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Further refinement of helicopter capture for Australian chital deer (*Axis axis*)

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ABSTRACT

This study improves a technique to capture wild chital deer (*Axis axis*) in northern Australia by darting from a helicopter. We quantified several metrics, including the frequency of adverse animal welfare events. Mortality at the time of capture was 15%, but no animals died post-release, and the frequencies of hyperthermia and hypoxaemia were lower than in previous operations. This study can be used as a template for iterative refinement of high-risk capture methodologies.

Keywords: animal welfare, chital deer, darting, helicopter capture, mortality, stress, telemetry, ungulates.

Introduction

Capture of wild animals is essential for numerous management and research purposes but can result in unwanted animal welfare outcomes, including mortality (Arnemo *et al.* 2006) and morbidity from capture-related injuries. Chemical immobilisation via helicopter darting has many inherent animal welfare risks, including stress, ballistic injury, hyperthermia and adverse effects from anaesthesia (Hampton *et al.* 2016). There is limited information available on immobilisation of cervid species in Australia when compared with overseas (Hampton *et al.* 2019). The present study built on an earlier investigation (Hampton *et al.* 2021*a*) that quantified animal welfare outcomes for helicopter darting of chital deer (*Axis axis*), a species known to be temperamental and have a high risk of mortality from handling (Arnemo *et al.* 1993; Johns *et al.* 2020; Hampton *et al.* 2021*a*). Our objective in this study was to further refine a capture technique for chital deer in order to reduce the frequency of adverse animal welfare events during capture and immediately post-release.

Materials and methods

The present study was conducted at the same location in the north Queensland Dry Tropics, where wild chital deer females were darted from a helicopter and fitted with GPS collars in four stages between July 2018 and August 2022, with the first three stages being reported in Hampton *et al.* (2021*a*). The present study (stage 4) was approved by the Queensland Department of Agriculture and Fisheries Animal Ethics Committee (approval no CA 2021/03/1486) and occurred over 4 days in August 2022.

Methods utilised follow stage 3 of our previous study and are described in detail in Hampton *et al.* (2021*a*), with refinements specified below. Duration data were recorded as per Hampton *et al.* (2021*a*), including Total Time (TT), the time from when the animal first moved in response to the helicopter until it regained its feet after sedation and remained upright. The same helicopter pilot and shooter were used as in previous stages of the program, and although dart gun power setting 3 (zeroed at 20 m) was used initially, it was re-set to 5 for most of this study. Darting was conducted on all four mornings and two afternoons when the ambient temperature was below 22°C. After darting, deer were monitored for signs of anaesthesia, but not re-darted, even when the

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dart bounced. Reversal of the medetomidine was via atipamezole (0.5 mg/kg) injected intramuscularly approximately 30–45 min after darting – slightly later than the stage 3 method described by Hampton *et al.* (2021*a*). A pulse oximeter was attached to the vulva rather than the tongue, lip or ear to monitor deer vital statistics. Intranasal oxygen was administered to every animal captured, irrespective of oxygen saturation levels, for the full duration of recumbency at an increased rate of 3–4 L/min (stage 3 used 1 L/min), using a portable oxygen cylinder. For any animals that died during or after capture, and for which cause of death was unclear, necropsies were performed where possible, and organs were sampled into formalin for histopathological investigation at the Queensland Department of Agriculture and Fisheries Biosecurity Sciences Laboratory, Coopers Plains, Qld.

With the small sample size we had, it was problematic to perform sufficiently powerful statistical tests with results from past capture operations. Any tests run would have had low power to detect biologically realistic changes in parameters between operational capture stages (Hampton *et al.* 2021*a*).

Results

We present all findings in comparison with data from previous stages (stage 1–3) of the same capture program as reported by Hampton *et al.* (2021*a*) in Tables 1–3. We captured 20 of 22 deer darted during this study (stage 4 in Tables 1–3), with 49 darts fired, at an average of 2.5 darts fired per deer captured. Of the darts fired, 45% struck and were embedded, 14% bounced out and 41% missed. Two deer were darted but escaped without capture or collaring. One deer failed to become recumbent, was not re-darted and allowed to escape, and the other escaped helicopter observation during induction (after darting) in thick vegetation and remained hidden (potentially recumbent) despite an extensive search. Hyperthermia was observed in 39% of captured deer, as was hypoxaemia (Table 1). In total, 25% of captured animals needed manual restraint.

