Journal of Sea Research 99 (2015) 74–82

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Using non-systematic surveys to investigate effects of regional climate variability on Australasian gannets in the Hauraki Gulf, New Zealand☆

Mridula Srinivasan [a,*], Mariela Dassis [b], Emily Benn [c], Karen A. Stockin [d], Emmanuelle Martinez [e,d], Gabriel E. Machovsky-Capuska [d,f,**]

[a] National Marine Fisheries Service, 1315 East-West Highway, Silver Spring, MD 20910, USA
[b] Facultad de Ciencias Exactas y Naturales, Instituto de Investigaciones Marinas y Costeras, Universidad Nacional de Mar del Plata-CONICET, Funes 3350, 7600 Mar del Plata, Argentina
[c] School of Biological Sciences and The Charles Perkins Centre, University of Sydney, Sydney, Australia
[d] Coastal-Marine Research Group, Institute of Natural and Mathematical Sciences, Massey University, Auckland, New Zealand
[e] Pacific Whale Foundation, 300 Ma'alaea Road, Wailuku, HI 96793, USA
[f] The Charles Perkins Centre and Faculty of Veterinary Science, School of Biological Sciences, University of Sydney, Sydney, Australia

ARTICLE INFO

Article history:
Received 5 September 2014
Received in revised form 16 January 2015
Accepted 9 February 2015
Available online 25 February 2015

Keywords:
Seabirds
Climate variability
Apex predators
Hauraki Gulf
New Zealand

ABSTRACT

Few studies have investigated regional and natural climate variability on seabird populations using ocean reanalysis datasets (e.g. Simple Ocean Data Assimilation (SODA)) that integrate atmospheric information to supplement ocean observations and provide improved estimates of ocean conditions. Herein we use a non-systematic dataset on Australasian gannets (*Morus serrator*) from 2001 to 2009 to identify potential connections between Gannet Sightings Per Unit Effort (GSPUE) and climate and oceanographic variability in a region of known importance for breeding seabirds, the Hauraki Gulf (HG), New Zealand. While no statistically significant relationships between GSPUE and global climate indices were determined, there was a significant correlation between GSPUE and regional SST anomaly for HG. Also, there appears to be a strong link between global climate indices and regional climate in the HG. Further, based on cross-correlation function coefficients and lagged multiple regression models, we identified potential leading and lagging climate variables, and climate variables but with limited predictive capacity in forecasting future GSPUE. Despite significant inter-annual variability and marginally cooler SSTs since 2001, gannet sightings appear to be increasing. We hypothesize that at present underlying physical changes in the marine ecosystem may be insufficient to affect supply of preferred gannet main prey (pilchard *Sardinops* spp.), which tolerate a wide thermal range. Our study showcases the potential scientific value of lengthy non-systematic data streams and when designed properly (i.e., contain abundance, flock size, and spatial data), can yield useful information in climate impact studies on seabirds and other marine fauna. Such information can be invaluable for enhancing conservation measures for protected species in fiscally constrained research environments.

Published by Elsevier B.V.

1. Introduction

Many studies have explored quantitative and qualitative relationships between ecosystem state and seabird vital rates and life history parameters within the context of climate change impacts (Ainley and Blight, 2009; Chambers et al., 2011; Dann et al., 2003; Mills et al., 2008), predominantly natural climatic fluctuations. Seabirds are subject to the vagaries of both terrestrial and oceanic changes as they breed on land but spend the majority of their lives at sea (Lack, 1968). These long-lived marine apex predators are well known "biomonitor species", offering opportunities to detect and assess the biological effects of changes in physical parameters (sea surface temperature — SST, salinity, depth of thermocline and environmental oscillations) of the marine ecosystem (Furness and Camphuysen, 1997; Schreiber and Schreiber, 1984).

To date, research into climate impacts on marine ecosystems tends to focus on biogeochemical and lower trophic effects (Doney et al., 2012; Ito et al., 2010). However, this is changing with recent studies now involving an understanding climate variability effects on top marine predators, as reviewed in Hobday et al. (2013) and ecosystem forecasting and downscaled modelling in fisheries ecology (Hollowed et al., 2013). There is also a wealth of literature on climate impacts on seabird reproductive biology and population characteristics (reviewed in Sydeman et al., 2012), although, studies in waters around Australia

☆ Author contributions: KAS collected part of dataset, MS, MD, EM and GEM-C analyzed the data. MS, MD, KAS, EM, EB and GEM-C wrote and edited the manuscript.

* Corresponding author.
** Correspondence to: G.E. Machovsky-Capuska, The Charles Perkins Centre and Faculty of Veterinary Science, School of Biological Sciences, University of Sydney, Sydney, Australia.
E-mail addresses: mridula.srinivasan@noaa.gov (M. Srinivasan), g.machovsky@sydney.edu.au (G.E. Machovsky-Capuska).

http://dx.doi.org/10.1016/j.seares.2015.02.004
1385-1101/Published by Elsevier B.V.

and New Zealand in the south-western Pacific are limited (Chambers et al., 2011).

Previous studies on seabirds indicate that they adapt variably to climate change — the effects are often dictated by intrinsic life history factors and indirectly, through increases or decreases in SST and other climatological factors (Chambers et al., 2012, 2013; Quillfeldt and Masello, 2013). Although seabird responses to environmental change are difficult to predict, there are certain consistent patterns (e.g. changes in distribution, phenology) that do enhance our ability to understand and forecast potential population level consequences in different geographic regions.

