Chemical immobilisation and satellite tagging of free-living southern cassowaries

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Background The southern cassowary *(Casuarius casuarius johnsonii)* attains 1.8 m in height and over 80 kg in weight. These large birds are equipped with large claws and, although not a direct threat to humans, they have caused serious injury to handlers and members of the public.

Methods and results This study describes chemical immobilisation, restraint, transport and post-monitoring (satellite tracking) methodologies for adult and juvenile southern cassowaries, captured and released from their natural environment.

Conclusions The described methods have improved the management and research opportunities for the southern cassowary and may be transferable to other species of large ratite.

Keywords anaesthesia; cassowary; ratites; restraint; telemetry; tiletamine–zolazepam

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Ratites (ostriches, emus, rheas, cassowaries and kiwis) are flightless birds inhabiting the southern land masses of Africa, South America, Australasia and New Zealand.[1] They have long held the fascination of biologists and the general public, and feature in numerous zoological collections across the world. Ratites are a prized food source and even currency among indigenous peoples.[2] Some species are production farmed for their meat, leather, eggs and feathers, requiring handling, physical examination and transport. Inadequate physical restraint may result in serious injury to the handlers because of the birds' size, temperament, powerful legs and claws.[3] Moreover, excessive struggling or excitement may also cause fractured limbs, haemorrhaging and death of the bird. Chemical restraint is usually desirable when handling larger ratites and a range of anaesthetics have been trialled with varying degrees of success.[4–9]

Injectable anaesthetic agents are typically used with large ratites and are generally administered intramuscularly using an injector pole or dart. The main concern with chemical immobilisation is the risk of self-trauma to the bird or injury to handlers during the knock-out and recovery phases.[6] The majority of studies on the chemical restraint of large ratites have been conducted in ostriches (*Struthio camelus*),[10] with the protocols being transferred to other species, with broadly similar results.[5,8] The drugs that have been used include ketamine hydrochloride on its own or in combination with xylazine, diazepam or alphaxalone;[4,11,12] a mixture of zolazepam and tiletamine;[4,13,14] etorphine;[15] butorphanol;[16] medetomidine;[9] and thiafentanil–dexmedetomidine.[8]

Medetomidine has been shown to provide satisfactory sedation of captive southern cassowaries and emus (*Dromaius novaehollandiae*) and with the aid of the reversal agent, atipamezole, the birds recovered without the violent recovery and convulsions that accompanied other commonly used sedatives.[5,9] Those findings surmise medetomidine to be the ideal drug for the chemical restraint of large ratites, but initial trials conducted by us showed that medetomidine was ineffective for wild southern cassowaries, because the long induction time (~15 min) did not provide a suitable level of chemical immobilisation before the birds fled into the thick rainforest. A likely reason why medetomidine may be less effective in wild southern cassowaries compared with captive birds is that the drug acts as an α_2-adrenoceptor agonist and its effects are negated by the increased adrenalin levels induced by heightened stress.[17] Wild ratites are much less habituated to human presence than captive individuals and will quickly become stressed if humans come too close or the bird feels threatened. The stress effect may be reinforced if the birds are trapped or injured, which often is the reason for capture in the first place (Lauridsen, pers. obs.). Given that high levels of stress can potentially decrease the effectiveness of medetomidine for sedating southern cassowaries in their natural environment, its use involves a risk to bird safety. In the wild, the birds are more vulnerable than in captivity and a disorientated bird may get injured.

The aim of this study was to document a chemical immobilisation and restraint methodology that is safe for the handling and transportation of southern cassowaries captured from (and returned to) their natural environment. We consider that the publication of these methodologies is now required because of the increased frequency of management interventions as a result of anthropogenic habitat encroachment and bird habituation to human-derived food sources. Furthermore, capture and handling is necessary for the translocation of aggressive birds[3] and to provide assistance to those that are injured, emaciated or disorientated.[18] Finally, there is an urgent requirement to extend our knowledge about ratite ecology and such research may require the birds to be sedated, transported or handled.[19]

We also document procedures for attaching satellite telemetry devices to adult and juvenile southern cassowaries. The methodology for satellite tracking and biotelemetry of large ratites is still in its infancy, with very few published reports,[19] which is at odds with the high volume of telemetry-based publications involving vertebrate wildlife,

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including smaller ratites.[20–23] Telemetry enables the user to collect highly accurate and precise data about an animal's interaction with its environment[24] and aids in the formulation of pragmatic species-focused management decisions.[25] We suspect that the reason for the lack of telemetry studies in large ratites may be related to the difficulty in attaching and retrieving the animal-borne devices. We envisage that the methodologies described here will support the research and management of the southern cassowary and may be applicable to other large ratites.

