Blue Carbon

Beyond the inventory

11-12 November, 2021

SCOTTISH BLUE CARBON FORUM

Foreword

On behalf of the people of Scotland and the Scottish Government, I would like to extend my personal welcome to you all. I greatly value this opportunity to bring together the international research and policy communities for the Scottish Blue Carbon Forum conference, "Blue Carbon: Beyond the Inventory". Regardless of whether you are attending in person or online, Scotland's hand of friendship extends to each and every one of you as we look to share knowledge and understanding and forge new partnerships.

For all of us working to address the twin crises of climate change and biodiversity loss, the eyes of the world are upon Glasgow for the 26th Conference of the Parties (COP26). All countries – with the support of civil society, business and people – have a collective responsibility to ensure COP26 is a success, to ensure we have inclusive and informed conversations and to ensure that past and future commitments are delivered in full. As an international community, it is essential that we are prepared to work together, to share our knowledge and expertise, to identify joint solutions and to take action together – building our collective capacity and amplifying our impact.

I welcome the conversations this conference will enable on the subject of blue carbon, an area, rightly, gaining increasing international interest with growing recognition of the role these ecosystems can play in climate mitigation, adaption and resilience. Scotland is part of a global endeavour to build and co-ordinate research excellence in this field and I look forward to seeing this continue to grow, as we contribute to and learn from international blue carbon research and policy.

The UN Decade on Ecosystem Restoration and UN Decade of Ocean Science for Sustainable Development mean there is no better time for the science community to come together on the subject of blue carbon. We have the opportunity to learn from existing approaches, such as the frameworks underpinning the restoration and protection of peatland habitats, and build new understanding – recognising the interconnectedness of terrestrial, freshwater and marine carbon. As First Minister of Scotland I welcome the level of ambition shown by this conference, we are in a climate crisis and our actions – green and blue – must reflect the pace and scale of this challenge.

I wish you all a very successful event and want to give a special thank you to our conference partners the University St Andrews, The Glenmorangie Company, The Royal Society of Edinburgh and the National Museum of Scotland.

Let this be the beginning of our conversation.

Nicola Sturgeon, First Minister of Scotland

Messages of support

Since 2010, the Intergovernmental Oceanographic Commission (IOC) of UNESCO has supported scientific efforts aimed at increasing knowledge on the potential of coastal blue carbon ecosystems – mangroves, seagrasses and tidal marshes – for climate change mitigation and adaptation, by co-sponsoring the Blue Carbon Initiative together with Conservation International and the International Union for Conservation of Nature (IUCN).

More recently, the IOC has taken a leading role in the coordination of the International Partnership for Blue Carbon (IPBC) together with the Australian Government, promoting the exchanges between the scientific community and national governments, international organizations and NGOs for the implementation of blue carbon policies and projects to combat climate change. Despite the ongoing global efforts, the potential of coastal blue carbon ecosystems is still underexploited, and significant knowledge gaps remain with regard to emerging blue carbon ecosystems, such as algae and mud flats. The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) provides a unique opportunity for the blue carbon scientific community to join efforts under a coordinated research programme on blue carbon, with the goal of providing the knowledge needed to fully support the formulation and implementation of climate change mitigation and adaptation policies, in particular the UNFCCC and its different mechanisms.

Dr. Vladimir Ryabinin (Executive Secretary) and Kirsten Isensee (Programme Specialist

With two coastal Distilleries, Glenmorangie on the banks of the Dornoch Firth in the Highlands and Ardbeg on the south coast of Islay, we are committed to reducing the impact of all our operations on the marine environment. We are proud of the example set by The DEEP project, where we are partnering with Heriot-Watt University and the Marine Conservation Society and which features as part of your conference programme today.

I look forward to welcoming you to the reception at the National Museum of Scotland this evening!

Thomas Moradpour President and CEO, The Glenmorangie Company

The International Partnership for Blue Carbon (IPBC) was launched at the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP21) in Paris in 2015 by nine founding Partners and has since expanded to almost 50 Partners in 2021.

The vision of the IPBC Partners is that all global coastal blue carbon ecosystems (mangroves, tidal marshes and seagrasses) are protected, sustainably managed or restored – contributing to climate change mitigation, adaptation, biodiversity, ocean economies and livelihoods of coastal communities. IPBC Partners work together to achieve three main goals:

- i increased international commitments to protect coastal blue carbon ecosystems;
- ii improved national policies to protect coastal blue carbon ecosystems; and
- iii accelerated on-the-ground implementation of blue carbon protection and restoration activities. The IPBC's mission is to be an open forum for Partners to connect, share and collaborate to build solutions, take actions, and benefit from the experience and expertise of the global community.

In particular, the IPBC connects government agencies with non-governmental organizations, intergovernmental organizations and research institutions that hold the technical expertise needed to formulate and implement effective blue carbon policies. In line with its vision, goals and mission, the IPBC welcomes the continuous efforts made by the global scientific community to increase knowledge of blue carbon and is committed to provide a platform to share knowledge and support action towards the conservation, restoration and sustainable use of blue carbon ecosystems, including as Nature-based Solution to climate change mitigation and adaptation.

IPBC Coordinator Team

Programme

Thursday 11th November

09:00 **REGISTRATION** – Teas & Coffees

10:00 **Session #1**

Opening Remarks – Professor Bill Austin (Chair Scottish Blue Carbon Forum, for Scottish Government)

Welcome on behalf of the RSE – Professor Marcel Jaspars (VP-International, RSE)

Welcome on behalf of the Scottish Government – Mairi Gougeon MSP (Cabinet Secretary for Rural Affairs and Islands, Scottish Government)

Scotland's Natural Environment – Professor Andrew Millar (Chief Scientific Advisor on Environment, Natural Resources and Agriculture, for Scottish Government)

Message of Support from the IOC/UNESCO – Dr Vladimir Ryabinin (Executive Secretary, Intergovernmental Oceanographic Commission)

Reflections from COP26 – Dr Kirsten Isensee (Programme Specialist – Ocean Carbon Sources and Sinks, IOC/UNESCO)

11:00 **2 minutes silence** – the eleventh hour, the eleventh day of the eleventh month.

11:05 **Session #2**

Blue Carbon Initiative: transforming science into effective policy and management – Emily Pidgeon, Kirsten Isensee, Dorothee Herr

Blue Carbon in NDCs – Case Studies in Ambition – Stacy Baez, Tom Hickey, Simon Reddy

Conservation and restoration of blue carbon stocks – Catherine E. Lovelock (Keynote)

12:00 **Lunch & Posters**

13:00 **Session #3**

Tiger sharks, scientists, and entrepreneurs partner to guide the discovery of world's largest seagrass meadow in The Bahamas – Wells Howe, S. David Harris, Carlos M. Duarte, Austin J. Gallagher

Estimating the Size of the Global Seafloor Organic Carbon Sink – Uncertainties and Data Limitations – Markus Diesing

Scotland's forgotten carbon: exploring the mechanisms that drive carbon burial and storage in mid-latitude fjords – Craig Smeaton, Cui Xingxang, Hangdong Yang, Negar Haghipour, Timothy Eglinton, Thomas Bianchi, William Austin

Interactive effects of climate change and land use change on carbon burial at millennial timescales – Kamenos NA, J Mao, RAR McGill, J Newton, P Gulliver, HL Burdett

How do we find macroalgal particulate organic carbon sinks and how do we protect them? – Ana M Queirós, Michel Bedington, Andrew Bell, James Clark, Christine Pascoe, Daniel Smale, Paul J Somerfield, Karen Tait, Ricardo Torres, Rob Wilson

Blue Carbon – An Irish Perspective – Grace M Cott, Andrea Fuchs, Lisa Jessen, Shannon Burke, Pedro Beca-Carretero, Dagmar B Stengel

15:00 **Tea & Posters**

15:30 **Session #4**

Blue Methane: Challenges and Opportunities Posed by Methane Emissions for Blue Carbon Accounting – J. Patrick Megonigal, James Holmquist, Genevieve Noyce, Kevin Kroeger (Keynote)

Estimating Aboveground Biomass and Biomass Change of Mangrove Forests in the Niger Delta – Nwobi, C.J., Williams, M., Mitchard, E. T. M.

Potential Contribution of Mangroves to Indonesia's Natural Climate Solution – J. Boone Kauffman, Virni Budi Arifanti, Subarno, Muhammad Ilman, Nisa Novita

Belize Blue Carbon: Establishing a national carbon stock estimate for mangrove forests – H.K. Morrissette, S. Baez, L. Beers, N. Bood, S. Crooks, J. Lefcheck, N. Martinez, K. Novelo, S.W.J. Canty

17:00 **Glenmorangie Partnership Lecture**

The 'DEEP' triple helix: Partnership working in environmental restoration and its role in blue carbon storage and management – William G. Sanderson

18:30 **Evening Reception at the Grand Gallery, National Museum of Scotland** (sponsored by The Glenmorangie Company; smart-casual; ends at 20:30) – welcome by Annabel Turpie (Director of Marine Scotland), opening remarks by Thomas Moradpour (President and CEO of The Glenmorangie Company), and address by Mairi Gougeon MSP (Cabinet Secretary for Rural Affairs and Islands, Scottish Government).

16:00 **Projection onto the RSE building** (ends 24:00)

WE ARE OCEAN | INTO THE OCEANIC Anne-Marie Melster, co-founder/director of ARTPORT_making waves, joins with the environmental artist Elizabeth Ogilvie and artist/filmmaker Robert Page to showcase an impactful art-science film project.

Friday 12th November

09:00 **REGISTRATION** – Teas & Coffees

10:00 **Session #5**

Academia meets policy: how do parliaments use blue carbon academic research to support policymaking? – **Roxana T Shafiee**, Damon Davies, Anna Brand, Alexa Morrison

The feasibility of establishing seabed sediment blue carbon MPAs a UK case study – **Graham Epstein**, Callum M. Roberts

Climate mitigation potential of the European shelf seabed: significance, risks, recoverability, value and management – Ruth Parker, **Lisa Benson**, John Aldridge, Natalie Hicks, Dorte Krause-Jensen, Michael Burrows, Carol Robinson, Tiziana Luisetti, William Austin, Johan van der Molen, Jordan Gacutan, Rui Vieira

11:00 **Tea & Posters**

11:30 **Session #6**

Towards shelf seabed carbon management in England – **Parker, R**, Aldridge, J, Bullimore, R, Mynott, F, Proctor, W, Lamb. P, Chaniotis, P, Cook, D

Guiding the restoration of our estuaries and coasts – **Benjamin C Green**, Eve Leegwater, Rachel Hudson, Will Manning, Joe Kenworthy, Mike Best, Colin Scott, Celine Gamble, Azra Glover, Joanne Preston, Alison Debney, Roger Proudfoot

Coastal and Marine Blue Carbon in a U.S. MPA: An Assessment and Guidance for Managers – **Sara Hutto**, Rietta Hohman ,Sage Tezak

12:30 **Discussion**

13:00 **Lunch and Posters**

14:00 **Session #7**

Operationalising marketable blue carbon – **Peter I. Macreadie**, Alistar I. Robertson, Bernadette Spinks, Matthew P. Adams, Jennifer M. Atchison, Justine Bell-James, Brett Bryan, Long Chu, Karen Filbee-Dexter, Lauren Drake, Carlos M. Duarte, Daniel A. Friess, Felipe Gonzalez, Quentin Grafton, Kate J. Helmstedt, Melanie Kaebernick, Jeffrey Kelleway, Gary A. Kendrick, Hilary Kennedy, Catherine E. Lovelock, J. Patrick Megonigal, Damien T. Maher, Emily Pidgeon, Abbie A. Rogers, Rob Sturgiss, Stacey M. Trevathan-Tackett, Melissa Wartman, Kerrie A. Wilson, Kerrylee Rogers (Keynote)

The interpretation of justice in blue carbon projects – **Mark Huxham**, Robyn Shilland, Anne Kairu

Requirements for Connecting Coastal Blue Carbon Projects to the Carbon Market and Evaluating Inclusion of Seascape Carbon – **Stephen Crooks**, Igino Emmer, Moritz von Unger, Lisa Beers, Leah Glass

A case for a UK Saltmarsh Carbon Code: Evidence, Intervention, and Investment – **A Burden**, M Reed, A Hipkiss, T McGrath, M Skov, W Austin, R Fitton, C Mahon, C Evans, A Garbutt, H Rudman, K Born, N Pontee, R Field

15:30 **Discussion**

Closing remarks on behalf of the Scottish Government – **Mairi McAllan MSP** (Minister for Environment and Land Reform, Scottish Government)

16:00 **Posters & Drinks Reception**

17:00 **Close of Meeting**

Talks

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Blue Carbon in NDCs – Case Studies in Ambition

AUTHORS:
Dr Stacy Baez[1], Tom Hickey[2], Simon Reddy[3]

Pew Trusts –
[1] Sbaez@pewtrusts.org
[2] Thickey@pewtrusts.org
[3] Sreddy@pewtrusts.org

Blue carbon ecosystems such as mangroves, seagrass, and saltmarsh provide a myriad of benefits to both people and nature. Well-known for their importance to fisheries and livelihoods, these ecosystems can effectively sequester carbon and provide climate adaptation benefits from storm defense to shoreline stabilization.

