EXAMPLE OF AN APPLICATION FOR THEME 2:

STRENGTHENING RESILIENCE IN THE FACE OF MULTIPLE RISKS IN A CONNECTED WORLD

Subject: Optimising science, technology and innovation for studying ocean acidification effects on commercial species (Ostiones)

Summary:

Ocean acidification is closely linked with climate change, as they share the same driver, the increasing atmospheric carbon dioxide (CO_2) causing threats to the ecological health and biodiversity of the marine environment. Seawater uptakes CO_2 from the atmosphere altering the chemistry of the oceans, decreasing pH levels making them more acidic (refer to as ocean acidification-OA). Ocean pH has decreased by about 0.1 units since the start of the Industrial Revolution and CO_2 concentrations are projected to increase by the end of the century as fossil fuel reserves are exploited. Evidence indicates that future OA will affect marine organisms, with repercussions for ecosystems and services. However, the understanding on the potential effects of OA on commercial species is still limited. This project aims to obtain new scientific knowledge on the OA effects on commercial shellfish species (scallops in Chile and cockles and scallops in the UK). This work will help to support the development of climate change adaptation strategies as well as planning and preparedness on aquaculture activities in both countries to support food security.

Description:

1.INTRODUCTION

Climate change effects are occurring at a much faster pace than originally expected (see Chapter XX, WG II, IPCC AR5[1]. Evidence suggests that absorption of carbon dioxide (CO_2) in the ocean has already decreased pH levels by 0.1 pH units since 1750, and CO_2 concentrations are projected to increase further by the end of the century as fossil fuel reserves are exploited [2,3]. The CO_2 increase is altering the chemistry of the oceans, making them more acidic (described as ocean acidification-OA). The potential effects of OA are poorly understood but have prompted considerable interest among scientists and concern among policy makers, NGOs and industry. There is a need to bring together existing ocean acidification effects observed in commercial species in UK and Chile. In Chile the scallop mariculture take place in up-welling areas, which are considered to be hotspots of acidified waters and in cases lacking oxygen [4,5]. Additionally, there here are many uncertainties relating to effects of OA the species and what will be the scale of socio-economic impacts and more importantly on food security. These issues have concerned scientists, policy makers, NGOs and industry. OA is a global scale threat but impacts will be felt at the local and regional level. This will be the case for the coastal waters ecosystems of the UK and Chile, as global CO_2 emissions will continue to rise. Both countries have extensive coastlines and a strong dependence on shellfish fisheries, aquaculture and mariculture. In the UK, fisheries generate more than GBP 800 million of revenue per year supporting around 30 000 jobs, additionally, aquaculture, generates GBP 350 million and supports 4 200 jobs. In Chile aquaculture and mariculture activities generate approximately 680 tonnes of production, generating USD1600 million and supporting over 17 800 jobs.

This project will provide evidence base science to inform local stakeholders depending on the local scallop fishery. This project will build on the current understanding, monitoring tools and applied experiments conducted for understanding of ocean acidification effects on commercial species developed in both countries, promoting the development of Institutional links and knowledge exchange on data and applications. These strategies will provide further information of adaptation strategies, which in turn will help to sustain marine resources and

food security for future generations depending on these resources.
The primary aim of this project will be to enhance the evidence-base knowledge on the potential effects of ocean acidification on commercially important species (e.g. scallops and cockles) in UK and Chile. This work will facilitate the exchange of science, knowledge transfer and production of outreach activities to inform a wide range of end-users. The results from this project will provide outputs to Chilean colleagues involved in the development of climate change policy and in the UK this work will help to develop further understanding of ocean acidification effects on commercial species, also assisting government and the industry.

2.Aims
The overall objectives of this study will be:

a)To examine the current methodology to undertake studies that measure the effects of OA on commercial invertebrate species through laboratory studies and different development phases. The results from this work will include a peer review publication documenting all of the national and global studies on effects of ocean acidification on commercial species and will add recommendations on how industry can adapt to ocean acidification changes (e.g. hatchery strategies on how to monitor and minimised these effects).
b)To discuss and assess monitoring and surveillance of pCO_2 and carbonate chemistry (pH, DIC, TA) strategies in Chile and UK territorial waters, where some changes have been already observed [6]. This work will help to standardise and provide consistency on the sampling methods currently employed as well as setting up the understanding of variability and change on these systems;
c)Dissemination and knowledge transfer on the key messages resulting from the scientific understanding of the effects of ocean acidification on commercial species in UK and Chile to end users (scallop mariculture sector, scientists and government representatives).

