EFFECTS OF A STORM ON COLONIES OF SEABIRDS BREEDING AT THE FALKLAND ISLANDS

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Received 18 November 2011, accepted 2 October 2012

Seabirds of the order Procellariiformes are particularly well adapted to strong winds, which they use to facilitate long-distance foraging for patchily distributed food resources (Davies *et al.* 2010). On land, albatross colonies are often distributed to maximise exposure to the prevailing winds, thus making it easier for birds to get airborne. At sea, most seabirds either use storm conditions to aid their movements, or avoid severe weather effects by flying away from a storm (e.g. Culik *et al.* 2000, Catry *et al.* 2004). It is when seabirds are on land, at their breeding sites, that they are most vulnerable to the effects of extreme weather events. Severe weather conditions can affect seabird colonies both directly, by causing the loss of eggs and chicks (e.g. Randall *et al.* 1986, Anderson & Cruz 1998, Hennicke & Flachsbarth 2009), or indirectly, by inhibiting adult feeding and thus reducing provisioning rates of chicks (Schreiber 2002).

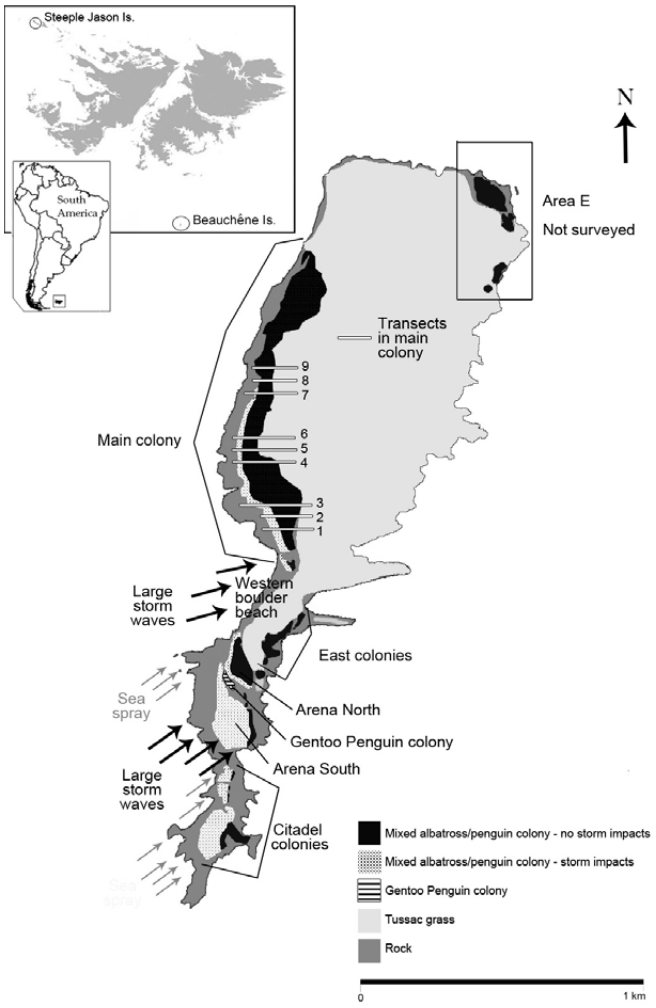

Fig. 1. The distribution of seabird colonies at Beauchêne Island, in the Falkland Islands archipelago, illustrating the relative impacts of the storm event on 13 December 2010.

Located in the southwest Atlantic Ocean, the Falkland Islands archipelago experiences a temperate oceanic climate, dominated by westerly winds; strong winds are frequent throughout the year, reaching and exceeding Force 8 on the Beaufort Scale (>63 km/h, 34 knots) 5–8% of the time from September to May (Upton & Shaw 2002). Storm conditions are not rare, but there have been no previous reports of storms having caused extensive damage to seabird colonies. Here we report the impacts of a storm event in mid-December 2010 on seabirds breeding at Beauchêne and Steeple Jason islands, in the south and north-west of the archipelago, respectively (Fig. 1). Both of these sites support globally significant seabird populations, including the two largest Black-browed Albatross *Thalassarche melanophris* colonies in the world (Agreement on the Conservation of Albatrosses and Petrels 2010). Although Beauchêne Island is rarely visited, two of the authors (ACW and SC) were on the island at the time of the storm; the other author (AMMB) was at Steeple Jason Island during the storm event. As part of a Falkland Islands archipelago-wide survey, a census of Black-browed Albatrosses, Rockhopper *Eudpytes chrysocome* and Gentoo Penguins *Pygoscelis papua* breeding at Steeple Jason Island and Beauchêne Island was conducted from 23 October to 14 November 2010 (Baylis 2012), approximately one month before the storm.