Their protection and restoration can also provide a measurable contribution towards a country's climate mitigation and adaptation commitments – indeed these are currently the only three marine nature-based solutions recognized by IPCC approved methodologies for this measurable mitigation benefit.

Under the Paris Agreement, the governments of Belize, Costa Rica and Seychelles have each submitted revised NDCs that include ambitious and specific commitments to the protection of their "blue carbon" coastal wetland ecosystems. Underpinning these commitments are country specific research projects that seek to advance both scientific baselines and build local research capacity.

Here we present an overview of the development, partnerships and implementation strategies of the blue carbon commitments within the updated NDCs of Belize and Costa Rica along with a deeper dive into the seagrass mapping and carbon assessment research project underpinning the NDC in Seychelles.

ACKNOWLEDGEMENTS
Pew would like to recognize its partners in this project, including WWF, The Smithsonian Institution, University of Belize, Conservation International, CATIE, Oxford University, The Nature Conservancy, University of Seychelles, Seychelles Island Conservation Society, and Seychelles Conservation and Climate Adaptation Trust.

Climate mitigation potential of the European shelf seabed: significance, risks, recoverability, value and management

AUTHORS:
Ruth Parker[1], **Lisa Benson**[1], John Aldridge[1], Natalie Hicks[2], Dorte Krause-Jensen[3], Michael Burrows[4], Carol Robinson[5], Tiziana Luisetti[1], William Austin[6], Johan van der Molen[7], Jordan Gacutan[8,9], Rui Vieira[1]

[1] Centre for Environment, Fisheries and Aquaculture Science (Cefas), Pakefield Road, Lowestoft, United Kingdom – lisa.benson@cefas.co.uk; ruth.parker@cefas.co.uk
[2] School of Life Sciences, University of Essex, Colchester, United Kingdom
[3] Department of Ecoscience, Aarhus University, Vejlsøvej 25, 8600 Silkeborg, Denmark
[4] Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll, Scotland, UK
[5] Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom
[6] Scottish Oceans Institute, University of St Andrews, St Andrews, Fife, Scotland
[7] Royal Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, The Netherlands.
[8] Global Ocean Accounts Partnership, University of New South Wales, Faculty of Law, The Law Building, Sydney, Australia
[9] Centre for Marine Science and Innovation, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia

Recent studies have illustrated the significance of carbon (C) stocks in offshore seabed systems. Many seabed C stocks are directly or indirectly under pressure from human activities, such as bottom-contact fisheries, and climate forcing. Consequently, C pools and their long-term storage may be disturbed, leading to unintended CO2 emissions. Management interventions, such as management of maritime activities in and around Marine Protected Areas (MPAs), if adequately focused on the protection or restoration of offshore seabed systems, may act as nature-based solutions (NbS) to climate change.

Despite a growing regional body of work focused on the extent of C stocks in offshore seabed systems, many knowledge gaps remain, which hamper efforts to couple this developing understanding with national, regional and international climate policy and economic considerations, including Natural Capital Accounting. To respond to this challenge, a EuroMarine Network-funded foresight workshop was held in September 2021 to review the present state of the evidence and future research priorities.

A case for a UK Saltmarsh Carbon Code: Evidence, Intervention, and Investment

AUTHORS:

A Burden[1], M Reed[2], A Hipkiss[3], T McGrath[4], M Skov[5], W Austin[6], R Fitton[7], C Mahon[8], C Evans[1], A Garbutt[1], H Rudman[2], K Born[9], N Pontee[9], R Field[3],

1 UK Centre for Ecology & Hydrology, Bangor anrd@ceh.ac.uk
2 Thriving Natural Capital Challenge Centre, SRUC
3 RSPB
4 Wildfowl & Wetlands Trust
5 School of Ocean Sciences, Bangor University
6 School of Geography & Sustainable Development, University of St Andrews
7 Finance Earth
8 IUCN National Committee UK
9 Jacobs, Natural and Environmental Sciences, University of Southampton

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Saltmarshes can play an effective role in climate change mitigation by trapping and storing carbon dioxide from the atmosphere. Sustainably managing these blue carbon habitats, and restoring and recreating habitat where possible, will protect and enhance the multiple benefits they provide to society. There is growing interest in the voluntary carbon market by businesses seeking to voluntarily offset their emissions of CO2, motivated by corporate social responsibility and aligning their businesses with the Paris Agreement on emission reduction targets. The development of a UK Saltmarsh Carbon Code will enable saltmarsh carbon to be marketed and traded as carbon offsets, whilst providing assurances to buyers that the climate benefits being sold are real, quantifiable, additional, and permanent. Revenue generated will create vital financing opportunities to create more habitat through restoration projects.

This project is the first to bring together key stakeholders required to develop a science-led and commercially viable carbon standard, including scientific, conservation delivery, and investment finance experts across the charity, finance and academic sectors.

The project aims to:

- Develop and pilot a Saltmarsh Carbon Code by evaluating current evidence on the efficacy of restoration methods on carbon sequestration. We will identify proxy methods and metrics for monitoring, reporting, and validating this carbon gain for a range of saltmarsh typologies.
- Apply the pilot code to a range of pilot sites to test and refine both the Code itself, and the investment documentation, providing a novel proof of concept.
- Develop the investment case with the intention of taking to investors, within the research project lifetime, to raise funding for restoration works.
- Promote wider discussions around the potential to replicate this approach to develop a wider UK Blue Carbon Code, with a range of methodologies for different habitats, extending options for blue carbon buyers.

Blue Carbon – An Irish Perspective

AUTHORS:

Grace M Cott[1], Andrea Fuchs[1], Lisa Jessen[1], Shannon Burke[1], Pedro Beca-Carretero[2,3] and Dagmar B Stengel[4]

1 School of Biology and Environmental Science, University College Dublin, Dublin 4, Ireland – grace.cott@ucd.ie
2 Department of Theoretical Ecology and Modelling, Leibniz Centre for Tropical Marine Research, Fahrenheitstrasse 6, 28359 Bremen, Germany
3 Department of Oceanography, Instituto de Investigacións Mariñas (IIM-CSIC), Vigo, Spain
4 Botany and Plant Science, School of Natural Sciences, National University of Ireland Galway, Galway, Ireland..

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Oceans and coastal marine systems play a significant role in the global carbon cycle, representing the largest long-term sink of carbon. Over the past decade international efforts to understand the blue carbon sink and utilize its potential in climate mitigation frameworks has increased. However, to date, little blue carbon research has been conducted in Ireland. Here, we outline the status of blue carbon research and detail current projects.

Ireland has 100 km2 of saltmarsh habitat that are classified according to their morphology and nature of the substrate (Curtis and Sheehy Skeffington, 1998). It is hypothesized that Ireland's saltmarshes are a carbon storage hotspot due high productivity rates (mild climate results in long growing seasons) and low methane emissions. Data from Dublin Bay saltmarshes have shown an average carbon density of 942 Mg Corg ha-1, which is three times the global average for saltmarshes. Work is underway to investigate how carbon densities vary across geomorphic settings and understand variations in carbon sequestration rates.

Ireland's seagrass beds are predominantly on the west coast and recent studies mapped 62 km2 (Beca-Carretero et al., 2020). However, it is estimated that seagrass ecosystems may cover an actual area of 165-300 km2 (Beca-Carretero et al., 2020; Hastings et al., 2020). The potential carbon stocks of Irish seagrass beds are estimated to be 0.6 Mt carbon.

Given the fact that Ireland's marine territory extends 880,000 km 2, 10 times its land mass and is one of the largest seabed territories in Europe, advancing opportunities to incorporate potential blue carbon ecosystems into climate frameworks will be a key component going forward.

Requirements for Connecting Coastal Blue Carbon Projects to the Carbon Market and Evaluating Inclusion of Seascape Carbon

AUTHORS:
Stephen Crooks[1], Igino Emmer, Moritz von Unger, Lisa Beers, Leah Glass

[1] Silvestrum Climate Associates
Steve.Crooks@Silvestrum.com

Conservation and restoration of vegetated coastal ecosystems offices sporadically around the world to protect wildlife, retore water quality and food production, provide measures of flood protection and sustain the quality of life of coastal communities. These measures also provide additional benefits in terms of greenhouse gas emissions reductions and climate mitigation.

Restoration and conservation of tidal wetlands – forest (including mangrove) and marshes – and seagrass meadows are a recognized project activity under the Verified Carbon Standard (VCS), as well as Plan Vivo at the community scale. Requirements and procedures for including tidal wetlands projects under the VCS are reviewed by Needleman et al. (2018). Broad principles require that the project demonstrates that emission reductions are real, additional, quantifiable, permanent, verifiable, unambiguously owned, cause no harm and can be practically delivered. In addition, the VCS methodologies (VM0007 and VM0033) provide procedures for deducting non-reactive allochthonous carbon that would be stored in the environment irrespective of the project existence, as well as guidance for recognizing impacts on sea level rise on carbon stock permanence. The VCS methodologies also provide default soil carbon sequestration values and the fate of carbon with erosion, and guidance on the avoided emissions on organic and mineral soils, calculating nitrous oxide emissions, soil profiling methods, sample size, prescribed fire, additionality and leakage.

Many of these coastal wetland procedures are unfamiliar to terrestrial carbon project developers. Projects have been slow to take up and challenging to apply at small scale (less that 2000 ha). Yet, largescale projects such as the 220,000 ha of mangrove reforestation in the Indus Delta are coming online.

Recognizing the potential to include additional marine ecosystems under its program under the VCS, Verra and Silvestrum have launched a Seascape Carbon Initiative. The intent is to provide a market mechanism framework to create an enabling environment for project and science integration. Potential project activities include: seaweed conservation and restoration, seaweed farming, open ocean carbon downdraw, and avoided emissions through seabed management. Advancing the seascape carbon initiative will require science to quantify lateral fluxes of carbon, storage of carbon as alkalinity, as well as inform safeguard requirements for scaled actions.

Additional advances in the carbon market may also include the development of simplified procedures to enable small scale actors to engage, approaches for more simply linking activities across the landscape and then seascape as well as the development of national programs, as being explored in the Australia and UK.

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BLUE CARBON TALKS

Estimating the Size of the Global Seafloor Organic Carbon Sink – Uncertainties and Data Limitations

AUTHOR:
Markus Diesing

Geological Survey of Norway, P.O. Box 6315, Torgarden, 7491 Trondheim, Norway – markus.diesing@ngu.no

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https://mareano.no

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Restreppo, G. A., Wood, W. T., and Phrampus, B. J. (2020). Oceanic sediment accumulation rates predicted via machine learning algorithm: towards sediment characterization on a global scale. Geo-Marine Lett. 40, 755–763. doi: 10.1007/s00367-020-00669-1.

Seafloor sediments are a globally important sink for organic carbon and their efficiency in carbon burial below the active zone of degradation determines the concentration of atmospheric carbon dioxide in the long term (Berner, 2003). The size of this carbon sink and its spatial variability put an important first order constraint on the ability of seafloor sediments to contribute to climate change mitigation via carbon storage. The size of the seafloor organic carbon sink has been estimated in various ways but remains relatively poorly constrained. Here I re-evaluate the size of that sink and its uncertainty by utilizing recently published global spatial predictions of organic carbon content, sediment porosity, sediment accumulation rate, and their prediction uncertainties (Lee et al., 2019; Restreppo et al., 2020). This approach leads to estimates of organic carbon accumulation and burial that are in line with previous results derived independently and using a variety of approaches. Organic carbon accumulation rates (measured in g C m-2 yr-1) are an order of magnitude lower when compared with Blue Carbon ecosystems (saltmarshes, mangroves, and seagrasses). However, seafloor sediments accumulate an order of magnitude more organic carbon (measured in Tg C yr-1) than Blue Carbon ecosystems due to the large areas they occupy. Claims that Blue Carbon ecosystems contribute nearly 50% of organic carbon accumulation in marine sediments (Duarte et al. 2005; 2013) are therefore unlikely to hold and the role of vegetated coastal ecosystems might have been overstated. Propagation of the uncertainties of the individual spatial predictions leads, however, to high uncertainties in the estimates of organic carbon accumulation, specifically in the deep sea. Potential ways of reducing the uncertainty as well as the need to account for non-depositional areas on global continental shelves when predicting sediment accumulation rates are discussed. These suggestions might help constrain the size of this important carbon sink in the future.

