ABSTRACT

Hit or miss could mean life or death for juvenile Southern Bent-wing Bats

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The Southern Bent-wing Bat (*Miniopterus orianae bassanii*) is a critically endangered obligate cave-dwelling bat that is restricted to South Australia and Victoria and has undergone significant population decline in recent decades. Only three maternity colonies are known, the largest at Bat Cave in Naracoorte Caves National Park, SA. Anthropogenic factors at maternity caves may adversely impact survival rates, especially juvenile survival. Fencing is often installed around cave entrances to restrict human access, but this can create a collision risk for bats, especially for juveniles learning to fly. Infrastructure around Bat Cave includes a fence and a large metal panel. Trapping was undertaken at the cave entrance as part of a separate research project in January 2016–2018, at the time when young commence flying, which enabled opportunistic observations on collisions rates with this infrastructure.

In 2016, four of the 387 (1.03%) juveniles caught over one weekend had broken limbs from colliding with infrastructure, and required euthanasia. Many other bats were heard to collide with the metal structures although the fate of those individuals was unknown. In 2017, the fence was covered with shade cloth in an attempt to reduce the rate of injuries. No injured bats were caught; however, 90 bat strikes on metal were heard over two nights of monitoring. In 2018, the fence and metal panel were both padded and covered with shade cloth. No injured juveniles were found, and no bat strikes were heard during four nights of trapping. Covering the metallic smooth surfaces with shade cloth may have improved the ability of the young bats' echolocation to detect it, with the padding reducing injury if any did collide.

This study highlights the need for careful fence design and placement, especially around the entrances of bat maternity colonies, and the importance of monitoring new, and even existing, bat cave fences for bat collisions.

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Introduction

The Southern Bent-wing Bat (*Miniopterus orianae bassanii)* is an obligate cave-dwelling bat with a restricted range in southeastern South Australia and southwestern Victoria. It has undergone significant population declines in recent decades, resulting in it being listed as critically endangered. Only three maternity colonies are known, the largest at Bat Cave in Naracoorte Caves National Park, World Heritage Area, South Australia. Bat Cave has a vertical window entrance (7 x 4 m) leading to a 10 m drop to the cave floor. The rim of the entrance is thin and undercut, making it hazardous for staff, researchers and tourists. The entrance is fenced to prevent 1) people from falling into the cave, 2) unauthorised access, and 3) disturbance to the bats and fossils within the Bat Cave.

The fence around the entrance to Bat Cave is a standard 1.5 m high galvanised iron fence with vertical rungs (typically used to fence swimming pools). It is positioned 2–5.5 m from the entrance (Figure 1). In addition, there is a smooth metal panel 12 m long and 1.5 m wide, located between the fence and cave entrance (about 1.5 m from the cave entrance). The metal panel is fixed on a 45 degree angle sloping away from the entrance. It was installed in 2012/13 to assist with undertaking population estimates by recording bats emerging from the cave using thermal imagery, but is now rarely used.

Figure 1. Left: Infrastructure surrounding Bat Cave, including the metal fence and smooth metal panel, and temporary set up of padded harp traps. Right: Harp traps set up to trap bats during January 2016-18 field sampling. Photos: Yvonne Ingeme

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Methods

Between 2016 and 2018, the field work component of Emmi van Harten's PhD research project 'Population dynamics of the critically endangered Southern Bent-wing Bat' was undertaken. The aim was to PIT-tag 1000 Southern Bent-wing Bats per breeding season with approximately half to be juveniles. This involved placing a large number of harp traps around the cave entrance. Harp traps comprise a large aluminium frame with two banks of vertical, fine fishing line with a canvas bag underneath. To reduce the risk of bats injuring themselves if they hit the metal uprights or cross bar, these poles were covered with foam. The traps were positioned immediately outside the fence and with the top of the bag below the height of the fence. Trapping was conducted in January and February to coincide with the period when juvenile Southern Bent-wing Bats commence flying.

Trapping commenced on dusk and continued into the early hours of the morning as it was found that the juveniles tended to emerge later in the night than the adults. The traps were under constant surveillance during the night, to enable bats to be removed as they were caught. Noise and lights were kept to a minimum, with red filters on the lights when they were used. The observers spent most of the time in the dark quietly listening, and this provided the opportunity to make observations on collision rates with the infrastructure around Bat Cave.

