Survey of the Buff-banded Rail (*Rallus philippensis andrewsi*) in Pulu Keeling National Park, Cocos Islands, Indian Ocean

Cocos Buff-banded Rail at nest on ground in Pulu Keeling National Park R. Thorn

Julian R.W. Reid

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> *"The depauperate status of birds on the main atoll is a legacy of human settlement. The indigenous forest has been cleared for coconut plantations, the seabirds and endemic rail were hunted for food, and rats and cats introduced.*
>
> *"North Keeling Island retains much of its original flora and fauna because it is isolated, difficult to land on safely, and access was historically restricted. These factors have fortuitously preserved it as one of the few remaining pristine tropical islands in the Indian Ocean."*
>
> **Stokes et al. (1984: 28)**

> *"Any species with highly restricted range is at great risk of extinction from spatially localized forces, such as cyclones or deforestation."*
>
> **Simberloff (1994: S105)**

Acknowledgments

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Summary and Recommendations

The Cocos Buff-banded Rail Rallus philippensis andrewsi*, historically confined to the isolated Cocos (Keeling) Islands, an Australian External Territory in tropical Indian Ocean, is classified as an Endangered subspecies. Formerly distributed widely across the 27 islands in the group, its range and abundance contracted severely through the twentieth century, until now it is confined to just one, North Keeling Island, the sole island comprising the northern atoll with 120-130 ha of land.*

The major factors in the rail's demise across 26 islands forming the southern atoll have been speculated to be predation by introduced cats and rats, the wholesale conversion of mixed native forest to coconut palm plantations, competition with feral chickens and perhaps human hunting pressure. Variously estimated at between 40 and 150, there had been no rigorous assessment of the size of the remaining population on North Keeling Island until now. The species is widely distributed through the south-western Pacific, Australasia, Lesser Sundas and Philippines with over 20 subspecies currently recognised. The subspecific status of some populations including that on the Cocos has been queried. While the biology of the species is reasonably well known, information on andrewsi *is scant and partly conflicting. Given the bird's conservation status this study was commissioned to:*

? *review existing information and gather new data on taxonomy, life history and habits,*
? *estimate current population size and prospects,*
? *recommend an appropriate monitoring program for the North Keeling population, and*
? *advise on priorities for recovery of the population including a reintroduction strategy.*

I visited the Cocos (Keeling) Islands for the study of the Cocos Buff-banded Rail in November 1999 during which two brief visits were made to North Keeling Island. The remaining time was spent on the southern atoll where no evidence for the rail's persistence could be found. Multiple, distance-based line-transect counts were conducted on North Keeling Island to provide a robust density estimate of 6.2 birds ha^{-1}*. Given the (reasonable) assumption that rails were distributed widely across habitats without obvious systematic variation, an island population size of 750-800 was derived (approximate 95% confidence interval: 550-1000). Rails were vocal and breeding at the time of the visits, and frequent agonistic encounters presumed to be territorial disputes were observed. The line-transect method under these conditions proved practical and efficient. However, the significant difference in rail detection frequencies between the investigator and three park-management staff raises some concerns about the robustness of the method for monitoring. Previous research has shown that observer differences, changes in bird behaviour between sampling events, and changes in environmental conditions and weather can all seriously bias results from line-transect counts, and so make comparisons through time – the interpretation of population trends – difficult and ambiguous. Despite these caveats, a population monitoring protocol is presented that uses the line-transect approach with certain adjustments made to the basic methodology employed in this study. These refinements cannot solve all problems seriously affecting population estimates, and so cautious interpretation of the data and analyses will be necessary.*

Three individuals were caught, measured, described and released; feather samples were collected for potential molecular study subsequently. The plumage of these birds and others observed in the wild was consistent with the type and subsequent descriptions. The Cocos Buff-banded Rail is distinctive morphologically. There is no reason to suspect that it shares close affinity with continental Australian populations, and doubts over its subspecific recognition appear unwarranted. However, a final determination will have to await a molecular survey across the species. The tarsus length of the three captured birds was greater than those measured at least 60 years previously, suggesting rapid evolutionary change may be in train.

Given the Cocos Buff-banded Rail population numbers in the several to many hundreds and under the reasonable assumption that annual variability is not great, the rail appears unlikely to go extinct through stochastic demographic failure. Rather, the population's greatest threat stems from the tiny size of its geographic range, just 120-130 ha. Recommendations on future management strategies to enhance the conservation prospects of the Cocos Buff-banded Rail are made in the light of these two assertions. ***Chief among these are the***

? ***well-recognised need to preserve the integrity and security of North Keeling Island, with adequate safeguarding against threats to its security,***
? ***the need to monitor the rail population, and***
? ***<u>the imperative to establish a second, geographically isolated, population</u>.***

This last imperative, the reintroduction strategy, requires focus and adequate resourcing. Horsburgh Island in the southern atoll is the logical site for reintroduction and revegetation has commenced there as part of a previously formulated strategy. The strategy needs to be revised and implemented without delay. Pending a positive feasibility study, priority should be given to the eradication of cats, rats and feral chickens from Horsburgh Island. Reintroduction should follow shortly after in conjunction with continued revegetation efforts.

Direct translocation of birds from North Keeling Island to the southern atoll appears feasible and is the preferred option over a captive-breeding program leading to reintroduction. Failing to proceed with or achieve the direct translocation objective, pursuit of a captive-breeding program is advised. A formal list of recommendations follows.

Recommendations

1. Monitoring of the CBBR population on NKI should be initiated on a quarterly basis through 2000 and 2001 at the completion of which a review of the program should be undertaken. The review would need a statistical component.

2. Any apparent crash in the population should signal alarm, and trigger an immediate intensive study to determine the (likely) cause(s) of the decline and to assess the need for establishing a captive population at a secure site – crisis response. The establishment of feral cats on NKI should also trigger a 'crisis response'. The establishment of rats on NKI or a direct hit by a cyclone should trigger more intensive population monitoring to determine whether translocation is required in the short term.

3. **Maintaining the security of NKI is the foremost requirement for persistence of the CBBR in the shorter and medium term**; PAN recognises this already; I can recommend

nothing further here; I commend current policy concerning, and management of, PKNP – continual vigilance is required.

4. A molecular survey of the CBBR in the context of the wider species should be commissioned by PAN so that its likely origins and systematics can be better understood. Provided DNA-bearing tissues can be obtained from a minimum of five individuals from the CBBR (*andrewsi*) and the Australian subspecies (*mellori*, *tounelieri*), the Flores subspecies (*wilkinsoni*), Timor population (*philippensis*) and several other near-Pacific island populations, a modest grant of <= $10,000 would be sufficient for this project (e.g. graduate Honours study). The Environmental Biology Unit at the South Australian Museum would be an appropriate and qualified institution.

5. **The establishment of a second, geographically separate, population is the crucial action needed to improve the survival prospects of the CBBR in the medium to longer term.** Greater financial investment and strategic planning are required to advance this objective.

6. Attempts to secure a viable site on the southern atoll should intensify and greater urgency be given to a reintroduction program. Horsburgh Island is already identified, and action to eradicate feral animals should be initiated as a priority. Eradication of cats, rats and chickens should take precedence over revegetation in terms of securing the site. Revegetation has commenced and it can continue, but the point is that it can proceed satisfactorily after a reintroduction occurs, whereas the eradication of feral animals must be completed prior to any reintroduction attempt. **The imperative rests with establishing a second population, sooner than later.** Removal of most of the island's interior coconut palms should facilitate feral animal control and revegetation programs.

7. Eradication of cats and rats from Horsburgh Island (*ca* 120 ha) will be difficult but should be feasible with dedication and persistence. Recent Western Australian experiences (A.A. Burbidge, CALM) should inform this program.

8. Provided the NKI population remains at current levels (500+), a reintroduction strategy involving direct translocation of wild birds is preferred to establishing a captive-breeding colony; a target of 40 birds should be aimed for, with a minimum figure set at 20. This is extremely unlikely to affect the NKI population's viability.

9. Notwithstanding Recommendation 8, the establishment of a captive-breeding colony would be desirable if external funds were forthcoming. Provided safeguards and protocols were strictly observed, a successful captive-breeding program would substantially reduce the immediate risks of extinction. There is the potential for far-reaching community education benefits as well as the provisioning of birds to augment the reintroduction program. Discussions with the Regional Zoos Association of Australia (and their bird Taxon Advisory Group) are recommended.

In conclusion, the priorities for enhancing the recovery of the Cocos Buff-banded Rail are:

1. **Undertake rail surveys on North Keeling Island four times a year for the next two years to establish a baseline.**

2. **Initiate work on rat, cat and feral chicken eradication on Horsburgh Island, pending approval from the Cocos (Keeling) Islands Council and external funding support.**
3. **Prepare a crisis strategy that covers stochastic disasters and the accidental introduction of feral animals to Pulu Keeling National Park.**
4. **Prepare a captive-breeding plan and obtain the necessary approvals/agreements; implementation following either a crisis event or sufficient funding.**
5. **Conduct an annual (or twice yearly) survey of rail daytime activity patterns.**
6. **Commission a genetic study of the Buff-banded Rail to clarify the taxonomic and systematic relationships of the Cocos subspecies.**

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Survey of the Buff-banded Rail (*Rallus philippensis andrewsi*) in Pulu Keeling National Park, Cocos Islands, Indian Ocean

Introduction

The Cocos (Keeling) Islands are a remote Australian External Territory located in the Indian Ocean (Fig. 1). The southern inhabited atoll comprises 26 islands and the uninhabited atoll, North Keeling Island proclaimed as Pulu Keeling National Park in 1995, is a single horseshoe-shaped island 24 km to the north. They are true coral atolls and attain only a few metres height above seal level. The two atolls are connected geologically by a submerged ridge of volcanic origin which rises from the ocean floor at a depth of some 5000 m (Parks Australia 1999).

The islands were settled by the Clunies Ross family of Scotland in 1827 and, with the assistance of many Malay settlers, much of the southern atoll was cleared of its original native forest cover for the development of coconut plantations. Rats (*Rattus* spp.), cats *Felis catus* and several species of birds were introduced then and in ensuing years, and the naturally occurring, large breeding seabird populations became staple food for the human immigrants and were soon depleted (Forbes 1885; Bunce 1988). North Keeling Island escaped the worst of this process of habitat transformation and attendant depredations due to its isolation and lack of safe landing sites (Stokes et al. 1984; Parks Australia 1999). The Cocos (Keeling) Islands became an Australian Territory in 1955 and in 1978 the Australian Government purchased the land from the Clunies Ross family at about the time that coconut operations became uneconomic. Today 470 Cocos-Malay people live in the kampong on Home Island while 100 people mostly from mainland Australia live on West Island (Fig. 1). The practice of hunting native birds was discouraged when a resident Government Conservator was appointed in 1987. Following proclamation of Pulu Keeling National Park under the *National Parks and Wildlife Conservation Act, 1975,* seabirds present on North Keeling Island as with all flora and fauna are now protected.

Being a small and extremely isolated oceanic island group – the closest vegetated land is Christmas Island *ca* 900 km east-north-east – it is not surprising that there are few sedentary landbirds known to have historically inhabited the islands. One such bird is the Buff-banded Rail *Rallus philippensis* and the Cocos (Keeling) Islands population was described as a distinct and endemic subspecies, *R. philippensis andrewsi*, by Gregory Mathews in 1911. This subspecies was classified as Endangered by Garnett (1992, 1993) following the bird's extirpation from the southern atoll. It is apparently now restricted to North Keeling Island, the small size of which (120-130 ha) raises doubts over the population's viability. Accordingly Parks Australia North staff on Cocos commissioned a study to determine its current population size, to assess the population's viability and threats to it, and to recommend ways to ensure its persistence and recovery. The decline of the Cocos Buff-banded Rail has been attributed to direct human predation, feral predators and competitors, and habitat change and loss (Stokes et al. 1984; Garnett 1992, 1993; Parks Australia North 1999).

Published information about the Cocos Buff-banded Rail is scanty. Its demise lagged behind but otherwise mirrored the near elimination of breeding seabirds from the southern atoll. This had occurred by late in the nineteenth century for seabirds (Forbes 1885), whereas the rail was still abundant in 1906-07 (Wood Jones 1909). The rail was in decline on the main atoll by 1941, and Gibson-Hill (1949) attributed this decline to human hunting pressure.

