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# Camera trapping and transect counts yield complementary insights into an endangered island endemic rail

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**Abstract.** Island endemic species are disproportionately represented in the tally of global extinctions. The island endemic Cocos buff-banded rail (*Hypotaenidia philippensis andrewsi*) is classified under the Australian *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Endangered. It is restricted to the remote Cocos (Keeling) Islands in the Indian Ocean where, until 2013, only the island Pulu Keeling supported a population of this species, following earlier extirpations of the bird from islands in the southern atoll. To establish a second viable population to mitigate against potential extinction of this subspecies, 39 rails were reintroduced from Pulu Keeling to Horsburgh Island in April 2013. As a component of post-translocation monitoring, we conducted intensive camera trapping from 29 May 2015 to 30 June 2016 (397 calendar days) to investigate recruitment success, behaviour and potential threats to the population. Biannual transect sampling to monitor and investigate long-term population density was also conducted. We found Cocos buff-banded rail persisting on Horsburgh Island with an increase in the founder population to 97 rails in February 2016. Ongoing recruitment with breeding activity on Horsburgh Island and the emigration of rails to nearby (2.5 km) Direction Island is indicative of short-term success. Images from the camera traps have documented behaviours that have not previously been described for the species. House mice were also identified as a potential threat to the Horsburgh Island rail population. Island rail species have suffered a high rate of extinctions, and their conservation remains a formidable challenge, given the risks of continuing introductions of invasive mammalian predator species.

**Additional keywords:** camera trap, Cocos buff-banded rail, *Hypotaenidia philippensis*, invasive species, island endemic, translocation

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## Introduction

Island endemic species are disproportionately represented in the tally of global extinctions, due to their inherently small population size, restricted geographical distribution, vulnerability to stochastic events, and susceptibility to introduced predators (Szabo *et al.* 2012; Russell and Holmes 2015; Doherty *et al.* 2016). The bird family of rails (Rallidae) has suffered one of the highest modern extinction rates of any vertebrate group – of the 167 rail species, 24 species endemic to individual islands or island groups are extinct, one is extinct in the wild, 30 are either critically endangered, endangered, vulnerable or near threatened and one is data deficient under the IUCN's Red List (available at http://www.iucnredlist.org/, accessed 12 June 2018). Renowned for their extraordinary dispersal and island-colonising skills, rails have a very extensive global distribution, being absent only from the polar regions (Steadman 2006). Of note is their unique 'instability of morphology' (Olson 1973) and therefore propensity for some species to rapidly become flightless (Steadman 2006). This evolutionary process was widespread on islands during times when mammalian predators were absent and the selection pressure for flight abated. As humans colonised islands and introduced various mammalian predators, the outcome for many rail species was rapid extinction.

Rails are ground-dwelling and generally cryptic in behaviour, inhabiting dense vegetation, preferring to walk or run rather than fly, and occupying patchy distributions. Many of these characteristics render them challenging to monitor using conventional approaches, so declines may go unnoticed, thereby compromising options for timely conservation responses. Detection is primarily reliant on vocalisations, with presence/absence estimates based on call-playback, passive aural surveys or transect surveys. Only scant observational data are available on even some of the more conspicuous rails, reaffirming their status as one of the most understudied avian families (Taylor 1998).

 

The buff-banded rail (*Hypotaenidia philippensis*) is one of the most widespread rails. Up to 26 subspecies are recognised, extending across mainland south-east Asia, the Philippines, Cocos (Keeling) Islands, New Guinea, Australia, New Zealand, Norfolk Island, Lord Howe Island, some south-west Pacific Islands, Macquarie Island and Chatham Island, with the latter two now extinct (Marchant and Higgins 1993). The Cocos buff-banded rail (*H. p. andrewsi*) is classified under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Endangered. It is restricted to the remote Cocos (Keeling) Islands in the Indian Ocean. This island group comprises 26 islands in the southern atoll (1400 ha), and Pulu Keeling (120 ha) situated 24 km to the north.

