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Original Articles

Managing for change: Using vertebrate at sea habitat use to direct management efforts

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ABSTRACT

To understand and predict current and future distributions of animals under a changing climate it is essential to establish historical ranges as baselines against which distribution shifts can be assessed. Management approaches also require comprehension of temporal variability in spatial distributions that can occur over shorter time scales, such as inter-annually or seasonally. Focussing on the Southern Ocean, one of the most rapidly changing environments on Earth, we used Species Distribution Models (SDMs) and satellite ocean data to reconstruct the likely historical foraging habitats of Antarctic fur seals (*Arctocephalus gazella*) from three populations during the non-breeding winter (Marion Island, Bird Island and Cape Shirreff), to assess whether habitat quality has changed in recent decades. We then quantified temporal variability in distributions to assess overlap with management areas (CCAMLR – Commission for the Conservation of Antarctic Marine Living Resources) and the potential for competition with fisheries. Despite notable physical ocean changes, the quality of foraging habitat during the non-breeding season has remained relatively consistent over 20 years at Marion and Bird Islands, but less so at Cape Shirreff, where reduced sea ice cover has improved habitat accessibility. Spatio-temporally explicit SDMs identified variability in habitats across the winter. Some areas overlapped significantly with fisheries activities, suggesting a potential for competition for prey resources at several key periods. A significant component of core habitat at all populations was not within the CCAMLR Convention Area. Although organisations such as CCAMLR adopt a precautionary, ecosystem-based approach to fisheries management, changes to the physical environment and developments in the fishing industry can affect how dependant species are impacted. The hindcasting of historical spatial distributions shown here are baselines against which future changes can be assessed. Given recent proposals for a system of marine protected areas (MPAs) in the Southern Ocean, our results can be used in the design and evaluation of MPAs, be they static or dynamic. Our study also demonstrates that the core habitat of species may fall outside of areas of active management, providing an important context for the interpretation of monitoring programs and management efforts.

1. Introduction

Recent changes to the Earth's climate are well documented, unequivocal and are effecting a wide range of species and communities from the equator to the poles in both terrestrial and marine ecosystems (e.g. Parmesan, 2006). Polar regions are experiencing some of the strongest and fastest large-scale physical changes anywhere on Earth, with rapid rises in atmospheric and oceanic temperatures (Meredith and King, 2005; Chapman and Walsh, 2007) and accelerating loss of ice sheet mass (Pritchard et al., 2012). In the Southern Ocean, there is increasing evidence of the impacts of such changes on biological systems at various trophic levels (e.g. McMahon and Burton, 2005; Montes-Hugo et al., 2009; Flores et al., 2012; Ropert-Coudert et al., 2015). Despite this, the links between physical changes and biological productivity remain poorly understood. However, any biological effects will ultimately be reflected in the responses of higher-trophic level species (seals, seabirds and whales) because they integrate and amplify the effects occurring at lower trophic levels (Hindell et al., 2003; Costa

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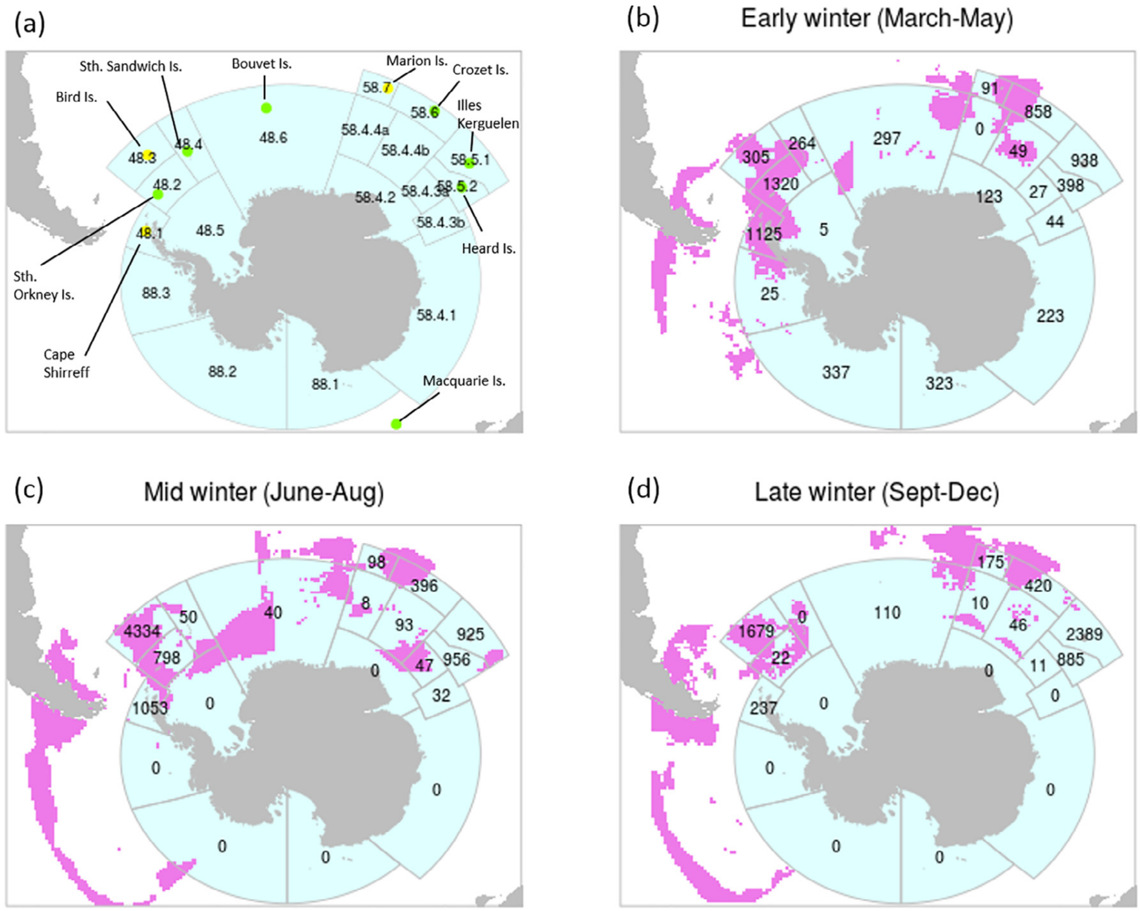