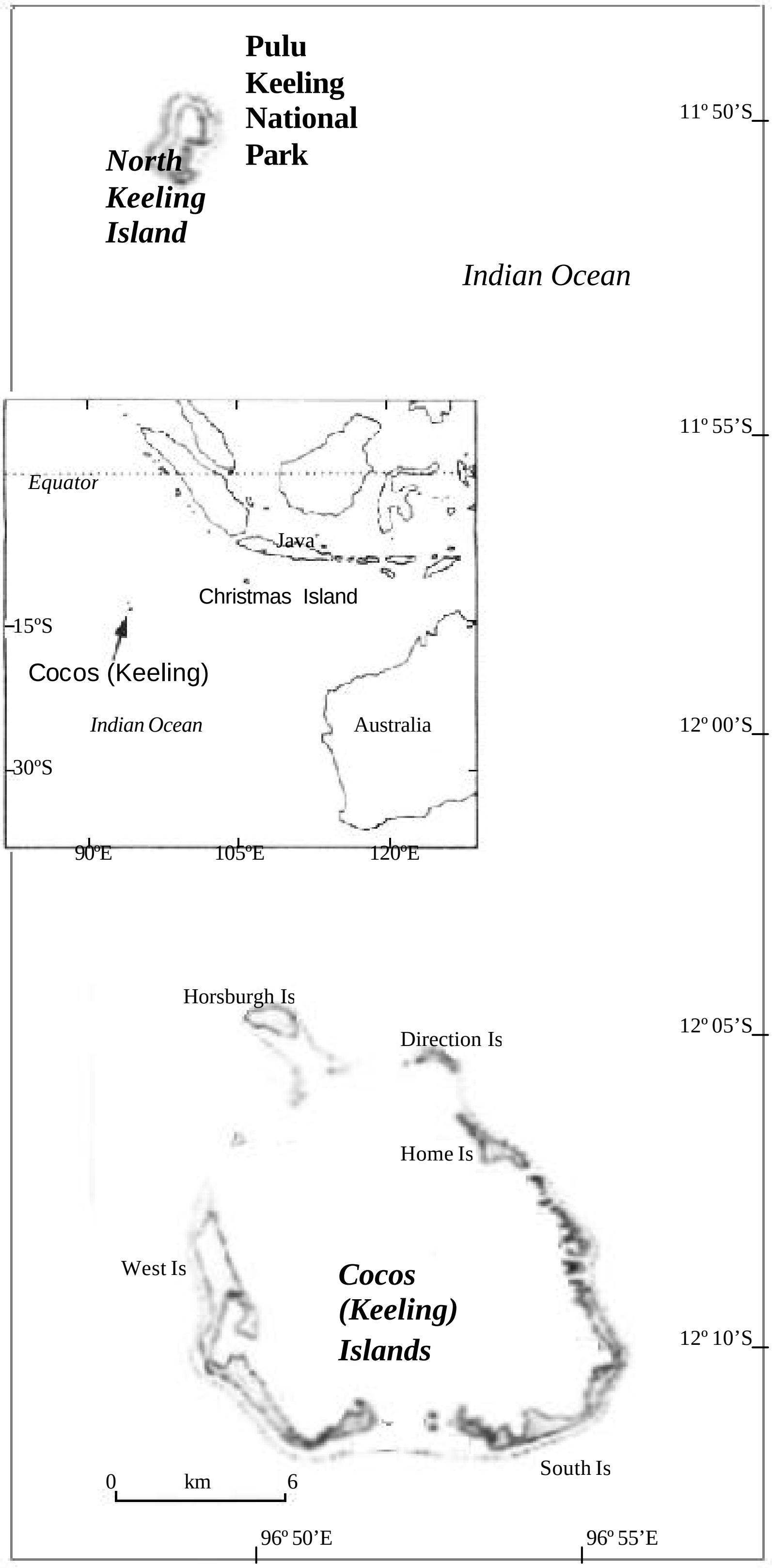

Figure 1. Location of Cocos (Keeling) Islands and Pulu Keeling National Park, Indian Ocean (after Parks Australia 1999: Fig. 1).

Gibson-Hill (1948) suggested that the Cocos Buff-banded Rail may have been deliberately introduced to North Keeling Island from the southern atoll. However, Stokes et al. (1984) and Parks Australia (1999) query this assertion, and even if southern atoll birds were translocated it is possible that a North Keeling population already existed. The last substantiated record of a rail on the southern atoll was that of a carcass collected in 1991 (Garnett 1993; Stokes 1994). This followed observations of 10-15 birds on West Island and individuals on two other islands in the early 1980s (Stokes et al. 1984). The population's extirpation from the southern atoll occurred very recently therefore.

Worldwide, rails are renowned for their lengthy extinction record in modern times. Steadman (1995) estimated that 1000+ species are likely to have become extinct in the Holocene, coincident with modern humans' seafaring activities (Polynesian then Asian and European). Flightless rails, in particular, many of which were endemic to tiny oceanic islands have been worst hit. It has been speculated that ancestral populations of the highly dispersive Buff-banded Rail were the progenitors of many of these flightless and now-extinct forms, formerly widespread through the Pacific. The species occurs in Australasia, eastern Indonesia, Philippines, and the near Pacific (Marchant & Higgins 1993; Taylor 1998). Within Australia and its offshore Territories, another differentiated form has become extinct in recent times – the Macquarie Island subspecies, *R. philippensis macquariensis*, was last recorded in the 1890s (Garnett 1993). Given the potential for rapid evolutionary change that the species exhibits, the remnant population of *andrewsi* in Pulu Keeling National Park assumes particular biological and conservation significance, and its protection, recovery and further study become all the more important.

Under Contract 'RM-87', Parks Australia North (PAN) arranged a consultancy for the author to undertake a brief study of the Cocos Buff-banded Rail late in 1999. The study had the following formal objectives. A more general objective was to collate previously recorded and new material in order to improve the knowledge base for this population.

Objectives

These Objectives are taken directly from the Consultancy Contract ('RM-87').

1. Provide background information on the biology and ecology of the Buff-banded Rail and relate this information to what is known of the Cocos subspecies.

2. Map and evaluate the habitat on North Keeling Island (Pulu Keeling National Park) with regards to suitability for the Cocos Buff-banded Rail.

3. Design a sampling program that will enable the population of Cocos Buff-banded Rails on North Keeling Island to be estimated and monitored by Parks Australia staff on Cocos (Keeling) Islands over time.

4. Design a monitoring program that will enable information to be gathered on breeding and habitat information, including seasonality, habitat preference, nesting requirements, causes of mortality and success rate.

5. Assess the possibility of catching Buff-banded Rails for reintroduction to the Southern Atoll at a later date.

6. Training of Park staff in monitoring and handling of the Cocos Buff-Banded Rail.

7. Assess the needs for a captive breeding program and identify a suitable zoo or fauna park.

Diagnosis of Problem

Historically, the endemic subspecies of Cocos Buff-banded Rail *Gallirallus philippensis andrewsi* (Mathews 1911) is restricted to the Cocos-Keeling island group and now appears confined to North Keeling Island having once had a more extensive distribution within the group (Garnett 1993). Because of the taxon's recent contraction to this one small island (120-130 ha), it was considered threatened with extinction by Stokes et al. (1984) and Garnett (1992, 1993). It is classified as Endangered in Part 1 of the Commonwealth's *Endangered Species Protection Act, 1992*.

The species' biology and distribution in the Australasian region have been comprehensively reviewed in Marchant & Higgins (1993:495-506). Despite querying the taxonomic status of *andrewsi*, Marchant & Higgins describe it as being morphologically distinctive: lacking much of the olive-brownish tinges to the dorsum thereby appearing much darker than the mainland (Australian) subspecies, and in the dorsal white spotting being much more prominent. While not addressing the status of *andrewsi* specifically, Schodde & de Naurois (1982) cautioned against unbridled subspecific recognition of differentiated island populations in the south-west Pacific.

Little detailed knowledge of the biology of *andrewsi* is available. Nests with eggs were found in the November-January period over two years (Stokes et al. 1984), but Gibson-Hill (1949) indicated that it bred in the dry season, finding eggs in May and June during a year-long stay on the island group. Similarly, whereas Gibson-Hill stated they nest on the ground, at least four of the five nests Stokes et al (1984) describe were located off the ground. Stokes et al. observed many birds feeding on crustaceans in stranded sea-grass beds along the lagoon shore, and described its abundance status on North Keeling as 'common' in the early 1980s.

Through informal discussions with PAN staff, it became apparent that a pilot study of *andrewsi* on North Keeling Island was required to make an initial, qualitative assessment of its current population size/health and to investigate the feasibility of determining population size through more rigorous sampling techniques. The spatial variation in relative abundance across the 12 different habitat types described and mapped by Williams (1994), and the food resources they contain, needed to be assessed. It was considered that useful opportunistic observations on diet, habitat use, breeding and mortality might also be gathered in a brief pilot study. However, population estimation aimed at developing an efficient annual censusing methodology by which trends through time could be gauged was the most urgent requirement. On the basis of a pilot study and the literature, a sound protocol for gathering baseline data and implementing a monitoring program could then be recommended. In the draft *Interim Recovery Strategy* for *andrewsi* (Anon. 1999), its current population was estimated to be 40-150 birds (e.g. Garnett 1992, 1993).

The expectation expressed by Garnett (1992:44), that management staff should be able to conduct population censuses, including the capture and marking of individual birds, and assess/effect threat-abatement planning for this endangered population, *as part of routine activities <u>during other monitoring visits</u>*, was considered unrealistic [emphasis added]. Rather, it was decided that outside expertise, *in combination with the skills and experience of management staff, critical in their knowledge of the local social and natural environment,* would best serve the recovery-planning process for the Cocos Buff-banded Rail. The thrust of Garnett's (1992) recovery outline for the population's management, and as expanded in the draft *Interim Recovery Strategy* for *andrewsi* (Anon. 1999), was considered sound.

As stated by Garnett (1992), a priority in safeguarding the subspecies' survival is to establish further populations. Whether this action needs to be pursued urgently in the short term (captive colony) or whether it can be delayed until a location and habitat are secured on the southern atoll will be the subject of some deliberation in this report.

Major Focus Required for this Study – Population Estimation

The most reliable means to estimate an animal's population size is through direct enumeration by visual methods, i.e. counting or censusing (Bibby & Burgess 1997). Rarely is it possible to count an entire population, either because of the unwieldy size of most populations or because of the cryptic nature or behaviour of animals in the wild. A sampling approach is then required and again direct census, preferably visual, techniques are preferred, provided certain assumptions can be met (Bibby & Burgess 1997; Anon. 1999). It was anticipated at the outset that the Cocos Buff-banded Rail might be too furtive and cryptic in its dense forest environment to enable an efficient visual detection-based methodology to be developed (R. Thorn, PAN, *personal communication*).

Buff-banded Rails on the Great Barrier Reef are strongly territorial in the breeding season (F. Manson, University of Queensland, *personal communication*). It was considered that playback methods – where the bird's song is played to elicit a vocal response and/or advance towards the player – and use of auditory detections generally could be trialled to see if they hold promise for censusing the North Keeling population. Playback methods have been used successfully both for this species elsewhere in its wide range (Elliott 1989) and for other rails (Beauchamp et al. 1998; Conway et al. 1993; Elliott et al. 1991; Johnson & Dinsmore 1986). Although playback and similar methods have been used extensively to monitor rail populations, Conway et al. (1993) showed they were an unreliable technique for one species, the Western Clapper Rail *Rallus longirostris*, in the USA. Elliott (1989) found that the response of birds to playback in his population of Buff-banded Rails varied through the year, and so it was considered there might be problems with developing a robust census procedure able to be consistently used in this case.

Ideally, in a more intensive study of the population, birds would be captured, permanently marked and fitted with radio transmitters to allow rigorous estimation of home-range size, home-range variations seasonally, short-term survival rates and, in conjunction with other methods, island population size estimation. Rails both of this species (F. Manson *personal communication*) and others (Beauchamp et al. 1998; Conway et al. 1993, 1994; Elliott et al. 1991) are trappable, while their weight (130-230 g) and the small size of the island indicate the North Keeling population should be eminently suited to telemetric studies. However, radio-telemetric studies require a high degree of infrastructure investment (towers), technical expertise and frequently innovation (e.g. Rohweder 1999), and so cannot be embarked upon lightly. The studies of Conway et al. (1993, 1994) and Smith et al. (1998) serve as a useful benchmark for the design of a suitably targeted telemetric study.

An efficient population-estimation routine needs to be developed to allow future monitoring and so the detection of trends. Pursuant to continuing monitoring and in the event that the population were to appear stable within acceptable bounds, other intensive biological studies, such as into the population's diet, behavioural ecology and reproductive success, may not be warranted. Along with a robust monitoring program, the successful establishment of a second population would appear to be the most urgently required action at this stage.

Methods

A field study of the Cocos Buff-banded Rail (CBBR) was conducted on the Cocos (Keeling) Islands (CKI) from 31 October to 27 November 1999. Over this period, two brief visits were made to North Keeling Island (NKI) – 8-10 November and 23-24 November – for the purpose of intensive study of CBBR and its environment in Pulu Keeling National Park (PKNP). Visits to PKNP were restricted to two nights and an overnight stay, respectively, due mainly to health and safety issues: the hazardous nature of the ocean and climate in terms of access on and off the island, and the potential for tropical cyclones. Three PAN staff (I. Macrae, W. Murray, R. Thorn) accompanied the author on both visits.