The Cocos buff-banded rail occurred on all islands in the southern atoll until the 1900s (Gibson-Hill 1949). However, clearing of native vegetation for commercial coconut (*Cocos nucifera*) plantations, hunting and an increase in the population of cats (*Felis catus*) and black rats (*Rattus rattus*) resulted in rapid declines, the population contracting down to only a few islands (Gibson-Hill 1949; Stokes *et al.* 1984; Stokes 1994). In 1941, it was reported as being restricted to Home Island, West Island in small numbers, Horsburgh Island and the isolated Pulu Keeling, where it remained plentiful (Gibson-Hill 1949, 1950). The last record from the southern atoll was of an individual reported as being killed by a cat on West Island in 1991 (Stokes 1994). Another rallid species, the white-breasted waterhen (*Amaurornis phoenicurus*), self-introduced to the Cocos (Keeling) Islands during the last 30–40 years. A survey conducted during 1981–83 did not observe this species (Stokes *et al.* 1984) and its range now extends over the southern atoll. The first waterhen observation on Pulu Keeling was in 2012 (I. Macrae, pers. comm.); however, the population appears to have remained restricted to just a few birds. The increase in abundance and distribution of the waterhen may pose a threat as a potential competitor to the Cocos buff-banded rail, as was the case on Iriomote Island, where it is thought to have displaced the slaty-legged crake (*Rallina eurizonoides*) (Buden and Retogral 2010).

Because of the extinction risk inherent in one small population restricted to one small island, a Recovery Plan for the Cocos buff-banded rail recommended reintroduction (IUCN/SSC 2013) to one or more suitable islands in the southern atoll where it once occurred – Direction Island (0.34 km$^2$) and Horsburgh Island (1.04 km$^2$) (Reid and Hill 2005). In April 2013, 39 Cocos buff-banded rails were translocated from Pulu Keeling to Horsburgh Island to establish a second viable population (Woinarski *et al.* 2016). The newly released population on Horsburgh Island was initially monitored with a combination of methods: radio-telemetry, transect surveys and an array of camera traps. Transect surveys were implemented for the long-term population monitoring and radio-tracking was used for short-term monitoring. To passively monitor the survivorship of the rails by means of their unique colour-bands, camera traps were deployed at the release sites for medium-term monitoring. As the rails spread over the island from the release sites, some colour-bands of the founding birds detached and new (unbanded) recruits entered the population, constraining inferences on survivorship. In addition to providing supplemental information on occurrence patterns, the array of camera traps provided useful information on their ecology and behavioural repertoire, including many previously undescribed behaviours (Znidersic 2017).

As monitoring is an essential component of measuring translocation success (IUCN/SSC 2013), the objectives of our study were to monitor a furtive threatened species, in a remote location that is costly and logistically difficult to visit, and to minimise disturbance risk. Here, we report on: (1) the current population estimate determined by transect surveys; (2) behaviours as recorded over a long-duration camera-trap deployment (exceeding 12 months) and incidental observations; and (3) potential threats, especially invasive mammalian species. These objectives were met with both conventional observation-based techniques (both formal transect counts and incidental observations) and the application of remote camera traps.

## Methods

### Study site

The Cocos (Keeling) Islands (12°10′S, 96°52′E) are located in the north-eastern Indian Ocean, ~900 km from the nearest land, Christmas Island (Fig. 1). The study was conducted on Horsburgh Island (Pulu Luar) (12°04′S, 96°50′E), the most isolated island in the southern atoll. It is located ~4–5 km from the two inhabited islands and 2.5 km from the nearest other island, Direction Island. Although supporting the largest area of remnant native vegetation in the southern atoll, Horsburgh Island has a mixture of native and introduced plant species (Williams 1994). There are several small lagoons (soaks) to the west and one large lagoon (0.9 ha) to the north of the island.

### Data collection

#### Camera traps

An array of 16–34 camera traps was deployed for ~57 weeks from 29 May 2015 to 30 June 2016. Three types of camera traps were used: Scout Guard KG-680, Scout Guard 530V (HCO Outdoors) and Reconyx HC600 (Holmen). When triggered by heat in motion, Scout Guard camera traps were set to record 10–15-s video footage with a 10-s interval, sensor level high, or to take a sequence of 2–3 still photographs with a 1-s interval. Reconyx camera traps were set to take photographs on a high sensor level, 2–3 images rapidfire, 1-s interval or with no delay, resolution 1080P. Camera traps were unbaited and mounted on vegetation or a star picket 2–80 cm above ground. For all camera traps, we used a horizontal alignment (focal plane perpendicular to the ground) or adjusted to an angle of ~10° facing downwards. We positioned the camera traps low to maximise the probability of including colour bands in the images. The number of camera traps varied throughout the study; however, each camera trap remained in the same location and positioning (alignment) unless completely removed due to malfunction. Placement of cameras was deliberately biased in their positioning to maximise detection (Meek *et al.* 2014) of the Cocos buff-banded rail. Minimal habitat modification occurred, with the exception of sites in the grassland area that were prone to high false triggers. Small patches 30–50 cm above the ground were cut under the dense foliage of the shrub *Scaevola taccada* to position camera traps in potential foraging and roosting areas. Locations were determined by indicators of presence such as feathers, faecal matter, pathways flattened by the rails through grass or repeated observations of rail activity (Fig. 2).

