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Note

Gillnet fisheries as a major mortality factor of Magellanic penguins in wintering areas

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ABSTRACT

The incidental capture in fisheries is probably the main conservation problem affecting seabirds. While the capture of albatrosses and petrels on longline hooks is well-known worldwide, the bycatch of diving seabirds in gillnets is an overlooked conservation problem. During a winter coastal fishing trip, the capture of Magellanic penguins (*Spheniscus magellanicus*) was recorded in driftnet and bottom setnet fisheries for the first time in southern Brazil. The highest captures rates were found in driftnets, from 146.5 to 545.5 penguins/km^2 of net and a total of 56 dead penguins were recorded. In the bottom gillnet, a total of 12 birds were killed and the capture rates varied from 41.7 to 125.0 penguins/km^2 of net. Although preliminary, the results presented in this paper were consistent between sets. If we consider the magnitude of driftnet and setnet fishing fleets, and that most dead penguins were adults, the impact upon Magellanic penguin populations is probably significant.

1. Introduction

The incidental mortality of seabirds in fisheries has focused on albatrosses and petrels in longline fisheries globally (*e.g.* Gales et al., 1998; Brothers et al., 1999) and in the southwestern Atlantic Ocean (Bugoni et al., 2008a; Jiménez et al., 2009). Furthermore, warp cables of trawl nets (González-Zevallos and Yorio, 2006; Sullivan et al., 2006; González-Zevallos et al., 2007; Watkins et al., 2008) and a range of small scale hook-and-line fisheries (Bugoni et al., 2008b) have also resulted in seabird mortalities in the region. The high-seas driftnet fishery for squid and salmon which operated in the North Pacific Ocean was a major problem in the 1970s and the 1980s, killing hundreds of thousands of seabirds, mainly diving birds such as shearwaters (DeGange and Day, 1991; Johnson et al., 1993). However, apart from these long standing studies, gillnet fisheries has generally received little attention. In a recent review, gillnet fisheries in general and coastal gillnet fisheries in particular, were regarded as a major threat for some waterbird populations, despite being an overlooked issue (Žydelis et al., 2009).

Chronic oil pollution and reduction in prey availability due to climate change and competition with commercial fisheries are suggested as the main causes of population decline of Magellanic penguins (*Spheniscus magellanicus*) (Boersma, 2008; García-Borboroglu et al., 2010). While incidental capture in fisheries is a major issue for several seabird species, it is frequently regarded as of secondary importance for penguin conservation in general, as well as for Magellanic penguins (Schiavini et al., 2005; Boersma, 2008). In the Atlantic Ocean, Magellanic penguins were incidentally captured in low numbers in bottom trawl fisheries in Patagonia, Argentina (Gandini et al., 1999; Yorio and Caille, 1999; González-Zevallos and Yorio, 2006; González-Zevallos et al., 2007; Yorio et al., 2010) and in midwater trawl fisheries in Argentina (Tamini et al., 2002). Gillnets are known to capture Magellanic penguins in southern Argentina, but, apparently, this has not been quantified (Schiavini et al., 2005); large numbers are also captured in Chile and Peru, in the Pacific Ocean, together with Humboldt penguins (*Spheniscus humboldti*) (Simeone et al., 1999; Majluf et al., 2002).

The Magellanic penguin has a global population estimated to be 2.5–5 million birds (BirdLife International, 2010) breeding along the Chilean coast in the Pacific Ocean, and in Argentina and on the Malvinas/Falkland Islands in the Atlantic Ocean (Williams, 1995; Woods and Woods, 1997). In the last century, populations fluctuated considerably, with an overall increase until the 1980s (Boersma et al., 1990; Williams, 1995). However, a subsequent decrease occurred in some large colonies such as Punta Tombo, Argentina, where a 22% reduction in the number of breeding pairs has been recorded since 1987 (Boersma, 2008). Other colonies

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increased or remained stable, but due to an overall downward population trend and a range of identified threats, the species is listed as 'near threatened' (BirdLife International, 2010).