Results

In 2016, the first weekend of trapping (8 and 9 January) was prior to the majority of juveniles commencing flying, and we only caught a few juveniles. By the second weekend of trapping (15 and 16 January), the juveniles had started to fly. During this trip we discovered some significant issues. On the first night, two bats caught in the harp traps were found to have recently broken limbs. Initially it was unclear if the injuries were caused by collisions with the harp trap frames or with the fence immediately in front of the traps. Therefore, on the second night, mist nets were used instead of harp traps, which covered a larger area with fewer vertical poles. However, a further two bats were caught with broken bones, well away from the mist net poles, but immediately behind the fence. This suggested that the injuries were a result of bats hitting the fence or metal panel rather than the harp trap frames, and that the momentum of their flight had just carried them into the traps. In total, four of the 387 (1.03%) juveniles caught that weekend suffered life threatening injuries in the form of broken limbs and required euthanasia. Many other bats were heard to collide with the metal structures during the night, although the fate of those individuals was unknown.

The Naracoorte Caves park staff were provided with an incident report following this trapping weekend. Park staff then installed temporary measures to reduce potential bat collisions, covering both the fence and the metal panel with shade cloth (Figure 2). No collision injuries were recorded during the trapping on the weekend of 19 and 20 February 2016, however by this time the young had been flying for over a month and may have been more adept in avoiding obstacles.

Figure 2. Temporary protection measures installed in 2016 with the infrastructure covered with shade cloth. Photo: Y. Ingeme

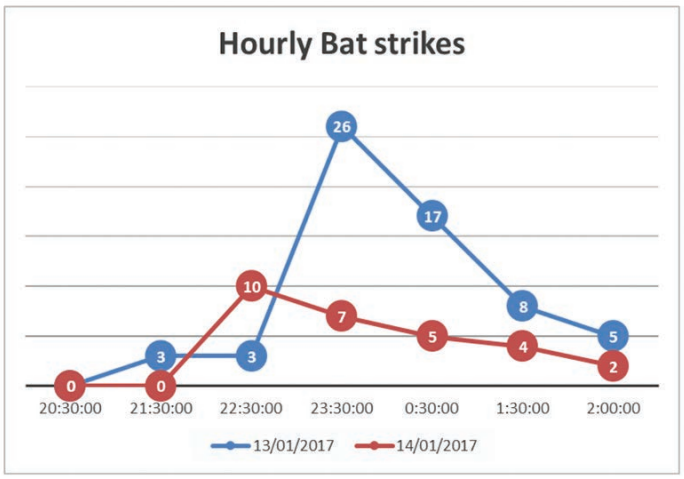


Figure 3. The number of times bats were heard to hit metal infrastructure around the cave during two nights of trapping in January 2017, between sunset and 2 am.

The following year on 13 and 14 January 2017, the fence had been covered with shade cloth in an attempt to reduce injuries, but no protection had been placed over the long smooth metal panel. The shade cloth was flush with the fence. No injured bats were caught in the harp traps, however, bats were heard striking the metal 90 times over two nights of monitoring (Figure 3). Most of the bat strikes were loud and sounded like they were hitting the smooth metal panel.

When the juveniles began emerging from Bat Cave on 13 January at approximately 22:30-23:30 hours (as determined by the age of trapped individuals), there was a distinct increase in the number of strikes heard on the metal infrastructure (Figure 3). The number of strikes heard on the second night was considerably lower than the first night. By the second weekend of trapping (3 and 4 of February 2017), no bat strikes were heard. We reasoned that the juveniles had gained more flying experience by this time and had learnt to navigate the fencing and metal panel.

In January 2018, further padding was added. The shade cloth was angled away from the fence to provide more 'give' and the top rung of the fence was padded with lengths of pool noodle foam (Figure 4). The metal panel was padded with inflated air mattresses and covered in shade cloth. No injured bats were found and no bat strikes were heard during four nights of trapping over two weekends, including in early January when the young had just commenced flying.

Discussion

Recently published work by Greif *et al.* (2017) found that bats may collide with objects with smooth surfaces, because the bat's echolocation calls are deflected away from the surface and not back to the bat until they are almost upon the smooth surface. Covering the smooth metallic surface of the metal panel with shade cloth changed the texture and may have improved the ability of the young bats' echolocation to detect it, with the padding reducing injury if any did collide. In addition, the shade cloth was cream in colour, which may have made it more visible to the bats.