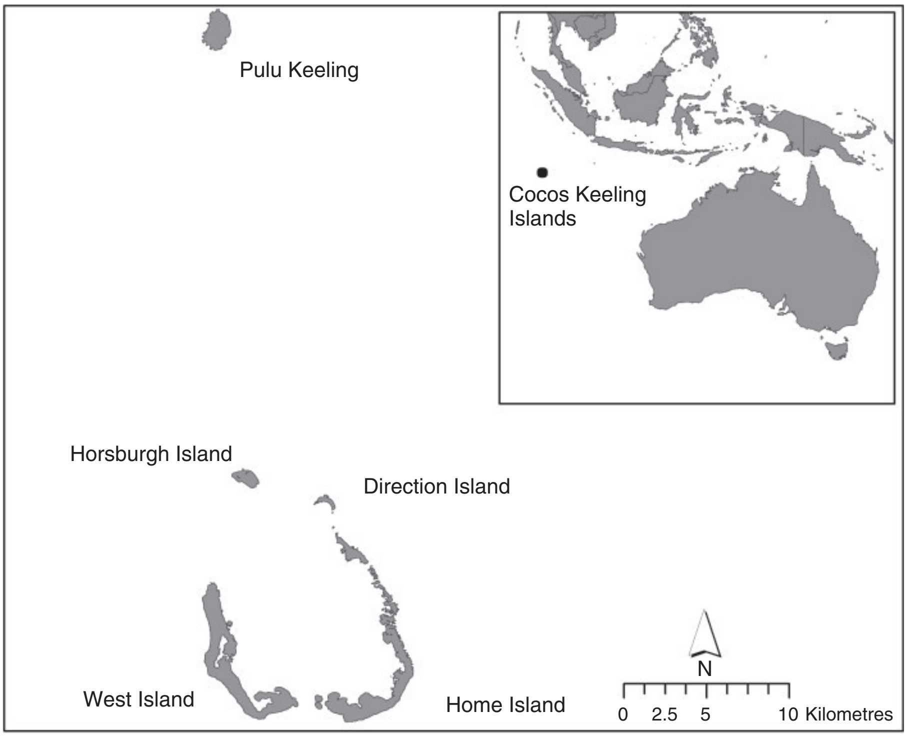


**Fig. 1.** Cocos (Keeling) Islands (Indian Ocean).

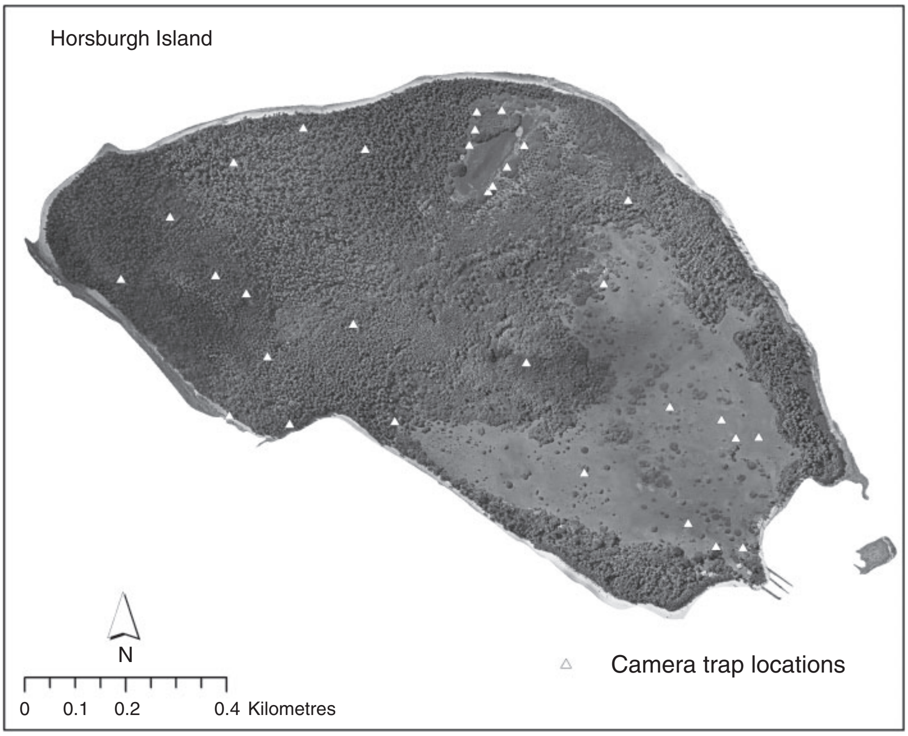


**Fig. 2.** Camera trap locations on Horsburgh Island.

Camera SD cards were collected during field trips to Horsburgh Island, then reviewed and species identified. Images of Cocos buff-banded rail were categorised into banded or unbanded (indicative of founder or new recruit) and age class (adult, juvenile, chick). Birds were aged on the basis of plumage, juveniles distinguished from adults by the lack of colour contrasts. Cocos buff-banded rail behaviours, potential interspecific interactions and occurrence of invasive species were also documented. Where multiple or consecutive images were a result of an individual in the camera detection zone for a prolonged period, we filtered the images into separate 'events' (Meek *et al.* 2014). Multiple images taken by one camera in the same minute or successive minutes were treated in the analysis as only one event, unless different individuals were demonstrably present. One camera trap day was defined as a 24-h period from 0000 to 2400 hours per operational camera trap (Meek *et al.* 2014). Camera trapping effort was calculated by the number of operational camera-trap-days from the beginning of deployment until retrieval of the SD card. Camera traps with electronic failure, SD card corruption or camera displacement were classified as 'not operational'. Operational periods for malfunctioning cameras were at times unable to be estimated as the last image date was not an indicator of malfunction date, therefore total deployment period was not used. As resource constraints dictated that three different models of camera traps be deployed, detection probabilities may have varied among brands (Meek *et al.* 2015; Newey *et al.* 2015), an acknowledged limitation for analysis and interpretation of the resulting data.

