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SHORT NOTE

Blinded by the light: Seabird collision events in South Georgia

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Abstract
Light-induced bird strikes on vessels occur frequently in association with areas of high seabird density, often resulting in bird mortalities. These incidents are poorly understood and likely under-reported by vessels. Here we present the details of four separate bird strike events (899, 206, 50 and 47 birds), which took place whilst vessels (two fishing trawlers and one tourist expedition ship) were navigating along the south coast of South Georgia, and discuss possible contributing factors. All species encountered in these events were burrowing petrel species in the family Procellariidae, with diving-petrel species (*Pelecanoides* spp.) being most commonly reported. All four events took place during the night in similar meteorological conditions, with poor visibility due to fog, light precipitation and low wind speeds. We identify the waters off the south coast, between King Haakon Bay and Drygalski Fjord, which have remained rat free and are of exceptional importance to breeding seabirds, as high risk for collisions and propose other high-risk areas. The different mortality rates recorded during these events are likely attributed to the varying actions taken by ship crew and persons on board. We propose actions that will help reduce the occurrence of events and mitigate the impact of bird strikes, including the avoidance of high-risk areas in certain night-time conditions. We give recommendations on what to do when birds land on board and stress the importance of reporting of events. Given the expected increase of both fishing and tourist ship activity in South Georgia waters, there is an increasing need to understand and mitigate this threat to seabirds.

Keywords Seabirds · Bird-strike · South Georgia · Artificial light

Introduction

South Georgia is home to globally important wildlife populations including seabirds (Poncet 2006; Forcada and Staniland 2009; Clark et al. 2012; Poncet et al. 2017; Rackete et al. 2021). Its importance as a wildlife haven is world-renowned and substantial efforts have been taken to understand and conserve the species found here (Poncet et al. 2017; Martin and Richardson 2019; Collins et al. 2021a). Seabirds, in particular the Procellariiformes, are one of the most threatened groups of animals on the planet (Dias et al. 2019). In order to give seabirds the greatest chance to adapt and survive in a changing environment, efforts must be made to identify and better understand man made threats so that they can be mitigated (Dias et al. 2019). Globally, the fishing industry poses one of the greatest threats to seabirds. This is particularly through incidental mortality (bycatch), in longline, trawl and gillnet fisheries, but also through overfishing of prey species (Dias et al. 2019). In South Georgia, the toothfish fishery has implemented strategies to almost eliminate seabird bycatch (Collins et al. 2021a). However, light-induced bird strikes on all categories of vessels operating in South Georgia waters, continue to pose a threat.

Disorientation of seabirds by artificial lights and bird collisions are common threats that remain poorly understood (Ronconi et al. 2015; Rodríguez et al. 2017b). These events affect many burrow nesting seabirds, in particular fledgling birds (Reed et al. 1985; Black 2005). Impacts of bird strikes on seabirds include: colliding with vessels and dying on impact, exposure to contaminants, such as oil, whilst on deck; and large-scale displacement of birds as a result of the distance travelled by the ship during the time the birds remain on deck. These events tend to occur during conditions when sources of natural light are not present and the