On the afternoon of 13 December 2010, a deep low pressure system of 95.0–95.5 kPa (950–955 mb) that had been building up from the Drake Passage reached the Falkland Islands. Wind speeds of 111–120 km/h (60–65 knots) were measured at the Mount Pleasant Complex, East Falklands (UK Meteorological Office, Mount Pleasant Complex, unpubl. data). Although wind speeds were not measured on Beauchêne Island, it was estimated that on the afternoon and night of 13 December, the wind speed had increased to an estimated 130–148 km/h (70–80 knots, Force 11 Beaufort Scale: violent storm conditions), resulting in open ocean swells in excess of 10 m. The wind and swell came from the southwest, making the south and west coasts of the island – where the majority of the seabirds nest – especially exposed (Fig. 1). Storm conditions persisted throughout the night. By the morning of 14 December, the wind speed had dropped considerably, but the sea remained very rough until 16 December.

As the wind increased in strength on 13 December, albatrosses nesting at Beauchêne Island were observed bracing their wings against the nests to anchor themselves down. By the evening of

13 December, waves breaking on the western coast had reached some of the nesting seabirds on the southern and western side of the island. A single wave was observed breaking over an area containing about 100 Black-browed Albatross nests, a similar number of Rockhopper Penguin nests, and about 30 Imperial Shag *Phalacrocorax atriceps* nests, pulling out to sea most of the adult nesting birds in the process. The landing sites along the western coast of the island, normally used by thousands of Rockhopper Penguins returning from foraging trips, were completely underwater, and being battered by large breaking waves. At the time of the storm, breeding Black-browed Albatrosses were either incubating eggs or brooding recently hatched chicks. Most Rockhopper and Gentoo Penguin nests contained small chicks, ranging in age from one to three weeks; Imperial Shag nests contained eggs.

From 14 to 19 December 2010 we conducted rapid assessments of the main seabird colonies at Beauchêne Island to examine the effects of the storm on the island's breeding seabirds. Based on the extent of abandoned eggs, chicks and empty nests, we estimated (Fig. 1) roughly the proportion of nests that had failed for each colony, and related this to the number of breeding pairs estimated during the archipelago-wide census that took place approximately five weeks before the storm.

The extent of breeding failure was significant, amounting to more than 22 500 failed Black-browed Albatross nests and 14 000 failed Rockhopper Penguin nests (Table 1, Fig. 1), but was not uniform across Beauchêne Island. On the basis of our observations, we assumed that the failure rates within the mixed colonies of Black-browed Albatrosses and Rockhopper Penguins were the same for both species. Even within colonies, the extent of breeding failure and loss of nest sites varied. For example, a small area on the southwestern (seaward) margin of the main colony (Fig. 1) was completely washed away by waves, and on the morning of 14 December was devoid of albatrosses and penguins. Large boulders had been shifted around, and the nests, guano and mud had been scoured from the area. To examine the variation in breeding failure in the main colony, which contains more than 100 000 nests (Table 1), we conducted nine transects across the width of the colony in which we counted active and failed nests in 20 m by 2 m contiguous strips from the coast inland. The proportion of total nests that were active ranged from 0% to 87%, increasing with distance from the coast and towards the north (Table 2). After considering likely breeding failure due to factors other than the storm, we estimated the overall storm-related breeding failure in the main colony to be between 5% and 10% of the number of pairs that attempted breeding (Table 1). The largest impact was in the Arena South colony, where we estimate about 90% of the nests failed due to the storm event (Table 1). The albatross and Rockhopper Penguin nests that survived the storm were located in elevated areas, mostly on the eastern side of the colony.

