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Tracking seabirds to identify potential Marine Protected Areas in the tropical western Indian Ocean

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ABSTRACT

We conducted a regional tracking program on seabirds in order to identify major forging hotspots and potential Marine Protected Areas in the tropical western Indian Ocean. Thirty-one species of seabirds breed in the region, totaling 7.4 million pairs. The main breeding grounds are in the Seychelles, in the Mozambique Channel and in the Mascarene. Seven pelagic species have been tracked so far from eight different islands of the region. Using count per sector analysis we identified five major oceanic foraging hotspots, among which three include the breeding colonies and two are oceanic areas not connected to a breeding island. We found important overlaps between most of these seabird foraging hotspots and potential threats (industrial fishery targeting surface dwelling tunas and marine pollution due to maritime routes) suggesting that in these regions seabirds may be at risk when foraging. Although this analysis is based on a limited number of tracking studies, the knowledge on seabird distribution at sea has increased tremendously in the last 6 years in the tropical western Indian Ocean, and this trend will continue, as research is ongoing. The data, we present here for the first time in a single synthesis show clear spatial patterns that identify high priority locations for designation as Marine Protected Areas in the tropical western Indian Ocean.

1. Introduction

Tropical pelagic ecosystems of the western Indian Ocean are a marine hotspot of biodiversity, with major concentrations of emblematic or economically important species such as cetaceans (Balance and Pitman, 1998), turtles (Lauret-Stepler et al., 2007), tunas and billfish (Worm et al., 2005) and seabirds (Le Corre and Jaquemet, 2005). In spite of this, Marine Protected Areas (MPAs) cover less than 1% of the oceanic and coastal surface of the region (figure derived from WIOMSA, 2010), and, except for the ongoing project of implementing a large MPA around the Chagos Archipelago (Koldewey et al., 2010; De Santo et al., 2011), there are currently no specific tools to protect pelagic ecosystems of the region (Game et al., 2009).

Although industrial fisheries have historically had less impact on the tropical Indian Ocean than in other oceans, since the late 1980s this is no longer the case. In the tropical western Indian Ocean, annual catches of tunas have increased 30-fold, from less than 40 thousand tons in the early 1950s, to more than 1200 thousand tons in 2007 (IOTC, 2008a). When top predatory fish like tunas are targeted, their collapses can lead to meso-predator releases and cause cascading effects throughout the food chain (Baum and Worm, 2009). In the tropics, most catches are made by industrial fisheries (long liners and purse seiners) and in the Indian Ocean, all purse seine catches and more than 80% of long line catches occur in the western basin (Ménard et al., 2007; IOTC, 2008), indicating that this region supports great productivity and is at risk from concentrated fisheries.

Fisheries impact seabirds in various ways, the main impacts include direct mortality by fishing gear (by catch) and competition when fisheries and seabirds target the same prey (e.g., Okes et al., 2009; Trebilco et al., 2010). Although these interactions can have large impacts on many seabird populations throughout the world (see Furness, 2003 for a review), our observations in the western Indian Ocean indicate that they do not have major impacts on seabirds in this region. There is little bycatch of seabirds in the tropical western Indian Ocean (Anderson et al., 2009 and pers. obs.), likely because seabirds in the western Indian Ocean community tend not to be attracted to fishing vessels. Fisheries and

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seabirds do not compete directly for a shared prey community because most tropical seabirds feed upon small epipelagic prey (Le Corre et al., 2003; Jaquemet et al., 2008; Catry et al., 2009a), whereas the tropical industrial fisheries target top predators such as tunas and swordfish, which are also predators of epipelagic fauna (Potier et al., 2007). Therefore, because fisheries-induced mortality of top predatory fish may lead to a release of epipelagic fauna (see for instance Polovina et al., 2009), it might be expected that industrial fishing would benefit seabirds. However, because tropical seabirds are strongly dependent on surface dwelling top-predators, we suggest this is not the case. Tropical seabirds rely on surface seizing and plunge diving (Harrison, 1990) to acquire prey, and very few are able to dive deeper than a few meters. Because epipelagic prey are distributed within the upper 50 meters of the water column, they are only accessible to seabirds when surface dwelling predators like tunas and dolphins pursue epipelagic prey and force them to flee toward the surface. Tropical seabirds take advantage of this phenomenon by frequently foraging over schools of tunas or dolphins to catch the evading prey. This interaction is so important for tropical seabirds that it has been termed a ''near-obligate commensalism'' between seabirds and marine top predators (Au and Pitman, 1986). At-sea studies in the Indian Ocean have confirmed that most seabirds are associated with surface dwelling tunas (Jaquemet et al., 2004, 2005).

Because fisheries of the western Indian Ocean target mostly surface dwelling tunas, including skipjack (*Katsuwonus pelamis*) and yellowfin tunas (*Thunnus albacares*) (IOTC, 2010a), this commensalism faces a high risk of disruption if tunas become overfished. The consequence of this disruption has never been quantified but may be very important for seabirds. Indeed, the depletion of surface dwelling tuna may reduce the foraging efficiency of many tropical seabirds, which could have cascading effects on their population dynamics (Le Corre and Jaquemet, 2005).

