Seabirds, fisheries, and cameras

Peer-reviewed letter

Who will win the fight over scarce sardines in the Benguela ecoregion? In this upwelling system off southern Africa, once vast pelagic (open-ocean) fish stocks have decreased substantially as a result of inherent population variability, climate change, and fishing pressure (van der Lingen *et al.* 2006). Off the coast of Namibia, catches of sardines (*Sardinops sagax*) and anchovies (*Engraulis encrasicolus*) are now < 2% of those taken during the 1960s, and populations of endemic Cape cormorants (*Phalacrocorax capensis*), African penguins (*Spheniscus demersus*), and Cape gannets (*Morus capensis*), all of which depend on these pelagic fish, have declined to < 20% of levels recorded prior to industrial fishing (Crawford 2007). Off the coast of South Africa, sardine stocks declined from 4.2 million to 0.5 million metric tons (t) between 2002 and 2009, and pelagic fish showed substantial distribution shifts (Roy *et al.* 2007; Coetzee *et al.* 2008). The remaining seabirds and purse-seine fisheries from South Africa's west coast are therefore bound to track the same scarce and elusive resources (Grémillet *et al.* 2008a). In this situation, modern fisheries are usually assumed to outperform other marine predators, given that the former have the logistical capacity to locate and harvest shoaling fish, even at very low densities (Valdemarsen 2001). Marine protected areas (MPAs) closed to fisheries have been proposed to protect the prey of vulnerable, endemic Benguela seabirds. Localized MPAs are being implemented on an experimental basis around some of the penguin colonies (Pichegru *et al.* 2010), yet are currently not considered for the protection of far-ranging Cape gannets, since this would require closing the entire southern Benguela area to fisheries (Pichegru *et al.* 2009). Alternatively, spatially managed fishing quotas may help to keep sufficient fish in the system locally to feed vulnerable marine predators. Here, we report on a case where compliance with fishing quotas established since the early 1980s allowed a colony of 70 000 Benguela seabirds to compete favorably for increasingly scarce sardines with a fleet of 79 purse-seiners.

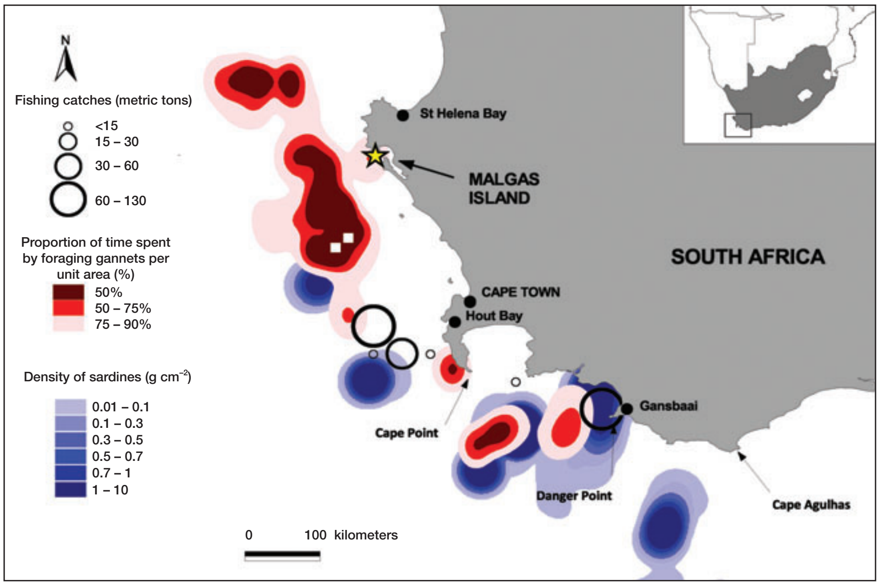

Figure 1. *Foraging zones (red color scale) of 21 Cape gannets breeding on Malgas Island (yellow star), relative to sardine aggregations (blue color scale) and sardine catches by fishing vessels (black circles) in October–November 2009 (maximum growth phase of the gannet chick; the most appropriate period to test seabird/fishery interactions). White squares indicate where the photographs displayed in Figure 2 (a and b) were taken. Each gannet was tracked for a single foraging trip by way of a GPS device recording position every second. Interruptions in the GPS signal of >1 second were due to plunge-diving behavior, and hence positions associated with these interruptions were used to identify feeding spots. We determined the spatial occurrence of sardines by hydroacoustics, using semi-stratified random sampling across the entire study area. Spatial distribution of sardine catch by purse-seine fishing vessels was compiled through log books, stating the catch volume, time, and position of each haul.*

