NUTS&BOLTS Annual Report 2023

Importance of Physico-Chemical cycling of nutrients and carbon in Marine Transitional Zones (NUTS&BOLTS)

Project PI: Peter Croot

1. Ongoing activities, in line with the IMBeR Grand and Innovation Challenges

(Among other uses, information will be used to update the IMBeR Annual Report to SCOR)

The NUTS&BOLTS project received IMBER endorsement in August 2020 and this is the 3rd report to the SSC since endorsement. This report covers the period May 2022 – Feb 2023. The project recently received a no cost extension for one year and will now end on January 31, 2024. Final field work was carried out in late 2022 and the focus since then has been on completing laboratory analyses and writing up the final report for the funding agencies. In October 2022 we acquired a SEAL AA500 nutrient analysis system, funded by Science Foundation Ireland, as part of the SFI Research Centre iCRAG (Irish Centre for Research in Applied Geoscience). This equipment has allowed us to further develop our capacities in nutrient analysis with direct benefit to work in NUTS&BOLTS.

1.a. Grand Challenge I

Understanding and quantifying the state and variability of marine ecosystems - with focus on Research Objectives 1 to 3:

***Research Objective 1**. Evaluate and predict the cumulative effect of multiple stressors*
***Research Objective 2**. Integration of climate change and climate variability*
***Research Objective 3**. Impacts on society – preparation for a changed future*

A central theme of NUTS&BOLTS is to evaluate the impact of multiple stressors on Irish marine transitional zones (MTZs). In this context we have been carrying out field sampling in 3 MTZ systems along the Irish west coast, a planned 4th site on the East coast had to be skipped due to logistical issues caused by the global pandemic. The NUTS&BOLTS project includes measurements for hydrography (temperature and salinity), nutrients, bio-optics (CDOM/FDOM) and trace metals, inclusion of these parameters allows for examination of the potential role of global warming, ocean acidification, deoxygenation, eutrophication, coastal darkening and sea level rise on ecosystem function at these locations.

1.b. Grand Challenge II

Improving scenarios, predictions and projections of future ocean-human systems at multiple scales - with focus on Research Objectives 4 to 6:

***Research Objective 4**. Development of integrated data systems and approaches for predictions and projections*
***Research Objective 5**. Development of predictive models and projections for use at regional scales*

***Research Objective 6**. Development of alternative scenarios to bridge the gap between physical climate sciences and humanities*

As noted in the previous report, a critical knowledge gap that was identified prior to the initiation of the NUTS&BOLTS project was the absence of an integrated data system for Ireland, coupled with a lack of predictive models for Irish MTZs incorporating any biogeochemical, bio-optical or ecosystem functionality. NUTS&BOLTS isn't a modelling project in itself but it is looking to provide baseline date to help develop predictive models going forward. In this respective we have had initial discussions with the Marine Institute in Ireland regards modelling of our three study sites and the Celtic Sea. In particular there is interest in supporting ongoing modelling efforts for Kinvarra Bay. Additionally the Marine Institute funded project COIR (Changing Ocean Ireland) which began in Oct 2021, lead PI (Prof. Croot), is examining future climate scenarios and their potential impact on fisheries. Ongoing discussions continue with the Marine Institute regards hosting NUTS&BOLTS data, as our data was being used a test case for the Marine Institute database, however this has stalled recently due to changes in personnel at the Marine Institute and over the issue of making the data and metadata easily discoverable.

1.c. Grand Challenge III

Improving and achieving sustainable ocean governance - with focus on Research Objectives 7 to 9:

***Research Objective 7**. Develop knowledge on best practices for multilevel governance approaches to ocean climate adaptation and mitigation*
***Research Objective 8**. Develop understanding on key ingredients for transformation towards more sustainable, equitable and inclusive governance approaches to fisheries and aquaculture*
***Research Objective 9**. Support implementation of post-2020 biodiversity targets for marine spatial planning and marine protected areas*

NUTS&BOLTS work is targeted towards supporting evidence based policy making decisions with regard to management of Irish MTZs and compliance with the EU MSFD and WFD. Our work will also support planning for new MPAs in Irish waters as part of UN SDG 14.

1.d. Innovation Challenge 3

To advance understanding of ecological feedbacks in the Earth System

NUTS&BOLTS research is examining ecological feedbacks in the MTZs where we are working and endeavouring to develop an initial conceptual framework that can be in the future more thoroughly assessed for inventories and fluxes and future scenarios examined in regional climate models.