### *Transect counts*

Transect surveys were a pre-existing monitoring approach, continued here both for continuity and as a point of comparison with the camera trap data. A set of 20 pre-existing transect lines (Woinarski *et al.* 2016) were sampled three times in October 2015 and three times in February 2016 (excluding one transect line in February 2016). One observer walked slowly (1–1.5 km $h^{-1}$) along the transect line with binoculars and reported all rails heard or seen. Transects surveys were conducted between 0600 and 1000 hours. The total length of transects was 4.13 km, with individual transects varying from 100 to 554 m. The program Distance 6.2 (Buckland *et al.* 2001; Thomas *et al.* 2010) was used to estimate density and total population. Following Woinarski *et al.* (2016), separate estimates were made for the open environment (grassland where rails had a higher probability of being seen over a longer distance from the transect line), and the dense vegetation (coconut and other forests more typical of Horsburgh Island).

## Results

### *Population estimate*

The transect survey results are summarised in Table 1. The October 2015 survey detected 58 rails from three complete survey replicates. The February 2016 survey detected 95 rails from three surveys of all transects (excluding one transect that was sampled twice only). During both survey periods, no rails were observed on Transect J, located in dense forest of *Calophyllum inophyllum* and *Cocos nucifera*.

The estimated density (individuals $ha^{-1}$) and overall population size (number of individuals) for the reintroduced population of Cocos buff-banded was derived from three transect survey samples. The total population was calculated from the density estimates and based on extent of grassland of 0.3 $km^2$ and extent of dense vegetation of 0.7 $km^2$. The population estimate in October 2015 was 82.7 rails and in February 2016, 97.0 rails.

In October 2015 the estimated grassland density (0.83 birds $ha^{-1}$ (95% Confidence Interval (CI) = 0.43–1.58)) is less than previously estimated as no rails were recorded on Transect B (grassland). In February 2016 rails were at higher density in the grasslands (1.50 birds $ha^{-1}$ (95% CI = 0.88–2.54)) than in the dense scrub (0.74 birds $ha^{-1}$ (95% CI = 0.46–1.21)), which is more consistent with previous surveys (Woinarski *et al.* 2016).

