How-to guide

Bioacoustic monitoring of black-cockatoo nesting

Project 3.2.2.4

Threatened Species Recovery Hub

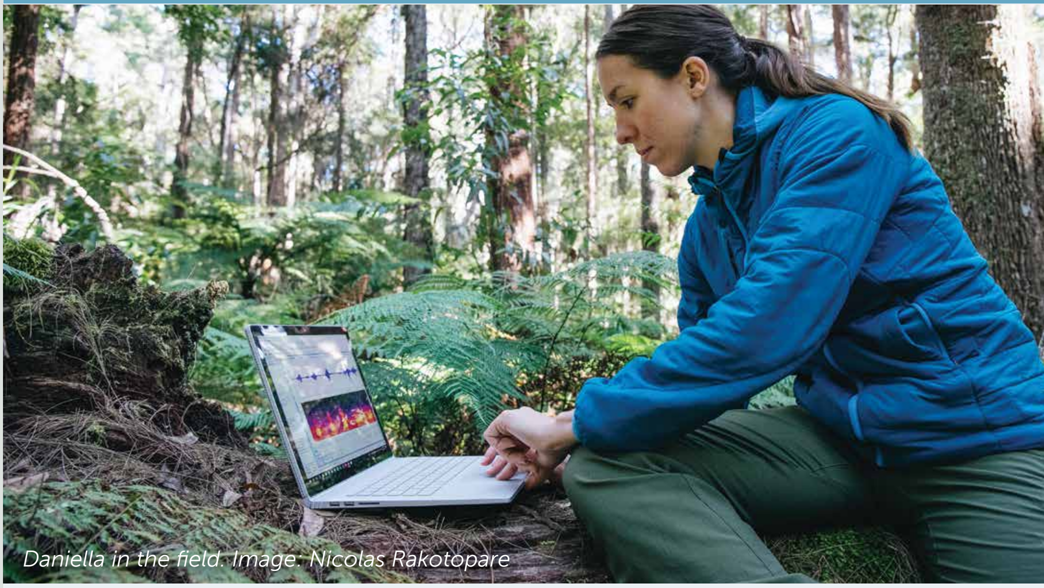
National Environmental Science Programme

Bioacoustics

Bioacoustics is the study of wildlife via their vocalisations – that is, their calls or, for some species, their songs. This is similar to but distinct from the monitoring of ecosystems via their soundscapes, known as ecoacoustics. Bioacoustics tends to focus on individual species, while ecoacoustics focuses on whole ecosystems. Today, bioacoustic monitoring usually involves using autonomous (remote/stand-alone) sound recorders that can be left in the field for extended time periods. Where species' vocal behaviours are known, sound recordings offer a potentially rich source of data that can be used to the benefit of conservation (Teixeira et al.; d).

A glossy black-cockatoo nestling. Image: Daniella Teixeira

Problem addressed



Daniella in the field. Image: Nicolas Rakotopare

Lack of breeding success is considered a key challenge in the recovery of several species of black-cockatoo. Accurate and spatially informed data on nesting success would enable the effectiveness of different management strategies to be assessed and for approaches to be improved in response to evidence.

This research has focused on two Endangered subspecies of black-cockatoo, the Kangaroo Island glossy black-cockatoo and the south-eastern red-tailed black-cockatoo. Bioacoustic monitoring of these subspecies, as well as other subspecies of glossy and red-tailed black-cockatoo, is attractive because nest monitoring by other, traditional, methods (using human observers) can be difficult and costly.

Bioacoustics offers a new approach to monitoring at large scales with minimal human involvement.

On Kangaroo Island, recovery program staff performed nest checks as part of their routine monitoring until 2017, when their funding was reduced. This limited data collection from nests, as critical nest maintenance works (to exclude predators from nests) took priority. Historically, for the red-tailed black-cockatoo, if nests were found, we didn't know if the nestlings had survived to fledging, which in turn made it difficult to gauge breeding success. Moreover, such human-observer nest checks, while still enabling estimates of nest success, do not afford the precision that recording actual fledging events can.