Materials and methods

Animals

Five adult cassowaries (3 females, 2 males) were restrained and tagged with satellite devices in Moresby Range National Park (17.541°S 146.076°E) and Etty Bay Road Conservation Area (17.577°S 146.084°E), North Queensland, Australia. The study was undertaken outside the breeding and nesting season and none of the males had chicks in their care. Although the exact ages of these birds were unknown, anecdotal observations by local residents suggested they were between 7 and 15 years of age. In addition, five juvenile cassowaries (3 males, 2 females) aged between 10 and 15 months, which had been orphaned either by traffic strike of the parent bird or found alone and emaciated after a large cyclone passed through the local area, were also chemically immobilised and tagged. These birds were transported to and held in the Queensland Government cassowary rehabilitation centre (17.817°S 146.099°E) for 3–6 months and then transported to a suitable release site.

Figure 1. Ideal stature of a southern cassowary prior to anaesthetic administration by injector pole. The centre of the cross defines the area for needle entry.

Chemical immobilisation and restraint

The chemical restraint of the birds was undertaken between 15:00 and 16:00 hours, which is outside the hottest period of the day and allows the bird to safely sleep off the effects of the drug. To administer the anaesthetic agent, the bird was enticed into a clearing and distracted with fruit. Once the bird had its head down and was feeding, the anaesthetic agent was administered into the well-developed muscle high on the thigh using a blow dart or a 1-m long injector pole (Wildlife and Animal Capture, Warwick, QLD, Australia) (Figure 1). A 1 : 1 mixture of tiletamine and zolazepam (tiletamine HCL 50 mg/mL and zolazepam HCL 50 mg/mL; Zoletil® 100, Virbac, Milperra, NSW, Australia) was administered at a dose of 7.5 mg/kg. Weight was estimated visually from approximate height and girth around the mid-section, in order to calculate the intramuscular anaesthetic dose. (Post-weighing of southern cassowaries has demonstrated that our expert opinion of bird weight was within 5 kg of actual weight; Lauridsen, pers. comm.)

Once anaesthetised, the bird was approached cautiously by two handlers and a noosed 10-mm rope was placed around each tarsometatarsus. Each rope was secured by a separate handler, the legs were supported at full extension and both feet were raised above the ground. A third handler approached from the dorsal side of the bird, controlled the head and neck without restricting respiration and covered the eyes using a purpose-made hood. Once immobilised, the birds were relocated into the shade and periodically doused with water to reduce the risk of hyperthermia.

To manoeuvre the bird for examination, the feet were raised further off the ground (but slightly apart) using the leg ropes while the third handler supported the bird's head. Using this technique, all aspects of the bird could be examined with minimal risk to handlers. Throughout the sedation period, heart rate was monitored every 10 min using a stethoscope and respiration rate recorded by visual inspection. Each bird was sexed by cloacal probing.

Approximately 20 min after tiletamine–zolazepam administration, each bird was administered a dose of 0.1 mg/kg of diazepam IM into the thigh muscle using a hypodermic syringe.

Tagging

A standard microchip (ISO-FDX-B passive integrated transponder, Oz Microchips, Peakhurst, NSW, Australia) was inserted into the skin at the base of the neck using a purpose-designed application needle. A GPS-based data logger was constructed for both the adult and juvenile birds and the dimensions and weight adjusted according to each bird's size and weight. The attached device consisted of the following elements: a purpose-designed canvas cuff with a 5-mm neoprene lining; GPS-based data logger (185 g, 5 × 3.5 × 2.5 cm; Telonics, Pheonix, AZ, USA) programmed to take a location on the earth's surface every 30 min; two-stage VHF radio transmitter duty-cycling from 7:00 to 17:00 hours; a timed mechanical release mechanism (48 g, 4 × 4 × 2 cm; Telonics); mortality switch that would be initiated if the tag was stationary for more than 24 h; and a surgical latex link

Figure 2. **Attachment of (a) GPS data logger and (b) timed mechanical release device with a canvas, neoprene-lined cuff around the tibiotarsus. The attachment cuff was cut exactly to fit the leg dimensions of each bird.**