Camera trap data were not used to derive a population estimate, but were a reliable indicator for the presence of founder individuals. Although many colour bands had dropped off or could be only partly discerned, survivorship of at least three rails from the founder population was confirmed, with records in October and November 2016, ~43 months after translocation. Incidental observations were also made by the Cocos (Keeling) community of Cocos buff-banded rail on Direction, West and Home Islands.

### *Behaviours*

The camera trapping effort from 29 May 2015 to 30 June 2016 resulted in a total of 10 736 camera-trap-days ($n = 397$ calendar days) (Table 2). Not all camera trap SD cards were retrieved (collection intervals of ~35–68 days) during each collection period so mean trapping days varied across the period. A high proportion (~94%) of camera traps captured rails in each deployment period, with all camera-trap locations capturing rail events during the study. Data management complications were experienced when downloading data from the SD cards, resulting in the loss of some data in 2015. This was rectified in 2016 to enable further analysis; however, the loss of some 2015 data constrained analyses for the overall study.

The camera trap effort in 2016 yielded 24 525 images (Table 3). Of these, 4602 (~18%) comprised images of rails, with 4036 (~88%) of these being of adults, 166 (~4%) of juveniles and 340 (~8%) of chicks. Images collected in February 2016 ($n = 12 739$) had a very high false trigger rate caused by vegetation movement.

Rail chicks occurred at 22 camera trap sites with 37 events during the total deployment period, with a peak in breeding activity during January–March 2016. Chicks were observed in all months except August and December. The number of chicks varied by event, with 27 events of one chick, six events of two chicks, three events of three chicks and two events of four chicks (mean = 1.5 (±0.86)). Juveniles were present in all months other than December. They occurred at 24 camera trap sites with a peak during March 2016 to May 2016. Camera trap images revealed that waterhen was also breeding on Horsburgh Island. Camera traps at five sites recorded events of waterhen chick occurrence, four camera trap sites with one chick and adult, one camera trap site with two chicks and one adult (mean = 1.2 (±0.45)).

In addition to Cocos buff-banded rail and waterhen, camera traps collected occurrence data on the following resident species: eastern reef egret (*Egretta sacra*), nankeen night-heron

**Table 1. Summary of results from transect surveys for the Cocos buff-banded rail undertaken in October 2015 and February 2016. Records include rail calls and sightings, and total kms of transect surveys**

| Transect | Broad habitat | Length (m) | No. of surveys, October 2015 | No. of rails reported, October 2015 | No. of surveys, February 2016 | No. of rails reported, February 2016 |
|---|---|---|---|---|---|---|
| A | Dense vegetation | 152.8 | 3 | 3 | 3 | 3 |
| B | Grassland | 331.9 | 3 | 0 | 3 | 25 |
| C | Dense vegetation | 127.0 | 3 | 1 | 2 | 2 |
| D | Dense vegetation | 202.9 | 3 | 4 | 3 | 3 |
| E | Dense vegetation | 112.9 | 3 | 0 | 3 | 1 |
| F | Dense vegetation | 186.2 | 3 | 3 | 3 | 2 |
| G | Dense vegetation | 130.1 | 3 | 3 | 3 | 1 |
| H | Dense vegetation | 176.3 | 3 | 2 | 3 | 5 |
| I | Dense vegetation | 204.9 | 3 | 3 | 3 | 3 |
| J | Dense vegetation | 104.5 | 3 | 0 | 3 | 0 |
| K | Grassland | 263.4 | 3 | 4 | 3 | 4 |
| L | Dense vegetation | 262.5 | 3 | 3 | 3 | 1 |
| M | Dense vegetation | 142.2 | 3 | 1 | 3 | 3 |
| N | Dense vegetation | 174.8 | 3 | 2 | 3 | 2 |
| O | Dense vegetation | 273.4 | 3 | 2 | 3 | 7 |
| P | Dense vegetation | 318.0 | 3 | 3 | 3 | 2 |
| Q | Dense vegetation | 112.3 | 3 | 1 | 3 | 1 |
| R | Grassland | 201.0 | 3 | 5 | 3 | 9 |
| S | Grassland | 83.0 | 3 | 1 | 3 | 4 |
| T | Grassland | 551.0 | 3 | 17 | 3 | 17 |
| Total | | 4.1 km | 12.4 km | 58 | 12.3 km | 95 |