BLUE CARBON TALKS

The feasibility of establishing seabed sediment blue carbon MPAs: a UK case study

AUTHORS:
Graham Epstein[1] & Callum M. Roberts[2]

University of Exeter, Centre for Ecology and Conservation, Penryn Campus, Cornwall, TR10 9FE.
[1] g.epstein@exeter.ac.uk

Marine protected areas (MPAs) can directly mitigate climate change by promoting the sequestration and storage of atmospheric CO2 or by conserving marine organic carbon (OC) stores. Subtidal marine sediments contain the ocean's biggest OC store; however there is increasing evidence that mobile demersal fishing is depleting this store through physical disturbance and the resultant remineralisation of OC to inorganic compounds

Here, the UK exclusive economic zone (EEZ) is used as a case study to investigate the feasibility of establishing seabed sediment blue carbon MPAs. Existing data on OC stocks and fishing disturbance are combined with published modelled estimates on the impact of mobile demersal fishing on OC. Further, fisheries displacement is modelled in a variety of scenarios to calculate whether a net carbon benefit to MPA designation would be expected.

Results suggest that the total loss of OC from the top 10 cm of sediments due to mobile demersal fishing in the UK EEZ is 8.7 Mt per year. A proposed MPA network of 31 areas was selected to cover high densities of current or future OC losses. In total this proposed MPA network covers 16% of the UK EEZ, 24% of total OC stock and 43.0% of the predicted OC loss.

Following mean fisheries displacement the predicted net saving from the network was 2.6 Mt OC yr-1 or 29.5% of total OC loss across the study site. The MPAs with the largest net saving of OC were located at the Fladden Grounds, Western Scotland's inland waters and Haig Fras with 0.8, 0.5 and 0.3 Mt OC yr-1 respectively, together saving 18.6% of total OC loss across the EEZ. There were 6 other MPAs which contained large estimated carbon benefit: the North Channel of the Irish Sea, Northeast Coast, Celtic Deeps, Moray, Forth & Clyde Firths and North Fladden, which together save an additional 7.3%.

This study suggests that even when considering fisheries displacement, protecting areas of the seabed due to their current carbon value is practicable and should be considered in future marine planning.

The changing value of saltmarshes through time

AUTHORS:
Angus Garbutt[1] and Simon Read[2]

[1] UK Centre for Ecology & Hydrology, Environment Centre Wales, Deiniol Road, Bangor, LL57 2UW, UK ag@ceh.ac.uk
[2] Middlesex University, Department of Visual Arts, London

The popular perception of saltmarsh in the UK has undergone several evolutions since medieval times, often undervalued and never universally appreciated. It is perfectly consistent with a body of land that changes its identity twice daily as the tide floods and ebbs that, according to the popular imagination, it should harbour an equally shifting and untrustworthy community. The industrial revolution changed perceptions of the natural environment to one of leisure and offered redemption to societies living on the edge. In recent decades huge efforts have been made to restore and manage saltmarshes to maximise the benefits they provide.

We will describe these reoccurring themes portrayed in popular literature and the changing place that saltmarsh occupies in the popular psyche up to the 21st Century emphasis on carbon capture and storage.

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https://valuing-nature.net/about

Guiding the restoration of our estuaries and coasts

AUTHORS:
Benjamin C Green[1], Eve Leegwater[1], Rachel Hudson[1], Will Manning[1], Joe Kenworthy[1], Mike Best[1], Colin Scott[2], Celine Gamble[3], Azra Glover[3], Joanne Preston[4], Alison Debney[3] and Roger Proudfoot[1]

[1] Environment Agency, Kingfisher House, Peterborough ben.green@environment-agency.gov.uk @saltmarshben
[2] ABPMer, Town Quay, Southampton
[3] Zoological Society of London,
[4] Institute of Marine Sciences, University of Portsmouth.

There has been a lack of UK-wide guidance setting out how to practically carry out an estuarine & coastal habitat restoration project. This is a barrier, causing a lack of clear information for groups wanting to undertake restoration. The uncertainty around the complex regulatory process of gaining licences and permissions is also a barrier to progress. To resolve this, COP26 will see the launch of three new UK and Ireland Restoration Handbooks for restoring Blue Carbon habitats funded by the Environment Agency and Defra, as part of the Restoring Meadows, Marsh and Reef (ReMeMaRe) initiative.

The three handbooks cover the restoration of (i) saltmarsh, (ii) seagrass and (iii) intertidal habitats using dredged sediment, and partner with a fourth handbook for native oyster restoration launched in 2020. All aim to provide foundational and practical guidance on the restoration and conservation of these blue carbon habitats, from pre-project planning through to post project monitoring. They are aimed at catchment/coastal partnerships, eNGOs, industry or community groups looking to undertake small scale feasibility projects to as larger, more complex seascape-scale projects. These handbooks provide new standards for the restoration of blue carbon habitats, and aim to make it more achievable and accessible for all.

Coastal and Marine Blue Carbon in a U.S. MPA: An Assessment and Guidance for Managers

AUTHORS:
Sara Hutto[1], Rietta Hohman[2]; Sage Tezak[2]

[1] Greater Farallones National Marine Sanctuary – sara.hutto@noaa.gov
[2] Greater Farallones Association

Coastal and marine ecosystems play a significant role in the global carbon cycle, sequestering and storing carbon over long timescales (Sabine et al., 2004; Nellemann et al., 2009). Well-managed marine protected areas (MPAs) protect valuable blue carbon habitats and processes, and are a critical tool for reaching global climate mitigation goals (Hoegh-Guldberg et al., 2019; Simard et al., 2016); however, blue carbon is often overlooked in climate mitigation policies. Further, resource managers of the largest network of U.S. MPAs, the Office of National Marine Sanctuaries (ONMS), have not incorporated blue carbon into their management plans or policies, which can result in unintentional carbon emissions and lost opportunities to further protect carbon sequestration in MPAs. Guidance for how to apply blue carbon information in MPA management is lacking, and for some sequestration processes, completely absent.

This 2-part report series from ONMS presents the findings from the first assessment of blue carbon in a U.S. federal MPA, recommendations for ONMS to improve its management and policy decision-making, and guiding principles for advancing blue carbon inclusion in MPA management. Two coastal blue carbon habitats, seagrass and salt marsh, and two marine carbon sequestration processes, kelp export and dead whale falls, in Greater Farallones National Marine Sanctuary, were found to have the potential to sequester 4,950 megagrams of carbon (MgC) each year which is valued at $925,650 in societal benefit annually. The Sanctuary plans to use this information to inform policy and management decisions, and to prioritize protection and restoration programs.

Understanding carbon sequestration within MPAs is key for managing changes to stored carbon, which has global climate relevance. This assessment and accompanying guiding principles are a foundational step in increasing the protection and enhancement of critical coast and ocean climate mitigation services. This talk will demonstrate that with modest time and resource investments, blue carbon resources can be more fully understood and protected.

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The interpretation of justice in blue carbon projects

AUTHORS:
Mark Huxham[1], Robyn Shilland[1], Anne Kairu[2]

[1] School of Applied Sciences, Edinburgh Napier University, Edinburgh EH11 4BN m.huxham@napier.ac.uk
[2] Department of Biological Sciences, Embu University, Kenya

Most blue carbon habitats are socio-ecological systems; they are places where lines between people and nature are blurred. Effective management of such habitats requires the engagement and inclusion of local communities, and when management may impose change and cost on people then justice demands their assent. Whilst much policy acknowledges the importance of justice it rarely explains what this means and how conflicts between different groups and different world views may be resolved. Here, we use the example of two community based blue carbon projects in Kenya to explore how concepts of procedural, distributional and recognitional justice are manifested in this cultural setting. Adopting an 'empirical justice' approach, and using documentary analysis and ethnographic data, we challenge the emphasis on 'elite capture' in the literature and show how market, regulatory and technical drivers on accountability and precision, often presented as essential for fairness, can conflict with the interpretations of justice held by local people.

Interactive effects of climate change and land use change on carbon burial at millennial timescales

AUTHORS:
Kamenos NA[1], J Mao[1], RAR McGill[2], J Newton[2], P Gulliver[3], HL Burdett[4,5]

[1] School of Geographical and Earth Science, University of Glasgow, Glasgow, UK – nick.kamenos@glasgow.ac.uk
[2] NERC Life Sciences Mass Spectrometry Facility, Scottish Universities Environmental Research Centre, East Kilbride, Glasgow, UK
[3] NERC Radiocarbon Facility, Scottish Universities Environmental Research Centre, East Kilbride, Glasgow, UK
[4] Lyell Centre for Earth and Marine Science and Technology, Research Avenue South, Edinburgh, UK
[5] School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh, UK

Carbon sequestration and storage by sediments and vegetated marine systems contributes to atmospheric carbon drawdown, but it remains poorly understood how climate change and other anthropogenic activities affect these processes. To overcome this, we used marine sediment organic carbon to determine the role of historic climate variability and human habitation in carbon burial on the west coast of Scotland over the past 5071 years. We found that climatic variability impacted carbon supply and burial at centennial timescales. Most notably, Little Ice Age cooling caused an abrupt ecosystem shift and an increase in marine carbon contributions compared to terrestrial carbon inputs. Although land use changes during the late 1800s did not cause marked alteration in average carbon burial, they did lead to marked increases in the spatial variability in the amount of carbon buried. Thus, while carbon burial by vegetated systems may increase with projected climate warming over the coming century, ecosystem restructuring and parallel changes in land use changes within catchments may produce unexpected changes in carbon burial and increase the complexity of the climate-blue carbon relationship.

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BLUE CARBON TALKS

Tential contribution of mangroves to Indonesia's natural climate solution

AUTHORS:
Boone Kauffman[1], Virni Budi Arifanti[2], Subarno[3], Muhammad Ilman[3], and Nisa Novita[3]

[1] Department of Fisheries, Wildlife and Conservation Sciences, Oregon State University, Corvallis, OR 97331, USA
[2] Research and Development Center for Socio-Economics, Policy and Climate Change, Ministry of Environment and Forestry, Jl Gunung Batu No. 5 Bogor, Indonesia
[3] Yayasan Konservasi Alam Nusantara, Graha Iskandarsya Floor 3. Jl. Iskandarsyah Raya No.66 C. Kebayoran Baru, South Jakarta, Indonesia

Indonesia has more mangroves than any other country in the World. Similarly, more mangroves have been deforested and converted to other uses resulting in significant greenhouse gas emissions. The mean ecosystem carbon stock of Indonesian mangroves is 1063 Mg C ha and when converted to other uses about 54% of this carbon stock is lost as greenhouse gas emissions. By comparison mangrove global ecosystem carbon stocks have been estimated to be 856 Mg C ha-1. The conversion of mangroves to land uses such as aquaculture coupled with differences in net ecosystem productivity between intact mangroves results in annual emission factors of 136.9 Mg CO2e ha-1 (extrapolated over a 20 year period) with a net deforestation rate of 12,818 ha yr-1.

While contributing only a small percentage of the total forest area of Indonesia, mangrove conservation and restoration can play a significant contributing role to Indonesia's climate change emission reductions goals. The emission reduction from changing the "Business as usual" rates of mangrove conversion which assumes that all deforestation of primary and secondary mangroves is halted, rehabilitation activities and mangrove management policies are successfully implemented results in an emission reduction equivalent to 6% of emission reduction target for the forestry sector in Indonesia's National Determined Contributions (NDC) by 2030. The emission reduction contributions from of mangroves to NDC largely arises from avoiding deforestation and degradation activities of standing forest.

Conservation and restoration of blue carbon stocks

AUTHOR:
Catherine E. Lovelock

School of Biological Sciences, The University of Queensland, St Lucia, Queensland, Australia – c.lovelock@uq.edu,au

Coastal wetlands harbour large stocks of carbon in their soils and biomass that are likely greater than 30,000 Tg C within 185 million hectares. The global extent of coastal wetlands has declined due to reclamation, conversion to aquaculture, agriculture and settlements, and over-exploitation. While rates of loss have declined over the past two decades, global losses continue and thus conservation strategies could potentially avoid emissions of 304 (141–466) Tg carbon dioxide equivalent (CO2e) per year.

There are ambitious global targets for restoration of coastal wetlands, which if successful, could deliver global benefits of carbon sequestration that could reach 841 (621–1,064) Tg CO2e per year by 2030, as well as benefits for fisheries production, biodiversity and coastal protection. However, large-scale restoration efforts are few and many have failed, while smaller projects may not deliver landscape-scale and thus the desired blue carbon benefits, even though they are more suited to management by community groups. The solutions to achieving global coastal wetland restoration targets and their promised blue carbon benefits range from alleviating socio-economic barriers to reducing risks from biophysical factors, including those associated with climate change. Sustainable coastal wetland conservation and restoration for blue carbon requires capacity building, both in institutions and communities, mechanisms to match restoration opportunities with prospective investors and global standardized reporting against restoration targets.

