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Extreme Weather Events: The Hottest, Wettest, and Coldest Year Coincides with a Decline in Barn Owl Productivity in Southwestern Canada

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HEAT DOME IN 2021 AND CONCURRENT BARN OWL REPRODUCTIVE FAILURES

Extreme weather events are negatively affecting species globally and increasing the risk of extinction events (Ameca 2013, Wan 2019). In 2021, between 25 June and 1 July, western North America experienced a heat dome, which is a rare weather event in which high atmospheric pressure conditions combine to act as a lid on the atmosphere so that hot air cannot escape, and overnight temperatures remain high (Wang et al. 2016). The heat dome broke more than 100 local temperature records, and the Pacific Northwest including British Columbia, Canada, was the most affected, with temperature records broken by several degrees in many cities (Environment Canada 2022).

The timing of the heat dome (25 June to 1 July) in the Fraser Valley, southwestern British Columbia coincided with the nesting season for many birds, and young birds yet to fledge perished during this period either due to heat exhaustion or from jumping out of the nest prematurely (CTV News 2021). During this period, the local raptor rehabilitation facility Orphaned Wildlife Rescue (OWL) admitted an influx of young raptors, primarily Cooper's Hawks (*Accipiter cooperii*), Merlins (*Falco columbarius*), and Bald Eagles (*Haliaeetus leucocephalus*) to their facility due to heat stress. These young raptors were found on the ground with heat stress symptoms such as panting and elevated breathing, dehydration, and lethargy (Bhaduaria et al. 2014, R. Hope, OWL, pers. comm.).

The Fraser Valley is part of the lower mainland region of British Columbia. The region consists primarily of the broad delta of the Fraser River and land here has largely been diked and cleared for agricultural use, and increasingly for urban development. We have monitored Barn Owl (*Tyto alba*) nests in the eastern portion of the Fraser Valley since 2002, and in the western portion of the Fraser Valley since 2007 (Fig. 1). The monitored population of Barn Owls nest in boxes that are placed inside structures or on single standing poles in fields. The boxes installed in the eastern portion of the valley are a minimum of 45 × 45 × 75 cm, and boxes installed in the western portion of the valley are 77 × 46 × 66 cm. All boxes are made out of 12.7-mm plywood, have 1–2.5-cm ventilation holes, and are checked two times during the spring or early summer, and typically once in the fall for second clutches. In 2021, we checked 144 nest sites (i.e., nest boxes) in eastern Fraser Valley and 69 nest sites in western Fraser Valley.

In British Columbia, 76% of barn owl young fledge in mid-summer (S. Hindmarch unpubl. data), which is fairly late compared to California, USA, where 88% of owlets fledge in the late spring (Bourbour et al. 2022). Hence the timing of the heat dome meant that most owlets had not yet fledged, and thus were inside nest boxes that reached extreme temperatures. Temperatures inside nest boxes can be up to 7°C warmer than the ambient air temperature (Catry et al. 2011). Based

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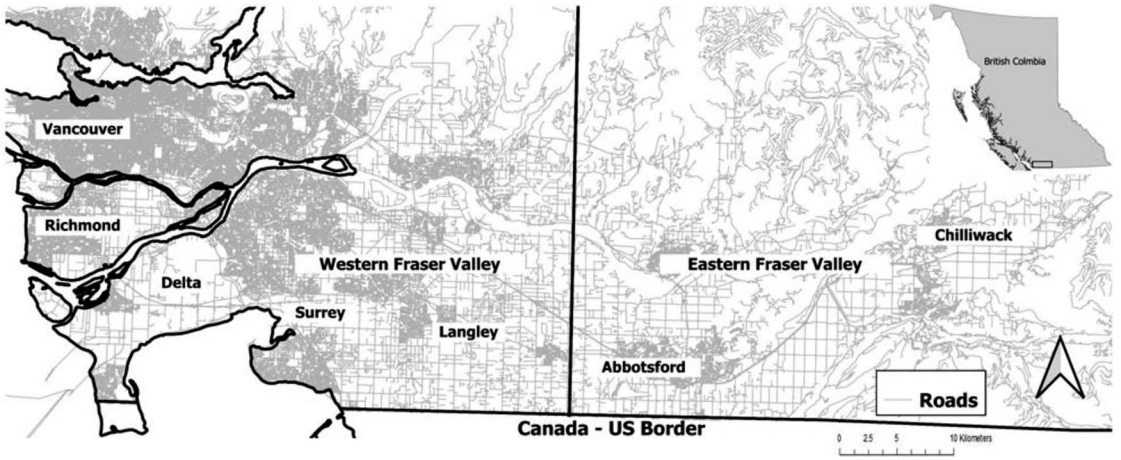

