Theme session H

Ocean acidification (OA): Understanding chemical, biological and biochemical responses in marine ecosystems (Session co-sponsored by PICES)

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This theme session was suggested by the ICES Working Group on Biological Effects in Contaminants (WGBEC) who along with the ICES Marine Chemistry Working Group (MCWG), The ICES Benthos Ecology Working Group (BEWG) and the OSPAR /ICES Ocean Acidification Study Group (SGOA) identified the increasing need to understand affect and responses of ecosystems to Ocean Acidification (OA). The session was co-sponsored by PICES.

OA and climate change share a common cause, increasing CO2 concentrations in the atmosphere. However, OA must be distinguished from climate change as it is not a climatic process but rather an alteration to the chemistry of seawater. The ocean is the largest natural reservoir of dissolved carbon and holds an immense buffering capacity for changes in atmospheric CO2 concentrations. Due to the rapid increase of atmospheric CO2 since the industrial revolution, oceans and seas are absorbing increasingly greater amounts of CO2. This process disturbs the pre-existing chemical equilibrium of the sea's carbonate chemistry, resulting in seas becoming more acidic. The affects of OA may have serious consequences for ecosystems and the services they provide over this century. The expectation is that OA may trigger affects through the marine foodweb that will affect ecological, biogeochemical, and socio-economic values globally. OA research has indicated that while some species will be negatively affected, others will benefit from the changes that are the result of more acidic conditions. Although it is certain that the pH in the world's oceans is decreasing at a high rate, research into the long term effects of acidification on ecosystems and the influence on the ocean's buffering capacity is still in its infancy and further research is needed to understand the real affects and how these will affect societies and what will be the need to develop adaptation to these changes.

This session was well attended with established and early career scientists. Overall, there were 13 oral and 4 poster presentations, covering aspects related to the projected decrease in efficiency of the ocean carbon pump and the consequences for organisms, ecosystems, and society. The session was divided into three broad topics namely monitoring, effects on invertebrates and effects on fish and fisheries and comprised of contributions from UK, Norway, Sweden, Greece, Italy, Japan, Germany and Portugal.

The need to understand natural diel, seasonal and interannual variations and distinguish these from anthropogenic signals was highlighted by the long term monitoring field observation studies presented. Long-term datasets provide information on the pH range organisms are naturally exposed, and their ability to withstand such oscillations. A PICES study was presented which considered predicted elevated CO2 concentrations on larval stages of the commercial species Ezo abalone (*Halitotis discus hannai*) in relation to diel cycles. Malformation, increased mortality rates and decreased shell length was emerged as a function of cumulative time during which the saturation degree of aragonite falls under 1, suggesting high importance of temporal variation as well as average state. Discussion followed on the need to understand the natural pH range and variations over a 24 h period before commencing laboratory based studies.

Our understanding of how individual species respond to OA and the mechanisms by which these individuals respond was identified as an emerging area of research by the recent OSPAR/ICES study group on OA (SGOA). It was encouraging to see presentations describing ongoing research considering these aspects as well as placing this information into wider context (e.g. 'scaling-up' these effects). In particular recent developments in the use of gene expression to identify the genes used in egg production and in larval shell formation and potential affects under increasing CO2 conditions on a multi-generational scale. Pelagic copepods exposed to predicted future atmospheric CO2 scenarios were found to show some evidence of buffering OA effects through transgenerational plasticity and selection. However, second generation adults were found to have decreased egg production at elevated CO2 concentrations linked to DNA replication and cell division. Similarly, studies on larval shell formation in Pacific oysters (*Crassostrea gigas*) found slower development under elevated CO2 conditions. Researchers were subsequently able to isolate 149 genes involved in the initial shell formation process, most of which are linked to ion transportation or protein binding. There are indications that it is not only egg production and shell formation that is affected by OA. There are indications that it is not only egg production and shell formation that is affected by OA. A number of research projects undertaken in the Atlantic have evaluated the effects of OA on the swimming ability, lateralization, shoaling and detection to predators in fish larvae. Larval stages demonstrated a loss of shoaling cohesion and individual lateralisation when exposed to elevated pCO2 for 21 days. Impairment of olfactory cues to predator was also observed under elevated CO2.

The species' ability to adapt could present some ramified effects for foodwebs, repercussions for economic implications to fisheries and may have implications for food security. Recruitment of the commercially important species, Atlantic Cod, may be affected by end of century predicted CO2 concentrations. Atlantic cod larvae from two different populations (Barents Sea and Western Baltic Sea) have both showed increased mortality rates under elevated CO2 concentrations. When these results were included in recruitment models, the recruitment collapsed.

Many studies only consider one climate stressor namely decreasing pH. However, the UK Defra funded project Placing Ocean Acidification in wider Fisheries Context (PLACID) project has investigated the effects of OA and with other co-stressors (mainly: temperature, feeding regimes) on commercial species. As these different stressors are in many cases interlinked. The aim of this programme is to quantify the economic affect of OA on UK shellfish and aquaculture industries. Model predications indicate loss by 2100 to shellfish fisheries and aquaculture under high emission scenarios of around £954 million.

Session Discussions/Conclusions

A diverse range of topics were covered throughout the day but despite this, common themes evolved during both discussion sessions. OA research is still very much in its infancy but there is growing evidence, that some species and life stages will be able to adapt to predicted CO2 concentrations. It was encouraging that research was moving forward considering multi-generational adaptation, genetics, early larval stages and consideration of the natural variability to which the species are being subjected, considering the natural systems rather than solely under controlled laboratory incubations. However, studies still often only consider short term exposure to elevated

CO_2 concentrations in isolation and do not consider wider implications of multiple stressors on ecosystems, such as increasing sea temperatures and contaminant availability. Additionally feeding/nutrient status appears to have an influence on the effects of pH in experiments. Although short term laboratory and mesocosm studies are important tools for basic understanding, participants highlighted the need for continuous high frequency long term monitoring, of both chemical and biological parameters, on a decadal scale to differentiate diel, seasonal and interannual variations from anthropogenic inputs. There should also be a common quality controlled approach to biological experimental design, with clear endpoints and consideration given to the inclusion of multiple stressors. The ICES/PICES/IOC symposium on HABs and climate change held in Gothenburg this year also flagged the need for standardization of laboratory culture protocols used to examine the affects of OA. The relationship between fisheries management and OA was also considered, with concerns raised that current fisheries management models do not consider climate change and increasing CO_2 concentrations. It is important that these along with potential socio-economic affects be included in future fisheries management scenarios

The session closed with a recommendation to ICES that an ICES OA multidisciplinary working group should be created with members working across different areas (e.g. conservation, government and academia) to ensure that the research and recommendation are targeted and applied, ensuring that some of the gaps are tested and the newly generated scientific evidence is fit for purpose.