**Table 2. Camera trapping effort on Horsburgh Island by deployment period, from 29 May 2015 to 30 June 2016**
CBBR, Cocos buff-banded rail

| Component of sampling effort | July 2015 | August 2015 | October 2015 | November 2015 | December 2015 | February 2016 | March 2016 | April 2016 | June 2016 |
|---|---|---|---|---|---|---|---|---|---|
| Camera trap effort (days) | 1081 | 758 | 1107 | 1316 | 735 | 2042 | 846 | 1390 | 1461 |
| No. of camera traps | 25 | 26 | 33 | 34 | 16 | 30 | 25 | 30 | 25 |
| Mean no. of trapping days | 50.9 | 36.1 | 41.0 | 47.0 | 45.9 | 68.1 | 33.8 | 46.3 | 58.4 |
| No. of days when camera traps not operational | 4 | 5 | 6 | 6 | 0 | 3 | 6 | 3 | 7 |
| No. of camera traps with nil CBBR images | 3 | 0 | 0 | 3 | 0 | 3 | 2 | 1 | 1 |

**Table 3. Camera trapping effort 2016 by total images and events for Cocos buff-banded rail (event = multiple images taken by one camera in the same minute or successive minutes were treated in the analysis as only one event, unless different individuals were demonstrably present)**

| Data-collection period | Total no. of images | Total no. of rail images | Total no. of rail events | No. of adults | No. of juveniles | No. of chicks |
|---|---|---|---|---|---|---|
| February 2016 | 12 739 | 2066 | 1478 | 1361 | 2 | 99 |
| March 2016 | 3332 | 1655 | 1034 | 768 | 72 | 196 |
| May 2016 | 3469 | 1601 | 1000 | 834 | 84 | 35 |
| June 2016 | 4985 | 1564 | 1090 | 1073 | 8 | 10 |

(*Nycticorax caledonicus*), Pacific black duck (*Anas superciliosa*), Christmas Island white-eye (*Zosterops natalis*), red junglefowl (*Gallus gallus*), green junglefowl (*Gallus varius*) and the vagrant common sandpiper (*Actitis hypoleucos*), pin-tailed snipe (*Gallinago stenura*) and eyebrowed thrush (*Turdus obscurus*). No interspecific interactions were recorded.

### *Behavioural observations*

Camera trap images recorded behaviours not previously described for buff-banded rail. Observations made on transect surveys and incidentally during fieldwork also yielded records of four behaviours. These behaviours were biased towards interactions with the landscape and were not observed on camera traps.

**Fig. 3.** (*a*) Cocos buff-banded rail driving the bill directly into the substrate with the torso lifted; (*b*) Cocos buff-banded rail carrying a large snail from capture location; (*c*) Cocos buff-banded rail adults and two chicks (adult #40 banded on Horsburgh Island).

Rails were observed feeding day and night, singly, in pairs or family groups (adult and chick, or two adults and chicks). They foraged in all habitats across the island: on the margin of the big lagoon on coral and mud substrate, standing in shallow water (then ducking the head beneath the surface in search of food), wet sand area on beaches, small soaks and grassland, particularly under *Scaevola taccada* where bare ground is exposed. In some cases, foraging substrates were shared with waterhen and reef egret in close proximity with no agonistic behaviour observed. Foraging postures varied; camera images frequently showed rails driving the bill directly into the substrate with the torso lifted high (Fig. 3*a*) or extending the neck with the body low to the ground probing substrate in leaf litter for invertebrates, appearing to rely primarily on visual cues. In one image, a rail was observed with a large snail in its bill and then observed carrying it away from the capture location (Fig. 3*b*).

Social organisation and social bond observations included pairs foraging, roosting and preening together. The rails appeared to remain in pairs all year, supporting previous reports of monogamy (Marchant and Higgins 1993; Manson 2003). One colour-banded bird was observed in the same territory from the time of its banding in March 2014 to November 2016 (Fig. 3*c*). Up to six rails were observed in separate events foraging along the substrate of the big lagoon at the same time from camera trap images and incidental observations.