When there was no fence covering in place, the number of bat collisions appeared to decline as juvenile Southern Bent-wing Bats became more experienced flyers. However, our observations indicate that there is a potentially significant percentage of the juvenile bats suffering life threatening injury per night during the first few weeks of juvenile bats emerging from the maternity cave. Continuing actions to mitigate these impacts are therefore critical.

So how long have these injuries been happening and what has been the likely impact on the bat population?

Figure 4. Additional padding on the smooth metal panel in the form of (colourful) inflated air mattresses and pool noodles on the top of fence. Photo: Yvonne Ingeme

Figure 5. Left: Photo of a fence around Bat Cave taken in 1977 (Photo: Jim Cundy, source Lewis 1977). Centre: The entrance of Bat Cave from within, showing how close the fence was to the cave entrance prior to 1986 (Photo: supplied by Steve Bourne). Right: A Southern Bent-wing Bat caught in a barbed wire fence that used to surround Sand Cave, Naracoorte (Photo: Steve Bourne).

Historical fencing at Bat Cave at Naracoorte

The fence at Bat Cave has potentially been posing an adverse risk to bats for a very long time. In the 1960s the fence was only 1-2 m from the edge of the cave entrance and was made of barbed wire (Figure 5). Barbed wire fences are known to be an entanglement risk to bats (*van der Ree 1999*).

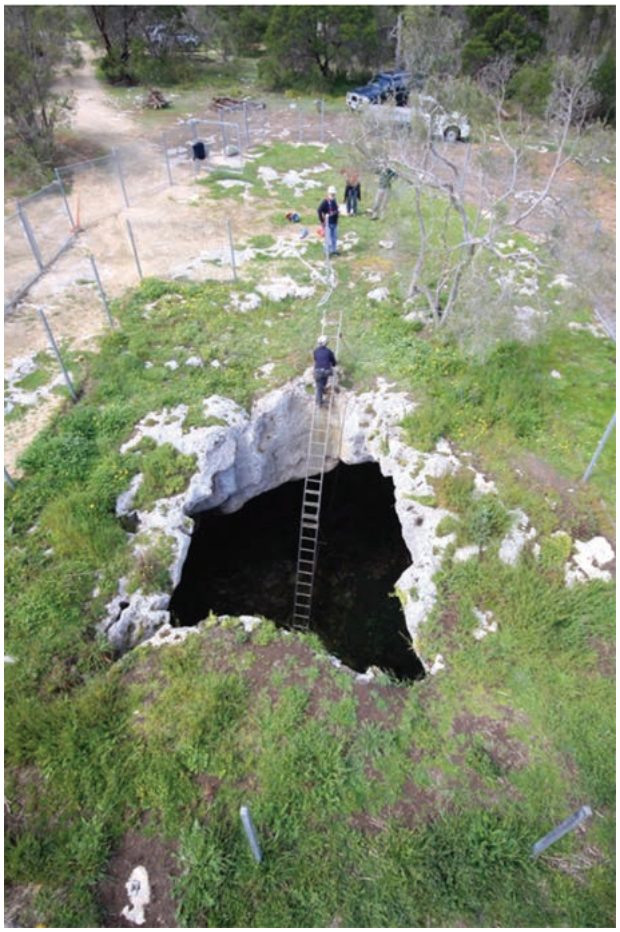
The fence was upgraded in about 1986 by Brian Clark (previous manager of the reserve), with a standard pool fence design that was located close to the cave entrance (Figure 6). Based on our current observations it is likely that this would have impacted the survival of some juvenile bats each year, however it is unknown how many.

During the summer of 2012, regular flyout counts of the bats at Bat Cave were undertaken using thermal cameras (*Lear* 2012). During that study, it was noticed that when the juveniles began flying, the number of bats hitting the fence increased dramatically. Several juveniles were observed to fall to the ground. One had a broken wing and had to be euthanased. In response, Lear (2012) covered the fence with tarps and observed that number of bats hitting the fence then dramatically decreased.

The fence was moved further away from the entrance later in 2012 for a number of reasons: Firstly, this improved the ability to undertake the flyout counts by extending the fence past the filming position and enabling the installation of the metal panel. Secondly, it improved the tourist interpretation and kept people further away from the entrance, and thirdly, it provided a safer buffer between the edge of the cave and the fence to reduce the risk for staff walking inside the fenced area. The construction of the new fence was staged, i.e. the second fence was built first and then the first fence removed (Figure 7). To reduce impacts on the bats, the fencing was undertaken once they had dispersed to other caves for the winter. When bats returned to Bat Cave later that year in spring they appeared to acclimatise to the new position of the fence over several nights (*Lear* 2012). However

Figure 6. Fence upgrade dating back to 1986 located close to Bat Cave entrance. Photo: Steve Bourne.