Offshore MPAs could potentially benefit species targeted by industrial fisheries (tuna and billfish) and help to sustain these fisheries ((Worm et al., 2009; Koldewey et al., 2010), although the conservation of highly migratory fish like tuna is more challenging (Steffansson and Rosenberg, 2006) and may require the implementation of dynamic MPAs (see for instance Hobday and Hartmann, 2006). Increased protection of resources targeted by fisheries could also afford increased protection for untargeted species vulnerable to bycatch (sharks, rays, turtles, marine mammals) and for the species associated with tuna, like seabirds (Le Corre and Jaquemet, 2005).

The second major threat, which may impact marine biodiversity of the Indian Ocean, is oil pollution. Thirty-six percent of the world's oil is produced in the Middle East, and most of it is exported via maritime routes throughout the Indian Ocean (figures extracted from http://www.nationmaster.com/graph/ene_oil_pro-energy-oil-production). Intensive maritime traffic increases the risk for low-level chronic pollution and potentially catastrophic oil spills (Vethamony et al., 2007; Sivadas et al., 2008). The impact of oil pollution on seabirds has been widely documented and most studies have shown that oil spills invariably produce massive seabird mortality (e.g., Ford et al., 1996; Votier et al., 2008; Munilla et al., 2011). The level of mortality is variable however and depends on various parameters including size of spills, weather conditions, seabird foraging behavior and seabird density (Tan et al., 2010). Seabird mortality associated with oil pollution is poorly documented in the Indian Ocean (but see Evans et al., 1993). However, given the intensity of the maritime traffic and the density of seabirds in this part of the world, there is a high risk of additive seabird mortality due to chronic or accidental oil pollution.

As seabirds are relatively easy to track at sea compared to most other marine top predators, we propose that their foraging distributions and movements can be used to identify oceanic areas of particular importance for seabirds and associated marine community assemblages. Indeed, there is a worldwide interest in using seabird telemetry data and at-sea surveys to identify marine Important Bird Areas (IBAs, BirdLife International, 2011) and potential MPAs (e. g. Hyrenbach et al., 2006; Louzao et al., 2009). The validity of determining protected areas from top-predator distributions has similarly been demonstrated in terrestrial areas (Sergio et al., 2005). Tracking data can also help to identify oceanic areas where seabirds are at risk of oil spills (Montevecchi et al., 2011).

BirdLife International has defined a set of criteria to define a zone as a marine IBA (BirdLife International, 2011) one of them being that the area must hold a least 1% of the global population of a given seabird species (BirdLife International, 2011). In this paper, we did not calculate such proportions with our tracking dataset. Instead we used our tracking data to identify ''population hotspots'' (BirdLife International, 2011) whatever the size of the populations studied, because we considered that these hotspots are indicators of important marine ecological processes. Thus we consider a ''population hotspot'' as an area where individuals of a given seabird population concentrate to forage.

In this paper, we analyze all tracking data available for seabirds of the tropical western Indian Ocean to identify these hotspots. Because seabirds forage mostly at places of great productivity and of important ecological processes, we propose to ultimately use these foraging areas as indicator of potential Marine Protected Areas in the tropical western Indian Ocean. In order to identify areas where seabirds may be at risk when at sea, we also compiled all spatially explicit data on industrial fisheries and on maritime trade routes in the tropical Indian Ocean, and we conducted an overlap analysis of these threats with our tracking data.

2. Material and methods

2.1. Seabird datasets

2.1.1. Breeding colonies

The abundance and distribution of seabirds at sea depend primarily on where they breed. We compiled all existing data on seabird colonies of the western tropical Indian Ocean. We define the western tropical Indian Ocean as the part of the Ocean located between the coasts of East Africa and the longitude 70°E and between the latitudes 10°N and 30°S. This compilation includes Mozambique (Parker, 2001), Tanzania (Baker and Baker, 2001), Kenya (Bennun and Njoroge, 2001), Somalia (Anonymous, 2001), Madagascar (ZICOMA, 2001), Comoros (Safford, 2001a), the Seychelles (Rocamora and Skerret, 2001), Mauritius (Safford, 2001b), Reunion and Iles Eparses (Le Corre and Safford, 2001). We compiled all areas of these countries identified as Important Bird Areas (IBA) because of their seabird breeding colonies (see references above). We also included in this compilation all other seabird breeding sites of the region, which are not yet classified as IBAs (Louette, 1988; Rocamora et al., 2003; Rocamora, 2004; Crawford et al., 2006; Anonymous, 2008; McGowan et al., 2008; Le Corre and Bemanaja, 2009).

2.1.2. Tracking data

Since 2003, we conducted a regional tracking program on seabirds of the tropical western Indian Ocean (see Weimerskirch et al., 2004, 2005, 2010; Catry et al., 2009b; Pinet et al., 2011). As far as we know this represents all the tracking data available for seabirds of the region, except the work of Asseid et al. (2006) conducted on masked boobies (*Sula dactylatra*) of Latham Island, and our own work on the migration of a great frigatebird (*Fregata minor*, Weimerskirch et al., 2006). We haven't included these data in