The Magellanic penguin is one of the most abundant top predators over the Patagonian continental shelf (Pütz et al., 2007), migrating northward during the austral winter, up to Rio de Janeiro in Brazil (*c.* 23° S) following the Argentine anchovy (*Engraulis anchoita*), its main prey in northern Patagonia (*c.* 46° S) (Williams, 1995; Pütz et al., 2001; Boersma et al., 2009). From July to December, thousands of dead penguins are found every month along the 620 km coast of Rio Grande do Sul, the southernmost Brazilian State (Mäder et al., 2010). Over 97% are first-year juveniles, mostly emaciated and with no recent food in their stomachs (Pinto et al., 2007; García-Borboroglu et al., 2010; Mäder et al., 2010). Strandings of large numbers of penguins on the Brazilian coast were known as early as 1927 (Vooren and Brusque, 1999), and isolated individuals were recorded in the 1500s in Vitória, Espírito Santo State (*c.* 20° S) by missionary Anchieta (Neiva, 1929). These facts led to the suggestion that the stranding of large numbers of penguins on Brazilian beaches was a natural phenomenon (Vooren and Brusque, 1999), or part of a 'population surplus' (Sick, 1997). However, with the intensification of human activities and development in the region, the contribution of each factor (*e.g.* natural mortality, competition with fisheries, incidental capture in fisheries, oil and plastic pollution) to the mortality and its effects on the population remains unknown.

In this study, we report the regular capture of large numbers of Magellanic penguins, mainly adults, in coastal gillnet fisheries (setnet and driftnet) in southern Brazil, and advocate that it has been a significant and neglected issue in the Southwestern Atlantic Ocean.

2. Methods

Data were collected from 16 to 31 July 2009 by the onboard observer L.G.C. on a gillnet fishing vessel typical of the Passo de Torres fleet, in southern Brazil. The vessel was 21 m long, built of wood, with a 360 HP engine, storage capacity of 30 tonnes of fish in crushed ice, and autonomy for 20 days at sea (Cardoso and Haimovici, accepted for publication). Two different gillnet fishing methods were used during the sampling trip, between 30°47′S–50°24′W and 31°05′S–50°29′W, from 1 to 3 km from the coast and water depth 17–30 m, as described below:

Driftnet fishing targeting bluefish (*Pomatomus saltatrix*): nine sets were carried out using nylon monofilament, net 1.86–2.38 km long, 18 m high and mesh size of 90 mm. Soak time varied from 6 to 7 h.

Setnet (bottom) gillnet fishing targeting demersal Brazilian codling (*Urophicys brasiliensis*) and stripped weakfish (*Cynoscion guatucupa*): eight sets were carried out using nylon monofilament nets, 5.9–11 km long, 4 m high and mesh size of 100 mm. Soak time varied from 18 to 23 h.

A range of fishing fleets operates with a variety of fishing techniques over the continental shelf in southern Brazil (Haimovici et al., 2006). Gillnet fleets from the ports in Rio Grande do Sul and Santa Catarina States work in southern Brazil with bottom setnets and driftnets. The number of vessels that operate with bottom setnets or driftnets is not quantified, since some of them use both types of gillnets alternately or together according to the season. This fleet was composed of about 280 vessels in both States and landed 342 tonnes of bluefish, 1611 tonnes of stripped weakfish and 1119 tonnes of Brazilian codling from May to October 2008 (IBAMA/CEPERG, 2009; UNIVALI, 2009).

For all sets, the number of dead penguins was recorded, while the number of live penguins was not, since they were released immediately by fishermen; so, bycatch rates presented refer to mortality. Because the age of the penguins was not recorded at sea, we obtained adult to juvenile ratios based on three photographs and one video obtained during the trip, in which 29.4% of the dead penguins are displayed, as well as an unknown proportion of live penguins.

Sampling effort is presented in linear km of net (*i.e.* net length) and km^2 of net (*i.e.* net area), and incidental capture rates reported as number of dead penguins/km^2 of net area deployed, allowing the comparison between both fisheries which have different configurations. Capture rates of bottom setnet and driftnet fisheries were compared by Mann–Whitney test. For comparison with other studies, the capture rate was also calculated as the number of dead penguins/km of net length per fishing day, since it is the most commonly reported bycatch rate (Žydelis et al., 2009). The deviation from the 1:1 adult to juvenile ratio was calculated by χ^2 with Yates correction for continuity (Fowler et al., 1998). Tests were calculated using BioEstat software, version 5.0 (Ayres et al., 2007).