The need for inter-decadal time series data has created impetus to establish target species or ecosystem-specific studies. However, such studies are not always possible with depreciating research capacity and budgets worldwide. Thus, alternative data sources need to be considered while acknowledging the limitations associated with these datasets.

Information gleaned from examining historic and current climate trends and purported correlation with species distribution or occurrence patterns, and other demographic parameters can help shape how future studies involving systematic and non-systematic data collection are structured and what parameters are influential. This is especially true for mobile species such as seabirds (Bunce et al., 2002) and marine mammals (Ballance et al., 2006) that feed at the top of the food chain, but are part of a complex food network that generally preclude direct correlations with physical and biological changes. However, they can respond to some systemic changes more strongly than others.

We consider a survey to be systematic if data was collected from a randomized study design with an equal probability of sampling all points in the study area, e.g., line-transect boat or aerial surveys (Buckland et al., 2012). Whereas, we consider non-systematic surveys to be data collected opportunistically from a boat or aircraft providing a reasonable coverage of the study area and similar methods of data collection.

The Hauraki Gulf (HG) North Island, New Zealand (Fig. 1) is recognized for its cultural, economic and ecological significance as a Marine Park (Hauraki Gulf Marine Park Act (2000), Parliamentary Counsel Office, Wellington, New Zealand). The HG, which encompasses an area of ca. 4000 sq km, is a shallow (maximum water depth ~60 m), semi-enclosed body of water riddled with islands and shallow reefs that

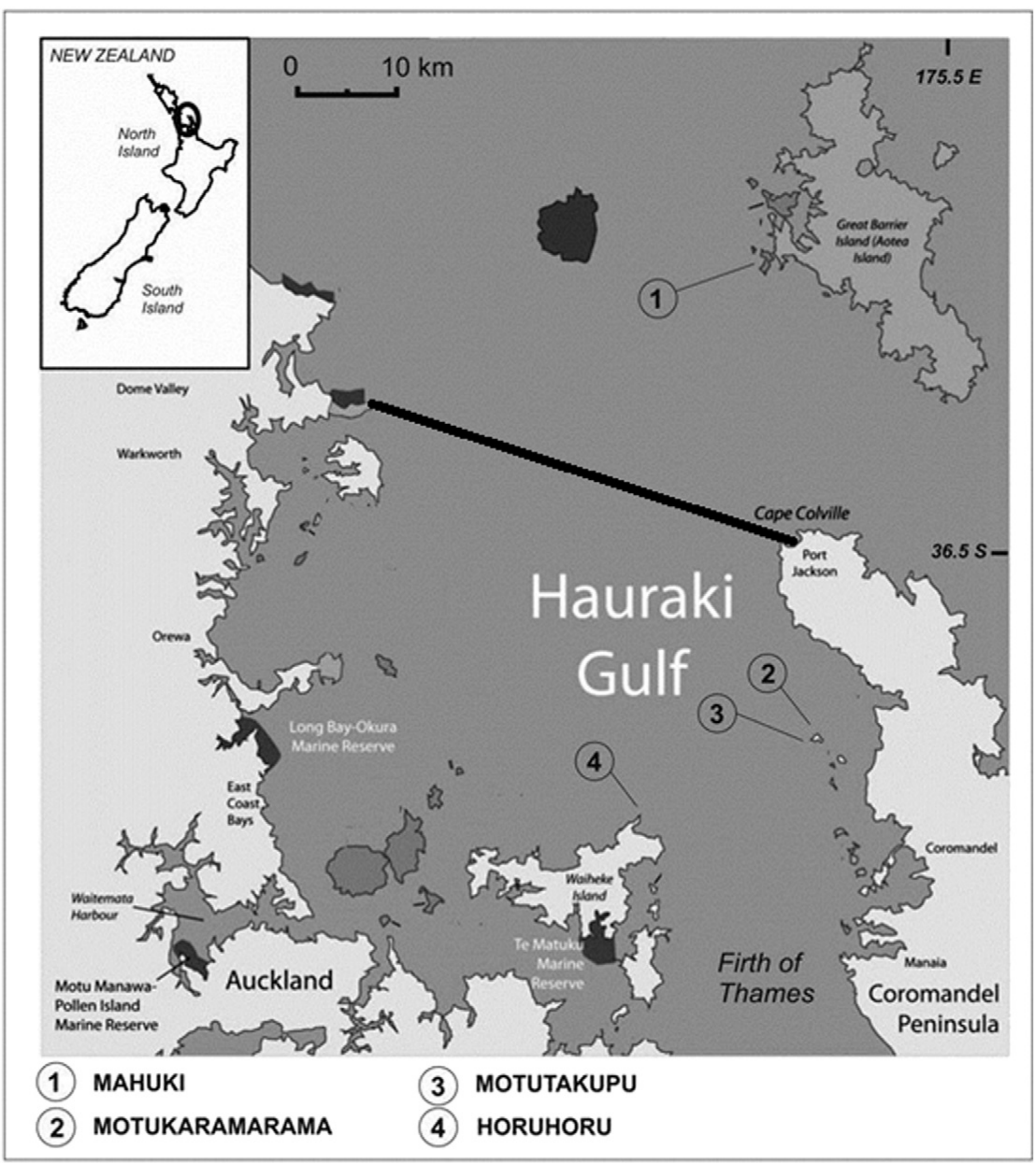

Fig. 1. Study area and location of the main gannet colonies in the HG (New Zealand). The solid black line indicates the boundary line between inner and outer Hauraki Gulf.