**1 | INTRODUCTION**

The world’s oceans and their ecosystems are changing due to accumulating pressures such as climate change, extractive activities (fishing, mining etc), and pollution (litter, land runoff etc) (Coll et al., 2008; Cooley et al., 2022; Hoegh-Guldberg & Bruno, 2010; Jennings & Kaiser, 1998; Pauly et al., 2005). The over exploitation of a single species or degradation of a habitat can have dire consequence at the ecosystem level (Coll et al., 2008; Jackson et al., 2001; Pauly et al., 1998; Worm et al., 2006). The methods for managing and protecting the world’s oceans have also changed with the adoption of marine protected areas, sustainable fishing policies, improved and reduced land-based pollution and runoff. Many of these policy decisions are targeted to specific regions or fisheries. For example, changes to fisheries management has led to Australian Orange Roughy stocks to recover and the fishery becoming sustainable (Doonan et al., 2015; Kloser et al., 2015), and marine protected areas in New Zealand and Australia have demonstrated increases in fish abundance and biodiversity (Allard et al., 2022; Edgar et al., 2014, 2017; Knott et al., 2021).

Climate change adds another layer of complexity and uncertainty. Global ocean water temperatures are warming or cooling, pH is altering, CO2 sequestration is changing, ocean currents are shifting direction and intensity, and the timing and quantity of sea ice melt is changing and this is having ecosystem level impacts (Boyd et al., 2016; Constable et al., 2014; Johnson et al., 2011; Wassmann et al., 2011). The changing oceans are resulting in changes to species distributions and leading to biological invasions, and range extensions or contractions (Johnson et al., 2011; Schickele et al., 2021). Understanding how these pressures and climate influence a species or whole communities is important to aid adaptive management, monitoring programs, and identify areas that require protection or greater management to avoid further loss (Arafeh-Dalmau et al., 2021; Emblemsvåg et al., 2022).

The Southern Ocean represents approximately 10% of the world’s oceans and it plays a pivotal role in oceanic primary production, exports nutrients and oxygen the world’s ocean and supports valuable biodiversity (Auger et al., 2021; Constable et al., 2014; Le Quéré et al., 2007; Van de Putte et al., 2021). However, the physical attributes the Southern Ocean, such as water temperature, CO2 sequestration, and ocean currents are changing (Constable et al., 2014; Van de Putte et al., 2021). The Conservation of Antarctic Marine Living Resources (CCAMLR), a leading management body for this region, have acknowledged the need to better incorporate the effects of climate change into decisions on resource, biodiversity, and ecosystem management in the Southern Ocean (Cresswell et al., 2021). The biodiversity of the Southern Ocean is unique and characterised by a high level of endemism in fish species (Constable et al., 2014). This is particularly driven by the sub-order Notothenioids, where 86% of species are endemic to this region (Eastman & McCune, 2000). This group of fishes is also the most abundant on the shelf regions of Antarctica and the Southern Ocean Island such as Heard and McDonald Islands. Both historical and predicted changes in Southern Ocean fish assemblages are mostly unknown. It is expected that the southward shifting ocean frontal systems is likely to have the largest influence on species distributions. However, interpretations of changes in distribution and abundance of fish communities need to be careful when incorporating the confounding effects of fishing and fisheries management.

The key to understanding these environmental processes and ecological change is to have suitable long-term data sets. Oceanographic data has been collected over large spatial scales for decades (e.g. NOAA ref). However, long term (>10 years) biological monitoring or ecological datasets (i.e. species’ occurrence and abundance data), while integral for detecting ecological changes, are relatively rare. In the era of big data, increased computing capacity and innovative approaches to ecological modelling, researcher’s abilities to ask more complex questions and to model at larger spatial and temporal scales had become increasingly possible (Franklin et al., 2017; Tikhonov, Duan, et al., 2020). This includes working with whole species assemblage data across large spatial scales using joint species distribution models (Norberg et al., 2019; Ovaskainen et al., 2017; Tikhonov, Duan, et al., 2020). These modelling approaches allow ecologist to explore correlations across environmental gradients and produce full-coverage ecological maps for each species as well as community attributes such as species richness. Ecologist are also interested in using the same model for making future predictions under different scenarios (Evans, 2012).

The Kerguelen Plateau, located halfway between South Africa and Australia in the Indian Ocean sector of the Southern Ocean is a large dominant geographic feature. It is a productivity hotspot, supporting a diversity of marine life as well as supporting a lucrative demersal fishery, primarily for Patagonian toothfish (Duhamel & Welsford, 2011; Hill et al., 2017). The location and geography of the Kerguelen Plateau means it is highly exposed to the effects of climate change through warming waters and changing ocean currents and polar fronts. Knowledge and information on how climate change is influencing the ecosystem is important for the management and conservation of biodiversity and for managers to meet the obligations of the CCAMLR convention. This includes providing the information needed by fisheries agencies, such as the Australian Fisheries Management Authority, to ensure these lucrative fisheries are management using ecosystem-based management practices. The management of this region is split with France managing the northern half of the Plateau and Australian managing the central portion of the Plateau. Australia has an exclusive economic zone that encompasses Heard and McDonald Islands. The uniqueness and ecological importance of this region were globally recognised with Heard Island and McDonald Island being World Heritage Listed in 1997 and the formation of a no-take marine reserve in 2002. Species of key economic importance have been well studied for stock assessment and fisheries management. There is a significant knowledge gap of how the fish assemblage as a whole is structured across the Plateau and if and how it has changed through time (Hill et al., 2017). Within the Australian EEZ, Patagonian toothfish and mackerel icefish are the two targeted species of the Kerguelen Plateau. The fishery started as trawl fishery in the 1990s but a change to long-line fishing started in 2003 to maximise catches of Patagonian toothfish while minimising bycatch (Welsford et al., 2011). There is still some trawling effort to target mackerel icefish. Historically this region was also exposed to significant illegal fishing. This has led to increase is surveillance of the area since the 1990s. Understanding how changes in management and fishery decisions and increased compliance have led to changes at a species assemblage level is important for ecosystem-based management.

In the study we aimed to establish if the benthic fish community of the HIMI region of the Kerguelen Plateau has changed through time. We then relate any changes in prevalence and abundance of benthic fishes to environmental change, marine reserve zoning or changes to management or fishery practices. To achieve this, we use a joint species distribution modelling (JSDM) approach. We were able establish how much of the variation in each species prevalence and abundance is due to environmental filtering and random process, and how these vary across spatial and temporal scales. This joint species modelling approach provides assemblage level information on the impacts of climate change and fishing and will provide information to facilitate the ecosystem-based management requirements of CCAMLR. The results from this study have the potential to be applied to other regions of the Southern Ocean and help better understand the implications of climate change, fisheries management, and conservation management at a much larger scale.