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Nonbreeding distribution of flesh-footed shearwaters and the potential for overlap with north Pacific fisheries

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ABSTRACT

Populations of flesh-footed shearwaters on Lord Howe Island, Tasman Sea, have declined recently, with mortality in longline fisheries likely to be one of the major causes. It is therefore imperative to increase our understanding of their distribution at sea, especially during winter. Although they are known to migrate to the north Pacific Ocean, until this study there was very little information available on timing of movements, distribution and habitat use of individuals. Ten to 16 flesh-footed shearwaters (37 in total) were tracked from Lord Howe Island in each of three winter seasons (2005, 2007 and 2008). All birds migrated to the north-west Pacific Ocean, with approximately 70% wintering to the east of Japan in the Kurashio and Oyashio currents, around the Bonin Islands in the north Philippine Sea, or in the eastern Sea of Japan. Others spent a varying amount of time in the Yellow and East China seas, or in the western Sea of Japan. These waters already support intensive fisheries and demand for seafood is likely to rise in tandem with the increasing human populations of East Asia. Consequently, results presented here show that members of the largest population of flesh-footed shearwaters winter exclusively in the north-west Pacific Ocean around Japan and East Asia, in areas they are likely to overlap extensively with a number of fisheries; it is therefore imperative to obtain more information on current and projected levels of bird bycatch and effort in these fisheries in order to developing management strategies for the conservation of the east Australian and New Zealand populations of the flesh-footed shearwater.

1. Introduction

Seabirds are among the most threatened groups of birds in the world; 28% of species are listed as Vulnerable, Endangered or Critically Endangered by the World Conservation Union (IUCN) (Croxall et al., 2012). They are at risk from a range of processes, both on land, such as destruction of breeding habitat or predation by introduced animals, and at sea, including incidental mortality in fisheries or reduction in prey abundance resulting from overfishing (Croxall et al., 2012). Marine threats are particularly difficult to quantify; in addition to the difficulties of observing seabirds at sea, many species migrate long distances. As they traverse multiple national and administrative boundaries, they move great distances from Exclusive Economic Zones where local breeders may be afforded legislative protection, into waters under different national jurisdictions or the High Seas, where they may be at much greater risk from fisheries, oil and gas extraction, other sources of pollution, and hunting, etc. (Moors and Atkinson, 1984; Tuck et al., 2003; Zydelis et al., 2009; Finkelstein et al., 2010; Montevecchi et al., 2012). Effective protection therefore requires information on their movements and distribution at sea, year-round. Procellariiformes (albatrosses and petrels) are especially wide-ranging, with individual albatrosses ranging throughout the Southern Ocean and a number of species of shearwater migrating between the northern and southern hemispheres (Marchant and Higgins, 1990; Klomp and Schultz, 2000; Shaffer et al., 2006; Rayner et al., 2011b). Hence, they are particularly susceptible to threats over wide areas.

All albatrosses, both giant petrel *Macronectes* spp., the five *Procellaria* petrels and Balearic shearwater *Puffinus mauretanicus* are listed under the Agreement for the Conservation of Albatross and Petrels (ACAP) (ACAP, 2012). However, several other species of migratory shearwater have also been identified as potentially deserving inclusion under ACAP (Cooper and Baker, 2008). This includes the flesh-footed shearwater *Puffinus carneipes*, which is a medium-sized shearwater that migrates to the northern hemisphere for the austral winter (Tuck and Wilcox, 2010; Rayner et al., 2011b). This species is currently listed as Least Concern by

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IUCN, which primarily reflects the lack of evidence for a decline in Western Australia, where the majority of birds breed but there is no long-term monitoring program (Birdlife International, 2012). Information on population status is better at Lord Howe Island, off eastern Australia, which holds 5–14% of the Australian, and 8% of the world population (Priddel et al., 2006; Brooke, 2004; Reid et al., 2013). Here, habitat destruction led to a 36% reduction in nesting habitat, and a decline of up to 50% in breeding numbers over the period 1978–2002 (Priddel et al., 2006).

Ship-board observations indicated that the flesh-footed shearwater was one of the most commonly-killed seabirds in longline fisheries off the east coast of Australia (Gales et al., 1998; Baker and Wise, 2005). During 1998–2002, an estimated 8972–18,490 were killed in the Eastern Tuna and Billfish Fishery (ETBF) (Baker and Wise, 2005), leading to the conclusion that by-catch was the principal factor driving the local population decline (Tuck and Wilcox, 2010). In recent years, there has been a reduction in the observed by-catch rates, from 0.38 birds/1000 hooks between 1998 and 2002, to less than 0.07 birds/1000 hooks between 2002 and 2007 (Baker and Wise, 2005; Trebilco et al., 2010). Nevertheless, there is evidence the Lord Howe population may be continuing to decline (Reid et al., 2013).

