NUTS&BOLTS Annual Report 2022

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

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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 so this is the 2nd report to the SSC since endorsement. This report covers the period May 2021 – April 2022.

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*

One of the main themes of the NUTS&BOLTS project 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 4th site on the East coast had not been sampled as yet 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*

A critical knowledge gap that was identified in the lead up to the start of the NUTS&BOLTS project was that there was no integrated data system for Ireland and also that the predictive models available for Irish MTZs currently lack biogeochemistry or ecosystem functionality. While it is not the direct focus of NUTS&BOLTS to develop predictive models at this time, it is hoped that the acquisition

of data on key parameters will help to enable such models in cooperation with the Marine Institute or other agencies/institutions. A new Marine Institute funded project COIR (Changing Ocean Ireland) started in Oct 2021, lead PI (Prof. Croot), will examine future climate scenarios and their potential impact on fisheries. Currently NUTS&BOLTS is being used a test case for the Marine Institute database to develop a pipeline with QA/QC checks and appropriate metadata for upload onto their database for Ireland.

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 is likely to increase over time through future cooperation with COIR and iCRAG (Irish Centre for Research in Applied Geoscience). We have been in contact with Future Earth Ireland committee, which is hosted by the Royal Irish Academy (RIA), however at present their focus has been on social science aspects, with no links to either IMBER or SOLAS, furthermore they are currently transitioning to a new committee and focus so we look to link with them more once they have established how they will be working in the future.

1.f. Innovation Challenge 5

Interventions to change the course of climate impacts

NUTS&BOLTS as a project is not a vehicle by itself for intervention to change the course of climate impacts but we can see that the data gathered could help to inform simulations of potential interventions within the MTZs we are studying. Going forward in NUTS&BOLTS, it would be helpful to have more information on potential actions for this challenge as the online information was very broad and hard to relate to specific project actions that could aid decision making around any potential adaptation-focused interventions (See also the comment in section 10 below).

1.g. Innovation Challenge 6

Sustainable management of Blue Carbon ecosystems

Our current work in NUTS&BOLTS is providing new data for assessment and sustainable management of Irish Blue Carbon Ecosystems. In this context, two of the NUTS&BOLTS PI's (Stengel and Cave) are part of the BlueC research team funded by the Marine Institutes 2021 Blue Carbon Call. This project is 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, May/June 2021

During the reporting period, the global covid19 pandemic did impact some of the initial planned activities of NUTS&BOLTS, however with the easing of restrictions in Ireland we were able to carry out a considerable portion of the field sampling and laboratory work.

• Continued sampling of Lough Furnace, an ecologically important tidal lagoon with low oxygen in the deep waters, indicates the likely presence year round of a community of green photosynthetic bacteria based on the detected bacteriochlorophyll pigments found there.

• Field sampling was repeated in the Shannon estuary in September 2021, where we were able to collect an initial set of samples from 4 stations for the radium quartet (^{223}Ra, ^{224}Ra, ^{226}Ra and ^{228}Ra). Preliminary data indicated much higher activities than was initially expected based on previous work along the coast of Ireland. Further nutrient and trace metal data, along with bio-optical parameters including hyperspectral downwelling measurements were also collected at this time.

• Near Monthly field sampling in Kinvarra Bay (Galway Bay) with further dilution grazing rate experiments have been performed at this site along with the collection of more hyperspectral data. A large bloom of dinoflagellates was detected in Sept 2021 and valuable data on the conditions before and during this bloom were obtained.

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****
Lyons, W.B., Carey, A.E., Gardner, C.B., Welch, S.A., Smith, D.F., Szynkiewicz, A., Diaz, M.A., Croot, P., Henry, T., Flynn, R., 2021. The geochemistry of Irish rivers. Journal of Hydrology: Regional Studies 37, 100881.	*3*	*This paper resulted from preliminary work informing NUTS&BOLTS.*
Schmid, M., Guihéneuf, F., Nitschke, U., Stengel, D.B., 2021. Acclimation potential and biochemical response of four temperate macroalgae to light and future seasonal temperature scenarios. Algal Research 54, 102190.	*3*	*This publication was a result of a collaboration with German colleagues.*
Baker, A.R., Kanakidou, M., Nenes, A., Myriokefalitakis, S., Croot, P.L., Duce, R.A., Gao, Y., Guieu, C., Ito, A., Jickells, T.D., Mahowald, N.M., Middag, R., Perron, M.M.G., Sarin, M.M., Shelley, R., Turner, D.R., 2021. Changing atmospheric acidity	*3*	*This paper arose from a GESAMP meeting connected to SOLAS activities.*