3.Methodology:

3.1 Location
Chile also one of the world's largest producers of scallops, Argopecten purpuratus, which are cultured in shallow and protected coastal embayments of northern Chile, chiefly Tongoy and Caldera and a much smaller fraction collected by artisanal divers [7]. Tongoy Bay is responsible for approximately 90% of this scallop production and is located on the lee of a large semi-permanent upwelling centre. This work will combine field and desk based work. The selected study area is located in Tongoy in the north of Chile. This study site has been proposed by the host institution as they have collected some baseline data and have recently deployed in-situ platforms to collect physico-chemical data as well as biological populations of the scallop Argopecten purpuratus.

3.2 Field and data collection
The work will work alongside industry and CEAZA colleagues to collect CTDO (conductivity, temperature, depth, oxygen) data and carbonate system parameters, including pH and total alkalinity inside and around the bay where human activities are concentrated. This area is influenced by coastal upwelling centres. CEAZA has collected initial baseline information in the Tongoy Bay area, helping to illustrate seasonal variability in the site. The existing and newly acquired in-situ data sets will help to understand the evolution of the nearshore physico-chemical environment in the study area. Furthermore, the area has been also subjected to influenced under El Niño conditions also altering the physico-chemical

properties of the water column, which will also be considered under the study of different stressors affecting the conditions of Tongoy Bay.

3.3 Database and data collection

Exiting baseline conditions of physico-chemical properties of the water column will be provided by CEAZA, which is a regional government centre with a duty to monitor and record current conditions. The data is stored in their data web portal (http://www.ceaza.cl/?s=CEAZA+data+base). This information will be used to determine the spatial and temporal variability in Tongoy Bay area, as well as helping to place into context the current natural conditions that the scallop population experienced in this area, as well as understanding their adaptability and resilience under different levels of stress. There will be additional in-situ measurements extracted from the equipment currently deployed at these sites (smart buoys).

3.4 Data analysis

Data from the existing data base available at CEAZA will be employed to produce baseline and characteristics of natural variability as well as to identify periods of clear variability and extreme events. The newly recorded data in the Bay of Tongoy will also be included in our overall analysis to showcase the current different levels of variability with the option to forecast these future patterns.

Data on shellfish aquaculture production data for Chile and UK will be obtained from the OECD Stat website (http://stats.oecd.org). Data series start in 1995 until the most recent available data, which normally refers to 2013. On occasion, individual time-series for some countries started at later date reflecting submission date of information to OECD fishery statistics. Data was collected by the OECD using the methodologies established by the Coordinating Working Party on Fishery Statistics (CWP) (www.fao.org/fishery/cwp/search/en). The immediate observed changes on these commercial species will be observed from the current hatcheries in the area (e.g. weight, length, development and survival) and will be also further augmented with global experiments conducted on OA research [8,9,10]. The new and existing OA results will be compared to assess the measured changes and key parameters (survival, larval stages, calcification). An overall comparative analysis of responses will be conducted to: (i) illustrate methodologies employed (type of experiments, exposure factors and type of end-points measured) and (ii) overall effects observed across commercial species.

4.Timetable

1. June: preparation of desk-based and field work
2. July-august: field work set-up, data extraction (physico-chemical and biological)
3. August-September: data analysis, preparation of manuscript and dissemination of work conducted in Chile with CEAZA UoC-EUHLA and government and industry representatives
4. October- November: draft scientific paper and final report from this fellowship. Seminar to disseminate overall results at Cefas and Defra, UK.

5.Expected results

The project is designed to promote knowledge transfer of technology and scientific expertise. The work will allow local capacity building and ensure that ocean acidification effects are identified can strategies can be adopted to enable industry adaptation of these changes. By

doing so, the commercial species can be safeguarded thereby, minimising risk on food security. This project will build on best practice developed in the UK and Chile through successful science and stakeholder dissemination (targeting industry and government representatives) based on knowledge transfer as well as applied institutional collaboration. Overall this project will raise awareness, promote knowledge exchange and will help to cascade ocean acidification understanding on commercial species on several levels (e.g. bottom up approach: from scientists to government representatives) helping to empower Chile and the UK in their understanding of the effects of ocean acidification effects. The science and dissemination material from this project will be summarised as fact sheets, and shared with CEAZA colleagues. This information can then be used in Chile to educate different groups (e.g. school level) and industry representatives in the study area. This information could be used in Chile and UK to foster understanding and pro-active engagements for safeguarding important commercial species, and fit-for purpose adaptation strategies in response to climate change effects.

