al., 2012). However, habitat creation has achieved differing degrees of success and improved understanding of the underlying biophysical processes is necessary in order to raise the success of these remediation measures. Moreover, there is growing acknowledgement of the enhanced vulnerability of coastlines in the face of global climate change, with some areas predicted to encounter more frequent and stronger extreme storm events (e.g. Webster *et al.*, 2005; Knutson *et al.*, 2010), while other areas face significant sea level rise (Sallenger *et al.*, 2012). This vulnerability, coupled with the recent disappearance and accelerating rate of decline of estuarine wetlands and mangroves (Duke, 2007; IPCC, 2013), has brought the topic to the forefront of coastal science.

Substantial progress has been made in the area of the interaction between vegetation and flow, at small (Nepf 2012a, 2012b) and large scales (D'Alpaos *et al.*, 2007; Fagherazzi *et al.*, 2012, Coco *et al.,* 2013; Zhou *et al.,* 2014). However, many large challenges persist. At the small scale, much previous work has been conducted in laboratory flumes using mimics or plants with approximately uniform or simplified morphologies. It remains an open question of how to best scale these results to incorporate the huge range of heterogeneity of bathymetry, densities and vegetation characteristics (e.g. stiffness, lengths etc.) observed within even one marsh area (Bouma *et al.*, 2007). One way forward is to develop hydrodynamic models that include vegetation dynamics, and indeed some modeling packages have incorporated flow over vegetation (e.g. Delft3d, Baptist *et al.*, 2007). Further work is needed on how to parameterize and integrate plant growth models (e.g. incorporating effects such as seasonal die back). Vegetation has been observed to both enhance erosion, particularly through scouring at marsh edges, but to also enhance sediment deposition through damping of energy. The precise balance between these two processes and feedbacks with plant growth, particularly on the larger scales from multiple patches to entire marsh scales only begins to be addressed (Marani *et al.*, 2010). Other biota can also modulate these processes through bioturbation and biostabilisation. Combining all of these processes over long-time scales, covering both extreme and normal conditions is a significant challenge (Bouma *et al.*, 2014). Even after these scientific challenges have been addressed, there remains the significant challenge of connecting the existing and future scientific knowledge with societal values, which can then be translated into policy.

Given the broad scope and interdisciplinary nature of these challenges and the relevance for policy-making and management of estuaries, we propose that the research area is ideally suited to being tackled by a SCOR working group. This working group would provide opportunities to bring together specialists whose work encompasses a range of scales, skills and processes. The group would bring together the mangrove and saltmarsh communities and also combine laboratory experimentalists, field-based scientists, and numerical modelers and scientists heavily involved with policy-making and assessment frameworks. Now is an excellent time to make progress on the key questions especially in light of new instrumentation allowing high-resolution measurements (Mullarney *et al.*, 2015) and improved remote sensing techniques (Silvestri and Marani, 2004). We note that to stay within the constraints of working group membership we have focused on saltmarshes and mangroves. However, it is envisioned that the wider community (for example seagrass and kelp researchers) would also be integrated through the proposed Chapman Conference on the broader topic of vegetation ecohydrodynamics.

The working group would provide assistance to integrate scientists from developing countries, who sometimes lack resources to attend international meetings. This involvement is crucial, noting that it is often in these regions that salt marsh and mangrove areas are being destroyed at the fastest rates (e.g. Vietnam, Thu and Populus, 2007).

Scientific Background

The presence of vegetation introduces significant spatial variation to flow, much of which is associated with the heterogeneity of natural canopies. Within a plant canopy, the key length scales are defined by the stem diameter and stem spacing (Figure 1). This change of scale results in damping of larger scale motions, but introduces turbulence (through vortex shedding) at the smaller stem scale. Inside a canopy, the bulk canopy drag increases with the density of vegetation. This additional drag reduces mean flow speeds and turbulence intensities with distance from the seaward marsh edge (Leonard and Luther, 1995) or can cause flow routing around areas of higher densities. Vegetation can also induce mechanical lateral and longitudinal dispersion owing to particles becoming caught in eddies behind stems.