A literature review into CBBR, the Buff-banded Rail species as a whole, rail biology generally and island biology was conducted intermittently over a three-year period (1997-1999) by the author. Following a brief physical description of the study area, the methods used to address the study's objectives are presented.

Description of Study Area

The natural history of the Cocos (Keeling) Islands has been extensively reviewed in a special issue of *Atoll Research Bulletin* (eds Woodroffe & Berry 1994). The papers contained in that series should be read in conjunction with Bunce (1988) and Parks Australia (1999) for detailed information.

The CKI are located on the southern margin of the equatorial low-pressure belt at 12 12'S 96 54'E in the Indian Ocean (Fig. 1). Climate is oceanic-equatorial and humid, with an equal mean annual rainfall and mean annual potential evaporation rate of *ca* 2000 mm, high humidity (65-90%), and uniform temperatures year round (average daily range: 24 –29 C). The South-East Trade winds dominate all year (15-30 km/hr most days) but with periods of doldrums during the tropical cyclone season (November-April). The maximum recorded wind gust during a cyclone is 176 km/hr (Parks Australia 1999). Rainfall recorded on the southern atoll in 1999 preceding this study had been below average resulting in unusually dry conditions on NKI (R. Thorn, *personal communication*). Rainfall variability and tropical cyclones seem to be the major natural agents of disturbance and environmental change on the islands themselves.

The southern atoll encompasses *ca* 14 km^2 compared with the 1.2-1.3 km^2 land area of NKI. Extensive fringing reefs surround both atolls. There is limited natural soil development on the southern atoll and on NKI sand to rubble predominate. Historically the vegetation of the two atolls was considered to be similar, with NKI containing fewer species than the southern atoll due to its smaller size (Williams 1994). As with most coral islands in the world the vegetation consists of taxa with wide pantropical or Indo-Pacific distributions (Renvoize 1979 in Parks Australia 1999). Much of the original forest cover on the southern atoll was converted to coconut palm plantations early in the islands' settlement, and so the forest types represented on NKI are the best examples of the CKI's original forests. Shoreline strands of trees and shrubs are still well represented on many islands, as are areas of saltmarsh (e.g. herbland) vegetation.

A range of terrestrial invertebrates occurs on the CKI but land crabs dominate the forest floor and other areas of ground (Parks Australia 1999). Carter (1994) compiled a list of 60 bird species, building on the reports of earlier workers (e.g. Wood Jones 1909; Gibson-Hill 1948, 1949, 1950; Stokes et al. 1984; Stokes and Goh 1987; Stokes 1994); presently, 14 indigenous and three introduced species of birds are known to breed on the CKI. Two species of junglefowl ('feral chicken') have been established in the CKI (Carter 1994). Semi-wild populations of the domesticated variant of the Red Junglefowl *Gallus gallus* occur on most if not all islands in the southern group. They used to occur on NKI but have gone extinct there. The Green Junglefowl *G. varius* of Java was introduced to West Island where a healthy population remains and a wild population of the Red Junglefowl seems absent. The third persistent introduced species is the Christmas Island Silvereye *Zosterops natalis* and it is confined to Horsburgh Island. The naturally occurring breeding bird species consist mainly of seabirds, but there are a few waterbirds as well, one of which, the Nankeen Night Heron *Nycticorax caledonicus*, colonised the CKI since 1941 (Carter 1994). The CCBR is the sole indigenous landbird historically known to be a breeding resident of the CKI. Large breeding populations of seabirds and the CBBR remain only on NKI.

North Keeling Island

NKI is located 24 km north of the southern atoll (Fig. 1) and is horseshoe-shaped, bearing a large shallow lagoon within the encircling land mass that varies in width from 150 m to 400 m over most of the island (Fig. 2). The northern and western portions of the island are the broadest (*ca* 300 m) and this is where the most extensive stands of forest are developed.

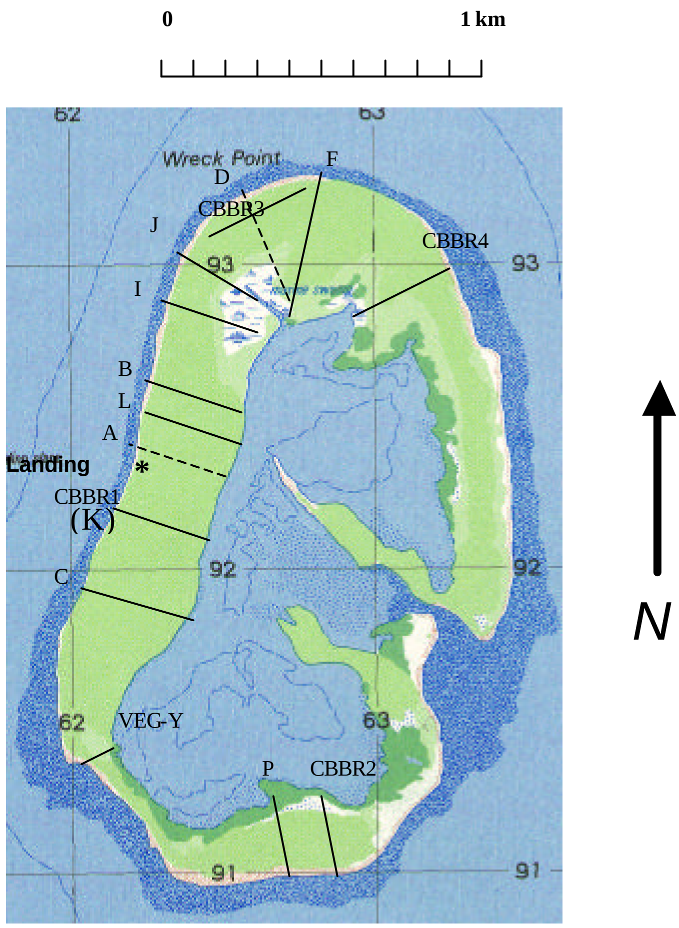

Figure 2. North Keeling Island, showing Red-footed Booby and Cocos Buff-banded Rail transect positions (after Royal Australian Survey Corp, Dept Defence, 1979).

Gibson-Hill (1948) mapped four vegetation units on NKI and this scheme was refined by Williams (1994) who recognised 10 types of vegetation and four unvegetated units. Parks Australia (1999: Fig. 3) have recognised eight vegetated units and seven unvegetated geomorphic units in the park's *Plan of Management*. The dominant forest units are open coconut *Cocos nucifera* forest, *Pisonia grandis* forest, mixed *Pisonia*-coconut forest patches, low ironwood *Cordia subcordata* forest, and tea-shrub *Pemphis acidula* scrub. Less dominant shrubs and trees are octopus bush *Argusia argentia* and cabbage bush *Scaevola taccada*. An occasionally tidally inundated flat on the north-western interior of the island carries a low sea purslane *Sesuvium portulacastrum* herbland. Areas of dense grass are found where the light regime and soil allow. The most extensive forest formations are those dominated by *Pisonia*, and this tree provides most nesting sites for the Red-footed Booby *Sula sula* and a range of other nesting seabirds. *Pisonia* trees, however, are susceptible to cyclone damage, and a direct hit by TC John in early 1989 considerably changed the forest structure on NKI (Kentish et al. 1996).

Apart from the island's abundant birdlife, a reduced range of non-marine animals occurs on NKI compared with the southern atoll (Parks Australia 1999). Only one of the three species of indigenous terrestrial reptiles occurs on NKI, namely the gecko *Lepidactylus lugubris* (Stokes & Cogger 1987). Fortuitously it seems no introduced vertebrate has established persistent populations in PKNP. Rabbits *Oryctolagus cuniculus* and feral chickens were deliberately introduced but failed (Parks Australia 1999), while there is no evidence for populations of rats, cats or the Asian House Gecko *Hemidactylus frenatus* ever having been introduced, despite their successful establishment in the southern islands.

Field Methods

Searches for CBBR and observations of all birds encountered were made on the larger islands in the southern atoll (namely Horsburgh Island or Pulu Luar, West Island or Pulu Panjang, South Island or Pulu Atas, Home Island or Pulu Selma, and Direction Island or Pulu Tikus) and several of the smaller islands (Pulu Kambing, Pulu Maraya, Pulu Blan, Pulu Blan Madar, Pulu Klapa Satu) during my four-week stay. Two visits were paid to Pulu Luar as it has been targeted as a likely reintroduction site for the CBBR (Garnett 1992), while most time was spent on West Island.

On NKI 13 'distance-measuring' line transects were established across the island. Bibby & Burgess (1997) describe the distance-measuring line transect method and their guidelines were adopted here. A constant walking speed of 1.0-1.5 km/hr was adopted with the observer halting only to record detections. The perpendicular distance of each bird from the transect line, whether detected by sight or hearing only, was estimated to the nearest meter, to a maximum distance of 50 m. All counts were conducted by the author between 0700 and 1100 on 9-10 November 1999. The length of each transect varied from 100 m to 400 m, and each detection was assigned to a vegetation or geomorphic unit. Table 1 lists transect details. Figure 2 shows the location of the 13 transects, while a fourteenth 'demonstration transect', in which the three PAN staff accompanied the observer, followed the path between the shed (landing site on west side of island) and igloos (west shore of lagoon). The data from the demonstration transect were not included in the statistical analysis.

Two trapping methods were trialled on NKI, baited cage traps and mist nets. Four wire-mesh cage traps (18 cm x 32 cm x 85 cm) were baited with tinned tuna and deployed during the daylight afternoon hours of 8-9 November. An 18-m mist net was set briefly on the morning of 10 November next to the shed following repeated observations of up to four CBBRs in the immediate area. On the return overnight visit, two 18-m mist nest were set in a line for six hours on 23 November, in the marshy area marked 'marine swamp' adjacent to the north-western portion of the lagoon (Fig. 2). This site was chosen as up to eight birds were seen foraging in the short purslane herbland characteristic of the area. Attempts were made to drive birds into mist nets, as it seemed unlikely that birds would fly into them otherwise.

It was originally intended to collect blood samples from all captured birds prior to their release. However, as there were unanticipated freight difficulties, the late arrival of bleeding equipment meant that birds captured on the first visit to NKI could not be bled. A few body feathers were plucked from captured birds instead and stored in DNA-buffered alcohol. Bands supplied by the Australian Bird and Bat Banding Scheme also arrived too late for birds to be banded. PAN staff assisted the author with trapping, handling and measuring birds.

General observations of CBBRs around NKI were recorded and the following details were noted in particular: calls, diurnal rhythms, foraging behaviour, agonistic interactions intra- and inter-specifically, signs of reproductive activity, habitat use (vegetation type and vertical activity), and location within NKI. To this end, all parts of NKI were visited, and most parts were visited on both visits. However, observations were centered on the mid-western portion of NKI, i.e. in the vicinity of the landing place and campsite. On the second visit (24 November), the three PAN staff each conducted two transect counts as a trial of potential monitoring procedures to follow changes in CBBR abundance through time.

Analysis of Transect Data

Two approaches were used to analyse data from the 13 transect counts. First, the cumulative count data were graphed against perpendicular band widths (of 10, 5 and 4 m). On the basis of visual inspection, a band width was selected within which it appeared that any bird had a maximum and equal likelihood of detection. This in effect truncates the method and data to a 'fixed-strip' transect approach (Bell & Ferrier 1985). While this approach is likely to lead to problems of bias if used as a monitoring tool – particularly if the behaviour of the population varies between sampling events and if the habitat or viewing conditions vary through time – data analysis is simplified greatly. Only observations falling within the selected band width are used computationally. I calculated a density for each transect, and then calculated a simple arithmetic mean density, standard deviation and standard error of the estimate of the mean density (n = 13). While the assumption of a normal distribution of errors around the mean density may be dubious given that the data were collected as counts, the distribution of density estimates did not depart from normality ($P > 0.05$, Kolmogorov-Smirnov one-sample test). The 95% confidence interval around the mean density was computed.

The method of Bell & Ferrier (1985:12-13) was followed to compute the mean number of CBBR detections using the distance-measuring line transect method of Bibby & Burgess (1997). A 4-m band width was selected to maximise the number of points along the abcissa (distance from transect line). A third-order polynomial with the linear term set to zero was fitted by least-squares regression to the data. The y-intercept (at zero distance from the transect line) provides the best estimate of abundance. This figure is converted to a density estimate by dividing the figure by the band area surveyed.

Extrapolating mean density estimates to a population estimate for the entire island requires several assumptions to be met. The most critical requires that there is no systematic variation in the distribution of CBBRs across NKI either geographically or by vegetation/geomorphic unit. This and other requirements are assessed in the Results and Discussion sections. However, a simple multiplication of the mean density estimate by island area yields the first quantitative population estimate for NKI.