Fig. 1. (a) Location of Antarctic fur seal breeding colonies. Study colonies are represented by yellow circles while all other colonies are represented by green circles. The CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) Convention Area is shown in light blue. Numbers represent the names of subareas and divisions comprising the Convention Area. (b–d) Seasonal Antarctic fur seal habitat in relation to the CCAMLR Convention Area and fishing effort for (b) early, (c) mid and (d) late winter. Core foraging areas for the Marion Island, Bird Island and Cape Shirreff colonies combined is represented pink shading. CCAMLR subareas and divisions are shown in light blue, overlaid with the cumulative total number of winter fishing days 2008–13. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2010), often making them useful indicators of wider ecosystem change.

A change in distribution is one potential response to climate change (Walther et al., 2002; Mueter and Litzow, 2008; Trathan and Agnew, 2010) as species are forced towards higher latitudes or altitudes. Recently, studies into the distribution of highly mobile marine predators have focussed on predicting species responses to future climate change (e.g. Péron et al., 2012; Hazen et al., 2013; Spencer et al., 2016). However, to properly understand current and future distributions it is essential to establish historical distributions as baselines against which changes can be assessed (Lotze and Worm, 2009). Historical records are often brief or fragmented (Swetnam et al., 1999) and biased towards terrestrial ecosystems (Elith and Leathwick, 2009). For marine environments, historical distributions are mostly available for species of commercial interest (Bellier et al., 2007; Nye et al., 2009) and typically do not exist for remote regions such as the Southern Ocean. Conversely, baseline environmental data from remotely sensed sources (satellite) have been available since the 1980's, before the widespread use of animal-tracking devices to observe habitat use and at-sea distributions. Environmental data can be used to construct habitat models or Species Distribution Models (SDMs), which correlate species occurrence with environmental variables to explain or predict a species' distribution (Robinson et al., 2011). The inclusion of historical environmental data has the potential to hindcast SDMs to the likely historical distribution of top predators (Louzao et al., 2013), providing a baseline to assess future change and inform and appraise management decisions.

As well as potential changes over decadal time scales, the spatial distribution of many pelagic predators can be highly variable over shorter periods, such as inter-annually or seasonally (Forney and Barlow, 1998; Pettex et al., 2012). This temporal variability is a major source of uncertainty in marine resource management and the effectiveness of SDMs as a management tool is determined in part by their ability to capture year-round habitat conditions (Becker et al., 2014). For species known to have pronounced seasonality in distribution, as is the case for many Southern Ocean predators (Cockell et al., 1999), SDMs that are spatio-temporally explicit at scales relevant to species movements and management objectives, will likely prove more informative. Although SDMs are under-utilised in marine species (Robinson et al., 2011) they have been effectively employed to inform habitat conservation, understand fisheries interactions and investigate the impacts of climate change in pelagic predators (See Robinson et al., 2011). Yet often, many do not consider the temporal shifts in habitat use and spatial distribution that can occur in wide-ranging animals.

In highly variable environments such as the Southern Ocean, significant environmental changes including the growth and decay of sea ice, seasonal movement of fronts, and fluctuations in primary productivity can occur on relatively short time scales of weeks to months (Gordon, 1981; Clarke, 1988; Sokolov and Rintoul, 2009). Such rapid environmental change can alter prey availability and the distribution of foraging predators (Cockell et al., 1999). Therefore, incorporation of temporal variability into SDMs for Southern Ocean predators is important for a variety of management approaches such as the design of