3. Results

All nine driftnet sets and seven out of eight bottom setnet sets captured dead Magellanic penguins, the single bird species affected. In the driftnet fishery, from 3 to 13 penguins were captured per set and capture rates varied from 146.5 to 545.5 penguins/km^2 of net, with a total of 56 dead penguins (Table 1). About 30 penguins were captured alive by drift gillnets and were released at sea.

In the bottom gillnet fishery, 0–3 penguins were captured per set and capture rates varied from 41.7 to 125.0 penguins/km^2 of net, with a total of 12 birds killed during the fishing trip. No live penguins were captured in the bottom fishery. The capture rate was significantly lower in the bottom fishery (Mann–Whitney test, $U = 3.87$, $P = 0.0001$).

Overall, 20 dead penguins were recorded in photographs and videos: 81% were adults and 19% were juveniles, a significant deviation toward adults ($\chi^2_{Yates} = 24.7$, $df = 1$, $P < 0.0001$).

A positive and nonsignificant Pearson's correlation between the number of dead penguins and the capture of bluefish was found in the driftnet fishery (coefficient of determination $R^2 = 0.31$, $P = 0.118$). However, the correlation becomes very strong and highly significant ($R^2 = 0.91$, $P = 0.002$) when one set with a large number of captured penguins was excluded (Fig. 1), despite the low capture of the target fish (Fig. 2). For the bottom fishery, the correlation between the number of dead penguins and fish target captures was also non-significant ($R^2 = 0.16$, $P = 0.37$).

4. Discussion

The driftnet fishery targeting bluefish in southern Brazil takes place mainly from July to October (Krug and Haimovici, 1989), coinciding with the largest numbers of Magellanic penguin carcasses found on the coast (Mäder et al., 2010). However, the link between this fishery and stranded penguins is not straightforward, since the fishery affects mainly adults (this study), while penguin carcasses on the beach are comprised of 97% juveniles (Mäder et al., 2010). Additionally, stranded penguins are frequently severely emaciated and have empty stomachs, indicating other causes than drowning in fisheries. Darby and Dawson (2000) mentioned that the main physical evidences of yellow-eyed penguin (*Megadyptes antipodes*) drowned in gillnets are subcutaneous injuries and internal hemorrhages, while external body aspects remain unaltered, with no changes in either body mass or plumage. Our records of large numbers of dead penguins in gillnetting close to the shore suggested that an unknown yet substantial proportion

Table 1
Summary of incidental captures of Magellanic penguins (*Spheniscus magellanicus*) in bottom setnet and driftnet fisheries, and mean catches of target-species. Values are mean ± 1 standard deviation (sd).

	Bottom setnet fishery	Driftnet fishery
Number of sets	8	9
Number of fishing days	6	4
Average (±sd) net length, in km	7.33 ± 2.41	2.06 ± 0.2
Min.–Max. net length, in km	5.9–11.5	1.86–2.38
Net height, in m	4	18
Bluefish mean catches (±sd) per set, in tonnes	0	1.05 ± 0.71
Weakfish mean catches (±sd) per set, in tonnes	445 ± 379.18	0
Brazilian codling mean catches (±sd) per set, in tonnes	590 ± 325.42	0
Average number (±sd) of dead penguins per set	1.71 ± 0.7	6.22 ± 3.46
Min.–Max. number of dead penguins per set	0–3	3–13
Average number (±sd) of dead penguins/km^2 of net area	66.34 ± 30.23	297.11 ± 147.27
Average (±sd) of dead penguins/km net per day	0.22 ± 0.16	2.65 ± 1.47
Total number of dead penguins	12	56

Fig. 1. Thirteen dead individuals of Magellanic penguins (*Spheniscus magellanicus*) captured during one drift gillnet set. Individuals were collected by the crew and then photographed. Arrows indicate individuals which are hard to see in the photograph. Photograph by Luis Gustavo Cardoso.

of penguin carcasses on the beach could be due to incidental capture.

