Climate change and roll-back in Scottish coastal habitats: the need for a holistic approach

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All of Scotland has recently (1992-2007) been experiencing relative mean sea level rise (RSLR), with many ports experiencing rates of 3-6 mm/yr, beyond the 3-4 mm/yr 'tipping point' when "widespread re-organisation of coastal landforms begins to be forced" (Rennie & Hansom 2011).

It is widely believed that RSLR will move unrestricted coastal sediment-based habitats landwards by a process of 'rollover' or 'roll-back' (Allen 1990). Recent observations on saltmarshes in west coast sea lochs (Teasdale *et al* 2011) and on the Solway (Haynes 2014) suggest that instead of rolling back, west coast saltmarshes are accreting upwards, keeping pace with RSLR. On the Solway Firth, a national saltmarsh survey commissioned by Scottish Natural Heritage (SNH) has revealed that pioneer saltmarsh has declined in area and density, but saltmarsh area has largely been retained, as pioneer vegetation has been replaced by lower saltmarsh, i.e. the saltmarsh is growing upwards on its seaward margins (Haynes 2014).

With differing responses to RSLR within estuaries or firths – dunes and shingle rolling back - saltmarsh accreting, there will be complex changes in sediment pathways and thus in currents, with additional complexity imparted by feedback on these processes; the above-substrate plant growth will encourage sediment accretion while rooting systems will inhibit erosion differently according to vegetation type. Should this pattern be confirmed on the east coast saltmarshes, it might be necessary to revisit policies based on roll-back and associated coastal squeeze.

The low-elevation western platform of the Uists and its associated low-gradient nearshore shelf, comprise a complex of highly inter-related habitats and land uses that pose special problems for the anticipation of climate change impacts. The storm of 2005 revealed that short-term elevation of sea surface can significantly disengage the wave base from the protective sea bed and kelp beds (Angus & Rennie 2014), but perhaps a greater level of change may be anticipated directly from RSLR. The inland waters are highly interconnected by an artificial drainage network and water table, so low-lying that water surplus can be discharged to the sea only at low tide – and low tide is rising. Saline infiltration already affects lochs over 1 km inland, and this influence will increase, ultimately transforming a range of habitats to more saline counterparts, adversely affecting crofting agriculture and its associated biodiversity, with onward socio-economic impacts.

Human response will be a critical part of the changes to Scotland's coast. For adaptation to prevail over resistance, adaptation must be fully informed to enable earlier and more effective planning. The natural dynamism of coasts must be understood and incorporated in this planning, with trends reliably distinguished from this dynamism. The many interdependent functional relationships within this dynamism must also be understood to enable all involved to plan an effective adaptive response.

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Crabs Unquiet in Noisy Seas

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Are you a student? Yes

Anthropogenic noise has profoundly changed the acoustic environment of terrestrial and aquatic habitats, with growing evidence that even a short exposure to man-made sound sources can negatively affect organisms. With noise levels in the marine environment having increased significantly over the last 50 years (Frisk 2012), it is necessary to investigate whether and how this noise affects aquatic organisms, populations and communities.

Contrary to earlier conceptions, it has now been realised that marine invertebrates can be very sensitive to sound, however whilst they represent a considerable portion of marine fauna and are essential components in ecosystem dynamics, how they are impacted by anthropogenic noise has received scant attention (CBD 2012).

We used a series of controlled laboratory experiments to investigate how the playback of ship noise affects both the behaviour (foraging and anti-predator) and physiology (oxygen consumption) of the shore crab (*Carcinus maenas*) (Wale *et al.* 2013a,b) Compared to exposure to playback of ambient harbour noise, ship-noise playback resulted in crabs becoming more distracted from food, taking longer to find shelter in response to a simulated predation event, and righting themselves more quickly when turned on their backs.

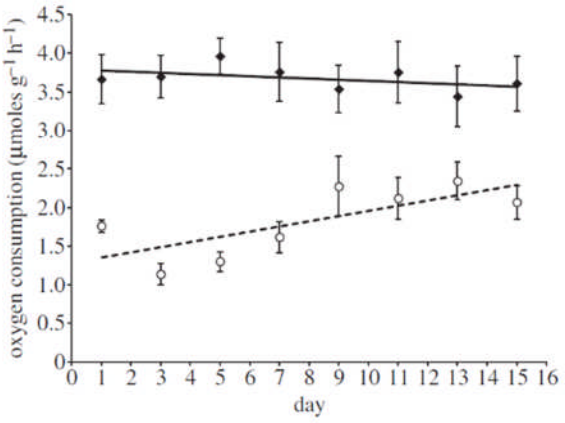

Fig. 1 – Oxygen consumption of shore crabs repeatedly exposed to playback of either ambient noise (open circles, dotted line) or ship noise (filled diamonds, solid line).