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Operationalising marketable blue carbon

AUTHORS:

Peter I. Macreadie[1], Alistar I. Robertson[2], Bernadette Spinks[3], Matthew P. Adams[4,5], Jennifer M. Atchison[6], Justine Bell-James[7], Brett Bryan[1], Long Chu[8], Karen Filbee-Dexter[2,9], Lauren Drake[10], Carlos M. Duarte[11], Daniel A. Friess[12, 13], Felipe Gonzalez[14], Quentin Grafton[8], Kate J. Helmstedt[4], Melanie Kaebernick[15], Jeffrey Kelleway[16], Gary A. Kendrick[2], Hilary Kennedy[17], Catherine E. Lovelock[18], J. Patrick Megonigal[19], Damien T. Maher[20], Emily Pidgeon[21], Abbie A. Rogers[22], Rob Sturgiss[23], Stacey M. Trevathan-Tackett[1], Melissa Wartman1, Kerrie A. Wilson[24], Kerrylee Rogers[16]

The potential global carbon drawdown that could be achieved via blue carbon is high (~3% of annual global greenhouse gas emissions); but the challenge is to design projects that are beneficial to both the natural environment and society, and are scalable, replicable, and cost-effective. We identify critical social, governance, financial and technological uncertainties impeding the operationalisation of blue carbon projects. We discuss key actions to enhance the natural climate solution (NCS) potential of blue carbon including: improving policy and legal arrangements to ensure equitable sharing of financial and other benefits; improving stewardship by incorporating indigenous knowledge and values; clarifying property rights; reviewing and investigating financial approaches and accounting tools to better incorporate co-benefits; developing technologies (e.g. sensors) and computational tools (e.g. artificial intelligence) for measuring blue carbon sequestration at low cost; and improving our understanding of lesser-known aspects of the blue carbon cycle (e.g. seaweed contributions). Addressing these actions and operationalising blue carbon will not only achieve measurable changes to atmospheric greenhouse gas concentrations, but will provide multiple co-benefits, deliver on several UN SDGs, and address national obligations associated with international agreements such as Ramsar Convention on Wetlands, and Convention on Biological Diversity.

1 Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, Burwood Campus, Burwood VIC, Australia. Peter I. Macreadie: p.macreadie@deakin.edu.au

2 UWA Oceans Institute and School of Biological Sciences, University of Western Australia, Crawley WA, Australia

3 Consulting & Implementation Services, Docklands, VIC, Australia

4 School of Chemical Engineering, The University of Queensland, St Lucia QLD, Australia

5 Centre for Data Science, School of Mathematical Sciences, Queensland University of Technology, Brisbane QLD, Australia

6 Australian Centre for Culture, Environment, Society, and Space (ACCESS), University of Wollongong

6 TC Beirne School of Law, The University of Queensland, St. Lucia QLD, Australia

8 Crawford School of Public Policy, The Australian National University, Acton ACT, Australia

9 Flødevigen Research Station, Institute of Marine Research, His, Norway

10 Pollination Group, Sydney, Australia

11 King Abdullah University of Science and Technology, Saudi Arabia

12 Department of Geography, National University of Singapore, Singapore 117570

13 Centre for Nature-based Climate Solutions, National University of Singapore, Singapore 117558

14 School of Electrical Engineering & Robotics, Faculty of Engineering, Queensland University of Technology, Queensland Australia

15 Department of Agriculture, Water and the Environment (DAWE), Australian Government

16 School of Earth, Atmospheric and Life Sciences and GeoQuEST Research Centre, University of Wollongong

17 Bangor University, Wales

18 School of Biological Sciences, The University of Queensland, St Lucia QLD 4072, Australia

19 Smithsonian Environmental Research Centre, Edgewater, Maryland, USA

20 Faculty of Science and Engineering, Southern Cross University, Lismore NSW, Australia

21 Conservation International, Arlington, USA

22 Centre for Environmental Economics & Policy, UWA School of Agriculture & Environment, and UWA Oceans Institute

23 Department of Industry, Science, Energy and Resources

23 Queensland University of Technology, Queensland, Australia

Blue Methane: Challenges and Opportunities Posed by Methane Emissions for Blue Carbon Accounting

AUTHORS:

J. Patrick Megonigal[1], James Holmquist[1], Genevieve Noyce[1], and Kevin Kroeger[2]

[1] Smithsonian Environmental Research Center, Edgewater, MD 21037, USA – megonigalp@si.edu

[2] U.S. Geological Survey, Woods Hole Coastal & Marine Science Center, Woods Hole, MA, 02543, USA

Tidal marshes, mangroves, and seagrasses provide opportunities to mitigate greenhouse gas emissions while also incentivizing conservation, management, and restoration of these ecologically important ecosystems. There is great potential for halting and reversing the loss of vegetated coastal ecosystems through greenhouse gas mechanisms such as national carbon inventories, carbon financing projects, nationally determined contributions, and natural climate solution programs. However, significant barriers remain to translating this potential into action. Chief among these is the challenge of understanding and quantifying methane emissions.

Methane is 45 times more potent as a greenhouse gas than carbon dioxide. Some portion of the climate cooling benefits of carbon sequestered by coastal ecosystems is negated by the climate warming impact of the methane they emit. From a climate perspective the most successful and profitable blue carbon activities maximize sequestration while minimizing methane emissions. Yet, the biology and ecology of the plants and microbes that inhabit these ecosystems puts significant limits on our ability to optimize for greenhouse gas mitigation. There is a strong tendency for actions that increase the capacity of coastal wetlands to sequester carbon dioxide to also increase methane emissions. We need a more nuanced understanding the biogeochemical processes by which methane is produced, oxidized, and emitted to defeat the tendency toward greenhouse gas homeostasis.

Methane is a waste product of a particular type of microbial respiration – methanogenesis – that yields very little energy and is dramatically suppressed by other microorganisms when competing for resources. High-salinity coastal wetlands are very attractive for blue carbon projects because the sulfate in seawater supports sulfate-reducing bacteria that effectively suppress methanogenesis. However, many of these ecosystems occur at lower salinity levels and thus emit substantial amounts of methane.

Methane-oxidizing bacteria destroy a portion of the methane produced in soils and sediments before it can escape to the atmosphere. Methane oxidation can be enhanced by increasing the amount of time the water table is below the soil surface, or by favoring plant species that transport oxygen into otherwise anoxic soils at very high rates. The effects of water table or flooding manipulation are well known, but there is little known about the ability of plants to reduce methane emissions by transporting oxygen. Attention to methane-reducing plant traits may be advantageous for coastal carbon restoration projects.

The high global warming potential of methane can be an advantage in cases where the project reduces emissions. Impoundments created by building dikes, roads, and similar activities isolate coastal wetlands from tidal flooding and the delivery of sulfate. The restoration of tidal flooding reconnects wetland and aquatic habitats and often lowers methane emissions. Recent inventory work shows there is significant potential in the United States to restore impounded coastal wetlands while also reducing greenhouse gas emissions.

Implementing blue carbon inventories or projects requires a full accounting of greenhouse gas sinks and sources. The sinks are relatively well constrained by plant biomass and soil carbon stocks, but accurate budgets for methane remain a challenge because the gas does not accumulate in the ecosystem and cannot be measured through stock change. A variety of data-model integration projects are underway aimed at providing tools that improve the spatial resolution of coastal wetland carbon stocks, stock change, and methane emissions. All these issues also apply to nitrous oxide, a more powerful greenhouse gas than methane emitted from many blue carbon ecosystems. Advances in blue carbon science demand that we delve deeper into the causes of spatial and temporal variability in greenhouse gas emissions and translate knowledge into tools to support blue carbon projects.

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Carbon sequestration in tidal marshes: importance of sea-level rise, time scale, physical setting, and methodology

AUTHOR:
James T Morris

Baruch Institute, University of South Carolina – morris@inlet.geol.sc.edu

Experiments with the Marsh Equilibrium Model were run to investigate the dependence of carbon sequestration on rate of sea-level rise (RSLR), physical setting, time, and methodology. The model reported carbon sequestration alternatively as the annual accumulation of refractory carbon and as the change in total belowground biomass. The model demonstrated: 1) sequestration and carbon inventory are only stable when marshes are in equilibrium with sea level; 2) the rate of carbon sequestration and inventory of belowground biomass are more or less sensitive to RSLR depending on the physical setting; 3) C-sequestration computed as refractory carbon production increased in the peat marsh with rising RSLR, while in the mineral-dominated marsh it declined; 4) computed as a change in total carbon inventory, sequestration declined in the mineral-dominated marsh with rising RSLR, while it remained nearly constant in the peat marsh; 5) by any measure, the peat marsh had higher rates of carbon sequestration than the marsh with clastic sediment, and 6) it is possible to have negative sequestration when computed as a change in belowground biomass, while sequestration can be positive when calculated as the rate of refractory carbon accumulation.

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BLUE CARBON TALKS

Belize Blue Carbon: Establishing a national carbon stock estimate for mangrove forests

AUTHORS:
H.K. Morrissette[1,2], S. Baez[3], L. Beers[4], N. Bood[5], S. Crooks[4], J. Lefcheck[2], N. Martinez[6], K. Novelo[6], and S.W.J. Canty[1,7]

1 Smithsonian Marine Station, Fort Pierce, FL, USA – morrissetteh@si.edu
2 Tennenbaum Marine Observatories Network, MarineGEO, Smithsonian Environmental Research Center, Edgewater, MD, USA
3 Pew Charitable Trusts, Washington, DC, USA
4 Silvestrum Climate Associates LLC, San Francisco, CA, USA
5 World Wildlife Fund, Washington, DC, USA
6 University of Belize Environmental Research Institute, Belmopan, Belize
7 Working Land and Seascapes, Conservation Commons, Smithsonian Institution, Washington, DC, USA

Mangrove ecosystems are among the most economically and ecologically valuable marine environments in the world. Despite their relatively small global extent, mangroves are effective at long-term carbon storage within their sediments, and are therefore of interest due to their natural capacity to mitigate effects of climate change. As part of the Paris Agreement, participating countries agree to provide plans for their reduction of carbon emissions, otherwise known as their nationally determined contributions (NDCs). However, despite mangroves' recognized importance as nature-based solutions, many countries still lack local data on carbon stocks and instead must use global or regional averages that might misrepresent the actual amount of carbon within that country. Here, we present preliminary results from an ongoing internationally-cooperative project to inform the national carbon stock estimate of mangrove forests for the NDCs of Belize. In September 2021, fourteen institutions collaborated in a field campaign to provide these data, with sampling that occurred at nine sites from north to south, and along the network of cayes, to provide representative sampling locations. An important component of this program was to provide training on methods and build capacity to allow for NDC updates to be conducted by local institutions. Key partners included the University of Belize, along with government agencies and NGOs engaged in the management of mangroves such as Coastal Zone Management Authority & Institute (CZMAI). In total, 102 sediment cores up to three meters in depth were collected and subsampled for bulk density, loss on ignition (LOI), and elemental analysis following standard practices to provide the first national carbon stock estimate assessment for Belizean mangrove ecosystems. These data support Belize's commitment to protect and restore mangroves as part of their NDCs, and serve as a blueprint for other countries seeking to conserve natural blue carbon sinks in meeting their climate targets.

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Estimating Aboveground Biomass and Biomass Change of Mangrove Forests in the Niger Delta

AUTHORS:
Nwobi, C.J[1], Williams, M[1,2] and Mitchard, E.T.M[1]

[1] School of GeoSciences, University of Edinburgh – ebuka.nwobi@ed.ac.uk
[2] National Centre for Earth Observation, University of Edinburgh, Edinburgh, United Kingdom

The conservation and sustainability of mangrove forests is a globally important topic due to their large stocks of carbon and other natural capital. The mangroves of the Niger Delta are the most extensive in Africa, but are threatened by urbanization, oil pollution and wood exploitation. While there are global mangrove biomass estimates, there is no locally calibrated aboveground biomass (AGB) map for this region. Here, we generate the first mangrove AGB map for the Niger Delta, for 2007 and 2017. We use data from 25 inventory plots to establish a relationship between field estimates of AGB and Advanced Land Observatory Satellite (ALOS) L-band Synthetic Aperture Radar (SAR) backscatter. The strongest relationship between radar backscatter and field estimates of AGB was from the combination of the HV band and the HV/HH ratio ($r2= 0.62$, $p < 0.001$). Using this relationship, we estimated the total AGB fell from 82 x 106 Mg in 2007 to 65 x 106 Mg in 2017, a 21% reduction. Deforestation accounted for 69% of AGB loss, and degradation accounted for 28%, with average forest AGB stocks falling from 90.5 Mg ha-1 in 2007 to 83.4 Mg ha-1 in 2017. These AGB values are considerably lower than estimates for the region from wide-scale mangrove biomass maps, even though the extent of mangrove we map is larger. This proves the importance of local field data. We further conclude that SAR instruments can provide effective monitoring of the carbon stocks in mangrove forest, and by extension deforestation, degradation and regrowth. Assessing carbon stocks of mangrove forests in the Niger Delta can create a baseline for regional conservation and regeneration plans. These maps can create opportunities for generating funding for conservation under international programs such as reducing emissions from deforestation and forest degradation (REDD+), and monitoring their success.

