Foras na Mara
Marine Institute

Cullen Scholarship: Spatio-temporal dynamics and controls of the carbonate system in Irish coastal and shelf waters

(PhD Award)

Background

Annual carbon dioxide emissions due to fossil fuel use and cement production are approximately 9.6 GtC yr^{-1} (Friedlingstein *et al*. 2020). The ocean is a CO_2 sink, removing about a quarter to a third of these emissions from the atmosphere, thus providing an important climate regulation service (Watson *et al* 2020, Gruber *et al* 2019). However, a consequence of drawdown of CO_2 by the ocean is rapid acidification with the surface ocean having acidified by approximately 25% since the start of the industrial revolution. The potential impacts of ocean acidification, along with warming and other stressors on marine ecosystems is an area of intense research.

The uptake of CO_2 from the atmosphere to ocean is spatially and temporally variable with temperature and mixing processes important drivers. Temperate shelf and coastal seas play a disproportionally important role in carbon drawdown, but in these areas carbonate system dynamics are considerably more complex and less well understood, with local physical, chemical and biological processes such as seasonal productivity and calcification mediating drawdown (Bauer *et al*. 2013, Hartman *et al*. 2018, Kitidis *et al*. 2019, Carstensen & Duarte 2019). Boundary carbon exchanges, i.e. ocean-shelf export, riverine inputs and water column – sediment exchanges, are poorly constrained i.e. (Sharples *et al.* 2019).

Over recent years a significant carbonate system dataset has been collected in Irish waters using a variety of platforms and some of this is now available in national and international databases such as SOCAT, GLODAP and ICES DOME. While ocean waters in the deep Rockall Trough to the west of Ireland are acidifying at rates similar to other ocean locations (McGrath *et al*. 2012, 2013), greater spatio-temporal variability is evident for Irish coastal waters with, for example, riverine inputs of inorganic carbon and alkalinity related to river-basin geology influencing coastal carbonate system locally, (McGrath *et al*. 2015, 2019).

Irish data generated over the last decade includes: underway atmospheric and surface water pCO_2 measurements on board the RVs *Celtic Explorer* and *Celtic Voyager* (General Oceanics 8050); a time series of vessel-based bottle sampling of Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA); and recently continuous sensor (pCO2, pH) and bottle data (DIC, TA) at fixed-point observatories , notably at Mace Head, County Galway, proximate to the WMO Global Atmosphere Watch Station, and at the SmartBay Observatory in Galway Bay. Additional pCO_2 and pH sensors are proposed for deployment at additional locations. This infrastructure and recent carbonate and other physical and biogeochemical data provides a resource to investigate the fluxes and variability of the carbonate system and acidification in Irish coastal and shelf waters and key drivers of system dynamics.

Proposal

We propose **a structured four-year PhD** on a full-time basis to investigate the spatial and temporal variability and controls on the carbonate system in Irish shelf and coastal waters

This will be achieved through compiling marine carbonate system data (pCO_2 ^{seawater}, pH, DIC, TA), pCO_2 ^{atm} and data for other related parameters from diverse sources. These will be primarily those collected using national observational infrastructure outlined above, but may also include data collected during the project and additional information from other sources such as international data products (e.g. SOCAT, GLODAP, CMEMS). Ensuring comparability and fitness for purpose of these data will be a key element of this project.

The project will aim to:

- Collate, cross-check and quality assure available carbonate system and related data for the study area from national and potentially other sources.
- Using available sea surface and atmospheric pCO_2 data, (for instance Mace Head observatory and research vessel), estimate the direction, magnitude and temporal variability of pCO_2 flux and the associated uncertainties
- Estimate the temporal (seasonal, interannual, diurnal) variability of pH and the carbonate system in shelf and coastal waters and investigate how this may be controlled by local physical, chemical and biological processes.
- Contribute to maintaining current observations and to developing observational capacity to gather carbonate system data to support this study. Additional field studies for example exploring local processes at specific locations or other boundary-exchange processes could form part of this work
- The project may also consider these data in the context of available regional carbon budgets and estimates of the carbon sink

Outcome

The expected outcomes from the project will be a quantification of the spatial-temporal variability of CO_2 flux and pH over the study period and an improved understanding of how local processes drive these.

Understanding these processes is important for projecting climate impacts and for also understanding how ocean acidification will affect shelf and coastal ecosystems. While documented long-term regional trends in the carbonate system is important, knowledge of evolving local conditions especially at key life-cycle stages for sensitive organisms, is necessary for predicting local ecological impacts.

The data will inform climate and downscaled marine biogeochemical models and may support improved estimates of the Irish marine environment as a carbon sink.

Links to MI Strategy

This proposal falls principally under Strategic Focus Area 3 - Research & Innovation, but also links to SFA 2 Forecasting Ocean and Climate Change and SFA 1 – Scientific Advice and Services, specifically in providing data and advice supporting various national reporting commitments and supporting improvement of climate adaptation strategies.

Specific Requirements

The scholar should have a primary degree in marine or environmental science or other related science discipline with chemistry and/or physics a major part.

Financial Details

Scholarships will be up to €27,500 per annum (maximum funding of €110,000 over four years). This amount comprises a maintenance award of €18,500 (Irish Research Council rate effective 1-Jan-21) to the student as well as payment of fees to the host higher education institution (HEI). The maximum fees payable to the HEI will be €6,000 per annum. The scholarship award also includes a budget of up to €3,000 per annum for eligible research costs (travel & subsistence, publication costs, consumables and other costs e.g. laptop) for the sole use of the student, and are payable on a reimbursement basis direct to the host institution where the postgraduate student (scholar) is registered. There are no overheads payable on the scholarship. Publication costs are intended to cover publications on which the scholar is listed as first author and are published under Open Access.

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