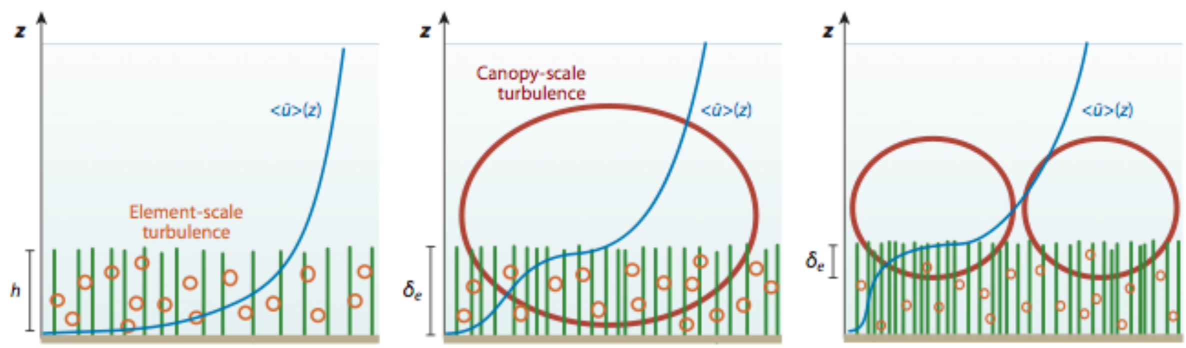

Figure 1: Schematic showing the change in velocity profiles and length scales associated with the presence of vegetation from sparse (left) to transitional (middle) to dense (right) submerged canopies. For the dense vegetation, shear at the top of the canopy induces monami (or waving) and canopy scale turbulence. Figure from Nepf (2012a).

Both laboratory and field studies have demonstrated that seagrass, sedges and mangroves are capable of dissipating wave energy. Indeed, salt marshes have been shown to effectively dissipate waves even during larger wave events and high water levels (Möller *et al.*, 2014). However, the extent of this dissipation is frequency dependent and also depends strongly on the vegetation characteristics (Mullarney and Henderson, 2010).

The tendency for vegetation to slow currents and dissipate waves can create sheltered regions of low flow, where sediments can deposit and marshes typically experience enhanced deposition (Coco *et al.*, 2013). However, recent measurements have demonstrated scour around stems at the marsh edge and the precise balance between the erosional and accretional processes is not yet clear (Tinoco and Coco, 2013). Despite these differences in observed sedimentation between studies, it is generally acknowledged that the three-dimensional structure of the vegetation is an important factor influencing sedimentation patterns within a salt marsh. Hence the vegetation, in part, controls the longer-term marsh scale evolution. However, as noted by Fagherazzi *et al.* (2012), many recent process based models are developed for specific locations and individual species and the wider-applicability of these models is not yet known. A working group would provide an excellent opportunity to answer some of these questions at this critical time.

Terms of Reference

The goals of this working group are as follows:

- Synthesize current knowledge of salt marsh and mangrove swamp evolution, focussing on the key processes (and similarities and differences between the two systems). Hence identify key gaps in understanding and make recommendations for collaborative future research directions. Particular attention will focus on growth and disappearance of marshes, ecosystem services such as wave attenuation, importance for birds/fisheries and carbon sequestration.
- Facilitate collaboration between observational and numerical modeling studies of saltmarsh and mangrove systems. In particular, we aim to:
  - Promote the migration of existing data sets into numerical models
  - Select benchmark dataset(s) that can be used to parameterize and validate numerical models.
  - Identification of existing models and discussion on their strengths and weaknesses.
- Produce a short article on management and restoration of these systems for policymakers. It is envisaged that this article will contain a 'salt marshes for dummies' section on the physics, chemistry and biology of salt marshes and mangroves, describing the key processes from a long-term perspective, and a section that quantifies the ecosystem services (benefits) of these systems that includes several case-studies/lessons learned.
- Convene international working group meetings and document the work of the group on a website.
- Produce two open-access review articles, one focused on the physical processes (possible journals – Reviews of Geophysics, Estuarine Coastal and Shelf Science, Advances in Water Research) and a second focused on management (possible journals - Conservation Letters, Ecological Engineering, Restoration Ecology).
- Write a proposal for a 2018 AGU Chapman Conference on the wider topic of vegetation ecohydrodynamics.

Working plan (logical sequence of steps to fulfill terms of reference, with timeline. Max. 1000 words)

Our first working group meeting will be held in 2016 in conjunction with the Fall AGU meeting in December. This meeting will focus on the following:

- Reviewing the terms of reference and adjusting them as necessary.
- Formulating a concrete action plan for the group.
- Review the state of knowledge and identify critical gaps.
- Discussion of existing data sets. Identify which are best suited for use by modeling community and strategies to make these datasets available.
- In light of the above, compiling components of the review article.
- Discussion and identification of potential sources for further funding.

