Sink or swim: drivers of copepod migration behaviour

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Diel vertical migration (DVM) of marine zooplankton is one of the most profound coordinated movements of organisms on the planet, and it contributes fundamentally to ecological interactions in both freshwater and marine habitats, and to global biogeochemical cycles. Yet, as this behaviour has been studied in more detail at higher spatiotemporal resolution, it has become apparent that behaviours of individuals do not necessarily reflect the apparent movements of the population. What controls variability in this behaviour at the individual level? To what extent do environmental factors such as light and physiological factors such as metabolism influence the migration behaviour of individuals? Here we deconstruct DVM patterns of individual organisms into component parts of activity, photobehaviour, and metabolism, using as a model one of the most abundant and ecologically important species within the mesozooplankton community, Calanus finmarchicus. This copepod has large lipid reserves and is the main trophic link between phytoplankton and higher trophic levels in the North Atlantic and Arctic. Through a series of field collections and laboratory experiments with the C. finmarchicus population of Loch Etive we present preliminary data showing differences in behaviour and respiration not consistent with our current understanding of DVM and suggest that, at the individual level, behavioural plasticity maybe an adaptive strategy for this copepod.

The work presented constitutes the output from a MASTS visiting fellowship in supporting Jonathan Cohen (University of Delaware).
Climate Change, Fisheries Policy & Behaviour: What are the distributional and resilience effects in the North Sea?

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Within Europe, the North Sea is an extremely important area for fisheries. It is also, however, an area that is likely to be strongly influenced by climate change. It has already experienced faster warming than most other parts of the ocean, and as a consequence species distribution, abundance, and composition have started to change (Brander et al. 2016; Heath 2005; Heath et al. 2012; Kirby et al. 2009). There is the potential that this will continue in the future as the effects of climate change on the North Sea become more pronounced. In this context, two features of the EU Common Fisheries Policy are especially important: the principle of relative stability and the landings obligation. This trifecta (composed of climate change, relative stability, and the discard ban) has the potential to create ‘choke species’ and to close fisheries prematurely (Baudron and Fernandes 2015; Jansen et al. 2012), thereby affecting both coastal communities and North Sea ecology in potentially unexpected ways. By extension, this trifecta has the potential change three inter-related features of the North Sea system: the distribution of income/benefits experienced by North Sea fisheries communities, the behaviour of North Sea fishers, and the resilience of the North Sea. In analysing this problem space, the North Sea must be viewed as a coupled socio-ecological system, the sustainable management of which must include an analysis of the impacts of heterogeneous human behaviour on that system. My PhD will address this research need implied by the existence of this problem space by developing an agent-based model (ABM) of fisheries on the scale of the North Sea Basin. The purpose of the PhD will be to couple this ABM with an existing North Sea ecosystem model to address the following over-arching question:

What are the potential consequences (through 2050) for the North Sea Basin of the interaction between Climate Change and the Common Fisheries Policy (given an explicit characterisation of fisher behaviour)?

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References

Are flagellated cells of *Phaeocystis* present when it blooms?

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The marine haptophyte genus *Phaeocystis* is a common component of the Scottish phytoplankton community. It has a polymorphic lifecycle comprised of colonial and flagellated cells. Only the former stage can be easily observed using routine light microscopy techniques. Blooms of *Phaeocystis* result from increases in the number of *Phaeocystis* colonies. Degradation of these colonies as the bloom ends can result in the formation of foam that can wash up on beaches. Owing to their small size (~5 µm diameter), the flagellated cells are more difficult to identify using routine methods and thus their role in the dynamics of *Phaeocystis* blooms in Scottish waters is unknown. Scanning electron microscopy (SEM) can provide the higher resolution required to view these flagellated cells in more detail and in some cases facilitate a species level identification. During late April 2017, a high abundance of *Phaeocystis* colonies was observed at the Scottish Coastal Observatory (SCObs) monitoring site at Stonehaven. Cells from broken colonies and flagellated cells were problematic to enumerate. Results from a first investigation into the presence and abundance of flagellated cells during this *Phaeocystis* bloom event will be presented.
Fitting the StrathE2E marine ecosystem model using Bayesian methods

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StrathE2E is an end-to-end marine ecosystem model that simulates nitrogen mass fluxes through the North Sea foodweb [1]. It also represents fishery mortalities and accounts for biogeochemical sources and sinks of nitrogen (e.g. river inputs and sediment nitrification processes). The modelled region is assumed to be horizontally homogeneous, and is vertically split into surface, deep, and sediment layers. Taxa are aggregated into eight guilds: phytoplankton, herbivorous zooplankton, carnivorous zooplankton, pelagic fish, demersal fish, filter-feeding benthos, carnivorous benthos, birds and mammals. Model applications are wide-ranging, and include assessing ecosystem impacts of altering fishing practises.