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Assessing breeding success

This project has developed and tested methods to monitor black-cockatoo nesting behaviour using bioacoustic sound recorders. In particular, this work focuses on the moment that the nestling or chick flies from the nest, which is known as fledging. Fledging defines a successful nest; the fledgling has survived the four-month nesting period to join the flock. (The nesting vocal repertoire of glossy and red-tailed black-cockatoos is described in detail in Teixeira et al. (a).)

By monitoring the sounds that happen at fledging, bioacoustics can tell us if and when a fledging event occurs. Additionally, if a nest fails, bioacoustics can tell us when failure happened, and the approximate age of the nest at failure. Together, this information gives a good picture of breeding success.

Alternative approaches to assess breeding success with bioacoustics might include listening for juveniles in flocks (although this is untested); however, that wouldn't tell you the proportion of nests that survived to fledge.

The methods described here can most likely be applied to any subspecies of glossy or red-tailed black-cockatoo. In fact, the principles underlying this approach are likely to apply to the other species of black-cockatoo as well (i.e., yellow-tailed, Carnaby's and Baudin's), providing their species-particular nesting vocalisations are known and have been described.

Before you start

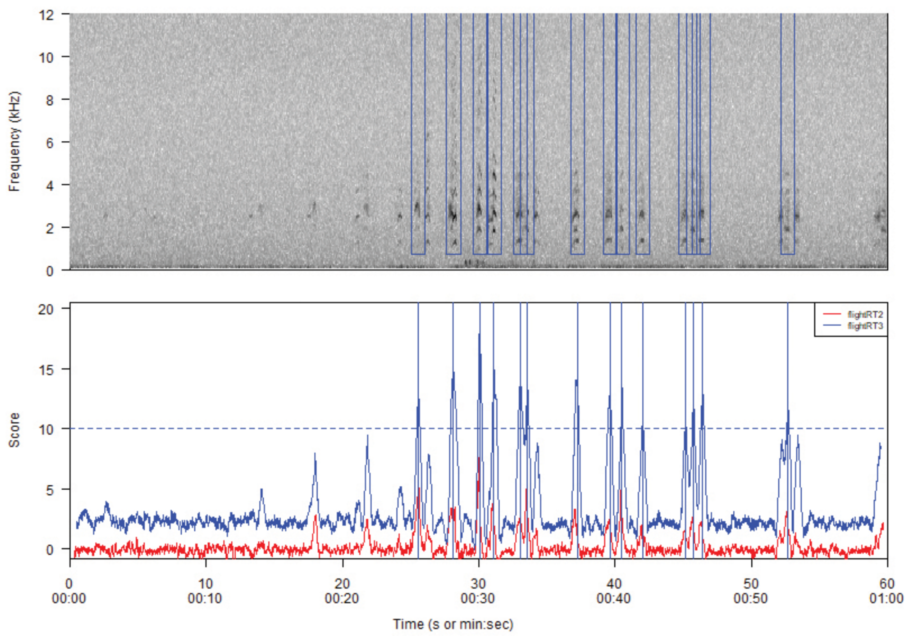
Two requirements are essential before you get started with bioacoustics monitoring of black-cockatoos. You will need to understand:

1. What vocalisations the nestlings make, in order to analyse the recordings. The nest-associated vocalisations of adult and nestling glossy and red-tailed black-cockatoo are described in Teixeira et al. (a). (This work will help future researchers describe the nesting vocalisations of other species of black-cockatoo.)
2. R statistical language, in order to use the call recogniser (discussed in Teixeira et al., in prep (b).

Steps at a glance

These are the key steps of the method. Each step is described in more detail below.