Results

Literature Review

This section is somewhat repetitive and prescriptive. It can be read as a separate essay detailing limited aspects of the known biology of the CBBR, and placing the information in the context of the biology of the species and, more generally, the rail family as a whole (comprehensively reviewed in the past decade, e.g. Taylor 1998). Critical gaps in knowledge of the CBBR are identified. Most of the material covered in the literature review has been incorporated into other sections of the report where appropriate. However, because some information is not presented elsewhere, I decided to present most of the material here as a block.

Two standout reviews of the Buff-banded Rail have been published, namely Marchant & Higgins (1993) and Taylor (1998); they specifically address the Cocos population *Gallirallus philippensis andrewsi*. Useful briefer treatments of the species but not the CBBR include Blakers et al. (1984), Pringle (1985), Schodde & Tidemann (1986) and Kingsford (1991).

Wood Jones' (1909:137) description of the habits of the CBBR are of interest, and so are cited in full:

> 'Native [Cocos-Malay] name, "Ayam utan."
> 'Very abundant on all the islands, and is everywhere very tame, it being a matter of some difficulty to make it take to the wing. It feeds on the shore when the tide is out, but it may also be seen perched high in papaia trees eating the ripe fruit, and it has a bad name for eating the eggs of domestic fowls. It nests in September, in tufts of grass about a foot from the ground; it lays from two to six eggs, very like the English Corncrake's. The young are all black when hatched, and can run directly they are out of the egg. The call-note is a shrill grating sound, and in the breeding season the cock adds a deep croak not unlike the noise made by frogs.'

Population Size, Social Organisation, and Territoriality

I have not uncovered density or population size estimates for any subspecies of Buff-banded Rail in the primary literature (e.g. Blakers et al. 1984; Marchant & Higgins 1993; Taylor 1998), apart from Elliott's (1989) study of *G. philippensis assimilis* in parts of New Zealand and recent estimates of the size of *andrewsi* on NKI (Garnett 1993; Taylor 1998). Elliott (1989) recorded a mean density of 0.75 birds ha^{-1} in coastal saltmarsh habitat on the north coast of South Island, New Zealand, while there is another New Zealand estimate of 0.7 birds ha^{-1} (Marchant & Higgins 1993). The New Zealand population was considered to be in decline at the time of these studies.

In Australia, although there are no published density data, the species is usually considered to occur at low densities in dense, grassy and marshy wetlands on the mainland, at least over most of southern Australia (Blakers et al. 1984; Pringle 1985; Marchant & Higgins 1993). By contrast, higher densities have been reported from some near-shore Australian islands, on which the species may behave more boldly and utilise drier and more open environments than is customary on the mainland (Blakers et al. 1984; Pringle 1985; Marchant & Higgins 1993; F. Manson, *personal communication*).

Monogamous pairs are thought to form and be stable over the breeding season, holding and defending a territory against other pairs and single birds (Dunlop 1970, 1975; Elliott 1989; Taylor 1998). Over several years Dunlop (1970) observed pairs driving the season's successfully fledged young out of the natal territory at the end of a well-defined spring-summer breeding season in south-eastern Queensland. Territoriality would indicate regular spacing of pairs through the breeding season. By implication, regular spacing could be expected to break down outside of the breeding season. Although the species is generally thought to be quiet and unobtrusive, the bird becomes highly vocal and aggressive to conspecifics at the commencement of the breeding season (Dunlop 1970; Marchant & Higgins 1993; Taylor 1998). When feeding, non-breeding birds are also known to chase off conspecifics at times, while at other times loose aggregations may forage together peacefully (Marchant & Higgins 1993). These reported behavioural changes fit with scattered observations made of the CBBR. They can be conspicuous and apparently abundant at times (e.g. Stokes et al. 1984), or retiring and rarely heard and seen at others (e.g. Carter 1994).

Breeding Biology and Diet

The Cocos Buff-banded Rail nests on the ground and low down in the base and forks of trees such as the coconut palm and *Pisonia grandis* (Gibson-Hill 1949; Stokes et al. 1984). The few descriptions of its nest and contents indicate that its nesting habits are the same as in the wider species. The following details relate to the species as a whole (from Taylor 1998): coarsely woven, grass, cup-shaped nest; usual clutch size of 4-8 eggs (36 x 28 cm, pale buff with reddish-brown blotches); incubation period 18-25 days; nest-building to rearing duties shared among sexes; chicks are precocial, departing nest soon after hatching, soon becoming covered in blackish then black down. Dunlop (1970) observed that chicks appeared to be capable of feeding themselves entirely after one week, but adults will feed and protect their young until fledging (Taylor 1998).

There is confusion in the scant literature over the breeding season of the CBBR (Gibson-Hill 1949, 1950: May-August; Stokes et al. 1984: November-January). Any future intensive studies of the CBBR should be linked to a dietary survey to determine if peaks in breeding activity occur, and if they are tied to a burst of a particular food type. Direct observation and faecal analysis (e.g. Beauchamp et al. 1998) are probably all that is required in the first instance, rather than detailed food availability studies (see Conway et al. 1993) which are very time consuming to undertake.

Within southern temperate Australia, the breeding season of the Buff-banded Rail is considered to be short, restricted to spring and single-brooded (Marchant & Higgins 1993). Further north in Australia and in equatorial populations the breeding season may be extended, aseasonal and involve multiple broods (Pringle 1985; Schodde & Tidemann 1986; Marchant & Higgins 1993; Taylor 1998). This kind of flexibility and pattern in timing of breeding is typical in birds with wide-ranging distributions (Wyndham 1986), and the CKI population of Red-footed Booby *Sula sula* is an example of a tropical species with the capability of breeding year round (Stokes et al. 1984; I. Macrae, W. Murray & R. Thorn, *personal communication*).

Conway et al. (1993) found that the fledging period of an endangered subspecies of Western Clapper Rail *Rallus longirostris yumanensis* in the USA coincided with the peak abundance of its preferred food, two crustaceans. For *Gallirallus philippensis andrewsi*, there are the opportunistic dietary observation (crustaceans: Stokes et al 1984) cited earlier. However, it seems just as likely that the breeding cycle of *andewsi*, should there be an obvious one, might be tied to the peak breeding time of island nesting seabirds that nest in abundance on North Keeling Island. The Heron Island population of Buff-banded Rails is opportunistic in its diet but scavenges extensively among the colonies of nesting noddies (*Anous* sp.) and times its breeding to coincide with this event (F. Manson, *personal communication*). The species is a generalist, opportunistic omnivore and a wide range of food has been recorded, including small chicks and eggs of other birds (Pringle 1985; Taylor 1998).

The most abundant birds breeding on NKI are the Red-footed Booby *Sula sula* and Common Noddy *Anous stolidus*, with approximately 20,000 and 7500 pairs respectively (Parks Australia 1999). Also common (low thousands) are two species of Frigatebird *Fregata ariel* and *F. minor*, and the White Tern *Gygis alba*. It is likely then, though unrecorded, that the CBBR feeds among these breeding colonies, scavenging disgorged food from the larger seabirds and perhaps preying directly on the nest contents of the terns. The boobies and noddies appear to nest throughout the year (Stokes et al. 1984; Carter 1994; Parks Australia 1999), and so food from this source would be in reliable supply.

Seabird breeding islands are known to enrich small oceanic islands greatly, with organic produce from the surrounding seas and nutrients being fed into the island ecosystem (Polis et al. 1997). This enrichment in turn can support large populations of detritivores and their predators, both in the immediate terrestrial and adjacent marine (littoral) environments (trophic cascades: Polis et al. 1997). Therefore, it is possible for generalist feeders like the Buff-banded Rail to capitalise on this trophic pathway. They may not be directly dependent on the disgorged food, chicks and eggs of the seabird colonies themselves for food, even though it is the presence of colonies that drives the enrichment process. Should enrichment be a factor in maintaining high population densities of CBBRs, thereby decreasing the probability of stochastic extinction, the absence of seabird rookeries from the southern atoll could impact upon reintroduction attempts.

There are conflicting statements about the Buff-banded Rail's daily activity and feeding cycles, and so it appears that the species may vary its time of activity dependent on seasonal or even daily conditions. It has been reported as being diurnal, crepuscular, and sometimes active at night (Longmore 1978; Marchant & Higgins 1993; Taylor 1998), but regular nocturnal roosting behaviour was also described by Marchant & Higgins (1993). In common with many waterbirds including some other dispersive rails, it has been suggested that migrations and other long-distance flights are undertaken at night (Marchant & Higgins 1993). Southern Australian populations are migratory, arriving to breed in late winter-early spring and departing late summer-early autumn (Marchant & Higgins 1993). Many other populations and subspecies appear to be sedentary, including island forms such as the CBBR. Elliott (1987) studied the daily activity patterns of a coastal population of the sedentary New Zealand subspecies, *G. philippensis assimilis*. He found they were most active in the early morning and late afternoon periods, as well as at any time immediately following a high tide, when they could forage more efficiently for their favoured food on the receding tide: a small crab and small snail.

Taxonomic Assessment

The subspecific status of the CBBR was queried by Marchant & Higgins (1993) presumably on the grounds that there has not been a recent review of the population. More generally, Schodde & Naurois (1982) cautioned that too many subspecies had been loosely described historically. Marchant & Higgins (1993) and Taylor (1998) describe it as a distinctively coloured and patterned population, however, in agreement with Mathews' (1911) original diagnosis (e.g. 'Poorly known but possibly highly distinctive': Taylor 1998:250).

Differentiating features are the greater amount of white spotting on the lower back and rump, and the almost complete absence of olive-brown tints in the dorsal plumage.

Taylor (1998:250) gives morphometric data for three specimens of *andrewsi*; tarsus measurements (mm) are 43 (type specimen, male), 42 and 46 (both unsexed, date of collection unknown). Gibson-Hill (1950) presented data on a large series he collected in 1940-41; for nine specimens apiece the average tarsus length was 50 mm and 48 mm for males and females respectively. These tarsus lengths averaged are greater than for any other of the 22 subspecies for which Taylor (1998) presents data. For instance, the mainland Australian form, *Gallirallus philippensis mellori*, has small tarsi (males 40.8 mm; females 38.8 mm), as does the Great Barrier Reef population, *tounelieri* (unsexed: 40.2 mm) (large series, data from Taylor 1998). Various subspecies to the north and north-east of Australia have larger tarsi, e.g. *sethsmithi* of Vanuatu (males 45.2 mm; females 41.1 mm) and particularly *goodsoni* of Samoa (males 47.3 mm; females 45 mm). In terms of the dark dorsal plumage, Timorese and Sulawesian populations of nominate *philippensis* and *wilkinsoni* of Flores may be most like *andrewsi* (descriptions from Taylor 1998). With respect to a host of characters they compared in most of the then described subspecies, Schodde & Naurois (1982) concluded they could not discern any obvious geographic trends that were consistent across subspecies. Instead, character states kept emerging and disappearing in a geographically baffling manner, suggesting that nearest neighbours may not necessarily be the closest relatives. Despite this caution, rapid evolutionary change within the species seems characteristic, and the closest relatives to *andrewsi* (and its ancestral stocks?) may be found in the eastern Indonesian (Flores-Timor) region.

A molecular survey of subspecific limits within the species, focussing on the taxonomic status of *andrewsi* in particular, would be required to shed further light on its systematics and evolutionary history. Ideally such a study should be commissioned in the medium term. Non-destructive tissue sampling (feathers, skin, blood) of living birds should be pursued in the shorter term, therefore, as part of any live-trapping-release component of future studies.

Results (cont.)

Field Studies : 1. Population Estimation and Trappability

No Cocos Buff-banded Rails were detected on islands of the southern atoll in the CKI. West Island, in particular, was intensively searched. The species appeared to be abundant, widespread and vocal on NKI. Notes on their general distribution and behaviour follow descriptions of attempts to estimate the population size on NKI and of the bird's trappability.

Population Estimation

Using the data from 13 transects undertaken by the author (Table 1), it can be seen that 119 individual birds were detected. Without knowing the home-range behaviour and movements of this population, it is of little use to speculate on the independence of all these detections – some individuals may have been double or even triple counted if they moved distances of several hundred meters around the island. However, provided it is unlikely that birds were, on the whole, attracted to counting activity and that larger-scale movements were random with respect to the timing and placement of transect counts, any such multiple counting of a few individuals should not affect results seriously. Figure 3 shows the pooled count data as a function of distance from the transect line and a steep shoulder is evident past 20 m. On this basis, a 40-m fixed band width (20 m either side of the transect line) was used for each transect to compute a mean density estimate. The raw data are presented in Appendix 1.

