Competition between two globally important Pseudo-nitzschia species under N and P limitation

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The genus Pseudo-nitzschia is cosmopolitan with most species producing domoic acid, a neurotoxin that can impact different levels of the food web and human health (e.g. Amnesic Shellfish Poisoning symptoms) (Trainer et al. 2012). *P. delicatissima* in particular, has been the focus of many studies due to its occurrence in Harmful Algal Blooms around the globe. *P. galaxiae* is also receiving increased attention due to its widespread occurrence and indications on its ability to produce domoic acid.

Pseudo-nitzschia is known to form multi-species blooms (Thessen & Stoecker, 2008) that are associated with nitrogen-rich freshwater inflows due to anthopogenic activities in the watershed (Spatharis et al. 2007). Despite the importance of quantifying the macronutrient requirements of *Pseudo-nitzschia* spp. to explain their dynamics, species co-occurrence in blooms and/or toxin production, studies on their growth kinetics remain scarce (Loureiro 2009).

In the present study, batch and continuous cultures were employed to establish the growth kinetic parameters (Ks and μ_{max}, Q) of *P. delicatissima* and *P. galaxiae* under nitrogen-N and phosphorus-P limitation. The species were isolated from a coastal system where they co-occurred in densities higher than $1x10^4$cells/L. In order to study the species' dynamics under nutrient limitation the measured parameters configured a model that was based on resource ratio theory.

According to the measured kinetic parameters, both species had a high requirement for N and low requirement for P supporting the occurrence of Pseudo-nitzschia blooms in nitrogen-rich conditions. The results of laboratory experiments, which closely matched model predictions, also showed that *P. galaxiae* is more competitive under N and P limitation compared to *P. delicatissima*.

This finding suggests that under prolonged periods of N and P limitation, *P. galaxiae* will outcompete *P. delicatissima*. Therefore, the question arises on which process enables the two species to co-occur in their natural environment that was characterized by alternating periods of N and P limitation.

To explore this process, a differential loss term was added to the basic resource-competition model. The model indicated an area of loss rates for each species under which the two species can co-exist and according to which, the loss rate of *P. galaxiae* was much higher than that of *P. delicatissima*. This loss process could be attributed to the species' differential sinking rates as *P. galaxiae* tends to form large aggregates and sink much faster. This trade-off of between *P. galaxiae*'s competitiveness under nutrient limitation and increased loss due to sinking, seem to allow the species to co-exist with *P. delicatissima* even under N and P limitation.

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Using survey data in a length-based approach to fisheries stock assessment

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Historically fish stock assessments have been limited to important commercial species. However, it is now recognised that ecosystem-based approaches to fisheries management require information on greater numbers of species than are routinely assessed. Unfortunately, standard approaches to estimate stock biomass and fishing mortality rely on catch-at-age data which are costly to obtain and likely only ever to be available for a few species. In contrast to age data, information on length distributions is more easily available from market sampling and from scientific surveys.

Varieties of length-based methods have therefore been used to assess stocks for which little age data are available. The model parameters are estimated by fitting to measured catch-at-length data. Although this obviates the need for age data, even the length distributions of commercial catches are not always routinely recorded, especially in regions such as the North Sea where the fishery involves fleets from different EU nations. Instead the total landed fish is weighted and reported.

Length distributions from the scientific survey data such as the North Sea International Bottom Trawl Survey (NSIBTS) are routinely available for all species. We therefore developed a new population model to make the use of the total landed biomass from commercial reports and the length distributions of fish from survey data (IBTS) as inputs into the model. It is a forward running length structured matrix in which growth increment probabilities and the distribution of recruits over length are modeled by gamma distributions. The average growth at length over time is modelled by the transformed von Bertalanffy growth function. Fishing mortality is modelled as a product of a time dependent and a length dependent factor, which is then added to the constant natural mortality to make the total mortality. Survey numbers are assumed to be proportional to the abundance by a logistic survey selectivity function and the proportion of sampling area over the time steps. The length-weight transformation function is applied to model the biomass distribution over length classes. The probability of landing is also logistically modelled to separate landings from discards.

The new model (survey-landings population dynamic model) aims to improve the assessment of the stocks for which age and catch-at-length are not available. It has been applied on simulated data and assessed and validated in twin experiment context. The model has then been applied to the North Sea haddock. Since there are both age and length data available for haddock, we are able to compare our results with the standard ICES assessment method. Results from the survey-landings model, including twin experiments, validation and sensitivity analyses, and the application on haddock will be presented.

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Climate change and mussel reefs: hanging by a thread

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Horse mussels (*Modiolus modiolus*) occur in dense aggregations and form biogenic reefs (Rees *et al*. 2008). The reef matrix consists of live mussels, dead shell, byssus threads (used to attach the mussel to a hard substrate) and organically rich biodeposits (faeces and pseudofaeces) produced by the mussels and associated fauna. As a biogenic reef, *M. modiolus* habitats are recognised for their conservation importance in Marine Protected Areas (MPAs) in Scotland.