We recorded 251 dead or severely injured adult Black-browed Albatrosses at Beauchêne Island, mostly in the Arena South colony (Table 1). Of the birds found dead in the colony, 24 were pinned under boulders that had presumably been moved by large

TABLE 1
Estimated impacts of the 13 December storm event on seabirds at Beauchêne and Steeple Jason islands

Site	Black-browed Albatross				Rockhopper Penguin				Gentoo Penguin	Imperial Shag
	2010 census estimates	Proportion nests failed	Total nests failed	No. dead & injured adults	2010 census estimates	Proportion nests failed	Total nests failed	No. dead & injured adults	No. dead & injured adults	No. dead & injured adults
Beauchêne Island										
Main colony	103 338	5–10%	5 167–10 334	24	79 567	5–10%	3 978–7 957	0		
East colonies	2 382	<2%			2 553	<2%				
Arena South	14 903	90%	13 413	142	9 083	90%	8 175	14	4	2
Arena North	6 225	25%	1 556	19	3 874	25%	969	4		
Citadel colonies	4 727	50%	2 364	0	1 927	50%	964	0		
Area E[1]	7 761	ns			8 439	ns				
Cliff[1]	462	ns			169	ns				
Pond[1]	0	ns			166	ns				
Boulder beach	na			66	na			0		
TOTAL	139 798		22 499–27 666	251	105 778		14 085–18 064	18	4	2
Steeple Jason Island										
All colonies	214 203	15–30%	32 130–64 261	113	121 396	15–30%	18 209–36 419	0		

[1] not surveyed after the storm (ns)

waves (Fig. 2). Smaller numbers of adult Rockhopper and Gentoo Penguins and Imperial Shags were also found dead in the Arena South colony (Table 1). In the days following the storm, some adult albatrosses, clearly exhausted and many waterlogged, were observed attempting to take off from the boulder beach, but were unable to gain sufficient height to fly over the large breaking waves. These birds were inevitably battered by the large waves, and some were observed being washed up on the shore of the western boulder beach, either dead or with broken wings. Seventeen of the injured or dead birds along the western boulder shore were entangled in kelp, wedged under *Poa flabellata* tussock bogs or under stranded *Nothofagus* tree trunks. The majority of severely injured birds that we were able to individually identify later died. However, we did not systematically search every section of each colony for dead and injured birds. Therefore the number of dead and severely injured birds recorded represented an unknown proportion of the total mortality. In addition, some dead birds, unrecorded by us, were probably washed out to sea. We do not know how many of the nesting Black-browed Albatrosses that we observed being washed out to sea on the evening of 13 December later died. Southern Giant Petrels *Macronectes giganteus* were observed mobbing weak albatrosses and scavenging albatross carcasses approximately 30 m offshore from the western boulder beach until 19 December, at which time we left the island. Compared with Black-browed Albatrosses, the substantially lower numbers of adult Rockhopper Penguin mortalities is not surprising, given their greater robustness and superior ability to swim in rough sea conditions, especially being able to dive under breaking waves.

Fig. 2. Adult Black-browed Albatrosses pinned under boulders at Beauchêne Island after a storm event on 13 December 2010.

The only Gentoo Penguin colony at Beauchêne Island is located in the area between Arena South and North (Fig. 1) and comprises *ca.* 680 pairs (Falklands Conservation 2011). During a survey of the area on 14 December, it appeared that this colony had suffered complete breeding failure; large numbers of dead chicks had been moved to an area about 30–40 m north of the colony. During a subsequent visit to Beauchêne Island from 15–19 March 2011, three large Gentoo Penguin chicks, close to fledging, were recorded at the colony.

At Steeple Jason Island, 2 637 incubating Black-browed Albatrosses were counted at three study colonies from 6 to 16 November 2010 (one month before the storm). Subsequent counts on 14 December revealed that 90 chicks remained within these study colonies after the storm, a failure rate of 97%. Opportunistic observations and a crude assessment of the remaining colonies at Steeple Jason revealed that, as with Beauchêne Island, the storm-related impacts were greatest in the lower-lying coastal areas of the island. Some colonies, including two of the study colonies, experienced 100% breeding failure, whereas others were little affected. Overall, we estimate that roughly 15–30% of the Black-browed Albatrosses and Rockhopper Penguin nests at Steeple Jason failed due to the storm, equivalent to a minimum of about 18 200 and 32 100 nests, respectively (Table 1). One of the study colonies contained 852 ringed adult breeders. After the storm 13 (1.5%) of these ringed birds were recovered dead in the colony. In total, 113 dead adult Black-browed Albatrosses were recorded at Steeple Jason Island. Given the spatial variation in the storm impacts and the extent of the colonies surveyed, we do not know what proportion of the total mortality this figure represents.