The second meeting will be held in 2017 (likely at the international conference River, Coastal and Estuarine Morphodynamics) and efforts will be concentrated on the following:

- Final discussion on the review articles with an aim to submitting shortly after the meeting.
- Initial discussions on a Chapman conference – identifying key participants (i.e conveners).
- Outlining report for policy makers and managers. Discussion on the best strategy for production.
- Ensure the website is up and running

The third meeting should be held in early 2018 (likely at AGU ocean sciences) and involve:

- Final discussion on applied report. Dissemination shortly afterwards.
- Prepare a final report outlining progress made and future directions of research.
- Continued organization for the Chapman Conference, which should be held before the end of the year.

Deliverables (state clearly what products the WG will generate. Should relate to the terms of reference. Max 250 words). A workshop is not a deliverable. Please note that SCOR prefers that publications be in open-access journals.

The group will strive to produce the following outputs:

1. A final report detailing the work of the group, including results of discussions on the identification of key knowledge gaps to guide future research.
2. An article designed for policy makers on the management and restoration of salt marsh and mangrove ecosystems.
3. An up-to-date website of the group's activities.
4. Two review papers (one focusing on physical processes and the other on management) in a peer-reviewed open access international journal.
5. A proposal for an American Geophysical Union Chapman Conference

Capacity Building (How will this WG build long-lasting capacity for practicing and understanding this area of marine science globally. Max 500 words)

With members spanning the 5 continents, our proposed group will help to build scientific capacity globally. In particular, we hope to build scientific capacity in Tanzania, Vietnam, and South America. As noted above, many developing regions are threatened by the conversion of wetland and mangrove areas; and by improving capacity in these countries, we hope to raise awareness of the ecological and economic values of these ecosystems. We will also seek advice from the SCOR committee on capacity building on how our working group can further enhance scientific development around the globe. Many members are associated with a range of international programs and this working group will enable all members to widen their professional networks.

Working Group composition (as table). Divide by Full Members (10 people) and Associate Members, taking note of scientific discipline spread, geographical spread, and gender balance. (max. 500 words)

Our proposed group has three co-chairs – Julia Mullarney, Iris Möller and Eric Wolanski. We have selected a chair covering all career stages and from both hemispheres. Each chair will take responsibility for a key deliverable and organizing one meeting (Mullarney will also take on the responsibility of organizing the first meeting and will be the overall point of contact for SCOR).

Our proposed working group contains 10 full members and 10 associate members, representing a balance of geographic locations, interdisciplinary expertise, seniority (all career stages are involved) and gender (see table). Given a large focus of the group is the parameterization of key processes for inclusion into numerical models; we have two members strongly linked to Delft Hydraulics (one associate and one full member). We have ensured membership encompasses scientists bringing together all currently available tools such as field observationalists, laboratory experimentalists, numerical modelers and members with expertise in remote sensing. Additionally, given one of the aims of the group is to bridge the gap between science and policy, we have several members with expertise in coastal policy; ecosystem based management, biodiversity offsetting, and integrated assessment frameworks. We are also currently exploring options for co-funding and support from other organizations such as LOICZ and the United Nations Environment Programme and are currently awaiting responses to our initial inquiries. We note that several other scientists have expressed interest in collaborating with the group in an informal capacity.

Full Members (no more than 10, please identify chair(s))

Name	Gender	Place of work	Expertise relevant to proposal	Career Stage
1 Julia Mullarney Co-chair	Female	University of Waikato, New Zealand	Small scale turbulence inside canopies/vegetation movement	J/I
2 Eric Wolanski Co-chair	Male	James Cook University, Australia	Estuarine ecohydrology	S
3 Iris Möller Co-chair	Female	University of Cambridge, England	Bio-physical interactions in salt marsh systems and their significance for decadal scale marsh stability, wetland science communication and stakeholder involvement	I
4 Hong-Phuoc Vo-Luong	Female	National University of Science, Ho Chi Minh City, Vietnam	Flows and sedimentation within mangroves	I
5 Tjeerd Bouma	Male	Royal Netherlands Institute of Sea Research (NIOZ), the Netherlands	Spatial ecology, conservation ecology, nature based coastal defense	S
6 Jasper Dijkstra	Male	Deltares, The Netherlands	Numerical modeling of vegetated regions	J/I
7 Heidi Nepf	Female	Massachusetts Institute	Vegetated	S