Highlighting and quantifying the services provided by different marine ecosystems shows the value of them to society, which can support decision making and marine spatial planning. However, the southern most limit of *M. modiolus* reefs is in the Irish Sea and it has been predicted that, with increasing seawater temperatures the most suitable habitat for *M. modiolus* will move further north (Gormley *et al.* 2013). Considering that *M. modiolus* reefs are also highly sensitive to physical impact (Cook *et a.l* 2013), additional pressures make this habitat particularly vulnerable, and therefore require appropriate protection.

The objectives of this study were to measure two ecosystem functions associated with *M. modiolus* reefs and to test whether these processes were modified by an increase in temperature. The two functions measured were biodeposition rate and byssus production. Biodeposition rates were also measured *in situ* on a *M. modiolus* reef using portable experimental units that were deployed and recovered by SCUBA diving. Control units accounted for background sediment deposition and the effect of the experimental units. The passive and active processes were separated using live mussels and dead mussels shells held together.

In the laboratory, Vortex Resuspension Tanks (VoRTs) were used to maintain *M. modiolus* under controlled conditions where the seawater temperature could be adjusted, and the natural feeding environment was otherwise simulated. The results provide the first evidence of the scale at which *M. modiolus* are able to provide ecosystem services, such as water filtration and sediment sequestration in the North East Atlantic. Increased seawater temperature can modify the function of *M. modiolus*, and therefore change the way that the biogenic habitats are formed and possibly also the benefits they provide to society.

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Optical closure: Are we there yet?

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Inherent optical properties (IOPs) of seawater itself and of materials suspended or dissolved within the medium strongly influence how light propagates under water. Underwater and water leaving light fields can therefore be modelled based on IOP measurements using radiative transfer modelling.

However, robust optical closure between measured radiometry and values obtained from radiative transfer simulations using *in situ* measurements of inherent optical properties (IOPs) has traditionally been seen as difficult to achieve. The availability of well-established optical models such as Hydrolight (Sequoia) points towards measurement uncertainties for both in situ IOPs and radiometry as the current limiting factors. Recent developments in IOP measurement capabilities suggest it is timely to reassess our ability to achieve optical closure.

Here we present data collected on a cruise along the west coast of Scotland in 2012, covering a wide range of water types, including CDOM-rich fresh water, sediment-dominated coastal waters, reasonably clear Case 1 waters and a *coccolithophore* bloom. IOPs were measured using a point-source integrating-cavity absorption meter (PSICAM), an ac-9 absorption and attenuation meter and a BB9 backscattering meter (both WET Labs). ac-9 absorption and attenuation measurements were corrected using a variety of scattering corrections including recently published Monte Carlo (McKee et al. 2014) and semi-empirical (Röttgers et al. 2013) versions. Hydrolight simulations were used to test the impact of alternative scattering correction approaches on optical closure, using a suite of *in situ* Trios radiometry measurements for validation.

This study shows the degree of optical closure obtained for surface reflectance. Error propagation is used to better understand practical limitations in the degree of optical closure that is achievable with current instrumentation. First results show an improvement of optical closure using the newest correction methods, especially for stations with high turbidity. The deviation between modelled and *in situ* surface reflectance values decreased from about 40% for standard scattering corrections to <15% when using the latest algorithms.

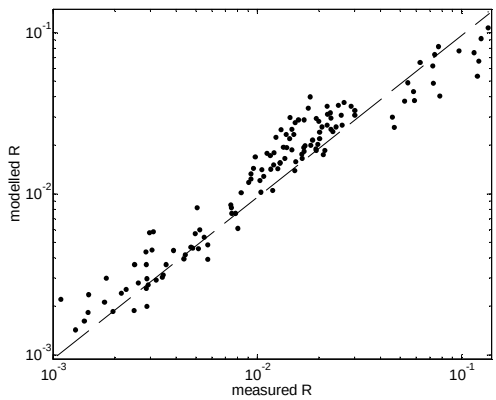

Fig 1: Loglog-plot of modelled surface reflectance based on Monte Carlo corrected IOP data against reflectance values derived from *in situ* radiometry.

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Winds, tides, freshwater, and their effects on the circulation in a Scottish sea loch

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The Scottish west coast features a complicated coastline with sea lochs of varying characteristics. This study focusses on the 60km long Loch Linnhe, which stretches from the opening at the Firth of Lorne to the head at Corpach in a SW-NE direction. Multiple side lochs with sills and large freshwater input, winds, and tides make this system complex and not well studied in physical oceanographic terms. A few studies evaluated energetic tidal forcing, for example (Allen and Simpson, 2002), but no recent work about physical processes has been published.

We focus on data from October 2012 to evaluate the effects of tides, winds, and freshwater on the circulation in the loch. Data include winds measured at the Glensanda Pier, currents from an Acoustic Doppler Current Profiler (ADCP) on the north shore of the outer loch, temperature, salinity and currents from a multi-parameter data buoy north of the Corran Narrows, river input into the upper loch from the National River Flow Archive, and currents from a vessel-mounted ADCP. The observations are complemented by a 19 day POLCOMS run for the system during the same time period forced with field-measured winds.