Model parameters were originally chosen by using simulated annealing to minimise differences between model output and data on annual abundances, production rates, and feeding fluxes averaged over 1979-1999 [1]. This produces a high-likelihood point-estimate for parameters and model outputs, but does not return information about feasible ranges for parameters. The uncertainty associated to model output was therefore unquantified.

A recent addition to Bayesian methodologies, Kernel Adaptive Metropolis Hastings (KAMH) [2], has allowed us to fit the StrathE2E model and calculate credible intervals around parameters and model outputs. Like other Metropolis Hastings algorithms, KAMH explores parameter space with random walks. However, by locally aligning the random walk covariance to the target distribution, KAMH avoids the common problem of becoming 'stuck' in high-curvature regions of parameter space. We encountered this 'sticking' problem when fitting StrathE2E using a globally adaptive algorithm [3]. When running StrathE2E in the Stan platform for Hamiltonian Monte Carlo [4], we found that the model has too many state variables and parameters to fit in a sensible time (many months needed for useful output!). The balance that KAMH strikes, between optimisation algorithm simplicity and efficient exploration of parameter space, seems well suited for complex models with lots of fitting parameters such as StrathE2E.

This presentation will summarise the StrathE2E model, provide detail about the KAMH algorithm, and display StrathE2E outputs with newly derived credible intervals.

Long-term Puget Sound plankton dynamics: A comprehensive parameter – space exploration in a new model

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Wild salmon populations in Puget Sound, USA have undergone a long-term decline with their survival correlating with decadal climate patterns for reasons yet unknown. The search for bottom-up ecological explanations requires reconstructing interannual variation and trends in phytoplankton production and bloom timing. Despite a long history of studies of primary production in the region, long time series are rare, and information on nutrient and light sensitivity of primary production in the area is limited. This study presents an optimal plankton model for Puget Sound built by coupling a generalised NPZD-style model to a 1-D physical model of the Puget Sound Main Basin, which includes vertical mixing and advection processes caused by estuarine (river-driven) circulation. The 1-D simplification is possible because along- and cross-channel gradients of phytoplankton and nutrients are small in this deep fjord. Hundreds of thousands of variants of the model were investigated, with variation of both internal and physical drivers as uncertain parameters. The goodness-of-fit of parameter combinations were determined by matching to phytoplankton blooms’ peak and timings, as well as seasonal cycles of nitrate, in a multi-year dataset. Unconstrained parameters and processes were systematically removed by conducting model reduction based on these observations. The ensemble model results allow testing of multiple hypotheses that have been proposed to link the continuously decreasing wild salmon pattern to phytoplankton dynamics.

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\textbf{Are you a student?} (Delete as appropriate): \textit{Yes}
From quadrats to coastlines: “scaling up” estimates of ecosystem function in the coastal margin

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Intertidal habitats such as saltmarshes and mudflats provide many benefits to society, including coastal protection, climate regulation, amenity value and habitat for key species of ecological and economic importance. Understanding how these benefits vary across the coastline is integral to conservation and defining appropriate habitat management.

In this study, we investigated how the importance of saltmarsh and mudflat habitats for the provision of coastal protection and climate regulation services varies over space.

The CBESS project collected data from two key regions of UK mudflat and saltmarsh habitat, measuring “quadrat-scale” physical characteristics and biodiversity/biomass of all phyla present, from bacteria through macrofauna and invertebrates to plants. At the “site” level, bird species were recorded, in addition to physical drivers such as wave energy. At the “bay” scale, human recreational use and preference data were collected.

By linking quadrat observations with metrics of larger-scale habitat structure, we investigated how ecosystem function of saltmarshes and mudflats varies over space, and how this contributes to the overall service provided. Based on maps of habitat extent covering the whole country, we derived metrics for tidal elevation, distance from marsh/creek/land edge, and wave fetch (exposure index). These provide a measure of habitat structure, and covariates which are linked to variation in quadrat level observations.

In the case of climate regulation, we used geostatistical methods to extrapolate from quadrat level observations. Within given area, regressions indicate strong relationships between driving physical characteristics and ecosystem function. However, strong regional and context specific dependencies were found, and we investigate how these might be accounted for in designing survey patterns.