Figure 1. Study area, the Fraser Valley, British Columbia, Canada. The study area is divided into a western portion where SRH has been monitoring nest boxes since 2007, and an eastern portion where DC has been monitoring nest boxes since 2002.

on historical weather data (1981–2010), the maximum temperature recorded in June for the Fraser Valley was 34.7°C (18 June 1982) but it reached a high of 42.9°C during the heat dome, which is an 8.2°C difference (28 June 2021; Environment Canada 2022).

In the eastern and western portions of the valley, our Barn Owl nest monitoring efforts documented higher than normal owlet mortality that coincided with the extreme weather event. In the western portion of the study area, 11 (31%) of the 35 nest sites with eggs failed. For these 11 nest sites, the entire clutches perished; in sum, 28 of 87 (32%) owlets age 20–45 d old died during this period. For the eastern and western portions of the valley combined, owlets were observed jumping out of nest boxes at eight sites. At one additional site, the owlets jumped out of their nest box but landed inside a haymow, away from the hot outer walls. The parent owls continued to feed the owlets and they survived.

The nest sites with owlet mortality were typically in boxes that were exposed to more direct sunlight, such as free-standing pole boxes or boxes close to exterior walls (Table 1). However, in the western portion of the valley, none of the owlets in pole boxes that were situated in the municipality of Richmond were affected, which was likely attributable to the locations of the boxes <350 m from the ocean, where the daily maximum temperature only reached 32.4°C (Environment Canada 2022). In summary, this is the first time extreme weather has coincided with documented high mortality of barn owlets during the breeding season in British Columbia.

ATMOSPHERIC RIVER AND ARCTIC COLD SNAP 2021

Six mo later in November 2021, a series of precipitation events termed atmospheric rivers hit the south coast of British Columbia and parts of Washington State. Atmospheric rivers are long flowing regions of the atmosphere that are shaped like a river and carry excessive amounts of water vapor (Dacre et al. 2015). The eastern Fraser Valley was hardest hit, and the two main cities of Abbotsford and Chilliwack received 541 and 616 mm of rain during this month, respectively, which is 2.5 times more than average (Environment Canada 2022). Large areas of agricultural lands, which are the core areas for the Barn Owl population in the eastern Fraser Valley, were flooded. The floods lasted

Table 1. Summary of box type, location, and orientation of nest boxes where entire broods of Barn Owl young died, likely as a result of heat-related causes ($n = 11$).

Type of Box	Direction Entrance Faces	If Indoor, Position of Box
Indoor	E	Flush against east wall
Indoor	S	Flush against south wall
Indoor	N	Flush against south wall
Indoor	N	Flush against south wall
Indoor	S	In middle of barn
Pole box	N	NA
Pole box	N	NA
Pole box	N	NA
Pole box	SE	NA
Pole box	E	NA
Pole box	W	NA

for almost a month, submerging important hunting habitat for the local Barn Owl population and likely reducing the availability of field voles (*Microtus townsendii*), the owls' primary prey in the region (Campbell et al. 1987, Hindmarch and Elliott 2015). Decreasing prey populations have been linked to overall declines in Barn Owl numbers in other locations (Taylor 1994, Klok et al. 2007). The atmospheric river was followed by a record-breaking cold snap in late December/early January when an arctic outflow brought snow and broke cold temperature records in southwestern British Columbia (Environment Canada 2022). Barn Owls are not well adapted to subzero temperatures and snow cover >5 cm (Marti and Wagner 1985, Altwegg et al. 2006, Roulin 2020).