1. Find a nest that you want to monitor, either active (to monitor outcome) or potential (to monitor usage and, potentially, outcome)
2. Fix a sound recorder on the nest tree or nearby structure
3. Leave it there for the breeding season, servicing it when you need to
4. Analyse the sound recordings to confirm fledging or failure (and other behaviours, if necessary)
5. If the nest failed, estimate age at failure



Example output from the call recogniser for the south-eastern red-tailed black-cockatoo. The spectrogram (top) shows the detected flight calls (blue boxes), which are those that met or exceeded the user-defined score cutoff, or similarity threshold, of 10 for the template named flightRT3 (bottom). Distant flight calls that did not meet the similarity threshold are not detected (boxes absent on the spectrogram).

Step 1: Find a nest

Finding nests may be your greatest challenge with black-cockatoo populations. The bioacoustics monitoring described here assumes that you know the location of nests. Different programs have different methods of finding nests; and while bioacoustics could feasibly be used to help find them, I have not yet attempted to use the method for this purpose.

Step 2: Fix a sound recorder on the nest tree

Choosing a sound recorder

Bioacoustic monitoring requires autonomous sound recorders that are robust enough to be left in the field for the duration of the four-month black-cockatoo nesting period. The market provides a number of options for good, hardy sound recorders. In my project, I used the Frontier Labs Bioacoustic Audio Recorder (BARs), for its advantages of price, robustness to weather, availability of local service, and ease of in-field set-up (program scheduling). A new low-cost option is also now available: Open Data AudioMoths. For the 2019–2020 breeding season of the south-eastern red-tailed black-cockatoo, the recovery team trialled AudioMoths. The devices worked well, if perhaps not as well as BARs, but their low cost warrants their continued use, with some improvement (I am currently working with the recovery team on this). Another new option is Cornell Lab of Ornithology's Swift recorder, which I have not yet had an opportunity to try out. We have purchased some, however, and will use them for the 2020–21 breeding season.

A major benefit of both the SMs and BARs is that they are GPS-enabled, which means that you can program the recorder according to the times of sunset and sunrise. This is important because of the months-long duration of the black-cockatoo nesting period. The other sound recorders need to either be serviced more regularly and their programming schedule updated, or programmed to record for more hours of the day in order to capture the critical times of day throughout the nesting period.

Programming and placing the sound recorder

Program the sound recorder to capture the time that the birds are most active and most vocal at the nest. For glossy and red-tailed black-cockatoos, this is around sunset. In my work, I programmed the recorder for three continuous hours each day, beginning two and a half hours before sunset. I used a sample rate of 44.1 kHz. Lower sample rates would probably suffice (and save on memory) if you don't need to do fine-scale acoustic measurements of the individual calls. Fine-scale measurements may be necessary for purposes such as describing calls that are unique to individual birds. With this information you could, potentially, determine whether a bird re-uses a nest in multiple seasons (i.e. nest site fidelity). For simply confirming whether a nest is active or inactive, all that is required is to confirm (or deny) that the species is calling.

Young male Kangaroo Island glossy black-cockatoos. Image: Daniella Teixeira

You can either place the sound recorder on the nest tree itself or on a nearby tree. Because cockatoos are loud, there is no need to place the recorder very close to the hollow or inside the hollow. Just place it as close as you can to the nest hollow without disturbing the birds. If I am placing a recorder when birds are present at the nest (e.g., early in the nesting period when the female is incubating an egg or brooding a small nestling), I use a nearby tree.

If a tree is collared to defend against predators (e.g., if it has possum-exclusion iron collars), be sure to place the recorder above the collar, as some animals will chew on the microphones. Climbing trees is risky and costly and therefore to be avoided as far as possible, so I tested the methods on recorders that I placed about 1.5 to 2 metres above ground level, and found that this worked well.

The most important consideration is that the recorder be closer to the nest of interest than to any other nest. That way, even if there are other nests nearby (which is common), the calls of the nestling from the nest of interest will be louder than the calls from other nests.

You can attach the recorder to the tree in any way that is secure for the area that you're working in. Most sound recorders come with an attachment device (e.g., a strap), but you might want to build something more secure if you're working in an area prone to theft. It's really important to ensure the recorder is attached securely, as any movement will generate noise, which will interfere with sound data analysis.