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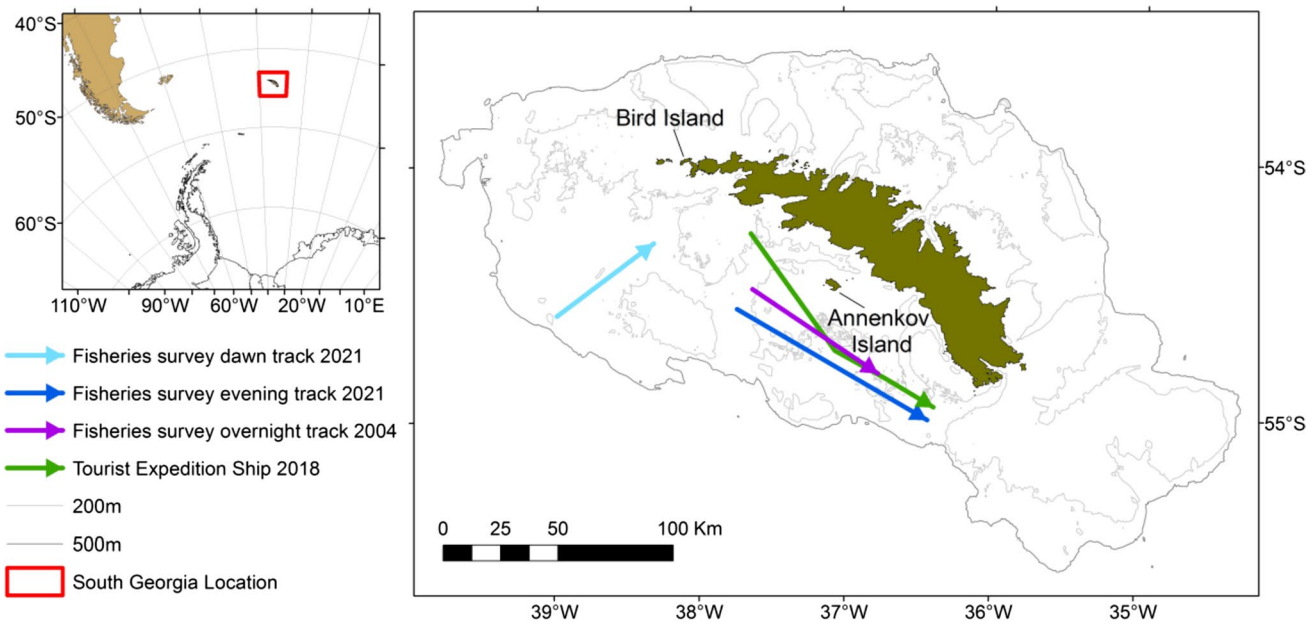

Fig. 1 Routes navigated by the three vessels along the south coast of South Georgia

abundance of young birds is high (Rodríguez et al. 2017a; Atchoi et al. 2020).

Norway (or brown) rats (*Rattus norvegicus)* were introduced to South Georgia soon after its discovery in 1775 where they remained, spreading across the coastal areas of the mainland (Piertney et al. 2016), except for the area between King Haakon Bay and Drygalski Fjord (Cook et al. 2010). Light-induced bird strikes have previously been recorded around South Georgia (Black 2005). Following the eradication of brown rats from South Georgia in 2015 (Martin and Richardson 2019), various burrowing petrel species are likely to increase in number; shipping movements around the island are also expected to increase (GSGSSI 2019). A better understanding of bird collisions with ships, and appropriate mitigation measures are necessary for the continued protection of the South Georgia avifauna.

Here we look at two recent and two historical bird strike events in South Georgia waters and the contributing factors which may have led to these events. Collisions involved two fishing vessels and one tourist expedition ship.

The incidents

Between 7 and 17 May 2021, a demersal trawl survey was undertaken in South Georgia waters on the FV *Robin M Lee* (70 m, Polar Seafish Ltd), chartered by the Government of South Georgia and the South Sandwich Islands (GSGSSI) (Collins et al. 2021b). Prior to dawn on 15th May, 30 birds were reported to have landed on board the vessel when navigating in thick fog, light south-easterly winds and calm seas approximately 30 nautical miles south-west of Bird Island, at the western end of South Georgia (Fig. 1). The birds were released by crew shortly, after first light, before identification was possible. Soon after, another 20 birds were found hidden on deck and released alive (Table 1). The second collision event took place the following night, during similar conditions, as the ship steamed south-east along the south coast of the island, approximately 10 nautical miles west of Annenkov Island (Fig. 1). At 21:00 (local time; GMT-2), a large number of birds were observed on deck. The officer of the watch was asked to reduce external lighting to a minimum which involved slowing the vessel to a speed that navigation was possible without the use of ice lights.[1] By the time the lights had been reduced, approximately 160 birds had collected on deck. Birds were found at various degrees of dampness and three were lightly oiled. The latter were kept separate to the remainder and cleaned repeatedly throughout the night prior to their release. Birds were grouped by species and placed in plastic crates (90 × 55 × 25 cm) with no more than 10 birds per crate, in order to reduce risk of stress and/or overheating. Due to the calm sea conditions, it was possible to keep birds in crates in an outdoor environment on the trawl deck, sheltered from wind and rain. Sweeps of the deck were made every 90 min throughout the night to find and box any new birds, and to assess the environmental conditions, most significantly visibility and precipitation, for release. A total of 202 birds comprising six different burrowing petrel species were collected, of which all were released

[1] It must be noted that throughout the entirety of the voyage all internal lights were blacked-out throughout the night.