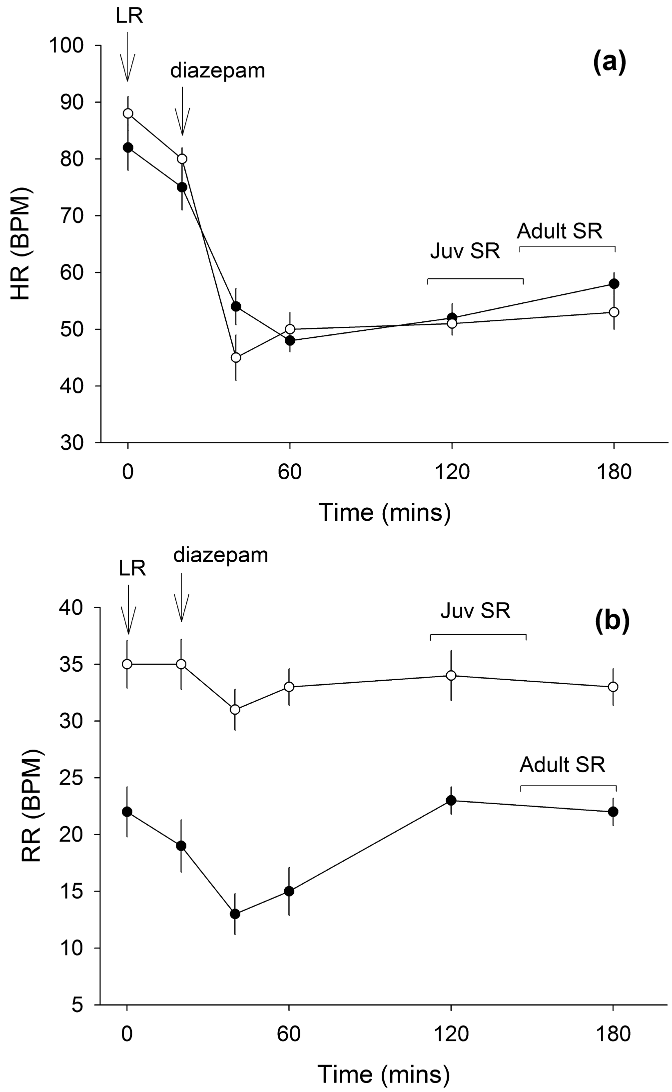

Figure 3. **Changes in (a) heart rate and (b) respiration rate for adult (●, mean ± SE, n = 5) and juvenile (○, n = 5) southern cassowaries following an intramuscular injection of tiletamine–zolazepam, succeeded 20 min later by an intramuscular injection of diazepam. LR, time of lateral recumbency; SR, time taken to achieve sternal recumbency.**

within the cuff to increase flexibility, allow for stretch and to act as a weak point to ensure tag detachment in the event of timed-release failure or entanglement by the bird.

The length and width of the canvas attachment cuff were tailored to each bird. The neoprene under-cuff was cut larger than the canvas cuff to ensure that there was neoprene padding between the canvas and the bird's leg (Figure 2a). Once the cuff was attached, it was ensured that the leg could flex unhindered. Any section of the canvas cuff that might cause abrasion of the leg was removed using scissors. The GPS and VHF unit was positioned on the outside of the leg (lateral aspect) and the timed mechanical release device positioned on the inside leg (Figure 2b). All external bolts on the cuff were covered with a two piece polymer adhesive (Knead-it; Selleys, Padstow, NSW, Australia).

Tracking of the birds' spatial movements after release into the environment was carried out for 14 days. However, the movements of two juvenile birds (1 male, 1 female) were tracked for a period of 4 months using newly developed quick-fix positioning GPS technology (Telonics). The tag size and attachment method for these two GPS-based data loggers were the same as for the other birds.

Recovery and transport

After tagging, each bird was placed into a purpose-built transport box lined with rubber and with 20 × 20-mm diameter holes on each of the side panels for ventilation. Long steel handles were fitted on two sides of the box to enable lifting by four adults. The end panel was removed from the box and the bird's head supported throughout by a handler. The ropes attached to each leg were first passed into the open side and out through the inspection hatch on the top of the box. Tension was maintained on the ropes by a single handler to guide the bird's legs. The back of the body was supported by two handlers and the bird was