Both parents were observed caring for chicks. Adults and chicks visited the same camera trap sites during the growth period to juvenile age. Chicks foraged independently when a few days old although other images revealed that they were also fed by the adults. An adult pair foraged with two chicks in a family group, each appearing to take care of one individual chick. Chicks were recorded nestling underneath the adult's breast and belly, standing between their legs with bill pointed up in a posture ready to be fed. In other images, when an adult found a prey item, the chick would run quickly to the adult's side to be fed. Roosting was observed from night-time images under *S. taccada* amongst the grasses in pairs and singly. One adult was observed with three chicks (~3–4 weeks old) roosting at night. These chicks attempted to roost beneath the adult, pushing each other out from under the adult bird that is sleeping. When roosting, they tuck their bill under one wing.

Camera traps collected a variety of social behaviours in both video mode and still photographs. An adult rail was observed nibbling around the bill of another rail (assumed partner), followed by vigorously gripping behind the back of the neck and throat for a few seconds, then resuming its stance beside the other bird. This behavioural sequence was also observed before copulation. Rails were often observed allopreening, particularly nibbling around the bill, head and wing coverts. A pair of rails was observed in a courtship act, both standing in an exaggerated upright posture, one rail calling with neck stretched and head tilted backwards while the other extended its neck at times while close to the other rail. In an example of behaviour preceding copulation, the (presumed) male pursued the (presumed) female, gripping her around the head and neck while flapping his wings. When the female stopped running, her posture changed, dropping her tail and torso, neck pointing down and body lowered. The female then bent forward to support herself with her bill partially implanted into the substrate, vent lifted high. When the male mounted, he grasped the female securely with his feet, then dismounted after ~3 s, upon which the female commenced preening. In another copulation act, a female rail foraging with a chick (~3–4 weeks old), was pursued by a male until she stopped running and the male mounted her. The female supported herself with her bill in the coral substrate.

During multiple field visits, when rails were disturbed they would run with their neck extended and low in profile to cover under vegetation or would fly low (0.5–1.5 m in height) over a short distance to cover. An adult was observed calling to chicks when separated from them; however, the chicks did not respond vocally and remained hidden in dense grasses.

The rails displayed neophobia (after Meek *et al.* 2014) towards the camera traps, demonstrated by approaching and looking into the camera, potentially attracted by their reflection or the flash. The same rail visited one camera trap almost daily, sometimes multiple visits on a single day for a 30-day period.

In a field observation, one rail was observed swimming ~45–50 m across the width of the big lagoon.

### *Potential threats*

House mice (*Mus musculus*), previously recorded from Horsburgh Island (Woinarski 2014), were recorded at eight camera trap sites, of which five also captured images of rail chicks, indicating co-occurrence of mice and active rail nests. Mice were present in all data-collection periods excluding July 2015 and December 2015 with no changes in distribution during or after peak rainfall. No black rats were recorded, consistent with previous reports of their absence from Horsburgh Island (Woinarski *et al.* 2016).

## Discussion

Conservation management of island endemic species typically involves extended fieldwork in remote locations. Moving researchers to and from the study area can be prohibitively expensive, often representing the biggest single line item in project budgets. Further, intensive on-ground monitoring of small populations may add to the disturbance of these individuals, which can potentially exacerbate threatening processes. Frequently, these budgetary, welfare and logistical issues constrain monitoring, limiting the regularity of data collection and diminishing the resolution of key performance indicators used to gauge effectiveness. Further complicating the conservation of island rail species is the spread of invasive mammalian species globally (Doherty *et al.* 2016) and one of the highest modern extinction rates for a bird family (Steadman 2006).

As for many threatened island species, limited biological data were previously available for the Cocos buff-banded rail (Gibson-Hill 1949, 1950; Marchant and Higgins 1993; Taylor 1998; Reid 2000; Woinarski 2014). However, as demonstrated here, camera traps can provide much behavioural information about rail species (Znidersic 2017; Colyn *et al.* 2017), with minimal disturbance over an extended period. In this study, camera traps were effective in collecting previously undescribed behavioural data, confirming persistence of the founder population and confirming presence of house mice within rail breeding sites. The limitation of this method is that the data collected from images are constrained by the limited coverage afforded by the camera trap field of view and placement (Fulton 2006, 2018).

