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SHORT NOTE

Large-scale hail-induced mortality in white-fronted tern (*Sterna striata*) and black-billed gull (*Larus bulleri*) breeding colonies on the Rangitata River, New Zealand

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Extreme weather events can pose a serious threat to bird populations due to the potential for direct impacts on vital rates such as survival and breeding success. There is increasing concern that extreme weather events may have even stronger effects on the population dynamics of some species than mean, long-term changes in climate (Moreno & Møller 2011; Jenouvrier 2013; Maxwell *et al*. 2019). For example, birds which flock or form large colonies for breeding are more vulnerable to localised stochastic events than more dispersed species.

Hail storms pose a potential threat to birds that breed or flock in open habitats, such as river beds. Large-scale avian mortality events resulting from severe hail storms have been recorded overseas across a range of avian groups, including shorebirds (Higgins & Johnson 1978; Narwade *et al*. 2014) and grassland species (Sarasola *et al*. 2005; Carver *et al*. 2017). Reports of hail storms affecting birds during the nesting cycle are less common. Carver *et al*. (2017) reported a 50% nest loss rate among *c*. 200 nests and widespread adult mortality among mostly Lark Buntings (*Calamospiza melanocorys*) following a hailstorm in northern Colorado, USA. Hightower *et al*. (2018) reported a similar nest loss rate in sagebrush songbirds at 47 hail damaged nests in central Wyoming, USA. Nest losses among several species were also reported among the damage during a series of severe hailstorms in Western India from February to May 2014 (Narwade *et al*. 2014). Over 62,000 dead birds from 35 species were recovered, in what appears to be the largest hail-induced mass mortality ever recorded.

The formation of large hail stones (larger than 2.5 cm in diameter), is often related to severe thunderstorms with strong convection and updrafts (Prein & Holland 2018). In many regions of the world, including New Zealand, the frequency of such storm events is increasing, or is predicted to increase, as a consequence of anthropogenic climate change (Trapp *et al*. 2007; Seneviratne *et al*. 2012; Brimelow *et al*. 2017; Sanchez *et al*. 2017; MFE 2018; Prein & Holland 2018).

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Given the potential for large-scale impacts of severe storms on local bird populations, it is important to document and build an understanding of species responses to these extreme weather events. Here, we describe the impacts of a severe hailstorm on two bird species which breed in braided river ecosystems. The white-fronted tern (*Sterna striata*) is a predominantly coastal native species currently classified as At Risk (Declining) by Robertson *et al*. (2017). The black-billed gull *(Larus bulleri)* is endemic, breeds mainly in braided river beds, and is currently classified as Threatened (Nationally Critical) by Robertson *et al*. (2017). We are unaware of any previous records of a severe hailstorm causing large-scale mortality or nest failure among bird populations in New Zealand.

On 14 November 2019, a large breeding colony of 3,000–4,000 white-fronted terns, with nests containing 1–2 eggs, was located by Department of Conservation (DOC) staff at the Rangitata River mouth, South Canterbury (44.19°S, 171.51°E). Approximately 100 black-billed gulls were also nesting in two areas, one at either end of the tern colony. A total of 42 gull nests were counted, each containing 1–3 eggs (n=50 eggs). No chicks of either species were observed. On 20 November 2019 between 12:48 pm and 1:20 pm, an extreme weather event producing large hail stones *c*. 2–4 cm in diameter (Fig. 1a) passed over the Rangitata River Mouth.

Following a report from a member of the public on 21 November 2019 of numerous dead and injured birds at the site, the colonies were revisited by DOC staff. On arrival at the colony on 21 November 2019, hundreds of dead and injured birds were observed (Fig. 1b, c). From 21–22 November, 267 white-fronted terns and 21 black-billed gulls were found to have sustained serious injuries and were euthanised. The carcasses of *c.* 300 white-fronted terns and 70 black-billed gulls (including many of the euthanised specimens) were recovered on 22 November, with a further *c*. 360 dead birds recovered on 27 November yielding a total of *c*. 650 dead white-fronted terns and *c*. 80 dead black-billed gulls. This equates to over 95% of the black-billed gull colony destroyed, and 16–22% of the white-fronted tern colony.

The great majority of injured birds had suffered significant and conspicuous injuries to their wings, including compound fractures, and were incapable of flight. Some birds had no obvious external injuries but made no attempt to move away when approached. All birds that were euthanised were essentially incapable of flight and were caught either by hand or using a short hand net. Some injured birds, especially black-billed gulls, entered the water (braids of the Rangitata River) when approached and were carried away downstream, unable to be recovered.

Figure 1. (a) photo taken during the hail storm showing the large size of the hailstones compared with a golf ball (scale; short side of NZD5 = 69 mm), (b) critically injured white-fronted tern following hail storm, and (c) section of the white-fronted tern and black-billed colony after the hail storm. Photo credits: Steve Cowie, Anna Aichele, and Clare Halpine.

In addition to the dead and injured birds, a large number of broken eggs of both species were noted. While it is possible that some of these eggs had been preyed on or scavenged in the 36 hours between the hail storm and the first visit to the site, or by adult birds stepping on eggs during the storm, it seems more likely that the majority of damage was caused directly by hail stones.

Impacts of the hail storm on breeding colonies appeared to have been very localised. Another large colony of white-fronted terns (thousands of birds) was recorded on the northern side of the Rangitata River mouth, only *c.* 600 m from the affected colony. This colony was also visited on 22 November, but fewer than 10 injured birds were observed, and all of these were still capable of flight when approached.

Damage to infrastructure, including broken skylights and spouting, was also reported by residents within the small settlement of Rangitata Huts (44.19°S, 171.50°E), immediately south of the colonies.

The damage observed at the Rangitata breeding colonies demonstrates the substantial impact that an extreme weather event producing large hail stones can have on local populations of threatened and at-risk bird species in New Zealand. While numerous studies have demonstrated large-scale avian mortality associated with extreme weather events, the longer-term population consequences are difficult to quantify given the rarity and randomness of these events, and the lack of long-term data over an appropriate time scale (Jenouvrier 2013). However, using 26 years of reproductive data, van de Pol *et al*. (2010) showed a decrease in local population viability of Eurasian Oystercatchers (*Haematopus ostralegus*) in response to an increased frequency of catastrophic nest flooding events.

In combination with other threats to braided river birds such as ongoing habitat loss and predation (Sanders & Maloney 2002; Cruz *et al*. 2013), the increased frequency of damaging extreme weather events is likely to negatively affect the population trajectories of already threatened and at-risk species. Braided river birds are often considered well-adapted to breeding within an unstable and flood-prone ecosystem and many species are able to renest in response to losses (Beer 1966; Hughey 1985). However, events that cause adult mortality in addition to reproductive failure are likely to have a disproportionate influence on population dynamics, as is usually the case for long-lived species (Sæther & Bakke 2000). It is therefore increasingly important that stochastic weather events are built into population models to inform future management.

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