We studied Cape gannets breeding at Malgas Island, South Africa (Figure 1). Once the world's largest breeding colony for this species, numbers have declined by 40% since the late 1990s. Because of the recent scarcity of their preferred prey (sardines and anchovies) on the west coast, birds now mainly feed on fishery waste from hake (*Merluccius* spp) trawlers (Grémillet *et al.* 2008b). However, in November 2009, sardines and anchovies suddenly reappeared in the gannets' diet (78% and 10% of diet by mass, respectively). We tracked the at-sea movements of 21 breeding gannets using miniature global positioning system (GPS) units attached to their backs. Their main feeding areas broadly overlapped with localized, low-density sardine aggregations detected during a concurrent hydroacoustic research survey (Figure 1). Data from the pelagic fishing fleet showed that, at the time of our investigations, purse-seiners targeted some but not all of the sardine patches, primarily off the fishing harbors of Hout Bay and Gansbaai (Figure 1), catching 356 t of sardines in total. This is < 1% of the maximum, and 3.5% of the average, monthly catch made by the purse-seine fleet fishing for sardines around the south African coastline during the past 23 years. During November 2009, the 70 000 Cape gannets from Malgas Island therefore caught nearly three times as many sardines (equivalent to ~1160 t, assuming that 78% of the birds' diet comprised sardines and that each bird required 710 g of fish per day; compare with Pichegru *et al.* 2007) as captured by fisheries. To better assess the co-occurrence of gannets and fishing vessels at sea, we equipped five birds with backward-facing cameras taking pictures every 15 seconds. Two of these birds were also fitted with GPS loggers. We collected 7700 photographs, showing that birds spent 60.9% of their time at sea in flight, 34.6% resting on the water's surface, and 2.4% plunge-diving for fish – a time budget similar to that determined using other techniques, such as motion sensors. Although 355 photographs showed numerous other gannets both above- and underwater (Figure 2a and b), no fishing vessels were photographed (however, a freight ship was; Figure 2c – indicating that this technology does allow vessels to be pictured). This confirms that gannets had exclusive use of some sardine patches (Figure 1). Such a favorable situation is likely explained by the fact that, as in previous years, 95% of the 2009 sardine fishing quota (90 000 t) had been caught by November, which reduced the motivation of the purse-seine fishing fleet to target patchy, sparse sardine shoals.

Cameras fitted to marine top predators have already proved useful in exploring the mysteries of their lives offshore, in particular their diving behavior and group dynamics (eg Davis *et al.* 1999; Williams *et al.* 2000; Takahashi *et al.* 2004; Watanuki *et al.* 2008; Sakamoto *et al.* 2009). Our pilot study – based on a limited number of individuals – demonstrates that, in the context of managing global fisheries, cameras affixed to seabirds can be used to monitor seabird surroundings at sea, and potentially identify interactions between these threatened species and fishing vessels. In areas where "pirate" fisheries occur, this technology may even allow remote identification and positioning of illegal fishing vessels.

Figure 2. *Five Cape gannets were equipped with cameras (same device as in Sakamoto* et al. *2009) recording pictures of their surroundings at 15-second intervals. Birds foraged for sardines in dense predator flocks, (a) taking close-ups of conspecifics underwater and (b) at the water surface. (c) Cape gannets equipped with back-facing cameras scanned the horizon while flying, here providing the picture of a freighter off the study colony in Saldanha Bay (see Figure 1).*

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