Table 1 The number and species of birds involved in four bird strike collision events on three vessels at South Georgia: 30/01/2004 (Black et al. 2005), 14/03/18 and 15/05/21 (this study)

Species		30/01/2004		14/03/2018		15/05/2021(am)		15/05/2021(pm)	
		Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Antarctic prion	*Pachyptila desolata*	27	240	0	3	0	1	0	0
Blue petrel	*Halobaena caerulea*	57	208	0	0	0	5	0	2
Fairy prion	*Pachyptila turtur*	0	1	0	0	0	0	0	0
Blue petrel/prion	*Pachyptila/Halobaena*	0	0	0	0	0	15	0	0
Common diving-petrel	*Pelecanoides urinatrix*	82	129	19	15	0	14	3	150
South Georgia diving-petrel	*Pelecanoides georgicus*	30	52	0	5	0	0	1	41
Diving-petrel sp.	*Pelecanoides sp.*	0	0	0	0	0	15	0	0
Black-bellied storm-petrel	*Fregetta tropica*	2	11	0	3	0	0	0	6
Grey-backed storm-petrel	*Garrodia nereis*	1	1	0	0	0	0	0	0
Wilson's storm-petrel	*Oceanites oceanicus*	16	40	0	2	0	0	0	0
Soft-plumaged petrel	*Pterodroma mollis*	0	2	0	0	0	0	0	0
Kerguelen petrel	*Aphrodroma brevirostris*	0	0	0	0	0	0	0	2
White-chinned petrel	*Procellaria aequinoctialis*	0	0	0	0	0	0	0	1
Total		215	684	19	28	0	50	4	202
Total		899		47		50		206	
Percentage Dead		31.43		67.86		0.00		1.98	

alive at first light (Table 1). Four birds, all dead, were found in the morning on the monkey deck (above the bridge). No obvious cause of death was apparent on examination with hypothermia the most likely cause.

On 30 January 2004, burrowing petrels were reported on board the MV *Dorada* (75 m trawler), during the course of a fisheries survey (Black 2005) in the waters west of Annenkov Island (Fig. 1). Weather conditions were similar to the 2021 events (overcast, light precipitation and no wind), and the vessel was using ice lights for navigation. Only a few birds were collected during the night and the full extent of the collision was not realised until the morning. In total, 899 birds were found including 215 dead, mostly attributed to hypothermia (no obvious cause of death and waterlogged feathers) or collision (birds with obvious bleeding or cranial damage). Live birds were stored in cardboard boxes in an unheated environment until fit for release.

Another event occurred on 14 March 2018 on board a tourist expedition ship (110 m) passing approximately 10 miles west of Annenkov Island whilst transiting between King Haakon Bay and Drygalski Fjord (Fig. 1). Forty-seven birds were found on deck, 19 of which died. Birds were collected continuously throughout the night and stored in boxes in a warm, dry place in accordance with guidelines from the International Association of Antarctica Tour Operators (IAATO 2012). Ice lights remained on through the night, although deck lighting was reduced. No birds were found dead on deck, but many died during the night in the boxes, potentially from overheating.

The 2004 and 2018 events took place during the chick rearing/fledging period (October–April) for South Georgia burrowing petrel species, in contrast to the May 2021 events which occurred after this period (Navarro et al. 2015).

Discussion

The bird strike events on board FV *Robin M Lee* in 2021 were very similar to the two previous reported events of 2004 and 2018 except for the mortality rates. There is anecdotal evidence that these are not isolated incidents and that many, equally large, collision events may be occurring in South Georgian waters (Sally Poncet, pers. comm.) raising concerns that bird strikes are under-reported here and most likely in other areas in proximity to breeding colonies of burrowing petrels. Collins et al. (2021a) noted that since 2002, 171 birds were recorded in the CCAMLR observer data as colliding with toothfish longline vessels operating in the South Georgia fishery (April–August), of which 117 were released alive. Reporting of birds colliding with vessels is not required under CCAMLR regulations and hence data were not collected in a systematic way and this number is likely to be a considerable underestimate.