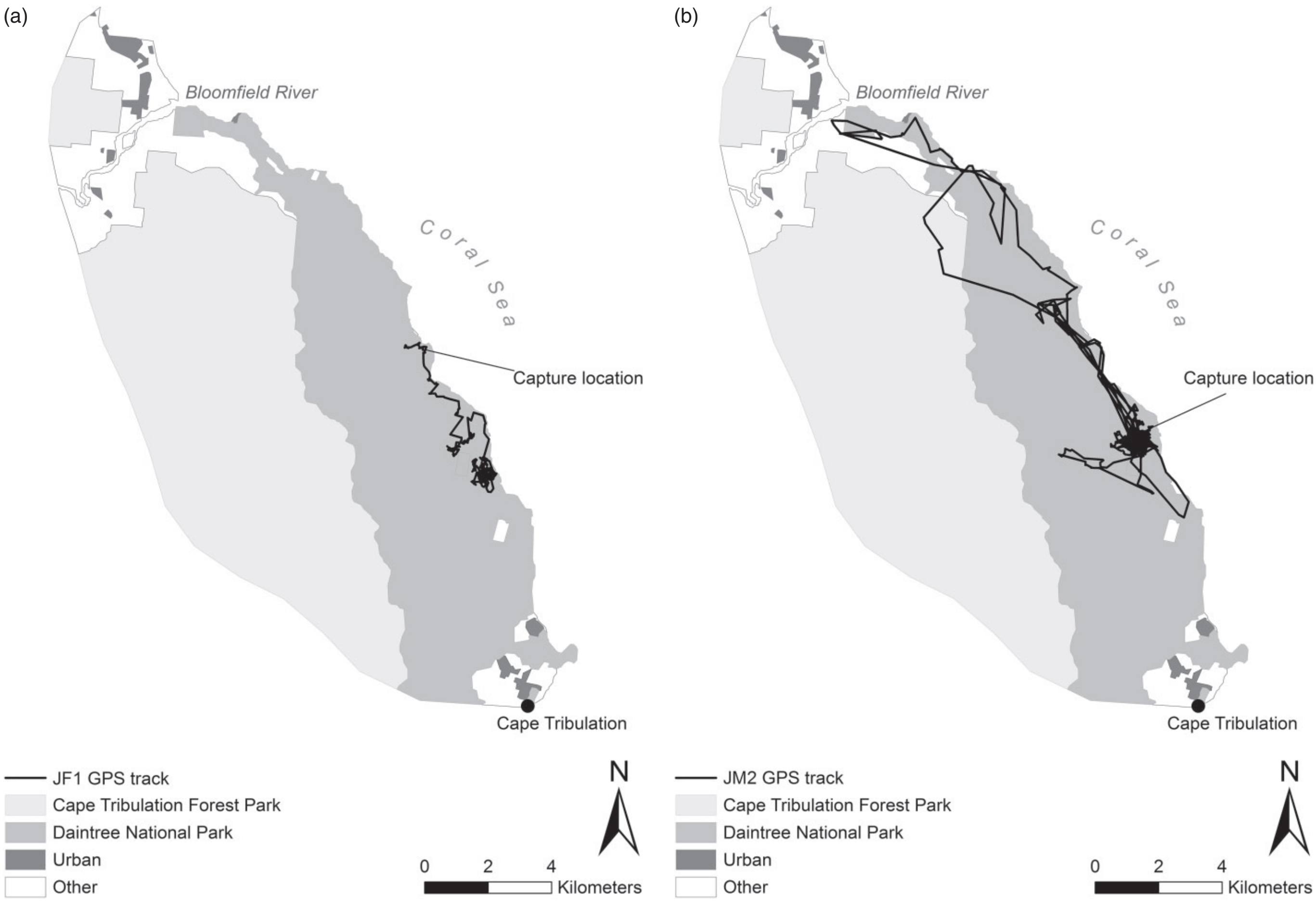

Figure 4. Land-use maps with overlay of the spatial movement of two reintroduced juvenile southern cassowaries on Cape Tribulation, North Queensland, Australia, over a 120-day period. (a) JM2, juvenile male; (b) JF1, juvenile female.

manoeuvred into the box. At this stage, the bird was in the box in a dorsal recumbent position. The legs were held in full extension using the ropes and the head placed into the box. The end panel was then inserted into position and locked. The leg ropes were removed through the observation hatch at the top of the box. Each bird was kept under observation through the hatch and heart rate and respiration rate were measured until the bird attained sternal recumbency, typically after 5–10 min. The bird's torso was doused with water every 5–10 min while in the box. Once sternal recumbency was attained, the box was transported to a safe and secure area for the night. At approximately 06:00 hours, the box was transported to the release site, the end panel removed and the bird released.