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BLUE CARBON TALKS

Towards shelf seabed carbon management in England

AUTHORS:
R Parker[1], J Aldridge[1], R Bullimore[1], F Mynott[1], W Proctor[1], P Lamb[1], P Chaniotis[2], D Cook[2]

[1] Cefas, Pakefield Road, Lowestoft, Suffolk
[2] Joint Nature Conservation Committee (JNCC), Monkstone House, Peterborough

The seabed is an integrated system which provides many ecosystem services. Awareness of the ecosystem service of carbon sequestration and storage provided by the seabed marine system and its potential in the mitigation of climate change is growing.

While the focus of Blue Carbon has been on vegetated coastal systems, recent publications at European and global levels have illustrated the significance of the stocks in the offshore seabed system. However, many seabed C stocks are under pressure from human activities and climate forcing itself which can lead disturbance of C pools, emissions and potential impact on accumulation. Hence, their protection or restoration, including using management of activities in and around MPAs (Marine Protected Areas), may act as significant nature-based solutions (NBS).

This study draws together the evidence components required and gaps in understanding which need to be filled to map how carbon stocks in English waters may be managed in future, to maximize the potential climate regulation or mitigation potential they perform.

Key components are:

- Carbon information on stocks and accumulation
- Carbon characteristics (source, lability)
- Change under pressures from human activities
- Understanding of C dynamics, recoverability and the associated timescales
- A framework and criteria to integrate these considerations and predictive tools to investigate management scenarios at appropriate scales, including displacement and trade-offs

This presentation will illustrate these key components using English seabed as an example and identifying where key evidence gaps exist (accumulation observations, biodiversity – C relationships, pressure and recovery trajectories, C characteristics and dynamics) which will need filling in future to allow carbon management strategies and decisions to be made in future with increased confidence levels.

Blue Carbon Initiative: transforming science into effective policy and management

AUTHORS:
Emily Pidgeon[1], Kirsten Isensee[2] and Dorothee Herr[3]

[1] Conservation International – epidgeon@conservation.org Twitter: @Aus_epidgeon
[2] Intergovernmental Ocean Commission – UNESCO
[3] IUCN

A decade ago the carbon storage and sequestration value of blue carbon ecosystems was largely unknown outside the specialized scientific community. Today, blue carbon ecosystems are explicitly recognized for their climate mitigation and adaptation value by the Paris Climate Accord and a rapidly expanding number of governments are including these ecosystems in their commitments to achieving that important milestone. Blue Carbon projects are now generating some of the most highly priced carbon credits which, in turn, provide long-term funding streams for sustainably managing these ecosystems and supporting the communities dependent on them.

The Blue Carbon Initiative (BCI) was formed in 2010 by Conservation International (CI), the International Union for Conservation of Nature (IUCN), and the Intergovernmental Oceanographic Commission of UNESCO (IOC–UNESCO) with the specific objective of expanding and accelerating conservation and restoration of coastal and marine ecosystems for climate change mitigation. To achieve this, the BCI has focused on integrating science and policy so that blue carbon related actions are both science-driven and practicable within policy, carbon markets and other climate related mechanisms. Such integration has only been possible through active collaboration within and between the science and policy communities.

The International Blue Carbon Scientific and Policy Working Groups formed through the BCI have been transformational tool in bridging science, policy, and finance. These groups have identified the specific science needed to drive policy change, communicated these priorities with the broader research community, created tools needed to support decision-makers, and ensured a strong representation of blue carbon science within key policy-related bodies such as the IPCC. Similarly, the working group members have actively led the development of robust methodologies for the carbon credit market and supported development of various financial structures. As a result of this progress there is now broad global recognition of and commitment to the climate importance of blue carbon ecosystems. Governments, communities, the corporate sector, and conservation organizations are now prioritizing and funding blue carbon projects across the globe.

This remarkable progress in such a short time is a direct result of the sustained and expanding engagement of the science and policy communities. More broadly, the compelling lesson from blue carbon is that in order to have an impact on the world, science research on its own is not enough. Scientists must themselves be active in driving that change.

How do we find macroalgal particulate organic carbon sinks and how do we protect them?

AUTHORS:
Ana M Queirós[1], Michel Bedington[1], Andrew Bell[2], James Clark[1], Christine Pascoe[1], Daniel Smale[3], Paul J Somerfield[1], Karen Tait[2], Ricardo Torres[1] and Rob Wilson[1]

[1] Plymouth Marine Laboratory – anqu@pml.ac.uk, @DrAnaQueiros
[2] North Devon UNESCO World Biosphere, Devon, UK
[3] Marine Biological Association of the United Kingdom, Devon, UK

Enhancing the ocean's role as a climate system stabilizer requires practical solutions to conserve habitats that deliver organic carbon sequestration. Few, recent field studies lend weight to the perspective that seaweed carbon export may drive important carbon sequestration rates across soft sediment systems. But this very limited evidence basis still prevents the consideration of seaweed carbon donors and sinks in carbon accounting as well as blue carbon conservation mechanisms. In this study, a combination of field-based research, laboratorial experiments and modelling, illustrates some of the pathways connecting seaweed organic carbon export to their sedimentary sinks. These are not always located in the deep ocean, where designation of sites may be impractical and difficult to enforce. Further field verification of pathways elucidated via modelling shown, and close collaboration with practitioners, may help guide the development of the next stage of seaweed blue carbon research. This should seek to provide policy makers with needed, constrained carbon sequestration rate estimations for spatially explicit carbon sources and sinks, so these may be included in future-proofed, actionable, conservation mechanisms.

The 'DEEP' triple helix: Partnership working in environmental restoration and it's role in blue carbon storage and management

AUTHOR:
William G. Sanderson

w.g.sanderson@hw.ac.uk
Professor Marine Biodiversity and DEEP Research Director, ILES, EGIS, Heriot-Watt University, Edinburgh, UK

Glenmorangie, in partnership with Heriot-Watt University and the Marine Conservation Society have pioneered the Dornoch Environmental Enhancement (DEEP). DEEP has brought together academia, business, government and non governmental organisations along with the oyster growing community in a common pursuit to restore native European oysters (Ostrea edulis) to the Dornoch Firth for the first time in over 100 years. The project has been an exemplar and source of inspiration for the many rapidly developing projects throughout Europe.

Acting in tandem with Glenmorangie's innovative Anaerobic Digestion (AD) plant, which has purified more than 95% of the waste water from the Distillery, the remaining 5% of the organic waste will be accounted for naturally by the oysters through their filter-feeding ability. DEEP is a carefully crafted partnership that has seen stages starting with environmental review, progressing to survival trials and more recently an optimisation phase where the road-map to operational restoration at scale has been tested and fine-tuned. Throughout this process, the project has benefited from systematic outreach and community engagement by the Marine Conservation Society as well as millions of 'opportunities to see' in global, national and local media.

Throughout DEEP, great importance has been placed on providing the scientific evidence to support the basis and operational efficiency for restoration. Increasingly, emphasis has also been placed on evidence to support the business case for restoration in terms of biodiversity gain and now carbon storage. In the UN Decade on Ecosystem Restoration and the year of COP26 in Glasgow, it is important to build strong partnerships with common purpose, clear foundations, optimised delivery tools and clarity in outcomes.

Academia meets policy: how do parliaments use blue carbon academic research to support policymaking?

AUTHORS:

Roxana T Shafiee, Damon Davies, Anna Brand and Alexa Morrison

Scottish Parliament Information Centre (SPICe), Scottish Parliament – roxana.shafiee@parliament.scot

Parliaments play a critical role in scrutinising government policy and supporting evidence-led policymaking, which includes holding governments to account on their actions to tackle the twin crises of climate change and biodiversity loss. In 2020, the Scottish Government published an update to its Climate Change Plan (CCPu) outlining how it aims to meet its target of net zero carbon emissions by 2045. Policies and proposals for enhancing or protecting Scotland's blue carbon stores were less developed compared to those of peatland and forestry, despite emerging evidence of important blue carbon stocks and ecosystems in Scotland's seas. In 2021, the CCPu underwent a period of detailed scrutiny by the Scottish Parliament, led by the Environment, Climate Change and Land Reform Committee. This culminated in recommendations from the Committee that the Scottish Government bring forward policies on blue carbon protection, with calls for carbon storage and sequestration to be a consideration in the designation of Scotland's Marine Protected Areas. This talk explores the journey of how academic research, in this case relating to blue carbon, is used by parliaments and how this can inform the scrutiny of government policy. This talk offers insights into how academics can make their research more accessible to policymakers and engage with parliaments to support blue carbon policy scrutiny, thereby increasing the impact of their research.

Scotland's forgotten carbon: exploring the mechanisms that drive carbon burial and storage in mid-latitude fjords.

AUTHORS:

Craig Smeaton[1], Cui Xingxang[2], Hangdong Yang[3], Negar Haghipour[4], Timothy Eglinton[4], Thomas Bianchi[5] and William Austin[1,6]

[1] School of Geography and Sustainable Development, University of St Andrews, UK – cs244@st-andrews..ac.uk
[2] School of Oceanography, Shanghai Jiao Tong University, China
[3] Department of Geography, University College London, UK
[4] Geological Institute, ETH Zurich, Switzerland
[5] Department of Geological Sciences, University of Florida, USA
[6] Scottish Association of Marine Science, Scottish Marine Institute, UK

Globally fjords are recognized as 'Hotspots' for the burial and storage of organic carbon (OC)1,2 and for their potential to provide an important long-term global climate regulation service.

Within the mid-latitude fjords of Scotland, the sediments that have accumulated since the end of the last ice age are estimated to hold 252 ﬄ 62 Mt of OC3 and each year a further 84,000 tonnes of OC is trapped and locked away4.

Here we will investigate the mechanism, which drive the temporal and spatial evolution of these nationally significant OC resources. By utilizing a multi-technique analytical approach (stable isotopes, biomarkers, radiocarbon, thermogravimetric analysis) it is possible to understand the source (terrestrial vs marine), age and stability of the OC stored in the fjord sediments. These factors when examined in conjunction with the physical characteristics of the different fjords and their associated catchments provides insight into:

i. The mechanisms that govern the spatial distribution of OC in fjord sediments.
ii. The temporal evolution of these sedimentary OC stores.
iii. The impact anthropogenic pressure on OC dynamics in these systems.
iv. The interaction of the terrestrial and marine C cycles at the land-ocean interface.

Through the exploration of these factors, it is possible for the first time globally to create a first-order sedimentary C budget for a fjord system, highlighting the role of fjords in the marine and wider C cycle, while further developing our understanding of the role of sedimentary systems in regulating global climate.

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Tiger sharks, scientists, and entrepreneurs partner to guide the discovery of world's largest seagrass meadow in The Bahamas

AUTHORS:

Wells Howe[1], S. David Harris[1], Carlos M. Duarte[1,2], Austin J. Gallagher[1]

[1] Blueprint, Beneath the Waves; PO Box 126, Herndon, VA, USA. wells@beneaththewaves.org

[2] Red Sea Research Center and Computational Biosciences Research Center, King Abdullah University of Science and Technology; Thuwal, Saudi Arabia

Seagrass conservation is recognized as a critical action in mitigating climate change due to the large amounts of carbon that seagrasses sequester and store in the seafloor. Efforts to protect this vital ecosystem are hindered by major uncertainties in the distribution of seagrass meadows across the globe. While the Bahamas Banks are the largest carbonate banks in the world, extending across shallow waters overlaying well-lighted carbonate sediments that are well positioned to support seagrass, the current documented area of seagrass is only ~2% of the Banks. We integrated multiple streams of data, including three independent remote sensing estimates, over 2,000 diver surveys, and benthic habitat classification reported from tiger sharks equipped with pop-off underwater video camera tags, to report a consensus area of at least 57,000 km2 and up to 92,000 km2 of seagrass habitat on the Bahamas Banks. This spatial extent makes the Bahamas Banks meadow the largest known seagrass ecosystem in the world.

The planet is losing 7% of its seagrass meadows every year. Based on our current modeling and monitoring of the area, degradation of the Bahamas Banks meadow is following in-step with this global trend. We are working closely with local partners, rightsholders, sovereign funds, and governments to utilize Blue Carbon as a mechanism to protect the important ecosystem services that the Bahamas Banks seagrass meadow provides. This is done through partnering with like-minded entities who are focused on offsetting their unavoidable emissions with Blue Carbon credits.

