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Review

Effects and mitigations of ocean acidification on wild and aquaculture scallop and prawn fisheries in Queensland, Australia

Russell G. Richards[a,b,*], Andrew T. Davidson[c,d], Jan-Olaf Meynecke[a,e], Kerrod Beattie[f], Vanessa Hernaman[g], Tim Lynam[h], Ingrid E. van Putten[i]

[a] Griffith Centre for Coastal Management, Griffith University, Brisbane, Queensland 4111, Australia
[b] Griffith Climate Change Response Program, Griffith University, Gold Coast, Queensland 4222, Australia
[c] Australian Antarctic Division, 203 Channel Hwy, Kingston, Tasmania 7050, Australia
[d] Antarctic Climate and Ecosystems Cooperative Research Centre, Private Bag 80, Hobart, Tasmania 7001, Australia
[e] Australian Rivers Institute – Coast and Estuaries, Griffith University, Gold Coast Campus, Queensland 4222, Australia
[f] Department of Agriculture, Fisheries and Forestry, Brisbane, Queensland, Australia
[g] Queensland Climate Change Centre of Excellence, Queensland, Australia
[h] Reflecting Society, Townsville, Queensland, Australia
[i] CSIRO Wealth from Oceans National Research Flagship, CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia

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ABSTRACT

Ocean acidification (OA) is caused by increasing levels of atmospheric CO_2 dissolving into the world's oceans. These changes are predicted to have detrimental effects on commercial and aquaculture fisheries. Here we examine the implications of OA on the prawn and scallop fisheries in Queensland, Australia, and compare the adaptive capacity of wild and aquaculture fisheries to address and mitigate its effects. We do this by reviewing the available OA literature for scallops and prawns to determine the likely impacts, and our confidence in these impacts, on Queensland prawn and scallop species. The tolerance of scallops and prawns to OA is determined by species-specific differences in their structure, life history, environmental preference, behaviour, physiology and sources of nutrition. Studies of similar taxa are used to supplement the sparse information available for the target species. Wild populations of prawns and scallops appear to be more vulnerable to OA and climate-induced stresses than aquaculture-based populations as ameliorating physico-chemical change in natural waters is difficult or impossible. Our analysis suggests the wild prawn fishery is more resilient to increasing OA conditions than the scallop fishery. We also conclude that aquaculture is likely to be more viable in the long term than the wild fishery as aquaculture facilities allow water quality monitoring and modification to avoid excessive exposure to the physico-chemical stresses imposed by OA and climate change.

Contents

* Corresponding author at: Griffith University, 170 Kessels Road, Nathan, Qld 4111, Australia. Tel.: +61 7 373 55018; fax: +61 7 555 28722.
E-mail address: r.richards@griffith.edu.au (R.G. Richards).

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1. Introduction

There is wide concern within the science community about the potentially rapid changes in ocean biochemistry and its impacts on marine ecosystems, including the consequences for marine-based fisheries (Royal Society, 2005; NRC, 2010; Le Quesne and Pinnegar, 2011). Under the 'business as usual' emissions scenario (IPCC, 2007), mean global seawater pH is projected to decrease 0.3–0.4 pH units by 2100 (Orr et al., 2005; Feely et al., 2008). Calcifying organisms (Cooley et al., 2011; Weinbauer et al., 2011) and organisms susceptible to the effects of hypercapnia (Schalkhausser et al., 2012) appear to be particularly vulnerable to such a decrease in pH.

Changes in pH, pCO_2 and calcite saturation state ($\Omega_{Calcite}$) threaten an annual global fish production that exceeds 140 million tonnes and is worth approximately $150 billion USD per annum (Kite-Powell, 2009). Narita et al. (2012) estimated that the total global cost of ocean acidification (OA) to mollusc fisheries by 2100 may be as high as $141 billion USD while Cooley and Doney (2009) predicted that OA-induced declines in commercial shellfish and crustacean harvests in the US alone at between $860 million and $14 billion USD, depending on CO_2 emissions, discount rates, biological responses and fishery structure.

Given the economic value of global fisheries, there is a critical need for vulnerability assessments of fisheries around the world to explicitly include OA. Such vulnerability assessments are typically strongly quantitative, drawing upon the pool of data and knowledge that have emerged from scientific research. However, the geochemical and biological impacts of OA are not well developed (Poloczanska et al., 2011) and therefore any such assessment needs to take place in an environment of strong uncertainty and variability. Furthermore, whilst OA and fisheries sustainability are global issues, the nature of the vulnerabilities and opportunities that exist are strongly context-specific and a regional approach is needed where the 'local' conditions are taken into account. Therefore, we propose a more qualitative approach to undertaking a vulnerability assessment based on the 'expert opinions' of the authors. We have endeavoured to provide a coherent and consistent approach to this qualitative assessment by classifying the amount of evidence and the degree of agreement (in the evidence) as a means of qualifying our confidence in the validity of our findings.

The Queensland commercial (wild capture and aquaculture) fisheries may be particularly vulnerable to the effects of OA because Queensland fisheries are dominated in volume and value by calcifying species (crustaceans and molluscs) (ABARES, 2012), and the projected decreases in pH for Queensland coastal waters are similar to those projected for elsewhere in the world's oceans (Orr et al., 2005; Feely et al., 2008; Hobday and Lough, 2011).

In this paper we discuss the potential impact of OA on commercially valuable but potentially vulnerable crustacean and mollusc species that are caught in wild fisheries and/or reared by aquaculture for the coastal area of Queensland, Australia. We consider the potential implications of OA for different life-stages of wild caught and aquaculture-grown scallops and prawns. They represent two of the calcifying phyla (crustacea and mollusca) highlighted as vulnerable to OA. Furthermore, they represent established (prawns) and emerging (scallops) contributors to Queensland fisheries. Finally, both scallops and prawns are cultivated through aquaculture in Queensland, allowing an assessment of the capability of aquaculture to mitigate the effects of OA and other co-stressors.

We consider the mechanisms and biological implications of OA-induced stress on these species, a process that includes an evaluation of the role of co-stressors such as increasing sea surface temperature in exacerbating these impacts. We then consider the structure, function and regulation of the scallop and prawn fisheries in Queensland.

Finally, OA coincides with climate-induced changes in the physical environment that will mediate the vulnerability of scallops and prawns to acidification (e.g. Boyd, 2013). While our analysis considers the impacts of OA in the context of climate change,