1.e. Innovation Challenge 4

To advance and improve the use of social science data for ocean management, decision making and policy development

The NUTS&BOLTS project currently has only a small interaction with social scientists but this has been developing recently through cooperation with COIR and iCRAG. As mentioned in the previous report we are in contact with the Future Earth Ireland committee, through links with the Royal Irish Academy (RIA), and as described above hosted a public talk with them in October 2022.

1.f. Innovation Challenge 5

Interventions to change the course of climate impacts

NUTS&BOLTS researchers, along with other researchers at the University of Galway, have been involved over the past year in conversations with commercial enterprises that are exploring geo-engineering or ecosystem rehabilitation projects mostly involving seagrasses or seaweeds in the context of carbon removal in the coastal and open ocean. To date no formal collaborations have been initiated. It is also noted that globally there are several studies now underway into alkalinization of the coastal marine zone, we are aware of potentially similar plans for pilot studies in Ireland that data from NUTS&BOLTS would help to inform.

1.g. Innovation Challenge 6

Sustainable management of Blue Carbon ecosystems

Synthesis of the data collected in NUTS&BOLTS is providing new information for the assessment and sustainable management of Irish Blue Carbon Ecosystems. In this context, a new PhD project (PI Croot) within the SFI Research Centre iCRAG builds on work performed in NUTS&BOLTS and will focus on primary productivity in Irish waters. The focus in this new project is to constrain estimates of phytoplankton productivity using a suite of primary productivity measurements. Also as noted in the last report, NUTS&BOLTS PI's, Stengel and Cave are now working in the BlueC research team funded by the Marine Institutes 2021 Blue Carbon Call, a project focused on the carbon storage capacity of saltmarsh and seagrass meadows around Ireland.

2. Selected highlights

2.a. Selected scientific highlights since last report (1-5)

Last report was submitted to SSC meeting, August 2022

During the reporting period, we continued to carry out field sampling and laboratory work, with almost all covid pandemic restrictions lifted.

• Analysis of nutrient and CDOM/FDOM samples from Lough Furnace, an ecologically important tidal lagoon with low oxygen in the deep waters, indicates that the community of green photosynthetic bacteria detected there previously inhabit a saline environment enriched in phosphate and silicate. Nitrogen speciation in the deep waters is dominated by ammonia. The overlying fresh waters are humic rich and while there is considerable organic carbon in the seawater zone it is clearer than the overlying freshwater.

• Continued field sampling in Kinvarra Bay (Galway Bay) was carried out during the reporting period. A further large bloom of dinoflagellates was also found in July 2022 (similar to that seen in Sept 2021). We were able to isolate cultures of some of the phytoplankton found in the bloom, including what appears to be a phycocyanin containing Synechococcus sp, which we had not previously detected due to its low chlorophyll content.

2.b. Publications since last report

Please add all publications since last report to the table below (see notes for details on "Class" and "Activity" fields).

***Publication** with DOI*	***Class 1, 2, 3***	***Activity****
Azcárate-García, T., Beca-Carretero, P., Cara, C.L., Villamayor, B., Cosnett, E., Bermejo, R., Hernández, I., Brun, F.G., Stengel, D.B., 2022. Seasonal plant development and meadow structure of Irish and southern Spanish seagrass populations. Aquatic Botany 183, 103569.	*3*	*This paper is an outcome of preliminary work informing NUTS&BOLTS.*
Simonella, L.E., Cosentino, N.J., Montes, M.L., Croot, P.L., Palomeque, M.E., Gaiero, D.M., 2022. Low source-inherited iron solubility limits fertilization potential	*3*	*This is a collaboration with researchers in*

of South American dust. Geochimica et Cosmochimica Acta 335, 272-283.		*Argentina on atmospheric inputs to ecosystems.*
Stipcich, P., Pansini, A., Beca-Carretero, P., Stengel, D.B., Ceccherelli, G., 2022. Field thermo acclimation increases the resilience of Posidonia oceanica seedlings to marine heat waves. Marine Pollution Bulletin 184, 114230.	*3*	*This is a collaboration with Italian and Spanish researchers examining the impact of marine heatwaves on seagrasses.*
Xu, H., Croot, P., Zhang, C., 2022. Exploration of the spatially varying relationships between lead and aluminium concentrations in the topsoil of northern half of Ireland using Geographically Weighted Pearson Correlation Coefficient. Geoderma 409, 115640.	*3*	*This work is an application of machine learning to geochemical datasets and forms an entry point for the data collected in NUTS&BOLTS.*
Zanolla, M., Romanazzi, D., Svenson, J., Sherwood, A., Stengel, D.B., 2022. Bromoform, mycosporine-like amino acids and phycobiliprotein content and stability in Asparagopsis armata during long-term indoor cultivation. Journal of Applied Phycology 34, 1635-1647.	*3*	*This paper presents results from a study on the Valorisation potential of invasive seaweed species in Ireland.*