Figure 7. Construction of the new fence several metres further away from Bat Cave entrance. Photo: Steve Bourne.



we are unaware of any detailed follow up monitoring to determine if the fence relocation reduced the number of bat strikes.

Observations made by Steve Bourne while manager of the reserve suggest that the adult Southern Bent-wing Bats fly up and out of the cave to clear the fence and then quickly swoop down low, potentially to avoid predation. He therefore questioned if moving the fence further from the cave exit may actually increase collision risk when the bats fly low as they disperse from the cave. Without further data, we do not know how different off-set distances might influence bat behaviour and the number of collisions with fences at cave entrances, however this warrants further investigation.

Recent fencing designs at Naracoorte Caves

Naracoorte Caves management has recently installed new fencing around other caves in the park (Figure 8), some of which have also resulted in fatalities. A juvenile Southern Bent-wing Bat was found dead at the fence junction at Wet/Stick Tomato Cave (Figure 8), nine days after being PIT-tagged. This individual may have had less than three weeks flying experience. A necropsy by Dr Peter Holz found that the bat was in excellent condition, with a stomach full of invertebrates, but had brain trauma, likely due to collision with the fence.

Some of the authors of this paper were approached by cave management in 2017 to provide feedback about proposed fence designs for Bat Cave, including a large glass viewing panel through which tourists could view the bats emerging from Bat Cave. The glass panel was not recommended because it was considered to have a similar effect to the smooth metal panel and hence would have likely resulted in further bat collisions.

Lear (2012) indicates that discussions were being held back in 2012 regarding improvements to the fence around Bat Cave stating that 'retractable shade covers may be installed along the top fence edge so they can be pulled out during times when the population is at its peak,

Figure 8. Fences at other caves within the Naracoorte Caves National Park. Left: Wet/Stick Tomato Cave. Photos: Emmi van Harten.

which will hopefully reduce the number of collisions on the fence' (p14). Discussions are again underway to install a more bat friendly fence around Bat Cave, however little to no information is available as to what a bat-friendly fence might look like. A *Scopus* and *Science Direct* search did not find any suitable references on the topic.

Designing a bat-friendly fence at Bat Cave needs to consider the behaviour and abilities of the juvenile Southern Bent-wing bats. The fence also needs to serve as a secure barrier to discourage unapproved access to the cave (for human safety and for protection of the roosting bats). The study undertaken by Greif *et al.* (2017) suggests that a fence should have a textured surface that can be easily detected by bat echolocation. From the recent observations of juveniles exiting Bat Cave, their flying skills can be very poor, with some individuals either not detecting the pool fence or not being agile enough to avoid it even if they did detect it. Therefore, a textured, padded, light coloured, sloping fence that was not too high may be best. A vegetated fence consisting of soft foliage may be an option, especially if far enough away from the entrance so that bats would not get tangled in the vegetation. This may look more aesthetically pleasing in a national park setting, although the vegetation would need maintenance to ensure the entrance does not become overgrown. This fencing option would restrict visibility for tourists, although an alternative viewing area has already been built up-hill looking down on the entrance to Bat Cave.

As we have discovered from these opportunistic observations, the impact of fence design and infrastructure can be critical to the survival of individual bats. Therefore, any new designs need to be tested first (e.g. filming using thermal cameras) to determine how the bats, particularly juvenile bats, interact with the infrastructure before final design, placement and installation occurs.

Conclusion

This study revealed that infrastructure at maternity caves can impact bat survival, especially for juvenile bats. These observations have implications for fence designs used to protect cave entrances world-wide. We suggest that greater consideration is given to the understanding of the natural functions of the cave when designing fences and seeking designs that protect these, while providing the necessary safety and prevention of access. In the case of Bat Cave, an analysis of bat behaviour and flight paths when exiting the cave should guide fence placement and materials used. We highlight the need for careful fence design and importantly this study suggests that new and even existing bat cave fences should be monitored for bat collisions, especially for maternity colonies, where inexperienced bats will be flying, because 'hit or miss' could mean life or death for juvenile cave-dwelling bats.

Acknowledgments

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