Data analysis

Great-circle distances from the release site were determined using custom code written in the R statistical programming language.[26] All maps were created in ARCGIS 10 (ESRI, Redlands, CA, USA). The activity rates for each bird during the 24 h after release were compared with the activity rates recorded over the following 13 days using an unweighted means analysis carried out in Instat 3.0 (Graphpad). Full details of location estimation from GPS-based data loggers on southern cassowaries have been described elsewhere.[19]

Results

Following administration of tiletamine–zolazepam, each bird would initially take flight before slowing down (<1 min) and falling into lateral recumbency (<3 min). If approached or handled before full sedation had been achieved, the bird attempted to lift its head or paddle its legs. The short time to recumbency prevented any of the birds from travelling into the forest, onto roads or other difficult to reach areas. Behavioural responses while under anaesthesia were minimal, but the birds would kick out occasionally. The power of the kick was diminished because the legs were held at full extension and supported by ropes. The cardiorespiratory responses showed similar trends for both adult and juvenile cassowaries (Figure 3a): >85 beats/min after administration of tiletamine–zolazepam, decreasing rapidly to <60 beats/min after the administration of diazepam, but remained relatively constant after that, increasing by <5 beats/min until sternal recumbency was attained. The respiration rate of the juveniles was approximately 40% less than that of the adults throughout the entire procedure (Figure 3b). Diazepam administration caused a depression of 10–15% in respiration rate for both juvenile and adult birds and this increased by approximately the same proportion by the time the birds attained sternal recumbency. The time from

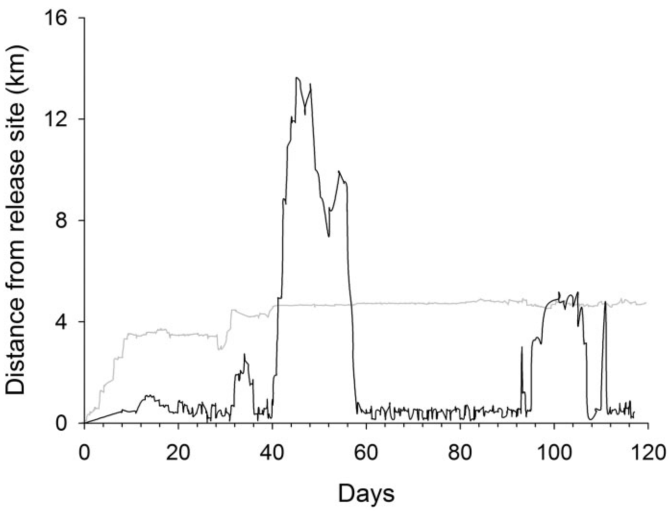

Figure 5. Daily distance travelled by the reintroduced juvenile male (grey) and female (black) southern cassowaries from the release site over 120 days post-release.

tiletamine–zolazepam administration to sternal recumbency was between 100 and 130 min for juveniles and 150–180 min for adults (Figure 3).

Upon opening of the transport boxes for release, all birds were found to be in sternal recumbency. Most birds would walk out from the box cautiously, although two juveniles left the box at full flight. Signs of anaesthesia were absent and the birds appeared to ambulate without grogginess. Four of the adults and two of the juveniles were observed to forage for food immediately after leaving the box.

All 10 birds carried the GPS data loggers for 14 days after release. All GPS data loggers detached from the birds' legs via timed mechanical release on the designated date. Two GPS data loggers attached to the juvenile birds did not produce data of adequate accuracy to enable movement calculations and were excluded from the statistical analysis. The location data showed that the average hourly distance travelled in the first 24 h (450 ± 5.4 m, mean ± SE, n = 8) was not significantly different ($P < 0.01$) to the average hourly distance travelled over the following 13 days (456 ± 8.6 m, n =8). All birds roosted/rested at similar periods of the diurnal cycle (17:00 until 05:00 hours) on the day after release and over the following 13 days.

The satellite tagging of two juvenile cassowaries (1 male, 1 female) enabled the recording of bird location and movement for 4 months post-release. The male remained in close proximity of the release site for 40 days, moving only short distances each day (Figures 4a, 5). After 40 days, however, he altered his behavioural pattern and travelled to a location >15 km north of the release site (the banks of the Bloomfield River, 15.928°S 145.365°E) in only a few days, remaining there for 14 days and then returning to the release site by a different route. He remained in close proximity of the release site for 30 days before undertaking a number of exploratory journeys >5 km distance from the release site, but always returning to the release area. He travelled a minimum distance of 150.3 km over 120 days. The female juvenile exhibited a very different behavioural pattern (Figures 4b, 5). Upon release, she travelled 5 km from the release site before confining her movements within a 1 km^2 area of rainforest. She travelled a minimum distance of 45.3 km over 120 days.