With Beneath The Waves' Blueprint conservation program actively being deployed in The Bahamas, avoided annual CO2e emissions may range in the tens of millions of tons, with verified Blue Carbon credit revenue – that is directly chartered to marry conservation, sustainable development, and climate change mitigation – ranging in the hundreds of millions of dollars for The Commonwealth of The Bahamas. Beneath The Waves' quantification of Blue Carbon, under its Blueprint program, provides a replicable conservation solution for other nations to follow. Beneath The Waves' long-term monitoring and partnership with tiger sharks, which have strong fidelity to seagrass meadows, proved essential to aid in the assessment of the largest seagrass meadow in the world and laid the Blueprint for one of today's greatest opportunities to fight anthropogenic climate change with nature-based solutions.

ACKNOWLEDGEMENTS:

We thank our Bahamian partners and those officials who continue to support this work, M. Paton, D. Phillips, T. Ferguson, and a variety of private funders including S+K Linblad, Pictet, P. Luckey, Disney Conservation Fund, R. Sant, D. Matsui, and S. Sant-Plummer, and The Grand Isle Resort.

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Gallagher et al., Tiger sharks guide the discovery of world's largest seagrass meadow. (In review)

INTO THE OCEANIC

WE ARE OCEAN | INTO THE OCEANIC

Anne-Marie Melster, co-founder/director of ARTPORT_making waves invited the environmental artist Elizabeth Ogilvie and artist/filmmaker Robert Page to come on board of the WE ARE OCEAN Global programme as well as WE ARE OCEAN @ COP26 to showcase an impactful art-science film project.
artport-project.org/we-are-ocean

into the oceanic
Ogilvie + Page
creative projections
at a fundamental level, marine life helps determine the very nature of our planet, with every second breath we take generated by the ocean.

Kelp forests, seagrass meadows and saltmarshes, amongst other ocean environments – our so-called blue carbon habitats – represent significant opportunities to offer a nature-based solution to mitigate and adapt to climate change and provide invaluable havens for marine life.

This visceral meditation on such ecosystems, recorded in Atlantic and North Sea waters, celebrates some of our greatest weapons to combat climate change by removing carbon dioxide from the atmosphere and proposes the vision of a dynamic collaboration for us all with the ocean – our revered partner.

Ogilvie is an environmental artist and academic creating experiences for her public. Her international practice is a fusion of art architecture and science, and water and ice are currently both medium and subject in the installations.

Page's work is a fusion of documentary filmmaking and fine art, and has led him to encounter many different places, peoples and societies.

The project will be presented next at ISMAR, Institute of Marine Sciences – National Research Council, ISMAR-CNR, during the Venice Biennale 2022.

intotheoceanic.org
elizabethogilvie.com
outofice.org.uk
robertpage.co.uk

Posters

Assessing the Vulnerability of Sedimentary Carbon Stores to Demersal Trawling within the UK EEZ

AUTHORS:
Kirsty E. Black[1] and William E. N. Austin[1,2]

[1] School of Geography & Sustainable Development, University of St Andrews, St Andrews, KY16 9AL, UK – kb99@st-andrews.ac.uk
[2] Scottish Association for Marine Science, Scottish Marine Institute, Oban, PA37 1QA, UK

Shelf and coastal seas hold cast quantities of sedimentary carbon, which if left undisturbed, will contribute towards long-term carbon storage which may otherwise enter the atmosphere. It is estimated that within the UK exclusive economic zone, 524 Mt of organic carbon is stored within sediments (Smeaton et al., 2021). However, the stability of this key component of global natural capital remains poorly quantified, particularly under anthropogenic stressors.

Demersal trawling activity is the most significant cause of anthropogenic disturbance to the seabed, leading to massive sediment resuspension events and wide scale impact to benthic communities. The impacts of trawling on benthic ecosystems and biodiversity are well reported within the literature (Hughes et al., 2014); however, a knowledge gap remains regarding the impact of trawl induced disturbance events on sedimentary carbon stores.

In order to improve our understanding of the potential areas which are at risk from trawling events, we have developed a carbon ranking index to signify the areas of the seabed where preventative protection would be most beneficial to help maintain our current carbon stocks while further research continues about the fate of carbon after trawling (e.g. carbon remineralization, transport, and consumption etc.). These maps have been developed within GIS making use of currently available fishing intensity, carbon and sediment distribution, and sediment lability datasets (ICES, 2014; Smeaton et al., 2021).

Our preliminary results show that the fjordic west coast of Scotland represents one of the key areas where sedimentary carbon is highlighted as being potentially at risk from bottom trawling. This is largely due to the high lability of the sediments as a function of both sediment type and the elevated organic carbon content present within these sediments. Our research shows that these hotspots are at risk to disturbance and should be considered for potential future safeguarding measures.

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BLUE CARBON POSTERS

Blue Carbon Stocks of Dublin Saltmarshes: A Climate Relevant Carbon Pool

AUTHORS:
Shannon A. Burke, Elke Eichelmann, and Grace Cott

School of Biology and Environmental Science, University College Dublin – shannon.burke.1@ucdconnect.ie

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Blue carbon ecosystems store as much as 50% of the carbon found in ocean sediments though they cover less than 0.5% of the seabed (Nellemann et al., 2009). Ireland's most prominent blue carbon ecosystem, salt marshes, cover at least 100 km2 (Mcowen et al., 2017), however little blue carbon research has been conducted to date. Determining the carbon stock of salt marshes in Ireland will further contribute to our understanding of the carbon storage potential of these ecosystems.

Samples were collected from the four salt marshes found across Dublin between September 2019 and April 2021. The combined area of these sites is 267 ha.

Soil cores were collected from these sites using a gouge auger of 100 cm length and 6 cm diameter to measure the soil and belowground biomass carbon pools, and a quadrat (30x30 cm) of vegetation was removed to measure the aboveground biomass. Soil organic carbon was determined using the Loss on Ignition method outlined in the Coastal Blue Carbon manual (Howard et al., 2014).

The estimated total carbon stock of Dublin's salt marshes was calculated to be 214, 067 ffl 862 Mg Corg with a carbon density of 801 Mg Corg ha-1. The carbon density calculated for the soil carbon pool is just over twice the average of salt marshes globally (Chmura et al., 2003).

This provides, to our knowledge, the first account of carbon density of estuarine salt marsh soils in Ireland. A larger, country-wide campaign is currently underway to investigate if this substantial carbon stock is consistent throughout Irish salt marshes.

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Assessment of Blue Carbon Resources in the offshore seas around Jersey, Channel Islands

AUTHORS:
Paul Chambers[1], Francis CT Binney[2], Samantha R Blampied[3]

Marine Resources,
Government of Jersey
[1] p.chambers@gov.je
[2] f.binney@gov.je
[3] s.blampied2@gov.je

In May 2019 the States of Jersey declared a Climate Emergency which included a 2030 target for achieving carbon neutrality. With few green carbon resources, carbon neutrality is relaint on emmissions reduction with any remnant being offset through other means such as carbon credits.

Jersey's carbon neutral strategy recognises a role for blue carbon (BC) resources and that research will be required to develop this. In March 2020 the government's Marine Resources team were tasked with assessing Jersey's BC resources.

This assessment has begun with a desktop study to estimate offshore BC resources and map their distribution. Based on the work of Burrows et al. (2017) government and other data relating to marine oceanography, ecology, sedimentary properties, biomass, carbonate content and SAR were synthesised into a single GIS model. Calculations were performed on over 37,000 polygons (each 6.25 ha) with the results grouped by broad habitat type. For each polygon an estimated weight of organic and inorganic carbon was calculated in relation to standing stock, production and sequestration.

The results classified habitats by their levels of production, standing stock and sequestration. The distribution of BC resources suggests that Jersey's shallow water reefs are important areas for organic carbon production and that its sedimentary basins have a high inorganic carbon content and a significant sequestration potential. An area of deeper water hard seabed west of the island has low blue carbon resources.

The total annual production of carbon for Jersey's offshore habitats is estimated at 94,000 tonnes against a standing stock of 99,000 tonnes (organic) and 12,700,000 tonnes (inorganic). Annual sequestration is estimated at 16,000 tonnes which equates to 60,000 tonnes of CO_2. By comparison, Jersey's annual CO_2 emissions for 2017 (latest year) were estimated to be 400,000 tonnes.

Field and laboratory studies for sedimentary habitats have started to truth the desktop assessment.

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Moving towards inclusion of coastal wetlands in the UK LULUCF inventory

AUTHORS:
Annette Burden[1] and Hannah Clilverd[2]

1 UK Centre for Ecology and Hydrology, Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, LL57 2UW, UK – anrd@ceh.ac.uk
2 Land Use, Land-Use Change and Forestry (LULUCF) GHG Inventory, UK Centre for Ecology and Hydrology, Bush Estate, Penicuik, Midlothian, EH26 0QB, UK – hanilv@ceh.ac.uk

Coastal wetlands has been subject to historic modification by drainage and land-use change, which is likely to have contributed to past CO_2 emissions, but which may now present opportunities to sequester CO_2 through activities such as rewetting, land-use change and managed coastal realignment. The mitigation potential of 'Blue Carbon' in the UK could be reconsidered and included in the Nationally Determined Contributions (NDCs) using guidance in the 2013 IPCC Wetlands Supplement. We assessed the necessary data requirements (extent, drainage, extraction, rewetting) to make the best possible progress on documenting whether emissions and removals from saltmarshes should potentially be reported in the UK GHG inventory over 1990-2020. We identified a number of data sources to enable the development of a base map of saltmarsh condition and land use to enable tracking of change over time. All formal rewetting of saltmarsh has happened since 1990, and therefore comprehensive data are available. Using Google Earth we were able to record the area of specific coastal habitats within restored sites, track change over time, and estimate when at least 10% of the area had been colonised by vegetation. Point locations of extraction activities associated with dredging are available, however there are currently insufficient area and volume data to estimate emissions. Using Tier 1 emission factors, the inclusion of the drainage and rewetting of coastal wetland above the high water mark could have a very marginal (positive) impact on the UK GHG inventory, which is likely to increase in in the future with restoration efforts. Next steps include further analysis of habitat base maps and ensuring that relevant extraction and rewetting data are collected so that both sources and sinks can be include in the GHG inventory.

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Long term variability in isotopic and elemental patterns among estuarine primary producers: implications for blue carbon studies

AUTHORS:
Marianna Lanari, Bianca Possomai, **Margareth Copertino**[1] and Alexandre Garcia

Institute of Oceanography, Federal University of Rio Grande (FURG), Brazil
[1] doccoper@furg.br
marga.copertino@gmail.com

Stable isotopes have been widely used in biogeochemical and ecological studies, relying on the assumption that different basal sources present distinguishable isotopic signatures. It enables their tracing up in coastal and marine systems to investigate the fate of organic matter throughout food webs and sedimentary carbon pools. Most studies, however, have implicitly assumed temporal and spatial stability of the isotopic composition in basal sources, rising constraints to detect the fate of carbon in coastal/marine systems. We investigated the seasonal and interannual variability in isotopic values (δ13C and δ15N) of distinct estuarine primary producers in a subtropical estuary (Patos Lagoon, Southern Brazil). Then, we evaluated the sensitivity of isotopic mixing models to ENSO-driven interannual variations in isotopic composition. Our results show that variability in carbon isotopic values among sources differed in magnitude and timescales, being large enough to confound source-specific values. ENSO-driven climate and hydrological changes interact with or even override seasonal patterns of variability in isotope composition of estuarine basal sources. The most pronounced δ13C variations occurred in macroalgae and widgeon grass, which are short living with high variability in seasonal abundance, compared to the more complex and perennial salt marsh plants. Such variations promoted overlapping δ13C values among producers under distinct ENSO conditions. While macroalgae and POM δ13C varied seasonally, ENSO effects prevailed for C3 and C4 salt marsh plants, highlighting the contrasting influence of local versus remote environmental drivers on short and long-lived primary producers, respectively. The interannual variability in freshwater discharges associated with ENSO events interact with seasonal fluctuations to promote changes in the isotopic values of primary producers, impairing the interpretation of the ecological studies based on mixing models. We conclude that overlooking the plant basal sources isotopic variability introduces bias and causes misinterpretation of trophic interactions and the fate of blue carbon in estuarine systems.