All events reported here took place in similar meteorological conditions with poor visibility due to fog, light precipitation and low wind speeds (< 7 knots). This is in line with other studies which indicate greater collisions in conditions with reduced visibility (Merkel and Johansen 2011; Ronconi et al. 2015; Guildford et al. 2018). Fog and

white-out conditions hide other light sources such as the stars and moon, thus hampering navigation by seabirds; they also disperse the lights from ships in such a way that causes birds to become disorientated (Guilford et al. 2018).

During the 2021 demersal trawl survey, the vessel circumnavigated the Island over 12 days, the incidents described here (15th May) were the only collision events observed despite similar meteorological conditions being encountered on multiple occasions (Coleman pers obs). A previous study in Greenland showed that there may be predictable areas that are of high risk for collision (Merkel and Johansen 2011). In this note, three collision events took place off the south coast of South Georgia in proximity to Annenkov Island. Annenkov Island and the adjacent south coast between King Haakon Bay and Drygalski Fjord have especially high concentrations of burrowing petrels (Trathan et al. 1996; Martin et al. 2009; Sally Poncet personal communication). Many of the small, burrowing petrel populations, including storm-petrels, prions and diving-petrels (see Table 1), had been extirpated by rats predating on small birds, their chicks and eggs (Pye and Bonner 1980; Martin and Richardson 2019) and therefore only bred successfully in rat-free areas (Poncet 2006). The south coast area has always been rat free (Martin et al. 2009). There are other areas that remained rat free that are equally as important for burrowing petrels (Martin et al. 2009) and therefore likely represent additional areas of high risk for bird strikes. In particular, Willis Island, Cooper Island, the islands of the Bay of Isles and Bird Island (Trathan et al. 1996; Martin et al 2009). Better reporting will allow sites like these to be identified and the collision risk to be evaluated making it possible to reduce impacts of vessels on birds by introducing mitigation measures, such as reduced night-time operations within these areas or whilst experiencing certain weather conditions (Glass and Ryan 2013).

All seabirds involved in the collision events reported here were burrowing petrel species. Diving-petrel species (*Pelecanoides spp.*) were the most abundant and suffered the highest mortality. This is possibly a result of their high abundance (Poncet et al. 2006) and low manoeuvrability in flight, so they are less able to decelerate or turn to avoid obstacles (Ryan 1991). Additionally, their smaller size allows them to crawl into hard-to-reach spaces on ships, where they are likely to remain undetected until the morning, increasing the chance of hypothermia.

The increase in area of rat-free habitat resulting from the eradication of brown rats from South Georgia in 2015 is likely to result in an increase in burrowing petrels across the main island (Martin and Richardson 2019). Given this likely increase in distribution and abundance, and the predicted increase in tourism and fishing vessel movements around South Georgia (GSGSSI 2019), there is probably a greater future risk of burrowing petrel collisions and the need for mitigation.

Two other variables often discussed in relation to night collisions are the light intensity and light colour (Syposz et al. 2021). The higher the intensity of light, the further it transmits and therefore more birds are likely to be affected (Syposz et al. 2021), high light intensity may also have a greater disorientating effect on birds (Glass and Ryan 2013). Therefore, the use of ice lights in polar environments are likely to increase the risk of collision. Syposz et al. (2021) showed that the colour of light influences how Manx shearwaters (*Puffinus puffinus*), another procellariform seabird, react, with shorter wavelengths deterring birds and longer wavelengths being less visible to birds. There is very little literature on how colour affects the number of collisions on vessels and it is likely that different species have different sensitivities to wavelengths, with implications for collision risk. On the basis of studies in the North Sea on perception of different wavelengths of light by birds (Marquenie 2007) vessels, including the South Georgia government vessel, MV *Pharos SG*, have replaced deck safety lighting with green lights. Better reporting from these vessels would allow for a comparison of the effectiveness of different coloured lights.