During the summer breeding season, flesh-footed shearwaters from Lord Howe Island generally spend their time off the east coast of Australia between ~22–42°S and 150–165°E (Thalmann et al., 2009; Reid et al., 2012). Bird by-catch rates in this region are relatively well known (Trebilco et al., 2010). However, mortality during the non-breeding season was identified as a fundamental uncertainty in assessing the impact of fisheries (Tuck and Wilcox, 2010). Evidence from at-sea sightings and from band recoveries suggests that non-breeding flesh-footed shearwaters forage in waters of the north-western Pacific Ocean (in particular off Korea and Japan) with occasional sightings off the coast of Canada, and the USA (Shuntov, 1998; Tuck and Wilcox, 2010). However, the colony of origin cannot be ascribed from at-sea sightings and the proportion of each population that inhabits each of these areas is also unknown. Banding records (13,000 banded; 1234 recovered as of May 2010) from Lord Howe Island show that all of the flesh-footed shearwaters recovered away from the southern hemisphere were in the north-west Pacific, mostly in the Sea of Japan near Korea, and others near the Tsugaru Strait or south of Japan (Tuck and Wilcox, 2010).

To more fully diagnose the continuing decline of the flesh-footed shearwater at Lord Howe Island, we need to improve our understanding of their distribution during the non-breeding season (austral winter). The development of a range of devices since the 1990s has greatly improved our ability to track bird movements, and small, leg-mounted light-based geolocators (Global Location Sensors or GLS loggers) have proven particularly effective for use on small seabirds (Shaffer et al., 2009; Rayner et al., 2011a). We deployed GLS loggers on flesh-footed shearwaters from Lord Howe Island in three different years in order to determine annual variation in timing of migration and non-breeding distribution, use of different water masses and oceanographic features, and levels of overlap and potential interaction with particular fisheries.

2. Materials and methods

2.1. Logger deployments

Lord Howe Island (31°30′S 159°05′E) is a small oceanic island in the northern Tasman Sea, situated approximately 600 km east of the Australian mainland. We tracked post-breeding adults throughout their migrations to the northern hemisphere, in three years. Two types of archival tags were used: LTD 2400 (Lotek, St. Johns, Newfoundland) in 2005 and 2007, and Mk7 GLS loggers (British Antarctic Survey, Cambridge, UK) in 2007 and 2008. Archival tags were fastened to the left leg of each shearwater using a 25 mm Velcro strip. Total weights, including attachment, of Mk7 GLS and LTD 2400 loggers were 5.1 g and 7.1 g, respectively (0.7–1.3% of adult body weight).

Tags were deployed on birds occupying burrows that were known to contain chicks during visits in April. As shearwaters breed annually (Marchant and Higgins, 1990), these birds were considered most likely to return to breed the subsequent year. We attached 20 loggers in April 2005, 22 in 2007 and 23 in 2008. Loggers were recovered during late October and early November of the following austral summer.

The LTD 2400 loggers recorded light levels, temperature and pressure (depth) every two seconds. The temperature sensor has a resolution of 0.05°C and accuracy of ±0.1 °C. The Mk7 GLS loggers sampled light levels every minute and at the end of every ten minute period the maximum light level was recorded. Additionally, every three seconds the logger tested for saltwater immersion, and recorded the number of positive tests every ten minutes; hence, values range from 0 (fully dry) to 200 (fully wet). The temperature sensor of these loggers is internal and takes ten minutes to stabilize, so temperatures were recorded after 20 min of continuous immersion. To conserve memory, another record was only taken after a subsequent dry event, followed by a further 20 min of continuous immersion. Shearwaters rest on the water for a number of hours each night and hence most records of water temperature were taken in the hours of darkness. The temperature sensors of Mk7 loggers had a resolution of 0.625 °C and an accuracy of ±0.5 °C. All loggers were calibrated for 2–7 days at the study site before and after deployment on birds. Temperature sensors were calibrated by taking readings of known temperatures between 5–35 °C in a salt water bath.

Several studies have examined the effects on foraging efficiency, trip duration or return rates of attaching devices such as GLS loggers or satellite-transmitters to wild animals (Phillips et al., 2003; Söhle, 2003; Igual et al., 2005; Vandenabeele et al., 2012). Past studies have not found major effects, and given its relatively large size, we did not expect to find significant effects of loggers on our study species. In order to determine if there was any effects of attaching tags, forty recently returned adult flesh-footed shearwaters (with devices, or randomly-selected controls) were weighed during October/November 2008. Birds were sexed using methods from Thalmann et al. (2007). The effects of sex and device deployment on body mass was tested using a model based on Equation 1 (using the R package r2winbugs);

$$Weight_i = \alpha + \beta_{j(i)} * Sex_i + \delta_{k(i)} * Attachment_i + \varepsilon_i \\ \varepsilon_i \sim Normal(0, \sigma^2) \quad (1)$$

where $Weight_i$ is the weight of bird i, α is the value for the base case (female with no attachment), β is the coefficient of the factor *Sex*, which could take three levels j (female, male and unknown) and δ is the coefficient of the factor *Attachment*, which can take two levels k (no and yes), with an error term ε. Importance of these variables is indicated by how far their mean and credible interval deviate from 0, with non-significant terms overlapping zero and those that had a significant effect not overlapping zero. In order to further compare the effects of these terms, we examined the Deviance Information Criterion (DIC) of four models using combinations of these terms (single term, both terms, interacting terms).

2.2. Estimation of at-sea movements

Positions derived from GLS loggers deployed on flying birds are known to be somewhat inaccurate, with mean errors of 186 km attributable to variation in sensor orientation, intermittent shading by plumage, time of year, and extensive, potentially non-linear