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Blue carbon stocks of mangroves, salt marshes and seagrasses in Southwestern Atlantic Ocean

AUTHORS:
Joel C. Creed[1], Vinicius F. Patire[2], **Margareth Copertino**[3], Hilary Kennedy[4], Pere Masque[5], Ximena Ovando[6], Vanessa Hatje[2]

[1] Departamento de Ecologia, Universidade do Estado do Rio de Janeiro (UERJ), Brazil
[2] Centro Interdisciplinar de Energia e Ambiente & Instituto de Química, Universidade Federal da Bahia (UFBA), Brazil.
[3] Institute of Oceanography, Federal University of Rio Grande (FURG), Brazil doccoper@furg.br; marga.copertino@gmail.com
[4] School of Ocean Sciences, Bangor University, UK
[5] International Atomic Energy Agency, Monaco
[6] Departamento de Zoologia, Universidade Federal de Juiz de Fora (UFJF), Brazil

Southwestern Atlantic holds millions of hectares of blue carbon (BC) systems, dominated by mangrove, salt marshes and seagrass meadows. We reviewed, compiled, and estimated data on carbon (C) content and stocks for soil and plant biomass, and areal cover for mangroves, saltmarshes, and seagrass meadows along the Southwestern Atlantic coast. The studied region extends from the Orinoco River (09°N) to Tierra del Fuego (53.8°S), across 14 marine ecoregions (Spalding et al. 2007). We used a range of peer-reviewed articles, thesis, and grey literature (total of 147 studies), complemented by our unpublished data. We produced a data set of 503 georeferenced plots containing biomass and soil data. We estimated C stocks from soil cores (198 for mangroves; 293 for salt marsh; 104 cores for seagrasses) and plant biomass samples (146 for mangrove; 227 for salt marshes, 275 for seagrasses). The C stocks were upscaled by multiplying mean stocks (Mg C ha -1; biomass + soil) by the total area (M ha) occupied by each ecosystem. We found a high variability in C stocks among sites and ecoregions, possible related to regional climatic, hydrology, geomorphology, and soil pedogenesis. Total C stocks averaged ~330, 390 and 90 Mg C. ha-1 for mangroves, salt marshes and seagrass meadows, respectively. Below ground stocks (biomass + soil) represent 78 % (for mangroves) and more than 98% (for salt marshes and seagrasses) of total C stocks. Total ecosystem stocks for the Southwestern Atlantic region summed up 512, 57 and 12 Tg of C for mangroves, salt marshes and seagrasses, respectively. Brazil alone accounted for 62% of mangrove C stocks; Argentina accounted for almost 90% of salt marsh C stocks, while almost 100% of seagrass C stocks were within Brazil. Converting to CO2 equivalent, the total C reservoir of Southwestern Atlantic (~ 2 billion tons of CO2) correspond to 4 times the Brazilian yearly emissions estimated during last decade. Our study raised the profile of the Southwestern Atlantic regarding blue carbon global estimates and points out hot spots for conservation.

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Future research needs for Scottish blue carbon

AUTHOR:
Caitlin Cunningham

Sustainable Coasts & Seas, NatureScot – caitlin.cunningham@nature.scot

Marine and coastal habitats, such as saltmarsh or seagrass, can help mitigate and adapt to climate change impacts, including through the storage and sequestration of carbon. These habitats fall under the term ‘blue carbon’. But whilst there is extensive literature on the role terrestrial habitats have in sequestering carbon, blue carbon is an emerging area of research with prominent gaps in understanding (Macreadie, et al., 2019). Through a systematic review process, evidence gaps relating to Scottish blue carbon habitats have been identified. Research effort differs across habitats and regions, with large uncertainties associated with a lack of Scottish-specific carbon sequestration and storage rates, for both mature and restored habitats. Interactions between habitat disturbance and carbon storage and sequestration capacity were also highlighted as key evidence gaps.

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Modelling marine sedimentary carbon transport processes in a Scottish sea loch

AUTHORS:
Hanna J. Ewen[1], Tom Cowton and William E. N. Austin

School of Geography and Sustainable Development, University of St Andrews
[1] hje2@st-andrews.ac.uk

Marine sediments across the West coast of Scotland are important stores of carbon. Organic carbon-rich sediments, or carbon storage hotspots appear as patches across the Hebridean shelf and are not evenly distributed. Understanding the location and the processes governing the distribution of these carbon burial hotspots is important to furthering our knowledge of sources and sinks of marine sedimentary carbon, as well as determining possible threats to these carbon hotspots. To this end, Delft3D and Delft Dashboard were used to initiate an approach towards modelling the hydrodynamics in a Scottish sea loch and beyond across the Scottish Shelf, using a nested model system. Hydrodynamics play an important role in determining transport from source to sink in the marine environment and the initial model results will be used to develop further models to highlight processes that may govern marine sedimentary carbon distribution at the present day and explain the importance of terrestrial inputs and their cross-shelf transfers.

Scotland's national saltmarsh carbon stock: an assessment of the "missing" saltmarsh habitat

AUTHORS:
Rhiannon J. Grant[1] and William E.N. Austin[2]

School of Geography and Sustainable Development, University of St Andrews, St Andrews, United Kingdom
[1] rg208@st-andrews.ac.uk
[2] wena@st-andrews.ac.uk

The Global Climate Crisis has placed Blue Carbon ecosystems at the centre of many nature-based solutions to mitigate climate change. Haynes (2016) Scottish Saltmarsh Survey aimed to provide a detailed survey of the extent of saltmarsh habitat in Scotland. However, a minimum threshold of 3 ha resulted in the omission of saltmarshes from the national habitat inventory. This research presents the first investigation of unmapped saltmarsh under 3 ha in Scotland, assessing the significance of missing saltmarsh in Fife to national habitat extent and carbon stock. Seven sites were explored including newly discovered small-scale saltmarsh habitats and Haynes (2016) mapped saltmarshes. Vegetation surveying and area measurements revealed an additional 0.60 ha unmapped small-scale saltmarsh exists on the Fife coastline. Field observations show the potential for a greater distribution of small, unmapped saltmarshes to be explored on the west coast of Scotland. Upscaled estimates for Scotland suggest an additional 125.22 ha (2.1%) of unmapped saltmarsh is omitted from the national extent. Furthermore, first order carbon stock estimates of Scottish saltmarsh soils (Austin et al., 2021) indicate that unmapped saltmarsh in Fife (0.60 ha) *contribute* 35.41 t OC to the national surface (10cm) soil carbon stock. Findings from this research show that Haynes (2016) survey of saltmarsh habitat in Scotland is a reliable representation of saltmarsh extent, with a small amount of uncertainty regarding habitat area. Additionally, further research into unmapped saltmarsh habitat in other regions of Scotland is necessary to obtain a greater understanding of the national distribution of saltmarsh habitat under 3 ha and the possible contribution of unmapped saltmarsh habitats to the overall potential of these national carbon sinks.

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Increasing Scotland's Blue Carbon Stock by Creating More Saltmarsh Habitats Through Managed Realignment

AUTHORS:
Alex Houston[1], William Austin[1,2], Colin Scott[3], Jo Smith[4], Annette Burden[5], and Daniel Crockett[6]

1 School of Geography & Sustainable Development, University of St Andrews, St Andrews, UK ah383@st-andrews.ac.uk
2 Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll, UK
3 ABPmer, Quayside Suite, Medina Chambers, Town Quay, Southampton, SO14 2AQ
4 Institute of Biological and Environmental Science, University of Aberdeen, Aberdeen, UK.
5 Centre for Ecology and Hydrology, Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, UK.
6 Blue Marine Foundation, South Building, Somerset House, United Kingdom.

Scotland's coasts are increasingly vulnerable to rising sea levels and increased storm intensity caused by climate change, with £1.2 billion of assets at risk by 2050 on current sea level rise (SLR) trends[i]. Due to past greenhouse gas (GHG) emissions some SLR is certain, though the rate is dependent on how quickly these emissions are reduced1. Engineered coastal defences are becoming increasingly costly to repair and upgrade, so natural defences are considered a lower cost solution with additional benefits[ii].

Saltmarshes are carbon rich vegetated intertidal ecosystems. They support unique biodiversity and provide coastal protection from storms and floods, alongside other ecosystem services[iii]. Saltmarshes cover approximately 54.8 km^2 of Scotland's coast, but due to its largely developed nature, they are prevented from migrating inland with SLR and are therefore at risk of becoming drowned or eroded – this is termed 'coastal squeeze'[ii,iv].

Managed realignment (MR) creates new habitats through the removal of 'hard' engineering structures, such as sea walls, which were positioned to allow coastal development for uses such as agriculture4. By removing these barriers, the habitat can migrate landward. Managed realignment of saltmarshes is a common practice in England (less so in Scotland) for coastal protection and habitat replacement, but the benefits of carbon storage have not been a criterion for implementation so far[ii,iii]. Consideration of these blue carbon gains could allow for further investment in MR projects and their implementation in Scotland, improving coastal resilience and the potential for climate adaptation and mitigation[iii]. Due to a lack of funding and policy gaps, there are only four MR sites in Scotland[ii,v]. This project will use a literature review to assess the potential for saltmarsh habitat creation through MR to assess the potential to create additional stores of carbon and the impact of MR on surrounding areas under future sea-level rise scenarios.

BLUE CARBON POSTERS

- Climate change is causing increased rates of SLR and storm intensity in Scotland.
- Recreating old saltmarsh habitats using MR can improve coastal resilience and may help Scotland reach net zero GHG emissions.
- The closure of policy and knowledge gaps will aid the implementation of MR projects in Scotland.

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Sounding out the carbon: the potential of acoustic backscatter data to improve spatial predictions of organic carbon in marine sediments

AUTHORS:

Corallie A. Hunt[1], Urška Demšar[1], Ben Marchant[2], Dayton Dove[3] and William E. N. Austin[1,4]

[1] School of Geography & Sustainable Development, University of St Andrews, St Andrews, UK – cah24@st-andrews,ac,uk
[2] British Geological Survey, Nicker Hill, Keyworth, Nottinghamshire, UK
[3] British Geological Survey, The Lyell Centre, Research Avenue South, Edinburgh, UK
[4] SAMS, Scottish Marine Institute, Oban, Argyll, UK

Marine sediments hold vast amounts of organic carbon (OC). Carbon (C) is buried naturally within sediments and this process helps to regulate the climate by locking C away. However, disturbance of buried OC could present a significant feedback mechanism to atmospheric greenhouse gas concentrations. To improve our understanding of how much OC is stored in marine sediments, knowing where to look is a key factor. Techniques to map sedimentary OC in sediments must develop to help us identify carbon hotspots on the seabed.

The seabed is routinely mapped using acoustic multibeam echosounders (MBES) over extensive areas and at high resolutions. Sound reflected off the seabed, known as acoustic backscatter, can provide information about sediment type. Sediment type is also a critical factor in C storage.

In this study we explore the potential of acoustic backscatter to predict the spatial distribution of sedimentary OC in a dynamic coastal location on the east coast of Scotland. We took an archive MBES backscatter dataset and collected primary and secondary sediment samples to interpret the acoustic signal.

Despite relatively low sample numbers we found significant relationships between backscatter intensity, sediment type and OC. We estimated linear mixed models to spatially predict OC using backscatter and sediment type as the predictor variables. Our results show that although sediment type was the stronger predictor overall, including backscatter also improved the precision of the model to a similar degree.

Backscatter shows considerable promise as a high-resolution predictor variable to improve the precision of surface OC maps, particularly where is a lack of coverage of sediment data. Applications of such maps have potential to support the design of conservation and management tools that consider marine sediments as valuable C stores and improve sedimentary C stock estimates.

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From Land to Sea: Monitoring the carbon dynamics of Northern Ireland's aquatic environment

AUTHORS:

Billy Hunter, Adam Mellor, Christian Wilson, Alex Callaway, Jay Calvert and Matt Service

[1] Fisheries and Aquatic Ecosystems Branch, The Agri Food and BIosciences Institute, Belfast

Carbon represents the fundamental unit for energy transfer and an essential building block for all life. Understanding the dynamics of carbon transport and storage is essential to understand both how ecosystems function and their potential role in climate change mitigation. The assessment of carbon storage in aquatic environments as a climate change mitigation requires a system-scale approach taking account of potential impacts on key ecosystem services associated with fisheries, flood protection and maintenance of water quality.

The Agri-Food and Bioscience Institute are developing a multi-platform environmental observatory to monitor the carbon fluxes and storage potential across a range of aquatic systems, from agricultural practices, through first-order streams, to lakes, and ultimately out through rivers and estuaries to the surrounding shelf seas. This builds upon existing monitoring networks of high-frequency automated monitoring systems in inland waters and lakes, regular oceanographic survey, seabed mapping and characterisation campaigns, and the established long-term oceanographic mooring in the western Irish Sea. In parallel, AFBI are developing a framework for integrated catchment to coast modelling which includes bio-extractive modelling of filter-feeding species to help understand carbon flows from terrestrial to marine systems. These will be used to support the integration of carbon sequestration assessment into marine spatial planning decisions.

AFBI will deliver an instrumented living landscape across the region to provide high frequency data on carbon transport fluxes, assess carbon storage potential across Northern Ireland's freshwater and marine systems, and support the development of effective policies to mitigate the impacts of climate change. AFBI's network of environmental monitoring systems will provide an excellent model system to monitor how climate change will affect the biogeochemical cycling of carbon across the boundaries of terrestrial, freshwater and marine systems in the northern temperate zone.