Southwestern British Columbia is on the northern extent of the range for Barn Owls in North America, which may make them vulnerable to starvation during cold weather events (Marti et al. 2020).

EXTREME WEATHER AND BARN OWL REPRODUCTION

The occurrence of the hottest, wettest, and coldest seasons on record within a 12-mo period may have had a negative impact on the local Barn Owl population. Specifically, we speculate that the heat dome limited owl productivity and therefore recruitment of young in 2021, and this, combined with suspected high adult mortality in the fall and winter due to starvation, significantly reduced the breeding population in 2022. This was most evident in the eastern Fraser Valley, where only 14 nest boxes out of 109 (13%) had pairs that laid eggs and an additional four nest sites were occupied (i.e., at least one adult present) during the subsequent 2022 breeding season. The average number of owlets fledged for nest sites that had eggs was 3.3 ± 1.2 per nest site in the eastern Fraser Valley ($n = 14$). In the western Fraser Valley, 65 nest sites were monitored in 2022, of which 77% had pairs that laid eggs. However, at accessible sites where we could determine the number of owlets, the fledging rate was low at 1.9 ± 1.1 owlets per nest site ($n = 39$). In comparison, in 2021 when the heat dome occurred, the average productivity was 1.3 ± 1.5 owlets per nest site ($n = 42$). Thus both 2021 and 2022 were well below the yearly productivity from 2016 to 2020 which ranged from 2.1 ± 1.5 ($n = 36$) to 3.3 ± 1.5 ($n = 31$), respectively, owlets per nest site. A concurrent decrease in annual road mortality in that region was also consistent with the observation of a sharply reduced Barn Owl population (Meyrom et al. 2023). In 2022, only eight Barn Owls were found dead along a regularly surveyed 60-km stretch of the Trans-Canada Highway in the eastern section of the Fraser Valley, whereas the average has been 39 ± 18 Barn Owls found dead annually between 1998 and 2018 (G. Powers unpubl. data).

Extreme weather events are predicted to become more frequent in the Pacific Northwest (Heeter et al. 2023). A heat dome of the magnitude experienced in 2021 was thought to be a one-in-1000-yr event, but climate change has made this phenomenon likely to occur once every 200 yr (Bartusek et al. 2022). To prevent future heat-related stress and mortality, free standing pole boxes and boxes attached to the outside of buildings in our study area have now been retrofitted with white sheet metal roofs that have a gap between the original and new roofing to increase air circulation and reflect heat. Trials showed that this design change was able to lower the peak daytime temperature in retrofitted boxes by 5–6°C. (C. McVittie and the Cascade Box Group unpubl. data). Our previous modifications to boxes to reduce temperature included a larger box size, 2.5-cm wide ventilation holes, and avoidance of installation at sites with exposure to direct afternoon/evening sun. Similarly, in central California there has been an increase in suspected nest failures due to heat (E. Philips pers. comm.). The new nest box designs for California recommend a heatshield on the roof and the back of the box, and a larger box size: 61 × 61 × 43 cm (Wild Farm Alliance 2022).

Barn Owls are an r-selected species, and as such should be capable of recovering from stochastic incidents such as extreme weather events (Taylor 1994). However, the frequency of these weather events has increased, as has been shown over this 12-mo period. Further, these weather events are compounded with other threats this species is facing such as habitat loss, collision with vehicles, and risk of rodenticide poisoning (Hindmarch et al. 2017). Consequently, the western Barn Owl population was federally listed as threatened in 2018 (Committee on the Status of Endangered Wildlife in Canada 2010, Species at Risk Act 2018). Retrofitting nest boxes with white roofing and protecting mature trees and snags with cavities that are suitable for Barn Owls are important measures to reduce the risk of owlet mortality from overheating. Furthermore, larger landscape-scale protection measures should be implemented to protect Barn Owls' hunting grounds. These measures should consider the importance of protecting natural areas, especially wetlands and natural grasslands, which buffer against flooding events. Incorporating conservation measures that promote landscape resiliency is vital to protect wildlife from extreme weather events.

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