6. Mutual benefits

This project seeks to analyse and compare existing and new data sets (physico-chemical and biological). Furthermore, this work through building capability and sharing knowledge from scientist and end-users in Chile and the UK will have a new set of tools required to expand on the understanding and to respond to ocean acidification. Drawing on UK information on the responses of commercial species to ocean acidification [11,12,13] and other multiple stressors [14], there will be opportunity to effectively transfer knowledge from the science to end-user communities and provide adaptation advice. I will work closely with CEAZA colleagues and local end-users (industry representatives such as Invertec) to ensure that dissemination clear and effective to inform on ocean acidification effects on commercial species. By engaging and cascading with local end-users I believe that the scientific outcomes of this project can be maximised to educate and created awareness on the likely risks on commercial species and overall repercussions for food security. I will develop appropriate governance structures to build professional and successful long-term relationships with colleagues across sites. The opportunity of developing joint peer-review publications will provide tangible scientific outcomes as key reference materials to inform assessments of ocean acidification on commercial species in Chile, UK and globally. I am also a member of several groups (e.g. ICES, Global Network Observatory Network, Ocean Acidification International Regulators Group OA-iRUG, and PICES), so I will promote an active participation of Chilean colleagues in these initiatives, as well as taking the opportunity to fully disseminate the conducted as part of this fellowship. I will seek further opportunities (e.g. developing join proposal and chairing join events with Chilean and UK colleagues) to expand the benefits from this partnership.

7.Hosting institutions

The Hosting institutions have offered comments and input during the development of this proposal. At both establishments, there is a core team of experienced scientists (with a strong track record in collaborations and production of scientific outputs). The host organisations have stable government funding via different R&D projects, they also have available the required equipment, support personnel and technology to undertake and analyse the proposed work during the visit. Moreover, both Institutions regularly host and develop multidisciplinary collaborations nationally and overseas, and are used to dealing with targeted research to ensure the maximum outputs form these forms of collaborations.

8. Relevance to the selection criteria

8.1 The proposed aims under this project will produce a tangible scientific contribution based on the developed programme. The Ostiones project will contribute with knowledge, science and understanding common knowledge gaps, concentrating mainly on understanding the OA effects on commercial shellfish species (mainly scallops, known as "Ostiones" in Chile and cockles and scallops in UK). In particular the project will promote: (1) new understanding of OA effects on shellfish fisheries, including economic consequences and magnitudes; (2) shared knowledge on existing experiments (considering different life stages) to investigate the effects of different stressors (oxygen, temperature and food changes) based on OA work conducted in Chile and UK laboratories to maximise efficiency and improve on current experimental methods; (3) the project will take account of existing and new in-situ monitoring data (TA,DIC, pH) and thus provide insight into spatial variability of pH and the carbonate system in waters around the coasts of Chile and UK, thus supporting of long-term statutory monitoring requirements, which can feed into international initiatives to develop OA 'observatories'. The new science generated from this work will help to adapt to climate change effects and provide strategies to support food security in both countries. Furthermore, I will work closely with CEAZA, UoC- EUHLA and local end-users (industry representatives, in the area: Invertec) to ensure that dissemination is fit for purpose to educate many groups on the OA effects on commercial species. By engaging and cascading with a range of users, I believe that the scientific outcomes and research up-take will be cascaded through different communication routes in both countries. I will ensure to develop a professional and long-term relationships (via agreement of an MOU between Cefas and CEAZA). The opportunity of developing joint peer-review publications will provide key reference materials to inform assessments of OA on commercial species in Chile, UK and to global networks. Overall, this work will promote international and scientific cooperation between both countries facing similar risks to sustain and secure shellfish aquaculture systems under current climatic changes.