Our report of 68 Magellanic penguins killed in 17 gillnet sets during only eight fishing days in gillnet fisheries in southern Brazil is of an unprecedented magnitude in the Atlantic Ocean, and probably in penguin bycatch in any fishery worldwide. In the Atlantic Ocean, 26 Magellanic penguins were reported to be killed in 200 sampling days from 1995 to 1997, by the trawl fishery (Gandini et al., 1999). Yorio and Caille (1999) reported one dead penguin in 394 trawl sets. González-Zevallos and Yorio (2006) recorded 26 dead penguins in two consecutive summers and 89 hauls. González-Zevallos et al. (2007) reported 25 dead penguins in 52 hauls during a 5-month study in 2004/2005 while, in the same period, Yorio et al. (2010) reported 37 and 105 dead penguins in the hake and shrimp trawl fisheries, respectively. Tamini et al. (2002) found nine dead penguins in nine sets in a mid-water trawl fishery in Argentina. Even though the estimates of the number of penguins killed each year by the whole fleet refer to hundreds or even thousands of birds for some of these fisheries, the capture rates and the overall capture do not seem to be as high as the ones occurring in Brazil. However, in gillnet fisheries in the Pacific Ocean, at least 120 Humboldt penguins were killed per year between 1991 and 1996, and a lower number of Magellanic penguins (Simeone et al., 1999; Skewgar et al., 2009), despite the fact that estimates were based on stranded birds or anecdotal comments made by fishermen and thus not fully quantified. Furthermore, the mortality of Magellanic penguins under investigation also demonstrates that the species is captured incidentally throughout the year, affected by fisheries adjacent to Argentinean breeding colonies in summer and by southern Brazilian fisheries in winter. In the only other study of penguin bycatch comparing drift and bottom nets (Majluf et al., 2002), higher captures in driftnets were also reported. However, once a bird is captured in bottom nets the probability of death is higher than if it were caught in driftnets. As we have reported in this paper, no live penguins were caught in the bottom nets. Similarly, no common guillemots (*Uria aalge*) were caught alive in bottom gillnets in the Baltic Sea (Österblom et al., 2002). Capture rates in this study (0.22 and 2.65 penguins/km net length per day) are

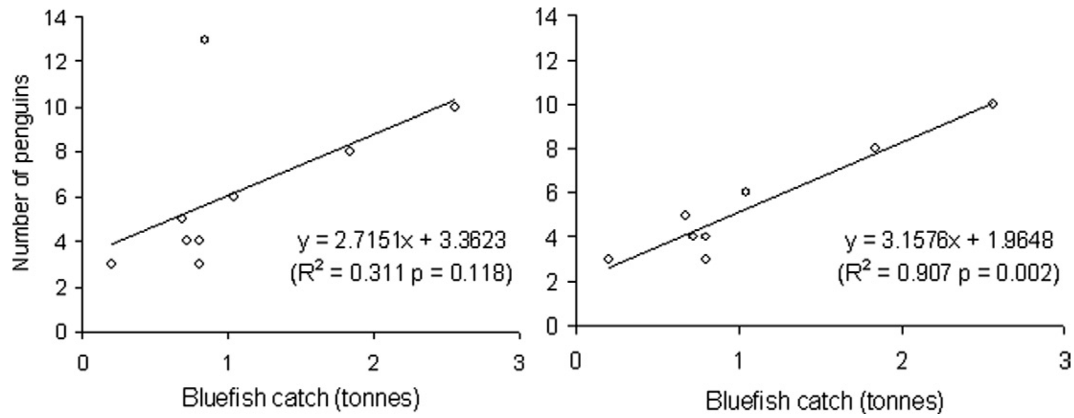

Fig. 2. Correlation between numbers of Magellanic penguins (*Spheniscus magellanicus*) captured dead and bluefish (Engraulis anchoita) catches in all drift gillnet sets (left), and outlier set excluded (right).

comparable to a range of waterbird bycatch in gillnet coastal fisheries in the Baltic and North Seas; this number ranging from 0.33 to 3.7 birds/km net length per day (Žydelis et al., 2009). Rates reported in the current paper are conservative since there was no correction for birds dropping out of the net during hauling; this usually accounts for 2–13% of the recorded numbers (Ainley et al., 1981; DeGange and Day, 1991). Potential post-release mortality of injured birds was not included, either.