Single exposure to playback of ship noise also led to significantly higher oxygen consumption; indicating a higher metabolic rate and potentially increased stress, with larger individuals affected more strongly. When repeatedly exposed to ship-noise playback over 15 days, crabs continued to consume oxygen at an elevated level, providing no obvious evidence of habituation or tolerance (Fig 1).

In combination, these results highlight that invertebrates, like vertebrates, may also be susceptible to the detrimental impacts of anthropogenic noise, and that elevated risks of starvation and predation may arise. Moreover, our study showcases that more detailed studies into the impacts of anthropogenic noise on marine invertebrates are needed, a point I am now addressing through PhD research conducted at Edinburgh Napier University.

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Sponges as biogenic structures in two Cold Water Reefs of the North East Atlantic

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Are you a student? Yes

Cold Water Reefs (CWRs) constitute deep-sea ecosystems with high commercial and ecological value, having been characterised as "hot-spots" of biodiversity, biomass and carbon cycling (van Oevelen et al. 2009). Recent studies in the CWRs of the North East Atlantic have revealed a great diversity of sponges (Phylum Porifera) (van Soest et al. 2005, 2007; Roberts et al. 2009). Despite their presence, very little is known about the biology and ecology of these organisms in CWRs (van Duyl et al. 2008); this absence of information hampers our understanding about the contribution of sponges in the structure and functionality of these fragile deep-sea ecosystems. Taking into account all of the above, our research group participated in the "Changing Oceans" expedition that took place in May / June 2012, onboard the "RRS James Cook". Specimens of the sponge *Spongosorites coralliophaga* (Stephens, 1915) were collected from two reef regions i.e. the Mingulay Reef Complex (Outer Hebrides Sea, ~130 m) and Logachev Mounds (South West Rockall Bank, ~680-800 m) using the Remotely Operated Vehicle (ROV) "Holland I". This sponge has a massive body form and colonises dead coral fragments extensively. Sponge specimens and underlying coral framework were found to be colonised by various organisms. Taxonomic analysis revealed the presence of 12 Phyla, attributing to that species the role of a biogenic structure. Our investigations are expected to provide crucial information about the role of *S. coralliophaga* in the structure and functionality of CWRs in the NE Atlantic.

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The temporal and spatial variability of phytoplankton and mineral particles from ocean colour remote sensing: a case study in the Irish Sea

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Are you a student? (Delete as appropriate): Yes

Ocean colour remote sensing is important in monitoring both the physical and biological processes in shelf sea ecosystems and in modelling of the ocean-earth system. For example, the optical properties of the water column can act as indicators of the water quality, or give us an insight into the availability of light for the growth of phytoplankton.

Previously published work by Lee et al. (2002, 2009) has shown that the absorption and backscattering coefficients of the water column can be recovered from the optical signals measured by satellite. By considering these optical signals to be driven by phytoplankton and suspended mineral particles, with a relatively low constant influence from CDOM, we use a two-component partitioning procedure to determine the optical contribution of phytoplankton cells and suspended mineral particles to the total absorption and backscattering coefficients. Application of this partitioning method to 8 years of MODIS data for the Irish Sea shows seasonal cycles of both absorption and backscattering for each particle class. The temporal and spatial variability of these cycles are in agreement with known particle dynamics across the region, indicating the suspension of sediment throughout the winter months, the loss of sediments from the surface layer over the summer during stratification, and the timing of the phytoplankton spring bloom (Figure 1).

The partitioning of the ocean colour signals into phytoplankton and mineral components makes it possible to estimate the effects of the two classes of particles on the attenuation of visible light in the water column. Combining this, with the availability of a long time series of satellite data, allows key topics in shelf sea optics using remote sensing observations to be addressed:

(i) the relative importance of suspended minerals and phytoplankton in absorbing solar irradiance, which can be mapped spatially and temporally in unprecedented detail,

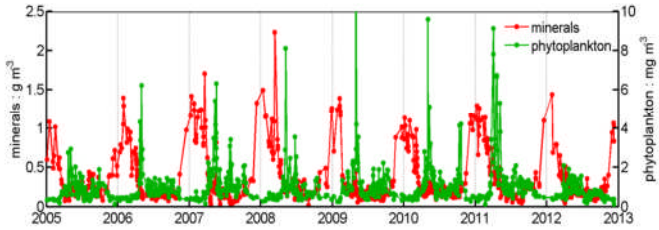

Figure 1: The temporal variability of phytoplankton (green) and mineral (red) particles in the southern Irish Sea over an 8 year period. The mineral particles peak over the winter months and minimise during the summer, whereas the phytoplankton can be seen to peak in the spring, occasionally with a secondary peak occurring in late summer.