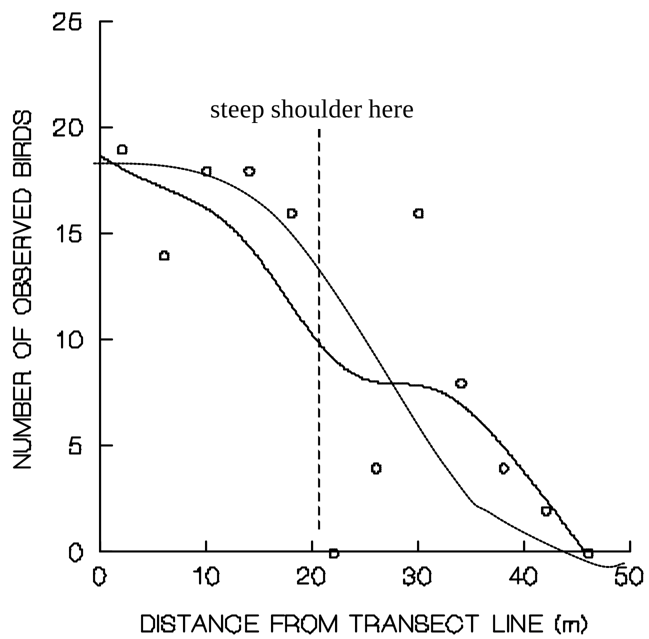

Figure 3. Number of recorded birds (seen/heard) in successive 4-m bands from central transect line, data pooled over 13 transects. Sharp decline in detectability beyond *ca* 20 m evident. The third-order polymomial fit is shown (dashed) with a 'better-fit' (locally-weighted least-squares smoothing) curve (solid) shown for comparison.

Table 1. CBBR transect details (n = 13) on North Keeling Island (see Fig. 2 for their location).

Name	Length (m)	Date	Time	Heard Only	Seen	Within 20 m	Density (ha^{-1})
RFB-I	300	9/11	0710-0720	4	3	3	2.500
RFB-B	300	9/11	0725-0735	4	7	7	5.833
RFB-L	300	9/11	0745-0800	4	5	5	4.167
RFB-A	300	9/11	0820-0835	4	5	8	6.667
CBBR-1	300	9/11	0850-0905	5	11	13	10.833
RFB-C	300	9/11	0925-0935	5	10	8	6.667
VEG-Y	100	9/11	0950-0955	1	0	1	2.500
RFB-P	200	9/11	1000-1005	1	4	5	6.250
CBBR-2	200	9/11	1020-1025	4	4	8	10.000
RFB-J	200	10/11	0715-0725	4	1	2	1.667
CBBR-3	200	10/11	0730-0740	4	2	5	6.250
RFB-F	400	10/11	0750-0810	6	11	13	8.750
CBBR-4	400	10/11	0830-0845	7	3	9	7.500
TOTAL	**3500**			**53**	**66**	**87**	**Mean 6.122**

Birds were detected on all transects (1-17) and while most detections were triggered by audial cues first, subsequent sightings of some of these birds meant that visual records outnumbered heard-only records. Density estimates for transects, using the fixed-width approach, varied from 1.667 to 10.833 birds ha^{-1} (mean = 6.122, *s.d.* = 2.838; *s.e.* = 0.787).

The distance-measuring approach and analytical method of Bell & Ferrier (1985), that of fitting a third-order polynomial to the 4-m band width data (Fig. 3), yielded an abundance estimate of 17.387 birds in a central 8-m belt spanning a cumulative 3.5 km (2.8 ha). This simplifies to an estimate of 6.210 birds ha^{-1}. Fitting a third-order polynomial without the linear term explained 48% of the variance in the data (adjusted multiple r^2: Table 2). It is immediately evident that the two methods yielded very similar estimates.

Table 2. Pooled transect CBBR data divided into consecutive 4-m band widths.

Bands (m)	0-3.9	4-7.9	8-11.9	12-15.9	16-19.9	20-23.9	24-27.9	28-31.9	32-35.9	36-39.9	40-43.9	44-47.9
No. birds	19	14	18	18	16	0	4	16	8	4	2	0

If we assume that CBBRs are distributed fairly randomly across NKI and that the transects sampled the population without serious bias, then it is a simple matter to derive a total population estimate for the subspecies. The land area on NKI is variously said to be 120-130 ha, and Table 3 presents the resulting population estimates. The likely validity of these estimates and underlying assumptions are evaluated in the Discussion after additional observations of the bird's distribution are presented. For now an estimate of 750-800 birds appears reasonable and consistent with their abundance and activity levels as gauged qualitatively while present on NKI. Recent estimates of 40-150 birds (Garnett 1992, 1993; repeated in Parks Australia 1999) clearly lie well below the true figure.

Table 3. Size estimates for the North Keeling Island population of Cocos Buff-banded Rail. Method 1: 'fixed-strip' approach, truncating the data to a central 40-m belt, with 95% Confidence Intervals (CI); Method 2: 'distance-measuring' approach through polynomial regression.

	Method 1		**Method 2**	
Island Area (ha)	120	130	120	130
Population Size	735	796	745	808
95% CI	(546 - 923)	(591 - 1000)		

The six transects conducted by PAN staff on 24 November were analysed using the fixed-strip, 40-m width approach, and yielded a mean density estimate of 3.576 birds ha^{-1} (with *s.e.* = 0.470 ha^{-1}). This estimate is significantly smaller than that obtained with the author's data. The discrepancy may reflect observer differences or, more disturbingly, differences in behaviour and detectability between visits. This figure scales up to a total population estimate of *ca* 450 +/- 50 individuals.

Trapping Attempts and Cursory Taxonomic Observations

Three individuals were captured, all appeared adult. The first was caught in a cage trap in the mid-afternoon, 9 November. Two individuals were captured near the shed on the morning of 10 November. R. Thorn watched a bird enter the shed and he successfully caught it. Another bird was rushed into a mist net next to the shed by PAN staff after it was noticed hanging around there. All three birds were fairly quiet in the hand once they settled down from the initial flurry and shock of capture. They became quite docile while measurements were taken of their bill, head and bill, tarsus, closed wing, and total bill tip to tail tip length (Table 4). Several photographs were taken by PAN staff. Feather samples were collected and stored in alcohol and subsequently lodged with the South Australian Museum (S. Donnellan). Weights were not recorded due to the absence of equipment; nor could the birds be banded.

Table 4. Measurements of trapped CBBRs.

Bird	**9/11/99, cage**	**10/11, shed**	**10/11, net**
Total Length (mm)	290	283	285
Head and Bill (mm)	70	66	70
Bill (upper mandible, mm)	35	30	35
Closed Wing (mm)	140	137	143
Tarsus (mm)	55	54	56
Iris Colour	reddish	reddish	-
Vial No. (feather storage)	J9678	J9676	J9679

A brief description was made of the captured birds' plumage, in respect of the features said to differentiate the subspecies *andrewsi* from other forms, particularly that of the Australian forms, *mellori* and *tounelieri*. Mantle, back and scapular feathers were dark grey-black without the olive-brown edges characteristic of Australian mainland birds; only a tinge of brown was apparent. The dorsal surfaces were heavily spotted with white all the way down to and including the rump; there was prominent white barring on the dark grey-black tail. Many close observations of wild birds confirmed the absence of olive-brown tinges on the dorsal surface of this population, and so subspecific recognition appears warranted. In addition the three birds each had much longer tarsi (54-56 mm) than Australian and New Zealand (*assimilis*) forms (34.5-46.0, *n* = 62; data from Marchant & Higgins 1993). It is noted, however, that due to the late arrival of my field equipment, I resorted to measuring the tarsi with a plastic ruler rather than vernier calipers. I double-checked my measurements and PAN staff confirmed the measurements (to the nearest millimeter). Cocos Buff-banded Rails are long-legged birds and it is speculated whether the population may be evolving towards increased terrestriality. It is possible though that increased leg size stems purely from random small-population effects (genetic drift). This is mere speculation, and I return to this point in the Discussion.

Two birds were rushed into the nets set north of the campsite on 23 November. Both became tangled in the bottom panel but managed to escape prior to the author getting a hand on them. Although only three individuals were captured overall, this small success for a relatively small investment of traps and trap time indicates that intensive and dedicated effort would allow many bird to be caught in the future. Captured birds were amenable to handling and scuttled away readily when released, apparently no worse for wear.

Habitat Use

Data from the 10 northernmost transects (CBBR-4 west and south to FRB-C: Fig. 2) were analysed to examine whether the CBBR displays any preference for different vegetation types. Four main vegetation units were recognised for this purpose, along with a fifth category termed 'lagoon shore'. The four vegetation units were the Coconut woodland, *Pisonia* woodland, Coconut and *Pisonia* woodland, and *Cordia* woodland mapped for NKI in Parks Australia (1999: Fig. 3). The proportion of each unit along the 10 transects was assessed visually from the Parks Australia map. Multiplication and addition allowed a composite proportion of each vegetation unit to be computed (Table 5). The lagoon shore unit was arbitrarily assigned a 5% value. Birds recorded on transects had been assigned to these habitat classes, and so the number of detections in each unit was readily computed (Table 5).

Table 5. Number of CBBR detections relative to proportions of five main habitats represented along 10 northernmost transects.

Habitat Unit	Percentage Habitat %	No. Birds
Pisonia	53	*57
Pisonia-Coconut	29	33
Coconut	5	1
Cordia	8	11
Lagoon Shore	5	5

* includes 6 birds recorded as being in '*Pisonia-Cordia*' habitat; one observation in *Pemphis* excluded

Clearly there is little evidence for strong habitat preferences. Because precise measurements of proportions of the different habitat types along each transect were not taken in the field, it would be unwise to conduct a goodness-of-fit test on the data presented in Table 5. The CBBR appears to use the different vegetation units in rough proportion to their occurrence on NKI.

The impression had been gained while visiting PKNP that rails were more abundant in the *Pisonia* and *Cordia* habitats (and in the interior of the island generally) than in the *Pisonia*-coconut mixed stands more prominent along the marine shores and outer parts generally. However, the data in Table 5 do not bear this out, and the impression may have arisen partly due to the difficulty in hearing birds close to the sea shore. The pounding surf is usually roaring, and on one of her transect sheets W. Murray (PAN) noted that rails might not be heard on the outer ends of transects. Transect CBBR-3 was placed to sample exclusively the coastal *Pisonia*-coconut unit, but an average number of birds was detected there (Table 1).

Only one individual of CBBR was counted in pure stands of coconut palms (Table 5). Coconut woodland, as mapped by Parks Australia (1999: Fig. 3), covers some 15% of the wooded area of NKI. Were CBBRs largely absent from this formation, the whole-island population estimate would need to factor out this percentage of island area. Prior to my visits to PKNP I had formulated an expectation that rails might avoid this habitat – my thinking was influenced by the notion that habitat transformation on the southern atoll (from indigenous mixed species forests to pure coconut palms) may have contributed to the bird's demise there (e.g. Garnett 1993). Accordingly I inspected three large pure stands of coconut on NKI – at the southern end, along the eastern strip of land (north of the lagoon inlet), and bordering the northern spit of the lagoon inlet channel. Rails were encountered in all three locations, and were particularly numerous in the last area. They were also common in the mixed stand of *Pisonia* and coconuts bordering the southern arm of the inlet channel. I am led to conclude that the CBBR was widely and relatively uniformly distributed throughout PKNP in November 1999. No evidence for either a strong avoidance or preference of areas based on habitat was obtained. The validity of this conclusion is not necessarily general, and habitat selection may be evident at other times.

Despite the conclusion just drawn the transect data are believed to be biased against detecting birds along the lagoon shore. Rails were never seen (within 50 m) in this environment when a transect was commenced on the lagoon side, due to disturbance (see below). Even when transects were conducted in the other direction it was difficult to pass noiselessly through the final thicket of vegetation and out onto the edge of the lagoon, and so I got the impression that at least some birds probably escaped detection. It was usually difficult to move quietly and easily through *Cordia* low forest, and some *Pemphis* thickets proved virtually impenetrable (e.g. CBBR-2). These units mainly occur in the interior of NKI adjacent to the lagoon. Table 5 shows that the *Cordia* formation appears to be a favoured habitat for CBBRs, and visits paid to both units outside of transect times, when I could sit quietly and observe/listen, revealed that there were generally birds within. For these reasons, I suspect that the density of birds may be greater in the interior portions of the island than in the middle tracts and marine shore sides. Therefore, whole-island population estimates derived from the transect count data may underestimate the true population size.

Field Studies : 2. General Observations

Birds were frequently encountered by the author and PAN staff during both stays on NKI. PAN staff were accustomed to the range of vocalisations and general habits of the CBBR and pointed them out to assist me in detecting and locating birds initially until I became more familiar with them myself. This learning exercise was rapid, facilitated by the absence of other landbirds on the island.

General Behaviour

The birds are terrestrial and were rarely seen above the ground during the day. Several roosting birds were located at night off the ground, however, perched in trees and shrubs to a height of 2.0 m. Two other roosting birds were startled from rank grass at ground level. One (presumably) roosting bird was observed to descent from its perch in a *Pisonia* tree at 0730 on 9 November, approximately one hour after first light.