as a modulator of nutrient deposition and ocean biogeochemistry. Science Advances 7, eabd8800.		
Xu, H., Croot, P., Zhang, C., 2021. Discovering hidden spatial patterns and their associations with controlling factors for potentially toxic elements in topsoil using hot spot analysis and K-means clustering analysis. Environment International 151, 106456.	*3*	*This work applies machine learning to geochemical datasets and is a precursor to related work to be performed in this project.*
Jordan, C., Cusack, C., Tomlinson, M.C., Meredith, A., McGeady, R., Salas, R., Gregory, C., Croot, P.L., 2021. Using the Red Band Difference Algorithm to Detect and Monitor a Karenia spp. Bloom Off the South Coast of Ireland, June 2019. Frontiers in Marine Science 8.	*3*	*This paper is connected to activities in a related remote sensing project.*
Hanna, G.S., Choo, Y.-M., Harbit, R., Paeth, H., Wilde, S., Mackle, J., Verga, J.-U., Wolf, B.J., Thomas, O.P., Croot, P., Cray, J., Thomas, C., Li, L.-Z., Hardiman, G., Hu, J.-F., Wang, X., Patel, D., Schinazi, R.F., O'Keefe, B.R., Hamann, M.T., 2021. Contemporary Approaches to the Discovery and Development of Broad-Spectrum Natural Product Prototypes for the Control of Coronaviruses. Journal of Natural Products.	*3*	*This review arose from a new collaboration between researchers in the US, UK and Ireland.*
Ramon, D., Morick, D., Croot, P., Berzak, R., Scheinin, A., Tchernov, D., Davidovich, N., Britzi, M., 2021. A survey of arsenic, mercury, cadmium, and lead residues in seafood (fish, crustaceans, and cephalopods) from the south-eastern Mediterranean Sea. Journal of Food Science 86, 1153-1161.	*3*	*This is an outcome of a collaboration with Israeli researchers initiated through the POGO-NF network.*
Beca-Carretero, P., Azcárate-García, T., Julia-Miralles, M., Stanschewski, C.S., Guihéneuf, F., Stengel, D.B., 2021. Seasonal Acclimation Modulates the Impacts of Simulated Warming and Light Reduction on Temperate Seagrass Productivity and Biochemical Composition. Frontiers in Marine Science 8.	*3*	*This paper resulted from preliminary work informing NUTS&BOLTS.*
Schoenrock, K.M., O'Callaghan, R., O'Callaghan, T., O'Connor, A., Stengel, D.B., 2021. An ecological baseline for Laminaria hyperborea forests in western Ireland. Limnol. Oceanogr. 66, 3439-3454.	*3*	*This paper resulted from preliminary work informing NUTS&BOLTS.*
Figueroa, F.L., Bonomi-Barufi, J., Celis-Plá, P.S.M., Nitschke, U., Arenas, F., Connan, S., Abreu, M.H., Malta, E.-J., Conde-Álvarez, R., Chow, F., Mata, M.T., Meyerhoff, O., Robledo, D., Stengel, D.B., 2020. Short-term effects of increased CO2, nitrate and temperature on photosynthetic activity in Ulva rigida (Chlorophyta) estimated by different pulse amplitude modulated fluorometers and oxygen evolution. Journal of Experimental Botany 72, 491-509.	*3*	*This is an outcome of a collaboration with Spanish researchers.*

**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 2019 | Publications prior to 2019

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.

Unfortunately due to the global pandemic NUTS&BOLTS team members were, like everyone else, constrained to mostly online meetings during 2021. Full project meetings were held online bimonthly during 2021 with the lab and field working group meeting fortnightly to discuss developments and options for lab and fieldwork activities. The NUTS&BOLTS external advisory board/committee meet twice virtually with the project team over the last year.

Prof. Croot attended the virtual 2021 International SCOR meeting as the Irish SCOR national delegate.

3. Input to management, policy and SOCIETY* over the last year

Add anything that is not covered under "1.c. Grand Challenge III"

**As previous reporting forms requested 'input to management and policy' only, please add any 'input to society' not captured in previous reports*

We are in the early stages of being able to feed into management and policy within Ireland and the EU, and are establishing good networking links with the relevant agencies.

4. 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/