Step 3: Leave it there for the breeding season, servicing it when you need to

Using the software provided for the recorder you choose, determine how often the recorder will need to be serviced for battery and memory (SD card). There are many factors to consider in determining these frequencies – batteries may expire before SD cards are full, for example. You can also save on battery life by reducing sample rate or the number or hours you record per day.

It's most likely that your recorder could be left for at least two months before it needs to be serviced. I used 128 GB Ultra HD SD cards in my research, which helped lengthen the time needed between services for them.

These times can be extended if, for example, a lower sample rate is used; or if recording happens only every other day, which might be the case early in the nesting period.

Retrieve the sound recorder after the expected time of fledging, or sooner if nesting failure is otherwise confirmed.

Step 4: Analyse the sound recordings to confirm fledging or failure

The aim of this step is to (1) confirm nest activity on any given day and (2) detect fledging.

Confirming nest activity relies on detecting the calls of nestlings. If you have placed your recorder well, you will find that nestling calls are more reliable than other call types. Adult calls can be rendered unreliable by recordings made of the calls of adult birds other than the nesting pair. Adults will also vary in their distance from the sound recorder, while nestlings, which are always in the hollow, will not. Nestling calls are one of two calls that are unique to black-cockatoo nests, the other being the call that the adult female gives as she enters the nest. However, the females won't necessarily give the nest-entry call every day, making it less reliable than nestling calls, which the chicks make every day from about six weeks.

Analysing the sound recordings is the most difficult and time-consuming step in bioacoustic monitoring. Three options are available: (1) manually inspecting spectrograms; (2) using a call recogniser in a fully automated method that operates at the level of the individual call; or (3) combining elements of both in a subsample method that operates at the level of the recording day. I use this latter subsample combination method.

I describe these three methods in detail.

(1) The fully manual method – no call recogniser

The fully manual method does not use a call recogniser. Instead, you verify detections by manually inspecting the spectrograms, which requires acoustic software. There are many options on the market, and I use and recommend Cornell Lab of Ornithology's Raven Pro. A good free option is Audacity.

Select three to five days at random that cross the early, mid and late stages of the recording period. View their spectrograms for nestling vocalisations. Continue to subsample random days and inspect spectrograms until you find the final date at which the birds are vocal.

Fledging is confirmed by the presence of the fledging vocalisations; failure by their absence (although not absence of fledging vocalisations per se, rather the absence of calling at a time earlier than expected fledging). In most cases, failure happens early in the nesting period, before late-stage nestling calls are heard. In rare cases, late-stage nestling calls can be heard but fledging is not recorded.

It can be difficult to determine whether the nestling fledged at a time not captured by the sound recording or if failure occurred late in the nesting period. In this scenario, you will have to draw on expert knowledge and/or other information collected in the field. This can include using a pole-mounted camera to look inside nests, although this is time-consuming. We also note if we see adults near the nest during site visits.

Daniella in the field. Image: Nicolas Rakotopare

To expedite the process, view the spectrogram in 15-minute chunks. Because the sound recorders are close to the nests and cockatoos are loud, the cockatoo calls are usually obvious, even when viewing 15 minutes in a single image. They normally appear as broadband bars. You can zoom in on these to confirm that they are, in fact, the black-cockatoos.

The calls of other cockatoos, especially sulphur-crested cockatoos and galahs, might also look like black-cockatoo nestling vocalisations, so this method can be slow.

(2) The fully automated method – using a call recogniser

I have developed a call recogniser to detect the nestling calls of both subspecies of black-cockatoo. It is implemented in R using the monitoR package, and can be made available to any group using this method of nest monitoring. The call recogniser is described in Teixeira et al. (in prep; b)

Although the call recogniser works by detecting individual calls, its performance can be at the level of the individual call, or of the recording day.

In the fully automated method, instead of subsampling days, you work at the level of the individual call. Run the call recogniser on all the sound files you have collected across the whole period of recording, and inspect the spectrograms for the latest date that nestling call detections were returned, working your way back in the time to confirm fledging or failure.