While useful at identifying emerging threats and generating new information on behavioural ecology, camera traps generally cannot provide the evidence for reliable estimates of population size without individuals within a species being uniquely identifiable (Karanth 1995). The transect results indicate that the reintroduced population of Cocos buff-banded rail on Horsburgh Island is persisting and increasing. The initial founder population of 39 birds taken from Pulu Keeling in 2013 increased to 97 rails (95% confidence intervals of 58–161 rails) in February 2016. At least short-term success of this translocation is also evident in the ongoing recruitment with breeding activity on Horsburgh Island, and occasional records of rails from other islands in the southern atoll (T. Flores, pers. comm.), presumed to be of individuals that had dispersed from Horsburgh Island.

The population estimate from transect surveys and behavioural data from camera traps indicate that Horsburgh Island provides adequate habitat for a breeding population of Cocos buff-banded rail. Although this will potentially not increase to the density on Pulu Keeling, where ~800 rails occur, it is significantly more than the founder population (Woinarski *et al.* 2016). The rapid population growth observed in 2014–15 is less apparent in 2016, indicating that Horsburgh Island may now be nearing carrying capacity. As recent records demonstrate, rails from Horsburgh Island are likely to continue to disperse to other islands in the southern atoll; however, establishment of new populations on these other islands may be unlikely given the presence of back rats and cats on them.

The conservation future of the Cocos buff-banded rail is dependent upon ensuring that cats or black rats are not introduced to the two islands supporting populations, with spread of rails to other islands in the group possible if these two mammal predators can be eradicated from more islands (Misso and Macrae 2014). There are many comparable examples globally (Pérez *et al.* 2012; Glen *et al.* 2013): for example, on Santiago Island in the Galapagos, the abundance of Galapagos rail (*Laterallus spilonotus*) increased after the eradication of pigs (*Sus scrofa*) (Donlan *et al.* 2007). Although not identified as a potential threat to the Cocos buff-banded rail in the National Recovery Plan (Reid 2000), house mice may pose some risks to the population on Horsburgh Island. In recent studies on islands elsewhere, where house mice were the only introduced predator, many bird species were found to be impacted (Cuthbert *et al.* 2004; Wanless *et al.* 2009; Fulton 2018), whereas house mice may have limited effects when they are part of a multispecies mammalian assemblage (Angel *et al.* 2009; Glen *et al.* 2013; Fulton 2018). These findings mostly relate to predation on seabird eggs and chicks (Angel *et al.* 2009; Bolton *et al.* 2014; Parkes 2014). Relatively few studies on native terrestrial birds have shown direct impacts of house mice; however, on Gough Island (South Atlantic Ocean) direct nest predation and competition by house mice are believed to have driven declines in the endemic gough bunting (*Rowettia goughensis*) (Cuthbert and Hilton 2004).

The small sample of occurrence data in this study indicates a low hatching/fledging success for Cocos buff-banded rail, with the majority of observations being of a single chick.

The interpretation of these data is constrained by the limitations of the data-collection method (camera traps) and the many potential explanations for what may be a 'normal' low hatching/fledging success rate of rail chicks on Horsburgh Island: predation, lack of resources, natural mortality, island effect (Blondel 2000). The clutch size for the Cocos buff-banded rail has been reported as 4–6 eggs and 5 eggs (Gibson-Hill 1950), and 2 and 6 eggs (Reid 2000). There is a high variation within the species of clutch sizes between 2 and 8 (Marchant and Higgins 1993), usually 4–8, 6–10 in captivity (Taylor 1998). Hatching success also varies within the species: *H. p. assimilis* hatched 1.6 chicks per nest with impacts of cats, and predation by swamp harrier (*Circus approximans*) and stoat (*Mustela erminea*) (Marchant and Higgins 1993), and *H. p. mellori* on Heron Island had a very high chick mortality in the first two weeks after hatching from predation by eastern reef egret and silver gull (*Chroicocephalus novaehollandiae*) (Manson 2003). For the Horsburgh Island rail population, low reproductive success per nesting event may be counter-balanced by multiple breeding episodes throughout the year.

Ongoing monitoring is a critical component of active threat mitigation, including estimating population and measuring success of translocations. Island endemics are of high risk to stochastic events such as cyclones and the introduction of an invasive species. Although the short to medium term (i.e. 3+ years) monitoring has confirmed the establishment of the Horsburgh population and some likely dispersal of these birds to other islands in the atoll, the outlook for the Cocos buff-banded rail remains insecure.

## Conflicts of interest

The authors have no conflicts of interest to declare.

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