Duration data and deer vital statistics are recorded in Table 2. Mean blood oxygenation was 92 ± 5% (range 65–99) (Table 2). Daytime temperatures at 1100 hours recorded at Spyglass Beef Research Station (19°24′S, 145°45′E) on the 4 days of darting ranged from 22 to 26°C (Table 2) (P. Gangemi, pers. comm.).

Mortality occurred in three deer at the time of capture, but no additional mortality occurred over 14 days of post-capture monitoring (Table 1). Two mortalities were caused by ballistic injury and one from an acute stress reaction (Table 3). One of the deer that died due to ballistic injury was struck by a dart in the back of the head (neurotrauma). The other animal was euthanised upon examination by the veterinarian because it had been struck in the jugular vein by a dart, causing massive haemorrhage that was likely to cause death via exsanguination. Necropsy and subsequent histopathology of the animal that died of a presumed acute stress reaction did not detect any abnormalities or disease process.

Discussion

The present study provides an instructive example of iterative refinement of a wildlife capture method. It builds on the demonstration of incremental improvement in animal welfare outcomes in the study of Hampton *et al.* (2016). Although the sample sizes were small, the trends towards improvement in key animal welfare outcomes were encouraging.

Of note, the mortality rate of captured deer at 14 days post-capture (15%) was lower than for any previous stages (1–3) of this capture program. The same observation applies to the frequency of hyperthermia (39%) and hypoxaemia (39%; only assessed previously in stage 3). A small improvement was seen in blood oxygen saturation between stage 3 (mean 89%) and stage 4 (mean 92%), likely arising from the decision to use intra-nasal oxygen supplementation more proactively and aggressively (flow rate of 3–4 L/min) in all animals regardless of oxygen saturation levels. Total time

Table 1. The frequency of adverse events from three initial stages (2018–2019) and a fourth stage (2022) of helicopter darting of adult female chital deer (*Axis axis*) in north Queensland, Australia.

Parameter	Stage 1 ($n = 25$)	Stage 2 ($n = 12$)	Stage 3 ($n = 12$)	Stage 4 ($n = 20$)
Mortality: time of capture	8 (1–26)	25 (5–57)	8 (1–35)	15 (3–38)
Cumulative mortality: 14 days post-capture	40 (21–61)	25 (5–57)	17 (2–48)	15 (3–38)
Target zone accuracy	26 (10–48)	27 (6–61)	85 (55–98)	30 (10–50)
Physical restraint	42 (22–63)	9 (0–41)	8 (0–38)	25 (9–49)
Hyperthermia	48 (26–70)	40 (12–74)	50 (21–79)	39 (17–64)
Hypoxaemia	NR	NR	58 (58–85)	39 (17–64)

Data expressed as percentages with 95% confidence intervals in parentheses. Data from stages 1–3 are reported in Hampton *et al.* (2021*a*).
NR, not recorded.

Table 2. Physiological and duration data from three initial stages (2018–2019) and a fourth stage (2022) of helicopter darting of adult female chital deer (*Axis axis*) in north Queensland, Australia.

Parameter	Units	Stage 1 (*n* = 25)	Stage 2 (*n* = 12)	Stage 3 (*n* = 12)	Stage 4 (*n* = 20)
Chase time (CT)	Minutes: mean ± s.d. (range)	3 ± 1 (1–5)	4 ± 2 (1–9)	3 ± 1 (1–5)	3 ± 2 (1–9)
Induction time (IT)	Minutes: mean ± s.d. (range)	15 ± 13 (5–46)	8 ± 4 (2–16)	8 ± 2 (5–13)	9 ± 4 (4–17)
Handling time (HT)	Minutes: mean ± s.d. (range)	23 ± 13 (4–87)	28 ± 12 (13–51)	31 ± 13 (12–57)	34 ± 7 (27–47)
Reversal time (RT)	Minutes: mean ± s.d. (range)	36 ± 30 (5–148)	30 ± 23 (1–67)	25 ± 59 (4–220)	18 ± 19 (2–69)
Total time (TT)	Minutes: mean ± s.d. (range)	82 ± 32 (48–172)	70 ± 21 (30–100)	68 ± 55 (29–246)	50 ± 18 (32–97)
Heart rate	Beats per minute: mean ± s.d. (range)	NR	NR	135 ± 26 (90–185)	101 ± 26 (50–153)
Respiratory rate	Breaths per minute: mean ± s.d. (range)	NR	NR	50 ± 18 (27–83)	44 ± 21 (16–87)
Blood oxygenation	Percentage: mean ± s.d. (range)	NR	NR	89 ± 4 (79–94)	92 ± 5 (65–99)
Max body temp	°C: mean ± s.d. (range)	40.3 ± 1.4 (36.4–42.5)	40.0 ± 1.1 (38.0–40.9)	40.7 ± 0.8 (39.2–41.9)	39.8 ± 1.2 (37.6–41.8)
Site temp: 11:00 hours	°C: range (number of days)	22–23 (5)	14–21 (4)	20–22 (4)	22–26 (4)
Sedation depth	Qualitative depth (1–5): mean ± s.d. (range)	2.2 ± 1.2 (1–5)	3.2 ± 1.2 (1–4)	2.9 ± 1.1 (1–5)	3.3 ± 1.0 (2–5)
Darting site	Percentage: shoulder, neck, rump, other	26, 44, 0, 30	27, 18, 0, 55	85, 7.5, 0, 7.5	30, 30, 0, 40