Within the forest floor environment, most birds were sighted individually, and when unalarmed they moved about seemingly randomly, at times slowly and at times quite quickly, looking at the ground and around and occasionally pecking at the ground. No prey was ever observed, and so presumably very small insects and bits of organic grit were being examined and consumed. Occasionally foraging birds would dash at objects above ground height (e,g, trunks, leaves) and scramble up to one meter in height to peck at things. When alarmed they invariably ran quickly away from the observer, generally heading for patches of denser ground cover, through which they would usually run rather than sheltering within. If disturbed suddenly at close proximity, most birds would fly/scuttle rapidly away for 10-40 m, often emitting a startled squeal or squeak, before dropping to the ground and running further. Most birds fled using this type of 'half scuttle half flight' behaviour, and no bird was seen to fly strongly or directly well above ground level. Modes of walking, running ands flight have been described adequately for the species by Marchant & Higgins (1993) and by Taylor (1998), and none of my observations adds to this knowledge. The behaviour of *andrewsi* seems typical of the species in this and other respects.

Birds were more wary when foraging in open environments, such as along the lagoon shore, away from the cover of the forest or scrub. Rails in this situation would invariably see an approaching observer at 50-100 m distance and dash into the adjacent vegetation. Only if the observer were still and/or hidden would birds wander past without appearing unduly alarmed. However, the lagoon shore and the open purslane herbland patch at the north-western corner of the lagoon were certainly favoured foraging habitat (confirmed by a much longer period of observations by PAN staff). Birds could be seen foraging in this environment most times an observer quietly sat at a suitable vantage point and scanned the shoreline with binoculars. It is curious that birds on NKI are so wary as there would appear to be no obvious predator on the island. The birds' habit of scanning the sky repeatedly while foraging in these open environments suggests they are accustomed to aerial assaults. I cannot think of a likely avian predator, however. Great Frigatebirds *Fregata minor* have been recorded as predators at tern colonies (Burger & Gochfeld 1994) but predation does not seem to be part of their usual repertoire (e.g. Marchant & Higgins 1990). W. Murray (PAN, *personal communication*) has not noted this species attempting to seize other birds on NKI (disregarding piracy). Nankeen Night Herons *Nycticorax caledonicus* will opportunistically take eggs and pulli of nesting waterbirds and terns (Marchant & Higgins 1990), but this species is only a recent colonist and so is unlikely to have shaped the rail's behaviour.

Within the lagoon shore environment rails seemed to be more abundant along the northern and western shores, and I speculate whether this was a response to a greater density of prey and organic matter being washed up along these shores in response to the prevailing wind direction (South-East Trades). Certainly at night there were considerable numbers of small isopods caught up in the foamy shoreline of the lagoon, and it was a common early morning sight to see birds foraging along this shore. Again however, no direct observation of foodstuffs consumed could be made.

The species is regarded as largely crepuscular (Taylor 1998). Birds on NKI were observed feeding throughout the day although foraging activity declined somewhat in the middle of the day. During the first visit (new moon) birds were observed to settle and roost at dusk around the campsite ceasing to call soon after dark, but this observation is restricted to a few individuals. By contrast, on the second visit when the moon was near-full, birds were calling throughout the night, but it was not possible to ascertain if they were active, i.e. foraging, or merely calling from roosting sites.

Agonistic interactions were frequently seen (and later heard, once the distinctive calls of fighting or quarrelling birds were learnt). Agonistic behaviour followed the descriptions given by Marchant & Higgins (1993) and Taylor (1998) – the aggressor would charge the other with head lowered and neck extended, accompanied by squealing or harsh squeaks (the aggressor gave these calls when the calling bird could be identified). In response the aggressed bird would dash off a short distance with head lowered and wings drooping. Once or twice, the roles of charger and chased were reversed during a bout – a short charge and chase occurred, both birds then stopped and fluffed out their plumage and walked around a little, before the previously chased bird lowered its head and charged at the other. There were many times when two, three and sometimes four adult birds were seen foraging loosely together, certainly in close proximity, without any evidence of antagonism. I cannot recall seeing agonistic behaviour when birds were foraging together in open exposed environments; such behaviour seemed (largely at least) confined to the forest and scrub habitats. As many as eight birds were seen loosely foraging together in the purslane herbland area. When groups of birds were foraging together, once an alarm call was given by any individual all birds would quickly dash for cover.

Calls

A wide range of squeaks, squawks and squeals were heard and attributed to CBBRs. The population was very vocal during both visits in November. None of the calls are particularly loud or melodious. A frequently given (? contact or territory advertisement) call consisted of three or four hissing notes in fairly rapid succession: 'swi – swi –swi –swi' (short 'i' sound). The calling birds would 'rise to attention' to give this call. The intensity and rapidity of notes varied considerably. A quieter version of this call was rendered as a bubbling 'ti-ti-ti-ti-ti'. In agonistic interactions, this sequence was lengthened and strengthened to a variable but greater number of (say, eight to ten) notes, but with each note given more quickly and in quicker succession, given by the charging bird. Sometimes this call was given in other than agonistic situations (signalling aggressive intent perhaps?); the bird would stand erect and deliver the sequence of notes which first rose then descended slightly in pitch and which increased slightly in volume before trailing off somewhat. Another variant of this call, perhaps used for maintaining contact between pairs, is a single drawn out, querulous sounding 'swiii', sometimes descending in pitch slightly at the end. Again this note varied in its length and intensity, sometimes being truncated and emphatic sounding.

A different call to that described above, used in alarm as when dashing away from an observer, is a squawk or shriek, an explosive, harsh 'cra(k)' or 'kswa(k)' (short 'a'). 'Cooing', 'braying donkey', and grunting calls, as described by Dunlop (1970, 1975) and as repeated in Pringle (1986), Marchant & Higgins (1993) and Taylor (1998), were not heard.

Reproductive Behaviour

A pair of CBBR was observed mating by R. Thorn near the shed at 1230 on 10 November. Another mating occurred in the same spot (presumably the same pair?) at 1330, and was witnessed by all four observers. As described by Marchant & Higgins (1993) and Taylor (1998) it is an unremarkable act. The presumptive male approached the presumptive female, hopped unheralded (to our eyes) onto the female's dorsum and copulation ensued for 5-10 s. The male hopped off, both birds shuffled their wings and feathers a bit and quickly resumed foraging, quickly wandering apart.

The following notes have been compiled from the observations of R. Thorn as communicated to the author over the past year. PAN staff attempt to visit PKNP at monthly intervals for the purpose of monitoring reproductive effort in the Red-footed Booby *Sula sula*. R. Thorn has noted a few instances of mating and nesting behaviour by the CBBR, usually incidentally while engaged in other management activities. Details follow. A pair was observed copulating on 6 May 1999. Then in the first few days of August, R. Thorn saw many rails perhaps more than ever previously. He found a rail's nest made on the ground in an open patch of grass on the edge of the lagoon. The presumed female had two eggs in a low cupped nest made out of dried grass. Each egg was approximately 20-25mm long, white with a few brown to reddish blotches scattered over the egg. Some photographs were obtained of the rail sitting on or approaching the nest (report cover). A second nest was found wedged about 1 metre high in a fork in a *Pisonia* tree. The nest was of a similar size and construction as the other one, but contained six eggs, and was attended by two birds. These observations are believed to relate to an incomplete and complete clutch of eggs respectively.

In 1999, birds in the CBBR population on NKI were breeding in May, July, August and November. If successful, the incomplete clutch of eggs found by R. Thorn in August would extend the known breeding period to include September. Similarly, copulation in May would extend incubation into June. The levels of calling and agonistic behaviour we recorded in November suggest that breeding was in full swing. Parsimony leads me to conclude that birds were breeding continuously from May to December. What proportion of the adult population was involved in reproduction over this period is unknown, but our November observations taken in conjunction with those made by R. Thorn in August, suggest a large-scale event extending at least over the July-December period.

The species is capable of producing multiple successful broods in an extended breeding season (Taylor 1998). It is a common pattern for wide-ranging species to have extended breeding seasons in areas closer to the equator than in more temperate areas (Wyndham 1986), and the Buff-banded Rail fits this model (Marchant & Higgins 1993; Taylor 1998). Although historical data only extend the known breeding season of *andrewsi* to January (Stokes et al. 1984), it seems likely that with further effort and documentation the Cocos population will prove capable of breeding in any month of the year[*]. One Indonesian subspecies is reported to breed year round (Taylor 1998). It remains to be determined whether an extended breeding season is customary for the CBBR or if 1999 was exceptional in this regard. Also it is unknown what proximate environmental factors, if any, may stimulate the CBBR to commence breeding. Most birds time their reproduction effort so that their offspring hatch about the time food becomes maximally abundant (or most readily harvested at any rate) (e.g. Conway et al. 1993). These topics, food and timing of breeding, are returned to in the Discussion.

[*] In fact, observations recently communicated (W. Murray, PAN) have confirmed this speculation – a nest with 6 eggs was found on the ground, 15/3/00; nest with downy chicks (<= 1 week) 1 m high in *Pisonia*, 20/4/00.

Discussion

It would be unwise to place too much reliance on information and data gathered over, at most, two days of intensive observation. With that caution in mind, however, the data gathered on the NKI CBBR population, along with accompanying analyses and interpretations as presented in foregoing sections, seem robust with respect to four of the study's stated objectives (Objectives 2, 3, 5 & 6). It was fortunate that PKNP was visited during the breeding season, as the rails were active, vocal and readily encountered. Their visibility was enhanced by the unusual openness of the forest floor, and R. Thorn (*personal communication*) advises that the birds are much harder to see normally. Thorn states that since I left CKI, heavy rains have broken the long dry spell, and that a burst of new growth on NKI has reduced visibility drastically thereby making direct observation of rails within the forest difficult. Despite the difficulties that might be expected if the study were repeated in lush conditions and when the population was not breeding, I can state that the following objectives were achieved:

- collation of the previous information collected concerning the natural history and basic biology of the CBBR, together with new data presented here, confirms that in all respects this population's life history is very similar to and falls within the range of that recorded for the species as a whole;
- it was established that the CBBR uses all habitats on NKI including pure stands of coconut palms, and that the bird appears to be fairly uniformly distributed across the entire island; in addition, matings and/or nests have been recorded adjacent to the sea shore, in the forest interior and adjacent to the lagoon shore, while nest placements have been observed on the ground, in dense grass, in palms and in *Pisonia* trees;
- a rigorous and efficient sampling program was established and successfully executed to enable a robust population estimate to be derived – line transects are a widely-used and standard procedure for estimating population densities;
- while the CBBR population remains at its high current density, I envisage no serious impediments to the development of an efficient and robust monitoring program, based on the procedures adopted here and consistent with PAN staff's capabilities (notwithstanding the two potential problems identified above);
- a suitable sampling program based on the 'distance-recording' line transect approach, modified to be more rigorous with respect to accuracy of distance estimation and habitat delineation, is presented below;
- although meeting with limited success, the trapping trials demonstrated that CBBRs are amenable to capture and easily handled and unlikely to be placed under undue distress; furthermore, it is anticipated that a focussed and intensive trapping program, involving the deployment of many more traps and nets than we trialled in November, would readily yield a suitable number of captive birds in the event that a translocation program was deemed necessary or desirable sometime in the future; current PAN staff based on CKI demonstrated their existing proficiency at both extracting birds from mist nets and handling captive birds showing due care for the animal's wellbeing;
- a range of options for future intervention in the management of the CBBR has been canvassed (presented below), having considered the range of potential threats and taken advice from experts involved with captive-breeding, translocation, and predator-control programs.

Evolutionary Divergence

The subspecific status of the CBBR appears valid, but further specimens (live-capture-release and blood samples) are needed to confirm this. Certainly morphologically, the population is distinctive and like no other described form (Taylor 1998). Australian populations of the Buff-banded Rail are not the likely source of the CBBR, but a full systematic review of the species using modern molecular techniques is required to progress further.

There is limited but fascinating evidence to suggest that morphologically the population is diverging rapidly, evolving before our eyes so to speak – tarsi lengths gathered from the three individuals caught in November were unusually large, and larger than all but two of the 18 specimens that Gibson-Hill (1950) measured. Should further examination confirm this pattern, the most likely explanation would involve the predilection shown by island rails (over evolutionary time periods at least) for adopting foot travel in preference to flight. Island birds have repeatedly evolved to the flightless state after reaching small isolated islands because of the great energetic costs that flight incurs. If food resources are not inherently patchy over large (island length) scales in space **and time** and if there are no predators to be evaded, flight (with its intricate = metabolically expensive baggage of supporting anatomy and physiology) becomes unnecessary and there are metabolic savings to be had. Birds that forgo the ability to fly presumably can channel the resources saved into additional reproduction and so increase their evolutionary fitness.