Discussion

We describe the use of tiletamine–zolazepam followed by diazepam administration for chemical restraint and satellite tagging of 10 wild southern cassowaries. The methodology used in this study has been developed from our previous personal experience sedating over 80 wild southern cassowaries in their natural environment using a variety of drugs, drug combinations and doses, including tiletamine–zolazepam with or without diazepam, medetomidine and isoflurane, for examination, treatment and translocation of the animals and research. We have found the methods described in this study to be reliable for restraining both juvenile (10–16 months) and adult wild southern cassowaries.

The success of immobilisation drugs delivered by dart or injector pole depends on the drug chosen, the dose, dart placement and drug delivery, as well as the physiological state of the animals prior to and during anaesthetic induction.[27] The chemical restraint agent used in this study was an off-the-shelf mixture of tiletamine and zolazepam administered by injector pole. This drug combination is particularly favoured for the chemical restraint of large animals when there is a risk of the animal harming the handlers or fleeing the scene,[28] because it induces lateral recumbency very quickly, it is less affected by the physiological state of the animal than other drugs and a relatively low dose is required.[7] In the present study, a dose of 7.5 mg/kg of tiletamine–zolazepam produced lateral recumbency in all southern cassowaries in <3 min. We favoured the use of this drug for the chemical immobilisation of free-living cassowaries, because the knock-out time is much shorter than that observed for other drugs (medetomidine 15 min,[9] thiafentanil–dexmedetomidine–telazol 15 min,[8] ketamine 7 min[29]).

Mammals chemically immobilised by a mixture of tiletamine and zolazepam have a smooth and uneventful recovery.[28] In contrast, recovery in the southern cassowary and other large ratites can be so violent the birds risk self-trauma.[4,13,14,16] A possible reason for this may be that the birds metabolise zolazepam quicker than tiletamine. From our personal experience, supplementing tiletamine–zolazepam with an intramuscular injection of diazepam negates the usual ataxia experienced during recovery. Placing the birds in a ventilated box, keeping them cool and undertaking the chemical immobilisation in the late afternoon further smooths the recovery process.

The heart rate and respiration rates of the southern cassowaries during chemical immobilisation with tiletamine–zolazepam were within the reference range for an anaesthetised ratite.[16] The additional administration of diazepam caused both heart and respiration rates to decrease, which was expected because diazepam induces general depression of the central nervous system.[30] The administration of medetomidine[9] and isoflurane gas[5] causes bradypnoea in ratites, resulting in respiratory acidaemia and low blood pH, which lead to further complications and require manual ventilation or supplementary oxygen.[5,8] As veterinary support and supplies are often limited in the field, we argue that an anaesthetic that does not induce bradypnoea is preferable when anaesthetising large ratites not in captivity.

This is one of the first studies to use satellite telemetry to monitor the movements of a free-ranging large ratite. The described methodologies enabled accurate location of individuals under the rainforest canopy and did not affect the birds' behaviour. Measuring rates of activity from the geographical location fixes allowed us to determine that the birds exhibited no behavioural ill-effects from the chemical immobilisation, restraint or transport. The first months after release into the wild are usually the most critical period for any reintroduced animal[31] and the behaviours exhibited by the two juvenile birds, tracked for 4 months, suggested they were successfully rehabilitating to their natural environment.

Great expense and effort is spent by the Queensland Government on the rehabilitation of orphaned and injured southern cassowaries. In the past, rehabilitated birds have been released with no post-monitoring, making it impossible to assess if the rehabilitation process was a worthwhile endeavour. Although the present study demonstrated that rehabilitated juvenile southern cassowaries can survive reintroduction into their environment, we strongly argue that longer-term satellite studies are required to assess if the birds successfully locate and establish a home range and develop into breeding adults.

Being able to safely restrain the southern cassowary without any harm to the bird or handling personnel is essential for effective management. There is much about ratite ecology that remains unknown, in particular their influence on landscape ecology, the dispersal of seeds from native plants and the propagation of weeds. The methodologies described here will aid researchers and wildlife managers to study free-living southern cassowaries and other large ratites.

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