This approach requires extra computing power, as you are running the recogniser on all of the sound files. I therefore recommend running the recogniser in batches of sound files rather than all at once.

(3) Combination subsample method – using a call recogniser

This combination method using the call recogniser works at the level of the recording day. Unless you need to detect every individual call (which is not likely), then it is more efficient to consider detections at this level.

The combination subsampling method works by categorising a recording day as 'nest active' or 'nest inactive'.

'Nest active' means that the nestling was vocalising, with the recogniser returning true positive detections. 'Nest inactive' means that the recogniser did not return any detections of nestling vocalisations.

As for method (1), subsample random days from throughout the entire recording period.

Run the call recogniser on the recordings from those days. This method has a further advantage of requiring less computing power than fully automated method (2).

Inspect the detections returned by the recogniser and verify them – that is, determine whether they are false positives or true positives. This will tell you whether the nest was still active on those days. You can verify detections in R, but I find it easier to either import the detections (using a csv or text file) into another acoustic software - I use Raven Pro for this – or write out spectrogram images from R,

which are then viewed as images (faster, but you can't playback the calls; you need to ID calls visually and therefore be confident in recognising their pattern).

Next, you can determine the date of fledging or failure by a process of elimination. Choose a date after the latest date that you can confirm that the nest was active. Run the recogniser on that day's recording. Keep doing this until you confirm with certainty the last date that the nest was active.

It is rare that a recording day will return no detections The bigger problem is false positive detections because of other cockatoo species, but it is quick to tell if detections are black-cockatoo or other non-target species – you don't have to view every single detection to know that a bout of calling is or is not the target species.

Step 5: If the nest failed, estimate the age at failure

Nestling vocalisations change during the nesting period, in a process known as vocal ontogeny. For example, the frequency, duration and amplitude of the nestling calls changes as nestlings mature (Teixeira et al., in prep; c). From analysis of these changes, it is possible to predict the age at which the nest failed.

Nestling vocalisations are not heard before about six weeks of age. Therefore, if nestling vocalisations are never detected, you know that the nest failed early.

While the nestlings are still relatively young, they will vocalise from within the nest hollow. This makes their calls softer and somewhat distorted. Vocalisations are also relatively rare at this stage, with perhaps just one or two per day. Less sensitive sound recorders (e.g. AudioMoths) are unlikely to pick up these faint vocalisations.

When the nestlings are older, they will sit at the entrance of the nest hollow, making calls in the presence of their parents that are loud and clear as well as frequent. This happens from about 9 – 10 weeks of age.

Applications

Bioacoustic monitoring allows researchers and conservation practitioners to quantify nest success and age of failure, which historically has been challenging. With improved technology (cheaper sound recorders, the innovation of call recognisers) it is now possible to collect data from many more nests than by methods involving human observers. It is likely this is more cost-effective than traditional methods.

Understanding nest success rates, and how they are influenced by location and habitat features (e.g., distance to food) can help with conservation decision-making. For example, such information about nest success rates may inform the planning for prescribed burning or the location of artificial nest boxes.

Combined with the monitoring of adult birds in flocks, which is commonly done for black-cockatoos, bioacoustic monitoring for nest success can help us understand whether poor breeding success is affecting population recovery.

Further, it is not uncommon to record potential nest predators in the sound recordings, for example, possums and ravens. If predation is a potential risk to the population, bioacoustics monitoring could be informative, and this is a topic for future research.

Sound recorders capture a diversity of vocal behaviours at nests. I have described the complete nest-associated vocal repertoires of glossy and red-tailed black-cockatoos (Teixeira et al. (a). Understanding these opens possibilities for the collection of more behavioural data, including behavioural interactions between parents and nestlings. The range of potential uses of these behavioural data is described in Teixeira et al. (in prep; a). It is likely this is more cost-effective than traditional methods.