The correlation between penguins and bluefish captures suggests that both species occur together due to their preference for the same prey, *E. anchoita*. This anchovy is the main prey of bluefish in southern Brazil during winter (Lucena et al., 2000), and is considered to be coupled with the northward migration of penguins (Pütz et al., 2000; García-Borboroglu et al., 2010). Fonseca et al. (2001) found cephalopods as the main penguin prey in southern Brazil, with negligible amounts of fish, but this study was based on stranded carcasses of mainly emaciated juveniles with empty stomachs, whose remains were hard cephalopod beaks which are retained in seabird stomach for weeks or months (Furness et al., 1984; Barrett et al., 2007), thus, it does not reflect the true diet of healthy penguins in the area. The close association between bluefish and penguins makes them more vulnerable to capture in driftnet fisheries. It has been suggested that the association between common guillemots and cod (*Gadus morhua*) targeted by setnets, and salmon (*Salmo salar*) targeted by driftnets, all preying upon sprat (*Sprattus sprattus*), is a key factor in the incidental capture of guillemots (Österblom et al., 2002). Furthermore, bluefish landings could potentially be used to estimate overall capture of penguins if the correlation between penguin and fish target proves to be consistent in further studies.

As expected, no correlation was obtained between target fish and penguin captures in the setnet fishery, considering that penguins feed mostly in the pelagic zone. Additionally, this fishery is more diffuse in terms of target species and area, but because it is a large fleet with about 280 vessels in Santa Catarina and Rio Grande do Sul States in 2008 (IBAMA/CEPERG, 2009; UNIVALI, 2009), the overall capture of penguins is probably significant.

This mortality affecting mainly adult penguins is worrying since it has been demonstrated that population decreases in long-lived seabirds appear to be strongly influenced by reduced adult survival (Weimerskirch and Jouventin, 1987; Croxall et al., 1990). This result contrasts with other gillnet fisheries and seabirds where young birds are more prone to be killed in nets (Österblom et al., 2002). A plausible explanation for the predominance of juveniles starved on the beaches, while mostly caught in nets are adults is that adults are much better at finding food than juveniles. The adults get caught in nets because they are where the food is, while juveniles starve and are found on beaches because they are not good at finding food and miss fish schools.

It could be argued that data presented in this study are not representative, since they are based on a single fishing trip and vessel and over a limited time frame. However, even if this trip was unusual, at least a few similar trips certainly occur every year, given the extension of the area (hundreds of km along the coast), the temporal spread of the fishing season (from July to October) and the magnitude of the fleet (280 vessels) (IBAMA/CEPERG, 2009; UNIVALI, 2009). Furthermore, the fishermen and the captain reported that gillnet interaction with penguins is frequent and affects large numbers of penguins. Finally, the regular occurrence of captures, in most or all sets of the trip, affecting several birds per set, indicates that data in this study are not unusual. Other diving seabirds common in the area, such as shearwaters (*Puffinus gravis*, *Puffinus griseus*, *Calonectris borealis* and *Calonectris edwardsii*) and Neotropic cormorant (*Phalacrocorax brasilianus*) are also potentially affected by southern Brazilian gillnet fisheries. Globally, other species of penguins (*e.g.* Humboldt, rockhoper *Eudyptes chrysocome*, and little *Eudyptula minor*, penguins) have been reported to be killed in different gillnet fisheries (Ryan and Cooper, 1991; Norman, 2000; Majluf et al., 2002; Stevenson and Woehler, 2007; Alfaro-Shigueto et al., 2010), but impacts are rarely quantified. The information presented in this paper highlights the gaps in our knowledge regarding factors threatening penguins and fishery captures in particular, similar to other penguin–fishery interactions elsewhere (*e.g.* Darby and Dawson, 2000). More investigations on incidental capture in gillnet fisheries, preferably with onboard observers, are required before wider extrapolations are warranted. The development and the implementation of mitigation measures to avoid the capture of penguins, such as those proposed by Melvin et al. (1999) for North Pacific diving birds, are needed.

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