Population Estimation

The line-transect 'distance-recording' method for estimating population size and density is a robust, highly developed approach to the problem of animal abundance estimation (e.g. Burnham et al. 1980; Buckland et al. 1993; Bibby & Burgess 1997). Where it can be used it is certainly a more preferable approach than less direct methods such as playback or labour-intensive and intrusive methods such as mark-recapture and telemetry that involve the capture and handling of animals. Transect counting requires minimal technological investment and is relatively non-intrusive. With sufficiently trained personnel, it is a cheap, efficient and reliable sampling method.

There are various customised software packages that can be used to enter and analyse data collected using distance-based line transect procedures. Perhaps the most widely used package is DISTANCE (Version 3.5: Thomas et al. 1998), freely available as a download from the Internet, as is an electronic form of the book by Buckland et al. (1993). However I considered it important to work through the data 'by hand' and to present two analytical methods that PAN staff could follow and repeat. However, I recommend the use of the DISTANCE software once the basic theory and computational approach are mastered.

The two analytical approaches I used gave very similar estimates of mean density of CBBR on NKI. This result was heartening. The simpler method – plotting out the distances of all detections (Fig. 3) and arbitrarily choosing a band width in which the observer is confident of detecting all birds actually present – is subject to more bias and inaccuracy than more sophisticated methods such as polynomial regression (as used here) or Fourier analyses (DISTANCE) (Bibby & Burgess 1997). I tried fitting several variants of polynomial expressions (up to fourth order, including the linear term etc.), but the expression recommended by Bell & Ferrier (1984: of the form '$x^2 + x^3 + c$') was intuitively appealing and explained almost half of the variance. (In fact a simple linear fit of the form $y = c - x$ fitted slightly better, but this response shape is unsatisfactory in theory.) In all cases the value of the y-intercept (where the modelled response cuts the ordinate, at $x = 0$) lay between 16 and

19.5 (compared with the preferred value of 17.2), suggesting that the estimate was fairly robust independently of the true shape of the distance decay function.

Bibby & Burgess (1997) list six assumptions that should be met or at least carefully considered when employing distance-based line transect procedures. Another requirement is that a minimum number of detections be recorded, and 40 is often cited as a minimum target, while 100+ is highly desirable (Bibby & Burgess 1997). PAN staff should consult this or a similar text when establishing a formal monitoring program for the CBBR.

The discrepancy between the data sets collected by the author (9-10 November) and PAN staff (24 November) is worrying; the two estimates of density are significantly different (t-test, $P < 0.05$). Two explanations are considered. First, PAN staff may have been either less observant or more cautious than the author in recording (possible) detections. Second, environmental conditions or the population's behaviour differed markedly between visits to NKI. Between-observer differences are the bane of multi-personnel population counting studies, and differences between observers can be considerable (e.g. Cunningham et al. 1999). However, the PAN staff seemed at least as competent as the author in detecting rails by sight and by sound, and so this cause seems improbable. It seems more likely that PAN staff exercised greater caution in attributing faint or brief calls to an actual detection, and that they may have been less inclined to attribute a series of punctuated calls to more than one individual, compared with the author. Also however, for reasons that could only be speculated upon, rails may have become less obtrusive during the second visit to NKI. I do not recall any obvious changes in their calling activity or visibility between visits, but birds' behaviour in general does frequently change through the day, from day to day, or over longer periods dependent on reproductive cycle and other factors (e.g. Bell & Ferrier 1985). For instance, if the majority of the population had moved from territory establishment activities to a nest-building phase between visits, then birds may have been calling less and becoming more secretive generally. This speculation is not supported by the fact that the proportion of 'heard-first' vs visual detections did not differ between data sets. Weather influences behaviour in the shorter term and it can affect observers' ability to detect birds, and so several possible explanations could be advanced if it were possible to demonstrate that a change in activity or behaviour actually occurred.

The above speculation is academic now, but a combination of factors is probably responsible for the different density estimates obtained. We know that Buff-banded Rails' behaviour is variable, that weather can have a strong influence (on birds, and humans' observational capabilities), and that observers differ in their observational skills and ways of interpreting their observations. Line-transect methods, in theory at least, should be able to circumvent some of these problems. If birds become more furtive, they are less likely to be detected at any distance, both the forward and perpendicular components, and so with sufficient data it should be possible to shadow such changes in behaviour; hence I advise that the two distances should be recorded for each observation. Also, the CBBRs as with most birds are more likely to be detected on the basis of audial cues (first) than purely visual cues; hence it is important to note whether the bird was detected first by sight or ear. If the population becomes generally silent but remains at the same density, the number of 'visual first' detections ought to remain fairly constant. In reality, however, a decline in foraging and calling activity may result in an apparent lowering of density estimates, particularly if birds in this mode can secretly move off the central portion of the transect in advance of the observer (Bell & Ferrier 1985; Bibby & Burgess 1997). On the other hand, if all birds within a narrow central band can be detected and detectability beyond this perpendicular distance falls away steeply, then density estimation should prove robust to changes in behaviour. This reasoning does caution against using a fixed-width belt transecting/analytical approach as the appropriate width will vary with detectability and because this analytical method is inherently wasteful of data (Bibby & Burgess 1997).

The population estimate for the NKI CBBR population of 750-800 birds (within the range of 550 to 1000) rests on the twin assumptions that 1) the density estimate is robust and reasonably accurate, and 2) the transect routes represent an unbiased or at least representative sample of the entire island land surface. Based on casual observations of birds around the entire island I am confident that rails were distributed fairly evenly across the island in November 1999. Rails do not appear to spend much time along the unvegetated sea shores, and so if the area of land involved was known, the island population estimate could be reduced accordingly. Also there is a possibility that rails are not as abundant in the coconut-dominated, eastern tract of forest north of the lagoon inlet. A few rails were detected in this tract, but there were fewer birds seen on the adjacent lagoon margins there than along the western lagoon shores (observation based on several scans of the eastern shore taken from the campsite). Several transects would need to be placed in this section (i.e. to the south of CBBR-4: Fig. 2) to evaluate this proposition. However, any reduced abundance in this part of PKNP (and the putative near-absence from the sea shores) is likely to be compensated for by the under-estimation of abundance of birds using the lagoon shores and adjacent thickets. I gained the impression that rails were particularly abundant in thickets of *Pemphis*, *Cordia*, cabbage bush (+/- coconut palms and *Pisonia*) adjacent to the lagoon, particularly across the northern, north-western, southern and channel inlet sections of NKI. I have previously outlined the reasons for my belief that birds went undetected within these thickets and along the lagoon shore to a greater extent than within the predominant, open forest-floor environment.

A population of 750 or more birds reveals that the CBBR is in healthier shape than was previously thought (Garnett 1992, 1993; Parks Australia 1999). Without knowing what are its effective population size and temporal variability, this number probably places the NKI population out of extreme danger of extinction through stochastic demographic and genetic processes that impact upon very small populations – figures of 50, 200 and 500 are often cited as a critical size in this respect (e.g. Soulé 1986; Quinn & Hastings 1988; Caughley & Gunn 1996). Effective population size depends on the ratio of adult males to adult females, the species' breeding strategy and spatial structure, and age structure of the population. At very low numbers, imbalanced sex ratios, expression of lethal genes, chance mortalities and poor breeding events, as well as 'environmental disasters' can result in the extirpation of small population (Caughley & Gunn 1996). It is important for PAN to find out the level of temporal variability in this population, and this will be one important objective of any future monitoring program. If high levels of variability are found, such that the population does swing to or towards an (arbitrary) threshold figure of 200, then intensive study and intervention might be urgently required.

The difficulty of statistically detecting medium-term trends through time increases with the short-term temporal variability of a population and with decreasing size of a population – it is a Catch 22 of conservation biology (e.g. Taylor & Gerrodette 1993; Lindenmayer & Burgman 1998), because the more variable and smaller a population the greater is management's need to know its trend! Taylor & Gerrodette's (1993) simulations with real data from an endangered porpoise illustrate the problem: there is less than a 50% probability (**power**) of detecting an annual decline of 10% in the population if the initial population size is less than a thousand as assessed after five years of annual surveys. Low power, such as in their example, means that managers would be unlikely do detect a **statistically significant** decline even after the population had halved after five years. Their results were dependent on the level of variance around their annual estimates, but they cautioned that their simulations undoubtedly underestimated the true variability around the estimates of population size. Lindenmayer & Burgman (1998) give similar sobering examples. Therefore, the implications are clear for the proposed CBBR population monitoring program – do not expect statistical trends to drive the risk-assessment and management-response process. Graphical analyses and interpretations will be pivotal to sensible decision making. A power analysis should still be undertaken, however, and it would be timely to do so after two years of quarterly sampling, when errors around the population estimates and actual temporal variability can be better explored and understood (e.g. Greenwood et al. 1994). Another apposite example that explores the power issue in some depth, involving an endangered seabird censused with distance-based, oceanic line transects, is provided by Becker & Beissinger (1999). Resampling techniques (e.g. bootstrapping) could be used to circumvent power problems and see Brindley et al. (1998) for an example.

Protocol for Population Monitoring of CBBR

Several refinements to the methods used in November are suggested. If adopted they would improve the rigour of the method and results, and provide additional information on the population's spatial distribution and habitat preferences. First, permanently marked transect routes should be established, using flagging tape or small tags. Second, one transect route should be marked with measured perpendicular distance flagging, so that all subsequent observers can be 'trained' to estimate distances accurately. The transect should be centrally placed and if multiple observers are involved, each should conduct a count along this route on each sampling visit prior to undertaking other transects. Third, the angle of the detection should be recorded (this is the angle made between the forward-looking transect path and the location of the bird) along with the two distance measures. Fourth, each transect should be divided into segments, either on a standard 50-m basis or a variable length could be used (but approximately 50 m) with segment ends coinciding with vegetation changes; all detections should be assigned to segments, and the time should be recorded when a new segment is entered. Fifth, the distribution of vegetation communities should be mapped along each transect.

Ideally, transects should be placed randomly, if systematically, around NKI – random placement is required to avoid bias (e.g. Kentish et al. 1996). In a draft of this report I recommended that 12 radial transects be established at random locations around the northern and western portions of NKI, but spaced to be 150+ m apart (measured at the lagoon shore). At current population levels, this number should easily allow a minimum of 40 detections per visit, generally many more. Transects could be any length, but 12 could be fitted around the broader parts of the island such that none is shorter than 200 m. The lagoon and sea shore should be included in the transects, as separate segments/habitats. However, in discussions with W. Murray (PAN) I have been convinced that the location of the Red-footed Booby transects is not seriously biased with respect to the distribution of vegetation types or other obvious forms of environmental variation. Ten booby transects are in current use, and two discarded routes can be added to achieve the target of 12 transects. PAN staff are mindful of the need to restrict human disturbance to a minimum in this wilderness-designated reserve, and so would prefer to use existing, marked routes. The mid-line of these existing transects will need to be clearly marked to ensure unbiased perpendicular distance estimation.

With three staff involved it would be a simple matter to conduct two counts per person per day in order to complete the 12 counts. If practical, counts should be undertaken in the early morning period (0630-0900) as there were some signs that rail activity had declined by mid-morning. Poor weather (moderate intensity to heavy rain, strong winds) should be avoided, and it ought to be possible (assuming visits of 2+ days, three staff) to complete all counts in one morning if necessary.

The need to restrict rail counts to the early morning period was questioned by W. Murray (PAN) on the grounds that this was the preferred time for PAN staff to do their booby nesting counts on account of the angle of the sun and attendant OH&S issues. I can only strongly recommend the desirability of undertaking rail counts during peak activity periods so that the number of detections can be maximised, with resulting smaller confidence intervals (= more reliable population estimates). The possibility of monitoring booby nesting effort in the late afternoon period is raised as one solution. A less satisfactory and time-consuming solution would be to calibrate early-morning counts against counts undertaken in the middle portions of the day. However, this may prove practical if the next suggestion is adopted.

It is recommended that four surveys a year be conducted for the first two years (2000-01), and that once a year a more intensive sampling program be undertaken such that each transect is counted three times (once by each observer assuming three observers). Early morning, middle of the day and late afternoon are the suggested sampling times for this exercise, so that some insight into the CBBR’s daily activity patterns can be gained quantitatively. A quarterly systematic sampling schedule will allow seasonal changes in behaviour and activity to be monitored. The program should be reviewed after two years, by which time a solid baseline will have been established. It may be possible then to reduce the sampling frequency or intensity, and concentrate monitoring activities more on risk surveillance (e.g. presence of cats, rats and other aliens). Were two surveys of rail daytime activity conducted in the early phase of the recommended two-year baseline program, using the same survey methodology each time, than the feasibility of calibration (raised above) could be further investigated.