**If appropriate, please list the IMBeR activity through / by / from / during which the publication arose*

*******Notes on publications********

Publications are logged in the IMBeR Zotero library which is publicly accessible online –

Publications since 2016 | Publications prior to 2016

Publications are categorised by "Class" and linked to "Activities":

Class 1 publications are specifically generated through/by/from/during ***IMBeR activities*** - for example, arising from IMBIZOs and IMBeR conferences such as the IMBeR open science meeting and the IMBeR West Pacific symposia and from the activities of the working groups, regional programmes and the SPIS scoping teams.

Class 2 publications are on topics relevant to the IMBeR Science Plan that benefitted from some interaction with IMBeR or ***IMBeR activities***, for example by IMBeR symposium attendees, past and present SSC members, working group, regional programme and endorsed project members, or national contacts.

Class 3 publications are on topics relevant to the IMBeR Science Plan but for which there is no direct link to or benefit from an IMBeR activity. These might include publications by SSC members, working group, regional programme or endorsed project members or members of the IMBeR international

community that were written as part of the normal scientific activity of the authors and would have occurred irrespective of IMBeR's existence. You can report Class 3 publications, but they will no longer be logged in the IMBeR database.

[See "What is an IMBeR publication?" for further information]

Why list 'Class' and 'Activity'? This helps us to declare authentically which publications IMBeR has helped to generate, and it makes it easier for us to demonstrate the value of the Regional Programmes, the Working Groups, and IMBeR in general, and it helps us to justify support for IMBeR activities when we can list tangible outputs.

2.c. Events, Meetings, and Workshops

List all international and national events, meetings and workshops. Describe the level of participation: e.g. chairing session/workshop, organising meeting. Include Endorsed Projects committee meetings and workshops.

Format: Title of event. Date. Location. Description of participation. Any other pertinent details.

The NUTS&BOLTS external advisory board/committee meet twice virtually with the project team over the last year. The funding agency (EPA) has no plans to return to in-person meetings at present.

During the reporting period, Prof Croot gave two public lectures on the data/policy/governance interface for marine systems using data from NUTS&BOLTS, and other studies, as test case examples.

"Marine data to inform policy" 12th Annual Marine Economics and Policy Research Symposium, Marine Institute, Galway, Ireland (6 Dec 2022).

"Science communication in the framework of the UN Decade of Ocean Science for Sustainable Development " iCRAG2022, Croke Park, Dublin, Ireland (1 Dec 2022).

Prof. Croot also attended the UN Ocean Conference in July 2022 in Lisbon, Portugal as a representative of the National University of Ireland Galway (now University of Galway).

3. International collaboration and links

The SAPHIRE project, which focuses on monitoring of elemental fluxes from Irish rivers draining peatbogs began in June 2022 and is in collaboration with colleagues at Ohio State University and Queens University in Belfast. This project is lead by Tiernan Henry of NUTS&BOLTS and is funded by SFI in the Republic of Ireland, NSF (USA), and DfE (UK).

In October 2022 we hosted a public seminar at the University of Galway, by Prof. Karen Wiltshire, vice-director of the Alfred, Wegener Institute (AWI) in Germany, entitled 'Coastal seas in the fast lane of climate change: Resilience and adaptation for a sustainable future.' This lecture was the third in the series of Royal Irish Academy Sustainability Series.

4. Education, outreach and Capacity Development

During the reporting period we rolled out NUTS&BOLTS activities in 7 local schools in Q4 2022, this was facilitated by scientific educator, Benny Joyce, and this will continue in Q1 2023. An example of this type of outreach work can be found online at https://cloonliffen.com/2022/12/14/science-workshop/ where Benny worked with local school children in making secchi disks. In this context, the scope and range of activities for schools is continually being assessed and evaluated and will be included into the final report to the EPA.

In September 2022, PI Croot participated in PS132 onboard the Polarstern from Bremerhaven to Cape Town as part of the onboard teaching team for the AWI/POGO/NF programme training international students at sea.

5. Changes to Organisational Structure and/or funding sources

As noted above a one year no cost extension to the project was granted in 2022 and the project will now finish in Jan 2024.

6. Appendices

Add appropriate meeting / workshop reports and include URLs (this helps to track where online content is missing)

Latest details on the project can be found either via twitter @riverflux2sea and at the project website http://nutsandboltsproject.ie/