8.2 Relevance to the theme objective: The proposed work addresses the objectives of the work and the direct relevance to the theme objective, which is to 'Managing Risks in a Connected World', which one of the central aims is to undertake research with the view to anticipate, understand and manage risks that impact could impact on different systems to achieve food security. This proposed research programme fit perfectly under this this theme. The work itself combines the use of field and desk based work, helping to understand the current issues associated to ocean acidification effects on commercial species. This work is centre mainly in addressing issues of natural variability, multiple stressors and the main issues that the aquaculture in Chile could experience as a result of increase pH changes and other stressors in the scallop Aequipenten purpuratus. As well as placing these effects into wider context in the UK and globally to ensure the results are transferable and can help other researchers globally working on this topic. The overview of these results could help to translate understanding, share best practice and jointly develop strategies in both nations to manage risk on commercial species in order to achieve food security.

8.3 Scientific excellence- The proposed work is innovative and has been discussed with host Institutions to ensure that the plan is realistic and clearly defined. The aims of this work are clearly defined and can be summarised in:
(1)Assessing in country the new available evidence on OA effects on shellfish (principally

scallops) and placing these 'potential risks', including economic consequences and magnitudes;
(2)Knowledge transfer on existing experiments (considering different life stages) to investigate the effects of different stressors (oxygen, temperature and food changes) based on OA work conducted in Chile and UK laboratories to maximise efficiency and improve current experimental methods;
(3)Analysing existing information and collecting new in-situ monitoring data (Total alkalinity-TA; Dissolved inorganic carbon-DIC and pH calculations) providing insight into spatial variability of pH and the carbonate system in waters around the coasts of Chile and UK. The data collection could support long-term statutory monitoring requirements, helping to optimise and feed into international initiatives to support global OA observatories.

This completion of these aims could be used as new supporting evidence and could be included in future OECD assessments on food security and potential risks for the aquaculture sector in both countries and well as feeding this new knowledge to the next IPCC assessment to illustrate the current levels of variability and future risks on commercial species resulting from OA effects.

8.4 Achieving the proposed goals- The work relies on field and desk-based data assessments. The host institutions have already the baseline information stored in their data portal. The additional biological and physico-chemical data will be collected whilst on country and augmented with exiting information available via papers and meta-analysis. The physico-chemical data will be collected by in-situ readers, which are sensors placed on smart buoys in Tongoy Bay. The biological data, will be collected over the different hatcheries in the area, which have a strong relationship with the CEAZA and will be able to record scallop parameters (e.g. size, weight, survival and calcification measurements). Detailed questionnaires will be also distributed to assess any other changes observed from the daily estimates (e.g. disease, deformities, mass mortalities, etc.) undertaken by the local industries. These data sets will be gathered and analysed to inform and support industry assessments. The wider data collection (from mussels, scallops and cockles) will be extracted from existing studies conducted by during my own OA experiments and augmented with existing meta-analysis (available in the peer-review literature [15]) to illustrate the current measurements (end points). All of this observed OA effects on these commercial species will be analysed and this work will take account of different commercial species' responses to OA and other stressors. This research will help to showcase and place into context methodological aspects and effects observed globally. The biological screening results will be then used to inform industry on observed organismal responses as well as to optimise measurements (e.g. focussing on a particular larval stage to assess sensitivity and vulnerability) in their hatcheries. These strategies can help to reduce excessive monitoring. An example of this strategy can be seen in the U.S.A in support of an oyster hatchery in Whiskey Creek [16].

8.5 Track record and achievements of the proposer
I am a marine ecologist and scientific advisor on issues related to benthic ecology and human activities for the understanding of long-term benthic changes resulting from climate change and ocean acidification on benthic infauna. Recently, my work has been targeted to understand the potential impacts of co-stressors (e.g. temperature, pH changes and metals) on commercial species. I designed and delivered a number of experiments and field sampling to record local and natural variability. I have experience in both leading and participating in

multi-disciplinary projects at national and international levels. I chair the ICES Benthic Ecology Working group (BEWG) and authored the on subtidal and shallow habitats review for the UK Marine Climate Change Impacts Partnership- MCCIP. I am also a Fellow of the Winston Churchill Travel Foundation for my dedicated research on benthic ecosystems. I have chaired and organised several special sessions for ICES and PICES on ocean acidification. I feel that this opportunity will help me to extend my networks as well as working on a new angle on this topic. I will also be able to cascade my gained UK knowledge on commercial species and the effects of multiple stressors. But more importantly, I will be learning from Chilean colleagues (scientists and end-users), facing similar issues and with different knowledge and resources on these new scientific challenges. For more details on my current and past experience please see my detailed CV.