To estimate coastal protection function, we used a method based on that of Burrows et al. 2008, calculating wave fetch and weighting this by distance over marsh and vegetation type to provide an index of protection.Overlaying this estimate with mapped population and infrastructure density allows appraisal of the relative services provided by different patches of marsh and mudflat.

Biodiversity tends to be an important factor only in corresponding biomass ecosystem functions. For instance, biomass of mudflat macrofauna (a determinant nutrient cycling) is linked to species richness of macrofauna. Biomass of saltmarsh invertebrates (a food source for birds) is linked to their species richness. While biodiversity is a useful indicator of ecosystem health, and contributor to amenity value, the functions comprising climate regulation and coastal protection are primarily provided by a smaller subset of the species present.

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References


Toxicity of titanium dioxide nanoparticle sunscreen formulations and simultaneous warming on corals’ symbiotic algae, *Symbiodinium* spp.

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Nanomaterials from sunscreen can be released into surface waters and/or sewage treatments plants through bathing and everyday usage and cleaning. Estimates show that between 16000 and 25000 tons of sunscreens are used in tropical countries annually and 25% of their ingredients are directly released into reef areas from recreational activities.

Sunscreens are either oil-in-water or water-in-oil emulsions with UV filters normally dissolved or dispersed in an oil phase. A common nanoparticle UV filter in cosmetic products is titanium dioxide.

To determine whether titanium dioxide nanoparticles (nTiO₂) are harmful to corals’ endosymbiotic algae (*Symbiodinium* spp.), nTiO₂ of varied size and surface coatings were selected for this study. Diverse *Symbiodinium* phylotypes, known for their different tolerance to environmental change and stress, were exposed to oil phase and different types of nTiO₂, commonly used as cosmetic ingredients, at both ambient temperature (26°C) and thermal stress conditions (32°C) to evaluate growth rate, photosynthetic activity and reactive oxygen species (ROS) production.

Results indicate that toxicity of the sunscreen is likely driven by the oil phase, with an inhibitory effect on algal growth and an increased production of ROS in all exposed algae. These negative impacts were found to be independent of the type of nTiO₂ in the oil dispersion. Toxicity was further enhanced during thermal stress.

Coral bleaching events worldwide are increasing in intensity and severity as global temperatures continue to rise and the accumulation of ROS in *Symbiodinium* cells in response to elevated temperature stress is considered to be the trigger to coral bleaching. The observed enhanced ROS production in the algal cells, derived by the simultaneous exposure to oil-based dispersions and elevated temperature, suggests that exposure to nanoparticle containing sunscreen formulations may pose a risk to coral reef ecosystems by exacerbating bleaching response in corals.

**References**


The foraging ecology of black guillemots in relation to marine renewable energy devices

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ABSTRACT:

An emerging driver of environmental change within the marine inshore is the construction of marine renewable energy devices such as tidal turbines. These devices may alter tidal current flow, and change benthic composition. Inshore diving seabirds such as black guillemots Cepphus grylle have been suggested to be vulnerable to these potential alterations to their foraging habitat. During foraging, individuals have been found to associate with tidal currents (Wade 2015) and are known to dive to depths at which tidal turbines will likely operate (Masden et al. 2013), and are therefore at risk of collision with turbine blades (Furness et al. 2012). However, the extent to which these devices will affect black guillemots is unknown. Further research using modern tracking technology is needed to address the potential impacts on spatial and temporal aspects of foraging behaviour and habitat use. This study addresses these knowledge gaps relating to the species’ foraging behaviour through the use of GPS tracking and intensive diet study using camera traps and visual observations.

In this study, 35 breeding adult black guillemots were GPS tracked during the 2016/17 summer breeding seasons on the Scottish islands of Stroma and North Ronaldsay. Foraging behaviour of black guillemots was found to be associated with tide direction and tidally driven processes such as eddies. Foraging locations were found to be associated with tidally dynamic areas which overlap with planned tidal energy developments. Individuals display strong foraging site preference with further individual variation in the distances travelled to specific foraging locations. Some foraging distances are the largest recorded for breeding black guillemots (>24km). Here we will present results from the 2016/17 field seasons, exploring relationships between foraging behaviour and tidal currents, benthic habitat, and prey species. This research highlights the extent of potential change to black guillemot foraging habitat arising from marine renewable energy devices.

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References