Bioacoustic monitoring: Pros and cons

Pros, compared to human observers:

1. You can collect daily data from more nests.
2. You don't need to revisit nests during the nesting period (other than to change batteries and SD cards, if required, though it is likely that improvements in memory and battery, including solar options, will negate the need for servicing entirely).
3. You are provided with a direct measure of the fledging event; it doesn't need to be assumed.
4. You may detect the presence of nest competitors and predators in sound recordings.
5. Your costs are lower than for sending staff into the field multiple times per season (especially once the sound recorders have been purchased, for example, in long-term monitoring programs where the recorders will be used for many years).

Pros, compared to camera traps:

1. You don't need to climb trees to put camera traps at the nest hollow. Cockatoos, especially red-tailed black-cockatoos, will often nest in dead trees, which are unsafe to climb.
2. You don't need the birds to "trigger" data collection. Sound recording will happen at the scheduled time of day, and will capture data from all animals within the acoustic detection space, not just the animals in front of the camera.

Cons:

1. You may find the upfront cost of equipment expensive.
2. You will require some knowledge of acoustic software.
3. If using the recogniser, you will require some knowledge of R language.
4. You will generate lots of data. This needs to be stored securely and backed up, which can be expensive.
5. You may find the logistics of servicing the sound recorders and acquiring the data challenging, if you are working in remote places.

Potential problems

- Sound recorders may malfunction, for example, if water gets into them.
- Ants sometimes get inside sound recorders, also potentially causing malfunction.
- Some SD cards don't have a write speed that's fast enough, which can result in poor quality recordings.
- Interference from noise (e.g., wind, rain, other animals) can be severe, masking the black-cockatoo calls.
- The call recogniser returns many false positives, so the time involved in verifying detections should not be underestimated.
- Animals can eat the microphone covers.

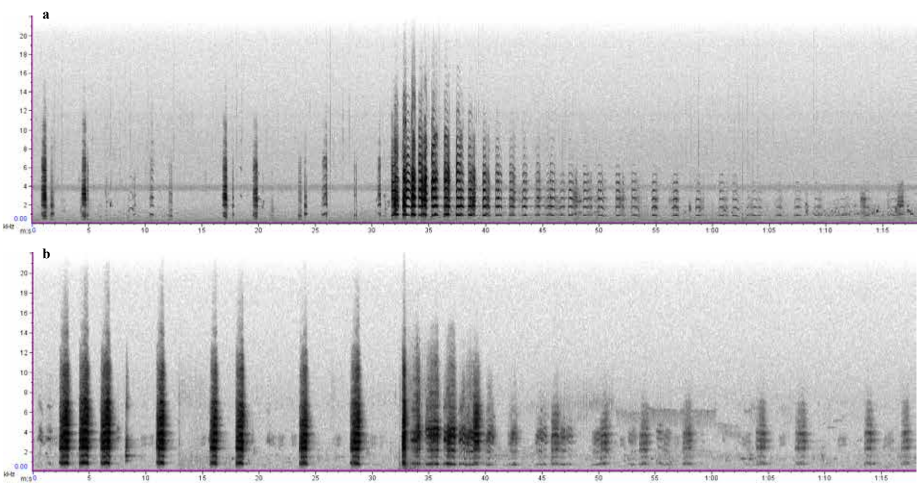
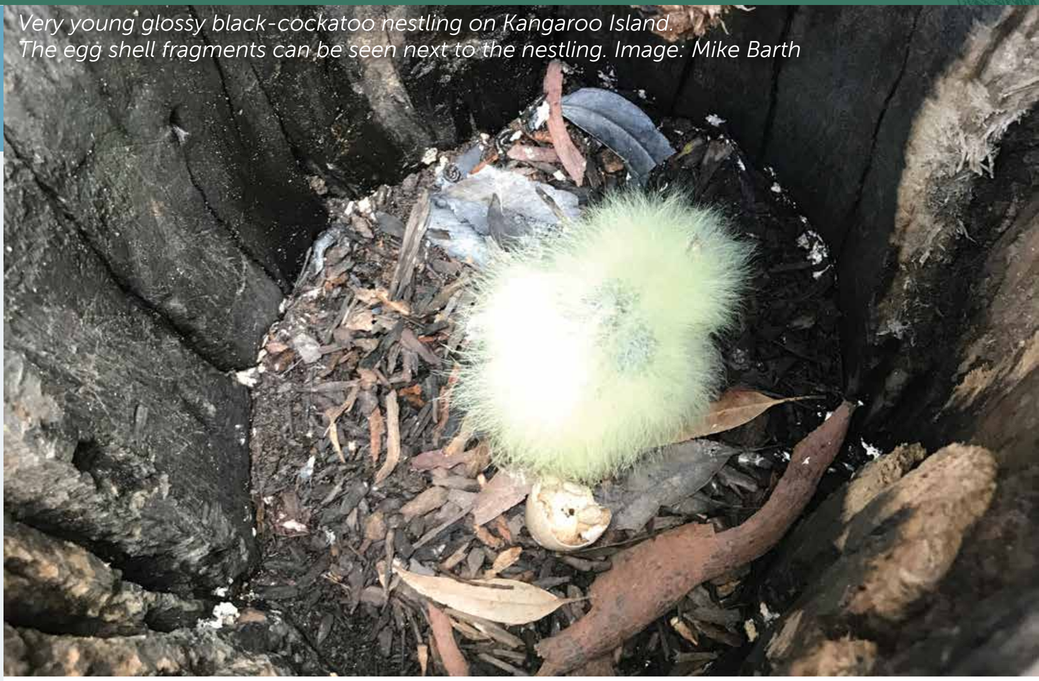