		of Technology, USA	hydrodynamics and morphodynamics	
8 Giovanni Coco	Male	University of Auckland, New Zealand	Geomorphology and biophysical interactions	I/S
9 Halima Kiwango	Female	The Nelson Mandela African Institution of Science and Technology, Tanzania	Estuarine ecohydrology (specifically water quality) and mangrove ecology.	J
10 Zeng Zhou	Male	Hohai University, Nanjing, China	Ecomorphodynamics	J

Associate Member (no more than 10)

Name	Gender	Place of work	Expertise relevant to proposal	Career Stage
1 Fernando Mendez	Male	University of Cantabria, Spain	Climate and waves, extremes, coastal climate change	I
2 Andrea D'Alpaos	Male	University of Padova, Italy	Ecomorphodynamics	
3 Dano Roelvink	Male	UNESCO-IHE, The Netherlands	Morphodynamic numerical modeling	S
4 Sergio Fagherazzi	Male	Boston University, USA	Geomorphic evolution of salt marshes/remote sensing of vegetated regions	I/S
5 Gerado Perillo	Male	Argentinian Institute of Oceanography, Bahia Blanca, Argentina	Oceanography, physical-biological interactions, sediment transport	S
6 Alice Newton	Female	University of Algarve, Portugal and Norwegian Institute of Air Research,	Coastal lagoons, integrated assessment frameworks (SAF and DPSIR)	S
7 Gail Chmura	Female	McGill University, Canada	Carbon fluxes and impacts of nutrient enrichment	S
8 Chen Wang	Female	Satellite Environment Center of the Ministry of Environmental Protection, China	Remote sensing/satellite imaging and GIS of coastal wetlands	J
9 Mike Elliott	Male	University of Hull, UK	Effects of human activities on biological systems, coastal policy, biodiversity offsetting	S
10 Marco Marani	Male	Duke University, USA	Observations and modeling interactions between vegetation species, erosion/deposition, intertidal landforms, and biodiversity	S

Working Group contributions (max. 500 words)

Detail for each Full Member (max. 2 sentences per member) why she/he is being proposed as a Full Member of the Working Group, what is her/his unique contribution?

The working group has been designed to bring together people with complementary primary areas of expertise. Mullarney focuses on smaller-scale observation measurements within vegetated environments and the movement of vegetation under hydrodynamic forcing. Wolanski is a leading expert in the areas of coastal oceanography and ecohydraulics. Vo-Luong's research focuses on flows and sediment transport within mangrove forests, and she takes a field and theoretical approach. Nepf is a world expert in flows within vegetated canopies, with particular emphasis on laboratory experiments. Bouma is a spatial ecologist with key research areas of ecological restoration and plants as ecosystem engineers. Dijkstra specializes in numerical modeling of vegetated regions (and salt marshes in particular). Coco has experience in laboratory and numerical modeling of biophysical interactions in estuarine environment; Zhou has recently completed a novel model that addresses feedbacks between marshes, physical processes and carbon dynamics. Moeller is a coastal geomorphologist with a research focus on the linkage between short term (event-based) plant-wave interaction and its significance for decadal scale coastal wetland evolution in the face of climate changed induced alterations to storm frequency and magnitude. More recently Möller has also been actively involved in addressing the communication gap between the academic community and stakeholders involved in coastal management. Kiwango's research into estuarine ecohydrology focuses specifically on water quality (physical, chemical and biological) and mangrove ecology.

Relationship to other international programs and SCOR Working groups (max. 500 words)

Many working group members have substantial linkages to other international programs and have been involved in successful SCOR working groups in the past (Wolanski, Perillo and Elliott). Mullarney and Vo-Luong (full members) and Fagherazzi and Roelvink (associate) are participants in the USA Office of Naval Research funded departmental research initiative "Dynamics of tropical deltas" studying flows and sediment transport in the Mekong Delta.

Key References (max. 500 words)

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Appendix

For each Full Member, indicate 5 key publications related to the proposal.

Julia Mullarney

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Eric Wolanski

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Iris Möller

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Hong-Phuoc Vo-Luong

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Tjeerd Bouma

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Jasper Dijkstra

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