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Socio-economic and management implications of range-shifting species in marine systems

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ABSTRACT

Climate change is leading to a redistribution of marine species, altering ecosystem dynamics as species extend or shift their geographic ranges polewards with warming waters. In marine systems, range shifts have been observed in a wide diversity of species and ecosystems and are predicted to become more prevalent as environmental conditions continue to change. Large-scale shifts in the ranges of marine species will likely have dramatic socio-economic and management implications. Australia provides a unique setting in which to examine the range of consequences of climate-induced range shifts because it encompasses a diverse range of ecosystems, spanning tropical to temperate systems, within a single nation and is home to global sea surface temperature change 'hotspots' (where range shifts are particularly likely to occur). We draw on global examples with a particular emphasis on Australian cases to evaluate these consequences. We show that in Australia, range shifts span a variety of ecosystem types, trophic levels, and perceived outcomes (i.e., negative versus positive). The effect(s) of range shifts on socio-economic change variables are rarely reviewed, yet have the potential to have positive and/or negative effects on economic activities, human health and ecosystem services. Even less information exists about potential management responses to range-shifting species. However, synthesis of these diverse examples provides some initial guidance for selecting effective adaptive response strategies and management tools in the face of continuing climate-mediated range shifts.

1. Introduction

Present-day shifting of species' range boundaries has been documented for numerous taxa, with many of these shifts attributed to global climate change (Parmesan and Yohe, 2003; IPCC, 2007; Perry et al., 2005). In marine systems, range shifts have been described for all continents, including Antarctica, and at least one Pacific Island (Sorte et al., 2010). Although climate variability has long been recognized to influence changes in the distribution of marine organisms (e.g. Dayton et al., 1999, Roy et al., 2001), the majority of recent published marine range shifts have been polewards in direction – symptomatic of broad-scale environmental changes such as those predicted under global climate change scenarios (Sorte et al., 2010; Perry et al., 2005). In light of even the most conservative future climate change projections (IPCC, 2007), and mounting evidence that climate change is at least partially responsible for shifts in many marine species' biogeographic ranges, examining the diverse consequences of climate-induced range shifts is essential for the development of adaptive management responses. In particular, there is remarkably little understanding of the ecological (but see Sorte et al., 2010) or socio-economic consequences of these shifts, despite mounting evidence that significant, global-scale consequences to socio-ecological systems may occur as a result (Cheung et al., 2010). Likewise, the appropriateness of existing or potential management responses to range-shifting species has not been comprehensively explored, again despite observed (Perry et al., 2005) and projected (Cheung et al., 2010) changes to many managed commercial fisheries globally. Range shifts

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caused by climate variability, while important, will not likely necessitate long-term socio-economic or management responses because these range shifts are not likely to be permanent. Given that the processes of and responses to range shifts caused by climate change versus climate variability are fundamentally different, we have restricted our analyses to the former. Importantly, as the global climate continues to change, range shifts driven by this globally ubiquitous process will likely broaden in both number and geographic extent (Cheung et al., 2010). Considering the socio-economic and management implications of these changes before they occur may help to mitigate their negative effects and develop effective adaptive response strategies.

Based on definitions used by Parmesan et al. (2005) and Sorte et al. (2010), we define 'range shift' as a change in the distribution of native species' boundaries from their previously recorded boundaries (i.e., expansions or contractions along range edges). This definition includes range contractions, range relocations and range extensions (Fig. 1), and we use the term range shift to denote any changes in the boundaries of a species' range (whether contraction, relocation, extension, or where the specific type of change is unknown) unless otherwise noted.

Australia presents an ideal location in which to explore the socio-economic and managerial implications of species' range shifts. It encompasses a wide latitudinal range spanning tropical to temperate ecosystems. It encompasses a diverse range of ecosystems, spanning tropical to temperate systems, within a single nation, thus allowing the socio-economic and management consequences of a diverse suite of examples of range-shifting taxa to be compared in the absence of confounding major differences in governance paradigms and economic structures. Furthermore, Australia's two major ocean boundary currents along the east and west continental slopes, the East Australian Current and the Leeuwin Current, play important roles in structuring marine communities along the coasts. These currents also provide an interesting case study of continental eastern and western boundary flows which are uniquely both poleward-flowing, thus increasing the likelihood of poleward range shifts in response to climate change on both sides of the continent. Historical observations and climate change projections suggest probable strengthening to both of these currents (Ridgway, 2007; Caputi et al., 2010), thereby presenting particularly useful opportunities to examine and compare the resulting ecological, socio-economic, and managerial consequences along these two coastlines.