Winds are steered along the loch axis due to mountains on both sides and these winds reached up to $10ms^{-1}$ during our observation period. We investigate the influence of the wind and find a high correlation with the surface currents. The influence quickly diminishes below 3m depth. In the top layer, around 30% of the current variance is explained by winds at daily time scales.

Tidal analysis shows a dominant semi-diurnal tide with vertical variability. Tidal ellipses present dominant cyclonic rotation at almost all depth levels.

Large freshwater input into the upper loch ($\sim 3550 \times 10^6 m^3 y^{-1}$) gets transported through the Corran Narrows. An example of surface salinity from POLCOMS is shown in Figure 1. The freshwater flows out of the loch along the northern shore due to the Earth's rotation, seen as a green/yellow band close to the coast.

Barotropic and baroclinic currents show fluctuations at different time scales, related to tides, winds - especially in the surface layer - and the buoyancy-driven flow due to the freshwater input.

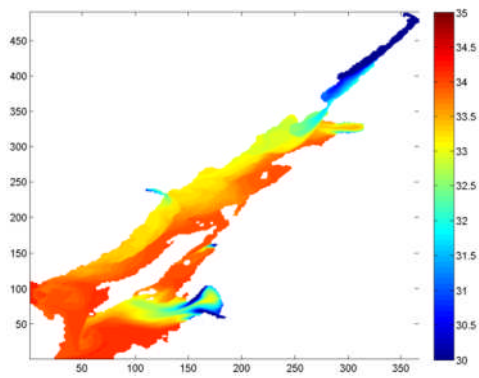

Figure 1: Snapshot of surface salinity from POLCOMS output demonstrating the fresh outflow from the upper loch along the northern shore.

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Environmental cues for spawning and hatching in a mid-trophic pelagic fish

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Many species of fish are known to use environmental changes as cues to spawn or hatch. These cues may be one or a combination of temperature, photoperiod, tidal or lunar activity. In this study we investigate possible spawning and hatching cues for the mid-trophic pelagic fish, *Ammodytes marinus*, the dominant species of sandeel in the North Sea. A key species in the North Sea, *A. marinus* acts as an important vector that transfers zooplankton energy into higher trophic levels and many seabirds in the North Sea are reliant on sandeels during the breeding season. However, a long-term decline in sandeel size-at-date, presumably due to changes in growth rate, hatching or spawning dates, has led to a temporal mismatch between peak energy requirements and adequate prey, resulting in detrimental effects on seabirds. This work rules out changes in spawning and hatching as the cause of this decline by showing that spawning and hatching in *A. marinus* shows little inter-annual variation and is actually triggered by predictable environmental cues. We propose hypotheses of tidal cued spawning and temperature-change induced hatching. Using a 10-year (2000-2009) time series of weekly measurements of abundance and length distributions, we derived annual density distributions of hatch dates. Then using data on the temperature dependence of egg development time for related species we backtracked from observed hatch dates to probable spawning dates, which provided evidence of synchronous spawning. Analysis of spawning dates and tidal phase suggest that *A. marinus* might spawn en masse in response to conditions associated with neap tide. Further evidence is provided showing that the switch from decreasing to increasing temperature in spring acts as a cue to induce hatching. By finally elucidating the mechanisms behind these important stages of the sandeel lifecycle, this work will inform future population models which operate as important stock management tools.

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Estimating Body Condition in Harbour Seals with Aerial Photogrammetry: A Proof of Concept Study

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Body condition has been linked to two critical life vital rates in a variety of taxa: survival and reproduction. Therefore, understanding where and when animals gain resources is of critical importance when monitoring populations that may be vulnerable to disturbance. Here we document the trial use of small unmanned aerial vehicles (UAVs) to measure body condition in hauled out harbour seals (*Phoca vitulina*) in Loch Fleet NNR, where the University of Aberdeen has conducted a long-term research program (Cordes & Thompson, 2013). The ultimate goal of this UAV-based research is to link land based measurements of condition with at-sea movements to determine where in their environment individual seals gain condition. This will form a critical baseline for evaluating the possible impacts of disturbance from wind farm construction in the Moray Firth on health of individual seals.

Individual body condition has been quantified using photogrammetry in a variety of species. Most of this photogrammetry has been done from the ground (de Bruyn, Bester, Carlini, & Oosthuizen, 2009), or from airplanes (Perryman & Lynn, 2002). However, the recent advance in UAV technology has opened up this avenue of research (Anderson & Gaston, 2013), allowing researchers access to places that are either difficult to access, expensive, or both.

To undertake this research program, we have conducted two field trials in Loch Fleet NNR, Sutherland, Scotland – in May and July. The goals of these trials were to assess: feasibility of the idea, field logistics, equipment & technical issues, legal issues, disturbance issues, and data issues.

In May 2014, we conducted trial flights in Loch Fleet using a quadcopter equipped with a fix mounted still camera, and a hexcopter equipped with a gimbaled video camera. Initial results indicate that images from the stills can be used to obtain key morphometric measurements that could be incorporated into condition indices. Futhermore, zoom images of seals recorded with the video were identified to known individuals. Here we highlight the utility of this research technique, and outline the many considerations involved in undertaking a UAV-based research program.

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