Beneath the surface: Insights in to the vertical and lateral movements of carbon and iron in a mid-latitude fjord

AUTHORS:
Celeste Kellock[1], Craig Smeaton[2], Nadeem Shah[3] and Christian Schröder[1]

[1] Department of Biological and Environmental Sciences, University of Stirling, Stirling, Scotland, UK.- celeste.kellock@stir.ac.uk
[2] School of Geography and Sustainable Development, University of St. Andrews, Fife, Scotland, UK
[3] Forest Research, Northern Research Station, Midlothian, Scotland, UK

Blue carbon is perhaps best known for the vegetation and organisms that play a crucial role in sequestering and storing carbon in our coastal and marine regions. We delve below the colourful habitats at the seafloor and investigate what lies beneath. Sediments in fjord environments have been identified as extremely effective carbon stores[i] with their ability to store carbon from both marine and terrestrial environments. Coastal carbon burial has been found to exceed that of the terrestrial environment.

Mineral binding can influence the transport and burial of organic carbon (OC) in sediments[ii], as such we investigate the biogeochemical cycling of OC and iron in Loch Creran, a mid-latitude fjord found on the West coast of Scotland.

Our results highlight the differing sources of OC and iron stored in this fjord environment and we observe decreases in OC from the head to the mouth of the fjord which is influenced by the changing input of terrestrial material. OC is up to three times higher in the inner basin of Loch Creran with a significantly higher proportion (~20%) of this material originating from terrestrial sources in comparison to the lower basin. The strength of the reactive iron signal is found in the cores vary vertically (with depth and time) and laterally (from upper – lower basin) within the fjord. Understanding the biogeochemical processes which enables material to reach the sediments and be incorporated into the long-term OC stock is necessary if we are to protect, enhance or try to utilize these environments to mitigate negative effects of the Global Climate Emergency.

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Balancing the equation: 'Blue carbon' and the native European oyster (*Ostrea edulis*)

AUTHORS:
Hannah Lee[1], Karen Diele[2], Ian Davies[3], John Baxter[1], Alexander Robertson-Jones[1] and William Sanderson[1]

[1] Centre for Marine Biodiversity and Biotechnology, ILES, EGIS, Heriot-Watt University, Edinburgh, UK hzl1@hw.ac.uk
[2] School of Applied Sciences, Edinburgh Napier University, Edinburgh, UK
[3] Marine Scotland Science, Aberdeen, UK

Four overlapping rows of a mix of small and large European native oysters with brown and cream shells

As blue carbon research has gained momentum, carbon storage in habitats formed by primary producers, such as seagrasses, mangroves and saltmarshes received initial attention. In recent years focus has broadened towards the role that non-vegetated habitats, such as bivalve beds and sediments play in the carbon cycle. Net carbon accretion occurs when carbon gain outweighs carbon loss. In the case of bivalve beds, carbon gain occurs through shell accretion, active deposition (biodeposition) and passive deposition (the influence of bed structure on deposition of particulate material from the water column), leading to material becoming integrated into the bivalve bed matrix. Meanwhile, release of carbon occurs through respiration and during the process of calcification. These processes underpin a net carbon equation, allowing the annual carbon cycling associated with the living bivalve to be estimated. Here we present measures of carbon deposition associated with the feeding activities of *Ostrea edulis* (Lee et al. 2020) balanced with measures of shell accretion and carbon loss through respiration and calcification. This is the first time that all three factors are considered jointly, in the context of environmental restoration and potential climate change mitigation. In the present study, work towards this more complete understanding of the carbon budget of restored *Ostrea edulis* beds is reported, and the results are discussed within the context of protecting and restoring degraded ecosystems and valuing the business models that support environmental restoration.

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Scotland's national saltmarsh carbon stocks: an assessment of organic carbon burial rates

AUTHORS:
Lucy Miller[1], Craig Smeaton[1], Angus Garbutt[2], William Austin[1,3]

[1] School of Geography and Sustainable Development, University of St Andrews, UK lm283@st-andrews.ac.uk
[2] UK Centre for Ecology & Hydrology, Bangor, UK
[3] Scottish Association for Marine Science, Scottish Marine Institute, Oban, UK

Scotland's saltmarshes bury and store organic carbon (OC) for extensive periods of time, and thus, could potentially contribute as a natural solution to combat climate change. Recent studies have calculated that the top 10cm of Scottish saltmarshes hold approximately 367,888 ffl 102,278 tonnes of OC[i]. Despite this new understanding of the surficial OC stock, the rate at which OC is buried is largely unknown. This study focusses on 10 contrasting saltmarshes around Scotland and presents an in-depth analysis of their total organic carbon (TOC) stocks and burial rates. Chronology data (provided by radioisotope analysis) provides information on the age of saltmarsh soils, as well as OC accumulation rates. Additionally, stable isotope analysis (δ13C and δ15N) allows improved understanding of carbon sources. Sediment carbon analysis, sediment descriptions and vegetation surveys were used to generate TOC stocks for each saltmarsh. The results showed that between 8,253 and 91,028 tonnes of OC is stored in these contrasting saltmarshes and OC burial rates range between 29.1 and 142.5 gC/m2/yr. This work highlights the role that saltmarshes play as a natural component in coastal climate mitigation and their wider significance as blue carbon environments contributing to Scotland's natural capital.

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How about a Blue Carbon Project in Nigeria?

AUTHOR:
Nwobi, C.J

School of GeoSciences, University of Edinburgh – ebuka.nwobi@ed.ac.uk

The global realization of blue carbon ecosystems as a viable strategy in climate change mitigation has stirred interests in conservation, research and restoration. Mangrove forests in West Africa contain about 14% of the world's mangroves (Bryan et al., 2020), but remains the most understudied. Mangrove forests in Nigeria is the fifth largest in the world (Bunting et al., 2018) but over the past 5 decades, since the inception of oil exploration, mangrove forests have been in steady decline. In recent times, the Niger Delta has lost about 12% of mangrove cover between 2007 and 2017 (Nwobi et al., 2020) resulting in increased nipa invasion within the region because of mangrove wood exploitation (Nwobi and Williams, 2021). The Nigerian environment ministry has proposed the creation of Marine Protected Areas in the Niger Delta mangroves for their conservation. This effort also includes community led seedling planting. Here, I propose the creation of a Blue Carbon Demonstration Project in Nigeria. A study in 2019 showed that despite deforestation and degradation occurring in Nigerian mangroves, there are regrowths occurring in some regions (Nwobi, 2019). Protected areas are important means of conservation only if they are "protected". The incorporation of research and community-led conservation is vital to the either success of a Blue Carbon Project (The Commonwealth Blue Charter, 2020) or Marine Protected Areas. This demonstration project will incorporate aspects of continued combined research in Nigeria, already ongoing community-led conservation in the region and aspects of sustainable use of mangrove resources. Research will involve the use of both fieldwork and remote sensing to explore regions with opportunities for protection and restoration. Results from research will then feed into targeted plans for seedling planting, restoration and direct policy making for sustainable wood harvesting and incorporating mangrove preservation in developmental projects.

BLUE CARBON PROJECT NIGERIA

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Nature-based Solutions for Climate Change Mitigation: Using a Choice Experiment Approach to Assess the Potential of Scottish Saltmarshes for Climate Change Mitigation Policy

AUTHORS:
Riegel, S.[1], Kuhfuss, L.[2], Stojanovic, T.A.[1,3] and Austin, W.E.N.A[1,4]

[1] University of St Andrews, School of Geography and Sustainable Development – sr216@st-andrews.ac.uk
[2] The James Hutton Institute (JHI)
[3] The Scottish Oceans Institute (SOI)
[4] The Scottish Association for Marine Science (SAMS)

The carbon storage potential of saltmarshes has recently gained interest in the policy arena. Yet, we know little about the economic value of this carbon resource in Scotland and the social acceptability of implementing measures for its successful management. This poster investigates how the Scottish population values saltmarsh ecosystem services with a focus on the carbon storage service; and, how these values translate in terms of recommendations for best policy interventions. It aims to contribute to enabling a full realisation of saltmarshes' potential in climate change mitigation strategies. We used a choice experiment to value saltmarsh ecosystem services by asking a representative sample of 620 members of the Scottish general public their willingness to pay to support interventions that would maintain or improve the provision of these services. A split sample approach was used to measure the effect of information on willingness to pay: half of the sample was randomly allocated to a treated group receiving additional information on the role of saltmarshes in carbon storage. Both groups had, on average, a positive marginal willingness to pay for all ecosystem services presented in the survey: carbon storage, supporting biodiversity, recreation and flood defence. We found that, against our expectations, the treated group had, on average, no significantly different marginal willingness to pay for carbon storage than the control group. The presented study will add to the limited literature on the saltmarsh carbon ecosystem service. Only few studies have considered carbon storage potential in saltmarsh ecosystem services valuations. Yet, these valuations can provide important information to policymakers regarding the acceptability of future habitat management and climate change mitigation policies. Our results demonstrate the Scottish public's openness to realise the potential of nature-based climate change mitigation solutions. Consequently, there is a remit to include considerations of carbon storage in future saltmarsh management policies.

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How we can map seabed habitats using big data and machine learning

AUTHORS:
Robert J Wilson, Ana M Queirós

Plymouth Marine Laboratory – rwi@pml.ac.ukk

Advances in big data, machine learning and ocean modelling are revolutionizing how we can map the seabed and blue carbon. We can now use machine learning to predict how rocky, muddy, sandy or gravelly the seabed is with high and constantly improving accuracy. In this talk, we will show how machine learning can be used to map these variables across the United Kingdom's waters using a leading-edge gradient boosting algorithm, catboost. The catboost models were trained using diverse environmental predictors, including high-resolution bathymetry, ocean models of wave and tide conditions, and water clarity data from satellites, with historical seabed substrate data taken from the British Geological Survey and EMODnet. Using a rigorous cross-validation method, we show that this approach produces credible maps across UK waters. We conclude by discussing how these maps can be used in mapping sedimentary carbon stores and species critical to carbon sequestration such as kelp.

How strong are blue carbon negative feedbacks on climate change following glacier retreat in West Antarctic fjords?

AUTHORS:

Nadescha Zwerschke[1*], Chester J. Sands[1], Alejandro Roman-Gonzalez[2], David K. A. Barnes[1], Alice Guzzi[3,4], Stuart Jenkins[5], Carlos Muñoz-Ramírez[6], James Scourse[2]

1. British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK
*nzwerschke01@qub.ac.uk
2. Exeter University, Treliever Road, Penryn, Cornwall, TR10 9FE, UK
3. Department of Physical Sciences, Earth and Environment (DSFTA), University of Siena, PO Box 53100, Siena, Italy
4. Italian National Antarctic Museum (MNA, Section of Genoa), Genoa, Italy
5. Bangor University, School of Ocean Sciences, Bangor, Gwynedd, LL57 2DG, UK
6. Instituto de Entomología, Universidad Metropolitana de Ciencias de la Educación, Santiago, Chile.

Climate change-forced warming is driving significant losses of marine ice around the polar regions. Around Antarctica, the retreat of tidewater glaciers is opening up novel, low energy habitats (fjords). These work as moderate, negative (mitigating) feedbacks on climate change. The new fjord habitats are being colonised by organisms on and within the sediment and act as a sink for particulate matter. So far, blue carbon potential in Antarctic habitats has mainly been estimated using epifaunal mega and. We investigated two further pathways of carbon storage and potential sequestration by measuring the magnitude of carbon of infaunal macrozoobenthos and total organic carbon deposited in the sediment. We took samples along a temporal gradient since time of last glacier ice cover (1-1000+ years) at three fjords along the West Antarctic Peninsula. We tested the hypothesis that seabed carbon standing stock would be mainly driven by time since last glacier covered. However, results showed this to be much more complex. Infauna were highly variable over this temporal gradient and showed similar total mass of carbon standing stock per m^2 as literature estimates of Antarctic epifauna. Total organic carbon mass in the sediment, however, was an order of magnitude greater than stocks of infaunal and epifaunal carbon and increased with time since last ice cover. Thus, blue carbon stocks and recent gains around Antarctica are likely much higher than previously estimated as is their negative feedback on climate change.

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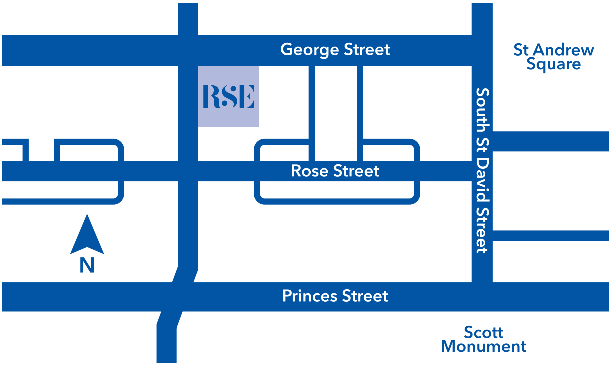

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