How our understanding of seagrass biology, ecology and restoration changed over 50 years

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Significant progress has been made in understanding the biology and ecology of the world's seagrass meadows, and the value of the many services they provide in the last five decades as noted in the increasing numbers of published papers, as well as papers and posters presented at many scientific meetings. During this time there have been paradigm shifts in our understanding of many fundamental processes that underpin the functioning of seagrass meadows.

Here I present some of the most important projects and advances of my career, and reflect on where we, as a discipline, go from here. These include: 1. The development of the world's largest SAV monitoring program, providing an example of what we can learn from these data and acting as a model for other programs; 2. The elucidation of seed dispersal mechanisms and the role seagrass seeds play in meadow development and maintenance both here and in Australia; 3. A unique method to describe and quantify the recruitment mechanism into seagrass beds of an iconic Chesapeake Bay species, the blue crab; and 4. Advancing the science of seagrass restoration, developing methods, demonstrating success, and showing the functional value of restored seagrass meadows.

The future of seagrass research is bright given the diverse global cohort of many young researchers in the field as they tackle many of the significant issues surrounding the survival of seagrass in a world of climate change and the role seagrass restoration plays in this context.

Sand capping to promote eelgrass restoration

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Recent studies along the Swedish NW coast suggest that eelgrass recovery and restoration are challenged by local regime shifts following the loss of eelgrass and their stabilizing effect on the sediment. This shift has increased sediment resuspension and turbidity that prevent growth of eelgrass. Monitoring shows a decrease in water clarity of ~2 m at historic eelgrass sites, and test-planting demonstrated that poor water quality prevented eelgrass survival at over 90% of the assessed historic sites. Moreover, losses of eelgrass continue today as the turbid water from historic eelgrass sites appear to spread to neighboring areas causing decreased water quality and collapse of the meadows there, in a chain reaction[1].

Since 2018 we have assessed if sand capping, i.e. placing a 10 cm thick layer of sand and gravel on top of the sediment, could stabilize the bottom, decrease sediment resuspension and improve the conditions enough to allow eelgrass growth at historic sites. The goal of the study was to assess if sand capping could be used together with eelgrass restoration to facilitate the return of eelgrass to historic sites, and stop the ongoing losses of eelgrass.

To assess if eelgrass could grow on sediment from a natural gravel pit on land (grain size 0.25-4 mm), if any negative effect of sand capping could be found on infauna, and to select the best site for a large-scale study, a pilot study was carried out where replicate 1 m^2 sand plots were placed at two different depths in four historic eelgrass sites along the Swedish NW coast and planted with eelgrass. The results showed higher growth rate of eelgrass, and similar or higher abundance of infauna on sand plots compared to natural sediment at all sites. Erosion and sedimentation on the sand plots was a problem at several sites where all planted eelgrass died within a year. High survival and growth of eelgrass was only found at one site (Askerön), where continuing studies were carried out.

To identify the necessary size and optimal location of a sand capped area to decrease sediment resuspension at Askerön, a high resolution, 3-D, hydrodynamic model was created for the study area (MIKE 3, Flow Model FM) coupled with a biophysical module to simulate sediment resuspension and turbidity (ECOLab, DHI). Consistent with field measurement, the model showed that wave driven sediment resuspension occurred mainly in the shallow part of the bay (<1.5 m), where turbidity was too high for eelgrass growth. It showed further that sand capping could decrease sediment resuspension in the bay and identified the optimal location to place a one-hectare large sand capped area to reach a tipping-point where eelgrass could show positive growth if planted on the sand.

To test if sand capping could reduce resuspension and promote eelgrass growth, a large-scale study was carried out in the March of 2021, where 1800 ton of sand and gravel were placed in a 10 cm thick layer at the selected area in the bay, covering a one-hectare large area at 1.3-1.9 m depth. The sand was transported to the site in shallow barges and spread over the area using an excavator placed on a barge and fitted with a high-precision GPS. The average thickness of the sand capped area was impressively even (9.3±1.3 cm) and monitoring showed that resulting sediment plumes from the work did not cause turbidity or sedimentation rates passed background levels further than 50 m from the capped area. Small patched of mussels (*Mytulis edulis*) and oysters (*Crassostrea gigas*) where found on top of the sand after the capping was terminated, indicating that they have moved up through the sand and apparently not harmed by the capping. The community of infauna within the sand capped and in adjacent areas will be compared in the fall of 2021 to assess any possible negative impacts.

In May to July 2021, 80 000 shoots of eelgrass were successfully planted on top of the sand capped area in 1x1 m checker pattern (16 shoots m^{-2} within planted squares). The survival and growth of eelgrass, wave attenuation, flow changes, turbidity, sedimentation rate and light conditions will be carefully monitored within the planted and adjacent areas in the years to come to assess the effect of the sand capping and eelgrass restoration.

Acknowledgement. We thank Mogens Flindt from the University of Southern Denmark for many helpful advice on sand capping, and Beatrice Allenius and Anders Olsson from the County Administrative Board of Västra Götaland for great collaboration within the project and providing all necessary permits. This study is supported by grants from the European Maritime and Fishery Fund and the Swedish Agency for Marine and Water Management.