In the collision incidents described here, there were differences in actions taken once birds landed aboard. This may have contributed to the differing mortality rates (31.43% in 2004, 67.86% in 2018 and 1.98% in 2021) of the seabirds involved. During the 2004 event (Black 2005), the significance of the collision was not fully comprehended until first light (04:00 local time; GMT-2). This meant that many birds were left all night on deck in wet conditions, which increased the risk of hypothermia and subsequent mortality. As a result, by morning, many birds on deck had died. Had the size of the event been detected earlier and frequent sweeps of the vessel taken place throughout the night in order to collect birds on deck, then the death rate may have been lower.

During the 2018 event, the ship followed guidelines which recommended keeping birds in boxes indoors in a warm environment (IAATO 2012). However, the storage boxes available were small and limited in number, and although birds were separated in boxes by species, the number of diving-petrels held in each box was high leading to stress. This, in conjunction with storing the boxes in a warm indoor environment, may have contributed to the high mortality from overheating.

The dawn collision event in 2021, took place shortly before first light, with the result that birds were detected within a few hours of landing and did not remain on deck for long. However, during the dusk collision event later that day, the four birds that were not discovered and remained on deck until dawn, all died.

The effects of bird strikes on seabirds may also include the impact of a significant spatial displacement of adult birds from their breeding sites, during the time they remain on board a vessel in transit. In particular, this may impact diving-petrel species whose foraging range during the breeding season is less than other species of petrels (Navarro et al. 2013; Zhang et al. 2019; Dunphy et al. 2020). Any displacement from their usual foraging areas arising from confinement on a vessel following collision may have implications for breeding success. Future studies should explore methods for identification of life-stages of birds to better understand if juveniles or adults are impacted most by ship strikes.

Light-induced seabird collisions are known to occur worldwide (Telfer 1987; Black 2005; Merkel and Johansen 2011; Glass and Ryan 2013); however, these events are still poorly understood and likely to be under-reported. In the Southern Ocean, the numbers of licensed fishing vessels and polar expedition ships are increasing, which poses an increasing risk of collision for birds. Based on the lessons learned from the four incidents described here, several recommendations are made.

In advance of events:

- Reduce light: All non-essential lighting should be switched off or blacked out during night-time navigation. If birds start to land on deck, then reducing speed to a minimum and reducing ice lights should be considered until conditions improve.
- Night-time navigation through high-risk collision areas should be avoided, especially during foggy or blizzard conditions.
- Vessels should have a plan in case of bird strikes and the necessary equipment and expertise to deal with an incident. This should include where to find boxes and store birds, and an understanding of reporting procedures.

During events

- *Continuous checks* Whilst conditions persist, the vessel should be continuously inspected for grounded birds to minimise time spent by birds on deck and maximise the chance of successful release.
- *Quick release* If conditions improve during the night (for example, reduced fog), an attempt to release birds should be made, especially when the vessel is underway, in order to reduce displacement distance from colonies. During release, ship lights should be reduced to a minimum.
- *Storage conditions* Ideally birds should be kept in a cool, dry, sheltered place especially if stored in boxes with multiple birds present, to reduce the risk of overheating.
- *Same species storage* If individual boxes are not possible, ensure that different species are kept apart in separate boxes to avoid unnecessary stress.

Reporting

- Reporting of collisions (both fatal and non-fatal) should be mandatory to better understand the impact of these events and inform mitigation measures. This will facilitate the identification of high-risk collision factors including locations, weather conditions and times of year. Data collected during collision events should include ice lights on/off, colour of deck lights, wind speed, temperature, number of birds, bird species, age of birds involved (if possible), number of birds per box, cause of death (if fatalities).

Recognising that bird collisions with vessels in South Georgia waters is under-reported, GSGSSI and Joint Nature Conservation Committee (JNCC) have established a project (Darwin Plus Project 143: https://dplus.darwininitiative.org.uk/project/DPLUS143/) to work with the tourism and fishing industries to improve procedures for reporting of bird strike events in order to develop new and better-informed conservation measures for minimising the impact of collisions and to reduce the number of seabird collisions.

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Declarations

Conflict of interest All the authors declared that they have no conflict of interest.

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