Figure 1: Spectrograms of a fledging event of (a) the south-eastern red-tailed black-cockatoo, Calyptorhynchus banksii graptogyne, *and (b) the Kangaroo Island glossy black-cockatoo,* C. lathami halmaturinus. *Loud nestling calls are evident until ~ 30 seconds, followed by the fledging event when the nestling leaves the nest. Nestling and adult calls are evident as the birds call in flight. Calls rapidly grow softer with increasing distance of the birds from the nest tree. Spectrograms created using Raven Pro 1.5 (Cornell Lab of Ornithology; Hann window; window size = 1024 samples; hop size = 512 samples; 50% overlap).*

Tips and recommendations

Based on my experience,
I recommend the following:

- Be conservative about servicing times (as batteries can fail sooner than expected, e.g., in cold weather)
- Purchase the best SD cards that you can afford; faster write speeds are best
- Always put silicon sachets in sound recorders to absorb moisture
- Use Raven Pro software
- Put data on www.ecosounds.org as a backup, and as easy way for collaborators to view the sound spectrograms
- Record for roughly three hours per day, around sunset. If your recorder is not GPS-enabled, this should be extended to capture sunset calling for all months that the recorder is deployed



Very young glossy black-cockatoo nestling on Kangaroo Island. The egg shell fragments can be seen next to the nestling. Image: Mike Barth

References

Teixeira, D., Hill, R., Barth, M., Maron, M. and van Rensburg, B. J. (2020). (a) Nest-associated vocal behaviours of the south-eastern red-tailed black-cockatoo, *Calyptorhynchus banksii graptogyne*, and the Kangaroo Island glossy black-cockatoo, *C. lathami halmaturinus. Austral Ecology*. doi:10.1111/aec.12921

Teixeira, D., Maron, M. and van Rensburg, B. J. (in prep; b) Fledge or fail: Nest monitoring of the endangered black-cockatoos, *Calyptorhynchus banksii graptogyne* and *C. lathami halmaturinus*, using bioacoustics and open-source call recognition. In prep.

Teixeira, D., Maron, M. and van Rensburg, B. J. (in prep; c) Vocal ontogeny and nestling black-cockatoos, *Calyptorhynchus banksii graptogyne* and *C. lathami halmaturinus*. In prep.

Teixeira, D., Maron, M., van Rensburg, B. J. (2019) (d). Bioacoustic monitoring of animal vocal behaviour for conservation. *Conservation Science and Practice*: e72. doi: 10.1111/csp2.72

Further information

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Threatened Species Recovery Hub

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