References
1. Moksnes P-O, Eriander L, Infantes E, Holmer M. 2018. Local regime shifts prevent natural recovery and restoration of lost eelgrass beds along the Swedish west coast. Estuaries and Coasts. 41:1712–1731. DOI: 10.1007/s12237-018-0382-y

Tweetable abstract

At #MASTSasm2021 the @zorrogroup presents new model simulations and large-scale field studies assessing if sand capping together with #eelgrass planting can stabilize the bottom and overcome regime shifts preventing recovery and #restoration

Twitter-handle: @zorrogroup

Robocean: Ecosystem Engineering

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I would prefer to deliver a talk.

Are you a student? Yes

Robocean is an innovative student start-up mechanising seagrass restoration to support large-scale habitat regeneration. Founded by nine MEng engineering students at the University of Edinburgh, Robocean is developing bespoke ROV technology capable of engineering entire ecosystems at the touch of a button.

Robocean understands that access to financial and material resources are some of the biggest barriers to enacting environmental restoration at scale. Therefore, Robocean seeks to remove such barriers through mechanisation to make seagrass restoration accessible to all.

At a little more than one year old, Robocean has already proven its ability to generate interest in mechanised seagrass restoration. Early on, the start-up won SIE's monthly Fresh Ideas competition as well the Edinburgh Innovations' Business Ideas Competition. It then progressed to Red Bull Basement 2021's Top 10 as NTT's wildcard entry to competition. Within The University of Edinburgh ecosystem, Robocean has received support through the both the University's Social Responsibility and Sustainability fund, and the School of Engineering's Innovation Fund.

Robocean is currently one of twelve start-ups competing on the Edinburgh Innovations' Summer Accelerator program. We have been using this opportunity to work full-time on prototype development, which we are on track to complete before the end of 2021.

Initially, we will be targeting Zosteraceae for restoration, with the intention of performing field trials in the United Kingdom during 2022. Providing that these trials are successful, Robocean anticipates that it can significantly accelerate and reduce the cost of seagrass meadow restoration.

The long-term goal of Robocean is to engineer AUVs capable of restoring seagrass meadows through data-driven systems and artificial intelligence. We aim to support this innovation with
an equivalent solution for mass seed collection, as well as meadow monitoring systems.

Robocean emphasises the importance of rewilding our natural world, therefore endeavors to follow a 'planet before profit' model which seeks to maximise its positive environmental impact.

Acknowledgements

Thank you to my co-founders Anushka, Caroline, David, Harry, Hiro, Izzy, Joe, and Lottie – without this team Robocean might still be a concept.

A special thanks to Dr. Lilley for his constant support, and for inspiring me to found Robocean in the first instance.

Without NTT's support following Red Bull Basement, it is unlikely that Robocean would be where it is today. I would like to give explicit thanks to Tim Wade for his excellent mentorship throughout, and NTT's marketing department for there incredible creative support.

Tweet - Robocean is the innovative student start-up mechanising seagrass restoration to support large-scale habitat regeneration. Our team of University of Edinburgh innovators is designing bespoke ROVs capable of engineering entire ecosystems at the touch of a button. #MASTSasm2021

San Francisco Bay Eelgrass Restoration: Progress and Possibilities

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I would prefer to deliver a talk. (I am scheduled to be in the afternoon session on October 6 on Innovation and Ambition)

Are you a student? (Delete as appropriate): No.

Restoration of eelgrass (*Zostera marina*) in San Francisco Bay, the largest estuary on the US West Coast, has progressed considerably in the last decade. Recent advances in our understanding of best practices have been guided by experimentation and careful study of planting methodologies, choice of source material (and utility of mixing sources), and synergy with native oyster restoration. Increasingly, eelgrass restoration is motivated by the plant's potential to contribute climate services such as carbon storage and local countering of ocean acidification (resulting from rising atmospheric CO_2), and as a component in nature-based adaptation to sea level rise ("living shorelines", restored habitats that also protect shores). This climate resiliency focus has been buoyed by several large voter-supported measures resulting in substantial funding for restoration of eelgrass and other coastal species and habitats. Still, our ambition of 3200 hectares of restored eelgrass in a 50-year span within San Francisco Bay is daunting. Site selection continues to be a challenge; however, a new habitat suitability modeling effort is underway to better predict successful locations for restoration today and with future climate conditions. Permitting efficiency is improving with the recent establishment of a coordination team with representatives of resource agencies meeting regularly to streamline the permitting process. We are building in resiliency by identifying locations where eelgrass may find refuge from episodic extreme events such as heat waves and low salinity from large storms, and assessing whether some natural eelgrass beds are pre-adapted to these stressors and thus good choices for source material as extreme events become more common. Finally, documentation of the values and services of eelgrass through restoration projects is lending support to strengthening protections for natural beds as we simultaneously innovate and advance restoration practices.

Please also provide a tweetable abstract first (max. 280 characters) to assist online promotion, along with ONE complementary image to go alongside the social media text (study species, map of location, photograph of your team, image of equipment etc.

San Francisco is known as a hub for innovation, but can we meet the region's ambitions for eelgrass restoration? @katharyn_boyer (professor @EOS_Center @SFSU) will discuss recent advances as part of an international panel on seagrass restoration at #MASTSasm2021.

If you are on twitter please provide your twitter handle @someone (or an appropriate account to tag). Don't worry if you are not on twitter as you will still be named.

@katharyn_boyer