Data from stages 1–3 are reported in Hampton *et al.* (2021*a*).
NR, not recorded.

Table 3. Inferred causes of mortalities of adult female chital deer (*Axis axis*) during capture by helicopter darting in north Queensland, Australia.

Inferred cause of mortality	Stage 1 (*n* = 25)	Stage 2 (*n* = 12)	Stage 3 (*n* = 12)	Stage 4 (*n* = 20)
Aspiration	4 (0.1–20)	NA	NA	NA
Acute stress reaction	4 (0.1–20)	17 (2–48)	8 (0.2–38)	5 (0.1–25)
Capture myopathy	28 (12–49)	NA	8 (0.2–38)	NA
Ballistic trauma	4 (0.1–20)	8 (0.2–38)	NA	10 (1–32)

Data expressed as percentage mortality with 95% confidence intervals in parentheses are presented from three initial stages (2018–2019) and a fourth stage (2022). Data from stages 1–3 are reported in Hampton *et al.* (2021*a*).
NA, not observed.

(mean 50 min) was also shorter in stage 4 than any previous stage. We suspect that the decision to delay administration of the reversal agent atipamezole had a significant influence on duration metrics. This was reflected in a mean reversing time of 18 min, which was considerably lower than in previous stages of the capture program (Table 2), but was marked by a trade-off with handling time, which was higher in stage 4 (mean of 34 min) than in any previous stage of the program.

When reviewing the causes of mortality in this study (Table 3), ballistic trauma contributed to a lot higher proportion of mortalities than was desirable, being responsible for two of the three mortalities we observed. This finding makes more sense when considered in light of the relatively low rate of target zone accuracy for darts (30%). The two most likely causes of these patterns are: (1) darts targeting the shoulder/neck instead of the rump/hindlimb (Table 2); and (2) the dart rifle power settings being set at an excessively high level. The power settings were initially set to 3 but then increased to 5 by the shooter due to misses associated with slow dart flight time, a small and fast-moving target and the helicopter down draft. There exists a fine balance between kinetic energy and accuracy in wildlife darting (Hampton *et al.* 2021*b*), but there is room for improvement in ballistic settings for helicopter darting of chital deer. It is expected that lower dart rifle power settings and targeting the rump/hindlimb area would both contribute to lower ballistic injury.

Inferring cause of injury or death in wildlife capture can be difficult in preliminary studies due to the multitude of variables involved combined with small sample sizes (Jacques *et al.* 2009). Nonetheless, we believe that refinements in the following areas have permitted incremental improvements in most animal welfare outcomes of this capture program: (1) selection of cool conditions; (2) refined drug regimes and doses; (3) use of supplemental oxygen; and (4) timing of administration of reversal agents. We believe that a combination of these factors, but especially factors (3) and (4), reduced post-release mortalities due to capture myopathy, which occurred at a rate of 28% in stage 1 but were absent in stage 4.

The animal welfare outcomes we report here are still relatively poor when compared with results from studies in the northern hemisphere, in which ungulates are captured during winter and more potent drugs (i.e. opioids) are more readily available. These factors were discussed in Hampton et al. (2021a). Very low rates of mortality (e.g. <2%; Arnemo et al. 2006) and morbidity in wildlife capture are also usually associated with long-running programs, whereby improvement has occurred over decades. The wildlife capture program we describe here is somewhat nascent, having only been run for 5 years, with <70 animals captured in total. As such, it is anticipated that further improvements will be made if the program continues. The authors welcome correspondence and recommend adopting the approach described here for any investigators using new capture methods.

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Data availability. The data that support this study will be shared upon reasonable request to the corresponding author.

Conflicts of interest. The authors declare no conflicts of interest.

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