The aim of this paper is to summarise the known examples of Australian range-shifting marine species and, based on these examples and others from the global literature, present a forward-looking analysis of observed and potential future socio-economic and managerial implications of climate-induced range shifts in marine taxa. We use a suite of marine ecosystems in Australia as a lens through which to evaluate potential effects and their interactions with other system attributes. First, we review the state of knowledge with regard to range shifts in Australian marine taxa. Next, we describe the observed and potential socio-economic effects and managerial responses and discuss their possible implications. Lastly, we outline which management approaches and tools may be more or less appropriate for reducing negative impacts and maximizing opportunities of marine range shifts in the face of ongoing global climate change.

2. Methods

An exhaustive search of range shifts in the Australian marine environment revealed 49 examples of reportedly range-shifting species (Table 1; Appendix 1) in the peer-reviewed literature. Additional reports of apparently range-shifting taxa were collated from non-peer-reviewed sources (and are categorized as such). ISI Web of Knowledge and Google Web and Scholar were used to search for peer-reviewed and grey literature (search terms included *range*, marine, Australia*, and *climate change*). Verified citizen science observations were collated from the REDMAP database (Range Extension Database and Mapping project, available at www.redmap.org.au) and anecdotal accounts were drawn together from the authors' collective knowledge.

To ascertain realized and projected socio-economic implications and management responses to range shifting marine species, we took a two-pronged approach. First we reviewed the above-mentioned studies of Australian marine range shifts (Table 1; Appendix 1) for discussion of socio-economic or management implications or considerations. Second, because there were very few Australian examples that mentioned these, we then broadened our search to analogous global examples to consider potential socio-economic implications and management responses. We did this through a global literature review, as well as by drawing on our collective expertise.

3. Evidence, drivers, and ecological impacts of marine range shifts in Australia

The overwhelming majority of Australian range shift examples documented in the peer-reviewed literature are from eastern Australia, and, notably, only two examples from the tropics were identified (Appendix 1). This is perhaps at least in part a result of a disparity in research effort, rather than a reflection of actual patterns of range shift intensity/distribution. The examples span a range of trophic groups, including apex predators, carnivorous and

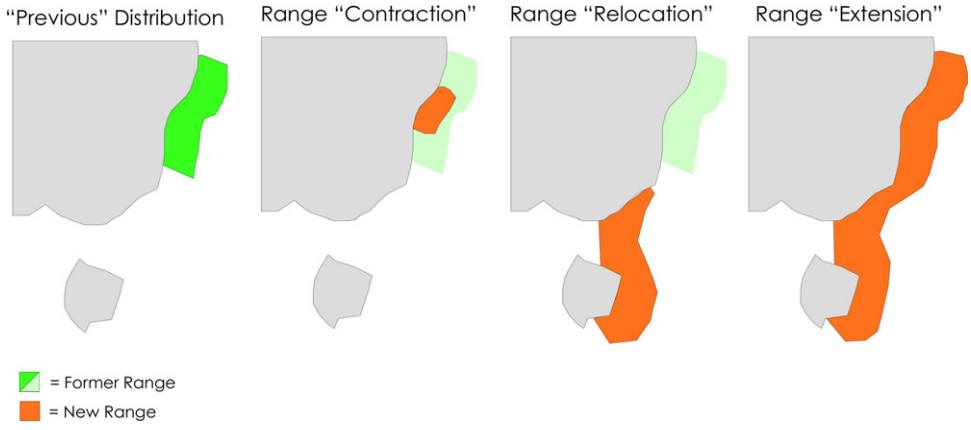

Fig. 1. Hypothetical examples of range shift categories.