Although severe impacts of storms and cyclones on breeding seabirds are not unusual (Langham 1986, Schreiber 2002, Hennicke & Flachsbarth 2009), the impacts normally relate to reduced

TABLE 2
Proportion (%) of total nests that were recorded as active along nine transect counts conducted across the main colony at Beauchêne Island following the storm

		Direction of survey (south to north) and number of transect; % of total nests active after storm								
		South								North
Location of 20 m section, moving inland	Contiguous 20 m section along transect	1	2	3	4	5	6	7	8	9
Coast	a	16	15	13	21	0	54	85	78	70
	b	44	57	52	23	29	42	83	78	76
↓	c	73	63	72	50	42	75	83	84	84
↓	d	72	70	83	79	74	87	84	71	81
	e	71	80	74	81	78				
Inland	f	62	86	75						

reproductive success (as reported here). Reports of storm events killing large numbers of adult seabirds are scarce (but see US Fish and Wildlife Service 2011, Heubeck 1999a, 1999b, Mallory *et al.* 2009). At Beauchêne Island, a minimum of about 300 adult Black-browed Albatrosses and 30 adult Rockhopper Penguins died after sustaining injuries caused primarily by large waves breaking close inshore and inundating sections of the breeding colony. At Steeple Jason Island, at least 113 adult Black-browed Albatrosses died, also due to injuries that we presume were brought about by wave action.

Although we did not observe the impacts directly, there was clear evidence from surveys carried out at Beauchêne Island on 14 and 15 December that waves had inundated large parts of the Arena South colony. The peak intensity of the storm during the darkness of night on 13 December, and early morning of 14 December, likely exacerbated the impacts, as the birds presumably had difficulties evading the waves. At Diego Ramirez Island in Chile, Black-browed Albatrosses have been observed sustaining injuries when they attempt to land in winds stronger than 120 km/h (65 knots; G. Robertson, pers. comm.), so it is possible that some of the deaths and injuries we recorded were due to the strong winds, rather than wave action. However, if this were the case, we would have expected to observe a greater number of dead and injured birds outside of the low-lying areas.

Although the lower-lying areas on the southern and western side of Beauchêne Island were most severely impacted, there was extensive breeding failure in the more elevated southern colonies of the Citadel (Fig. 1). In these colonies, we believe breeding failure was caused by exposure to strong winds and incessant salt spray. On 13 and 14 December large waves breaking against the offshore stacks and cliffs resulted in a constant deluge of salt spray over these colony areas. There were no dead adult birds found in the Citadel colonies, and large numbers of adults were still present, many occupying nests that were empty, or contained crushed eggs or dead, waterlogged, chicks. The impacts of the storm were likely exacerbated by the large numbers of newly hatched chicks, which would have been particularly vulnerable to the cold and wet conditions.

Although the loss of large numbers of eggs and chicks in the 2010/11 breeding season was substantial, these effects need to be considered in the context of high inter-annual variability in breeding success for Black-browed Albatrosses and Rockhopper Penguins (Prince *et al.* 1994, Catry *et al.* 2011, Falklands Conservation, unpubl. data), the two species most severely affected by the storm. Perhaps of greatest concern is the number of adult Black-browed Albatrosses that died as a consequence of the storm. As with other long-lived seabirds, adult survival of Black-browed Albatrosses is a critical parameter for long-term population viability (Catry *et al.* 2011). Although the proportion of the adult population that died following the storm is relatively small, a range of additional and ongoing factors may affect their population and conservation status, the cumulative effects of which need to be considered and assessed. These include fisheries mortality (Sullivan *et al.* 2006, Anderson *et al.* 2011), variability in the availability of prey (Croxall *et al.* 1998) and disease outbreaks (Uhart *et al.* 2004, Falklands Conservation, unpubl. data).

ACKNOWLEDGEMENTS

Research on Rockhopper Penguins and Black-browed Albatrosses was approved and supported by the Falkland Islands Government (FIG). Access to Beauchêne Island was approved by FIG. Work on Steeple Jason Island was permitted by the Wildlife Conservation Society (WCS). We are grateful to Leiv Poncet and Yoann Gourdet for safely transporting the teams to and from Beauchêne Island, and to Michael Clarke for trips to and from Steeple Jason Island. Leigh-Anne Wolfaardt and Rachael Orben are thanked for their assistance with field work and observations at Beauchêne and Steeple Jason islands, respectively. We are grateful to J. Van Franeker, A.E. Burger, A.J. Gaston and an anonymous reviewer for their comments on an earlier version of this manuscript.

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