8.6 Crossing disciplines- the proposed research will work with a wide range of scientists and end-users. The project itself draws together a multidisciplinary team of experienced scientists ranging from experimental ecologists and, biologists, economists, ecological modellers, end users, (see invitation letter from CEAZA). The aims of the proposed work will cover a range of interactions with different areas of knowledge, for example under the proposed objectives, specifically, these are: (1) assessing in country the new available evidence on OA effects on shellfish will required to interact with scientists, hatchery employees and students and technical staff undertaking direct measurements in scallops. (2) the understanding and knowledge transfer of on existing experiments to investigate the effects of different stressors based on OA work conducted in Chile and UK laboratories, could take the form of workshops to discuss techniques and improve current experimental methods. These discussions will attract a series of groups including scientists, students, hatchery end-users, government colleagues and socio-economic scientists to assess the risks that OA could have on these stocks and further consequences; (3) analysing existing information and collecting new in-situ monitoring data to understand spatial variability of pH and the carbonate system will allow the interaction with oceanographers, data-managers and modellers to assess and analyse available and new data. The analysis of monitoring data will be communicated to scientists and government colleagues committed to support statutory monitoring requirements.

8.7 Dissemination- This project will engage on a series of disseminations strategies, these are: production of scientific papers, ii) in country presentations to a series of end-users (from scientists, industry and policy makers), iii) Bringing this knowledge back to Cefas and Defra, UK. The newly generated outcomes will allow local capacity building and ensure that ocean acidification effects are identified, assess their importance and managed appropriately for commercial species and food security. This project will build on best practice developed in the UK and Chile through successful science and stakeholder dissemination with planned knowledge transfer to cement future institutional collaborations. Overall this project will raise awareness, promote knowledge exchange and will help to cascade ocean acidification understanding on commercial species on several levels helping to empower Chile and the UK in their understanding of these effects and pro-actively safeguarding these commercial species.

8.8.Potential impact-The proposed multi-disciplinary research demonstrates the need and the added value to understand current OA effects on commercial species and translating this evidence into the much needed advice for end-users and policy. This proposal will help to build a platform to bring different marine research communities together within the UK

(Cefas) and internationally (CEAZA and Universidad de Concepcion in Chile). We envisage that our new partnership will also engage with our government colleagues (via Cefas) in other on-going ecosystem initiatives such as the Marine Strategy Framework Directive, the UK Climate Change Risk Assessment and UK Marine Climate Change Impacts Partnership (MCCIP). Internationally, this work will provide further evidence to support ICES and PICES priorities on understanding the effects of multiple stressors (including ocean acidification) in marine ecosystems. The outcomes of this work will be presented to the Ocean Acidification International Coordination Centre (OAICC) and to the Latin American Ocean Acidification network (LAOCA). This work will enable several disciplines to work together, integrating knowledge and using novel statistical tools to translate ecological values into further analysis and advice.
I am an established ecologist and marine advisors to national and international organisations (see my detailed CV) and I envisage several presentations and key messages arising from this research that can help to develop applied strategies to minimised risk and ensure food security on commercial species.

8.9 Policy relevance- Since 2008, the UK Climate Change Act requires the government to conduct a Climate Change Risk Assessment (CCRA) every five years, and shortly after that, to put in place a National Adaptation Programme (NAP) that addresses the most pressing threats or enables the UK to capitalise on any opportunities. At present Chile is adjusting to the current rising environmental pressures from its rapid economic growth, strengthening its environmental institutions and introducing new instruments, including a carbon tax. Both nations, are clearly facing similar challenges and working together will certainly can provide many benefits to reduce the risk associated with climate change effects. I am based at the Cefas Marine Climate Change Centre and explicitly lead on marine climate change issues, to investigate gaps in knowledge, to educate future generations and to help the UK to develop a robust response to these important challenges. So, I see this project as a real opportunity to communicate and enhance the current understanding on OA effects on commercial species in both countries. Cefas is a government agency of the Department of Environment, Food and Rural Affairs (Defra). The proposed work under this project can help to create strong Institutional links with Chile, helping to develop expertise and tools for further understanding the wider effects of ocean acidification on commercial species. This project will provide inputs to the UK Marine Climate Change Impact Partnership (MCCIP), which I am a lead author [17] as well as the next UK Climate Change Risk Assessment (CCRA) in 2022, which Cefas also contributes with science and advice.

9. REFERENCES

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Where did you learn about the Programme?

OECD Internet site