(ii) the response of underwater light fields to seasonal and meteorological forcing,

(iii) the temporal and spatial variability of phytoplankton phenology in shelf seas,

(iv) the availability of remotely sensed data to aid in the modelling of complex shelf sea ecosystems.

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Governing marine stakeholder and coastal community engagement under conditions of high uncertainty: lessons from north-east Japan?

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Are you a student? (Delete as appropriate): No

This paper presents initial findings of empirical research carried out in Japan in summer 2014 into stakeholder and public engagement on issues of marine environmental risk and uncertainty. Particular attention is paid to the lessons that may be learned for the future governance of Scotland's marine and coastal areas with regard to energy and climate change.

The contamination of the marine environment in the aftermath of the March 2011 Fukushima Dai'ichi nuclear accident raises serious challenges for the governance of the marine environment in north-eastern Japan. Issues of high scientific complexity and significant uncertainty over long-term effects must be communicated to stakeholders and local communities, many of whom (i.e. fishers) relate to the marine environment not only as a source of employment but also as a site of great cultural significance. The case of north-eastern Japan therefore stands as a strong – if very unfortunate – case study for marine public and stakeholder engagement under conditions of rapid environmental change and pressure from energy infrastructure – issues with parallels to those Scotland may face in future.

This paper focuses on three sub-sets of research carried out by the author in Japan in summer 2014. The first of these looks at work carried out by Tokyo University of Marine Science and Technology in communicating ongoing physical science research into marine radioactive contamination to stakeholders (especially fishers) in the Iwaki district of Fukushima Prefecture in the aftermath of the nuclear accident. Extracts from interviews carried out with those involved in this engagement and communication process are presented here. The second sub-set draws on ethnographic research (passive observation) carried out in coastal areas of Iwaki, whereby the author visited areas affected by the earthquake, tsunami and nuclear accident to gain a fuller sense of the socio-cultural dimensions of responding to uncertainty from energy and environmental sources. Looking beyond the nuclear accident to alternative future forms of energy, the third and final sub-set of data considers the governance of the sub-seabed carbon dioxide capture and storage trial in Tomakomai Bay, Hokkaido – again based on interviews carried out with operators and stakeholders.

The severity of a nuclear accident on the scale of Fukushima is clearly orders of magnitude greater than the governance challenges likely to be faced in relation to energy and environmental change in Scotland. Nonetheless, the issue of engaging with stakeholders and coastal communities on issues of high scientific uncertainty with a significant emotive bearing is likely to intensify worldwide in coming years due to pressures from energy demand and climate change mitigation. This paper will therefore finish by considering how the lessons learned from communicating risk and uncertainty in Japan may be applied to future marine governance in Scotland and the wider world.

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Mechanisms of Differential Regulation of Dio2 Paralogues in Atlantic salmon (*Salmo salar*)

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Are you a student? (Delete as appropriate): Yes

Atlantic salmon are well known for making extensive migrations from natal freshwater streams out to seawater feeding grounds and back again. The transition from a FW juvenile parr to a SW smolt, known as parr-smolt transformation (PST), is a critical life history point for an anadromous salmonid.

Many studies have characterized the physiological changes which occur during PST, but knowledge pertaining to the molecular basis of these changes remains sparse. In mammals and birds, a family of selenoproteins called iodothyronine deiodinases (Dios) have been identified as being key in initiating seasonal responses by activating or inactivating thyroid hormones.

We previously identified 6 Dio genes in Atlantic salmon. The 2 Dio2 genes were shown to respond to different stimuli; Dio2a to salinity and Dio2b to photoperiod. In order to identify the mechanism of differential gene expression, *in silico* promoter analysis of the proximal Dio2 promoters was carried out, with particular emphasis upon osmotic response elements (OREs) and cyclic AMP (cAMP) binding sites (CRE).

A significantly higher than expected frequency of OREs was identified in the first 1,000 bases upstream of the start codon, while no highly conserved OREs were observed in the same region in Dio2b. This supports the identification of salinity responsiveness in Dio2a.

Furthermore, a 100% conserved CRE site was identified shortly upstream of the identified transcription start sites (TSSs) of Dio2b, as is found in the photoperiod sensitive mammalian Dio2 proximal promoter. The conserved CRE was also present in Dio2a.

Using an *in vitro* luciferase assay approach, the CRE sites in both Dio2a and b appear to be functional. Functionality was further confirmed by mutation of the CRE sites, which significantly reduced luciferase activity, however, there may have been a shift in the position of the TSS which could make the Dio2a CRE non-functional *in vivo*.

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