The DISTANCE package is recommended for data analysis, once the basic numerical procedures employed here have been mastered. I can assist with initial data analyses and the use of DISTANCE and would welcome the opportunity to be involved as an informal collaboration. A modified field data sheet is attached (Appendix 2) for conducting transect counts. As soon as practical after each transect survey, data sheets should be copied, with a copy sent off-island for secure storage. Data can be entered into a spreadsheet and there are macros for Microsoft Excel for preparing data for entry into DISTANCE available from the Internet (see DISTANCE home page). Graphs (e.g. frequency histograms) of perpendicular distances of all detections should be plotted after each survey (see Fig. 3) to allow visual appraisal of the summarised data.

Given the likely problems that will be encountered with statistical analysis of population trends through time, discussed above, graphical interpretation of the results should be employed in the first instance. There is likely to be insufficient power due to the small population size to detect a downward trend. However, a statistical approach should be attempted, provided it is coupled to an analysis of power, so that the appropriate conclusions can be drawn in the event that no significant trends are detected. A statistical review of the data should be undertaken at the end of 2001.

Bell & Ferrier (1985) elegantly demonstrated that distance-based transect estimates of population size in birds can be seriously biased; the only sure way to ascertain the extent of bias is to employ a second, independent method to estimate population size. In their examples, a large proportion of the adult sedentary population had been individually marked and territories mapped, such that by recording information on the abundance of recently produced offspring and unmarked ‘floating’ adults, they could estimate true population sizes with confidence. In the case of the CBBR, undertaking such an exercise would not prove as easy due to the more cryptic nature of the bird, the greater difficulty of catching them, as well as the problems associated with access and OH&S issues on a remote island. Also if the CBBR establishes and maintains territories only through the breeding season, as has been suggested in the literature for the species (Marchant & Higgins 1993), and shows no site fidelity between breeding periods, this would also increase the difficulty. Were subsequent resightings of individually marked birds found to be too infrequent, alternative techniques would need to be considered, probably telemetry. Because of the labour-intensive and expensive nature of mounting such a study and due also to the logistical problems noted, such an investment is not considered financially prudent currently, and there are doubts over its logistical feasibility.

Other Desirable Information Requirements

Ideally, quarterly estimates of seabird breeding activity along each transect would be recorded to investigate if systematic changes in rail density were correlated with this variable. A belt of 40-m width could be permanently established along the length of each transect, and in a quiet part of the day all nests and resting birds of all species could be counted. It is realised that this might more than double the workload (over censusing rails alone), and so PAN staff will have to decide if they can afford the extra effort/time.

A reporting scheme needs to be established so that interesting and general observations of the CBBR are regularly recorded and filed safely during and after each sampling trip to PKNP. In particular, dietary, foraging height, habitat use, daily activity cycles, calling behaviour and activity, and especially breeding details, should all be recorded.

Risk Assessment – Threats to the CBBR

To date five causes have been put forward for the demise of the CBBR on the southern atoll of the CKI. They are predation by introduced cats, predation by introduced rats, human predation, competiton with feral chickens, and habitat change, namely the conversion of natural mixed-species forest to coconut plantations (Stokes et al. 1984; Garnett 1992, 1993; Anon. 1999; PAN 1999). It is possible all factors acted in concert to cause the southern population's extirpation, and it is impossible to find out retrospectively which factor or factors may have been the most important. Latest opinion on the subject identifies habitat transformation followed by cat predation as the two most critical factors (Anon. 1999). One interesting facet of their demise is the decline lagged behind that of breeding populations of the larger seabirds (boobies, noddies and frigatebirds), at least by 50 years and perhaps by 100 years judging by the observations presented in Stokes et al. (1984). While the decline was certainly underway by 1940 (Gibson-Hill 1949), the southern population survived until 1991 (Stokes 1994), i.e. over 100 years after breeding by seabirds had virtually ceased.

One factor potentially contributing to the population's demise not canvassed to date is the loss of critical food resources attendant with the loss of the breeding seabird populations in the southern islands, either directly (eggs and scavenged food) or indirectly (productivity enhancement hypothesis: Polis et al. 1997). In addition to these various potential causes, possible threats to the small NKI population include the stochastic perils of genetic and demographic failure, and environmental catastrophes such as exceptional drought or a direct hit by an intense cyclone (see Caughley & Gunn 1996; Lindenmayer & Burgman 1998). The risk of genetic and demographic failure decreases with increasing size of the population, while the potential for environmental catastrophe will be negatively correlated with the population size and the smaller the geographic extent of the population (Simberloff 1994). Having a single, small, geographically restricted population is certainly a risk in itself as recognised in the draft *Interim Recovery Strategy* (Anon. 1999), and so the establishment of a second population becomes a management priority (Garnett 1992; Anon. 1999).

Risk assessment involves weighing the tradeoffs between costs and putative benefits of management actions against the risk to the population if that action is not taken, and against the risks involved with alternative actions. Financial resources are limited, and so the extreme 'precautionary principle' approach – to take action against all potential threats – is impractical and unaffordable. **Risk-assessment is pursued here for the twin issues of protection of the NKI population and establishment of a second population.** Both objectives must be met if the conservation status of the CBBR is to be improved, i.e. to remove it from the Endangered species/population category. Below, I state my views on the seriousness of the threats which have been advanced to account for the decline of the CBBR or which imperil the surviving NKI population or which may jeopardise reintroduction attempts. Knowledge of the natural history of the species is important here (Green 1994) and it is this knowledge, both of the rail and the most likely threatening agents, that should guide the recovery process, including appropriate responses by management should a threatening process be detected.

Very Small Population Risks – Genetics and Demographics

The CBBR population on NKI, estimated to be 750-800 birds, is believed to face a very low risk of stochastically-driven extinction through chance demographic or genetic failure (e.g. Quinn & Hastings 1988). I argue that this is the case based on its survival to date.

Small-number problems are more likely to affect a founder, reintroduced population that cannot be intensively managed like a captive-bred population. For this reason it would be ideal to introduce 40+ birds (with an even sex structure) to the chosen site for reintroduction in the southern atoll. A target of 40 birds may only be feasible if the birds have been captive bred, as there may be logistic or ethical problems with attempting to catch that many wild birds in PKNP for reintroduction purposes. Alternatively, smaller numbers (e.g. 10) could be directly translocated, but in the knowledge that failure of the reintroduction would be more likely.

Very Small Population Risks – Natural Environmental Disasters

The CBBR population on NKI would seem to be at greater risk from extreme weather events, whether an intense tropical cyclone or prolonged drought (e.g. Simberloff 1994). However, the population has survived the meteorological extremes experienced over the last 100 years or more and quite likely in the **absence** of recruitment (rescue) from dispersing birds on the southern atoll. The population survived when the eye of TC John was thought to pass over or close to NKI in 1989, but there is always the risk that a much more powerful storm could directly hit the island and effectively wipe out the population (if not at the time, then afterwards due to food shortages or chance factors). Extreme weather is predicted to become more frequent in most parts of the world under climate change scenarios, but I do not know the predictions for this part of the Indian Ocean. The risk of total demise would appear to be small (e.g. Ogden 1993), but the establishment of a second population should be pursued vigorously as the fact that intense storms can cause the extinction of small island bird populations has been documented (Simberloff 1994).

Any wild foundling population, such as on the southern atoll would be exposed to similar environmental risks, but at least the probability of both the southern and northern atoll bearing the full brunt of a massive cyclone would be small. A captive managed colony would be more secure from the threat of these risks. However, captive colonies, especially those in zoos and similar institutions, run the risk of being exposed to new infections, disease and parasites.

Human Predation

The risks from this agent appear small in the current social environment across the CKI. Were refugees or shipwrecked survivors be stranded on NKI for a period, it is unlikely that rails would be targeted for food, given there are several larger, more abundant and more approachable species. This potential threatening factor was probably only ever a small contributor to the CBBR's demise on the southern atoll, if at all (Anon. 1999). With a sound communications strategy in place, there ought to be no problems with a reintroduction program either.

Cat Predation

Wild cats were abundant on West Island during my visit – I was surprised at the frequency of encounters. Their numbers have obviously rebounded since an apparently successful cat-control program carried out in the early-mid 1990s (Garnett 1992, 1993). The introduction of cats has been implicated in the extirpation of many vertebrate population on small islands around the world (e.g. Burger & Gochfeld 1994; Collar et al. 1994; Sandlund et al. 1999; *IUCN Red Data Books*). Although rigorous evidence is lacking in most cited cases (as here), I consider it likely that they were the most potent agents of decline in the CBBR population on the southern atoll. The size of the Buff-banded Rail (adults: *ca* 200 g) and its terrestrial habits place the species within the cat's dietary size range (if not its preferred range: Pearre & Maass 1998) and in its preferred foraging zone (e.g. Jones 1977; Catling 1988; Barratt 1997; Paltridge 1997). Interestingly, Garnett (1993) concluded that cats and the Macquarie Island subspecies of Buff-banded Rail coexisted for 70+ years prior to the bird's sudden extinction, which he attributed to the later introduction of a larger congeneric rail (Weka *Gallirallus australis*), through predation, and the rabbit. Garnett (1993) concluded that cat predation may have eventually played a role in the demise of this population, speculating that the island's predator-prey dynamics altered following the rabbit's introduction (see Courchamp et al. 1999 for theoretical elaboration). That cats do prey on the CBBR was confirmed by the observations of P. Stevenson in Garnett (1993) – the last recorded individual on the southern atoll (West Island) was taken by a cat in August 1991.

Provided access to PKNP continues to be managed strictly, and with sufficient monitoring of unauthorised landings (or strandings, e.g. following shipwrecks), it appears improbable that a feral cat population could be accidentally established on NKI. Should such an unlikely event occur, however, immediate intervention would be predicated: an intensive eradication strategy would need to be implemented urgently, and an intensive rail-trapping program should be instigated to transfer animals to a safe haven, presumably a zoological institution. This requires PAN to have an effective strategy devised in anticipation of cats becoming established on NKI. It would seem prudent to prepare such a strategy as a matter of priority.

As reintroduced populations will inevitably be small to start with, it is essential that efficient predators, such as wild cats, be eradicated first. Cat eradication has proven difficult in other situations due to the extreme trap-and bait-wariness of some individuals in most populations, but there are now successful models for small islands that can be followed (e.g. Clout 1999: New Zealand; Huntley 1999: South Africa; A.A. Burbidge, *personal communication*: Western Australia).

Rat Predation

Two species of introduced rats are believed to be on the CKI, but as far as is known PKNP is free of them (Parks Australia 1999). Wood Jones (1909) collected specimens of the Brown Rat *Rattus norvegicus* and two forms of the Black Rat *R. rattus* from the southern atoll. In fact the Cocos-Malay name given to Direction Island, Pulu Tikus, refers to the endemic population of rats that lived there at the time of first human settlement (*R. rattus*?). The human-facilitated introduction of rats has been implicated in the extinction of many island birds, perhaps even more so than cats (Steadman 1995). Garnett (1993) recommends that rat control may be required to maximise the success of any reintroduction program in the southern atoll. The draft *Interim Recovery Strategy* (Anon. 1999) is equivocal over whether rat control would be necessary (or feasible?) for a successful reintroduction of the CBBR. The Government Conservator (W. Murray, *personal communication*) advises that the small distances between islands might allow rapid reinvasion even if rats could be eradicated. Since the favoured release site, Horsburgh Island, is 3 km from the closest island, the chances of unassisted recolonisation are probably small (A.A. Burbidge, WA CALM, *personal communication*).

Continual vigilance is required to minimise the risks of the introduction of rats onto NKI; a shipwreck/stranding of a rat-infested vessel appears to be the main threat in this respect. These risks are identified already (Parks Australia 1999). In the event that rats did establish on NKI, Parks Australia would face a dilemma: whether to attempt immediate eradication with the use of standard rodenticides, having the potential for consequent non-target impacts, or whether to delay such drastic intervention and instead monitor bird and other populations to evaluate the severity of any impacts. Again, a strategy, informed by expert opinion, needs to be formulated in advance so that a management response can be swiftly implemented as required.

Expert advice is also required to reach an appropriate decision about the need for rat control/eradication on Horsburgh Island and if there are means by which the likelihood of reinvasion from adjacent islands could be reduced to manageable levels. Ideally, rats would be controlled as part of a reintroduction strategy, given the major role that as a group they have played in the extirpation of rails, other terrestrial birds and seabird colonies on numerous islands (Temple 1986; Burger & Gochfeld 1994; Steadman 1995). Certainly, rat eradication is feasible with current technologies (poisoning – e.g. New Zealand: Clout 1999; Western Australian offshore islands: Burbidge 1999), and should be pursued.

Competition with Junglefowls

Virtually all islands in the southern atoll have wild or semi-wild populations of junglefowls. In some respects, particularly in their dietary catholicism and manner of feeding, junglefowls and the Buff-banded Rail (species-wide at least) are very similar ecologically, being terrestrial, omnivorous and opportunistic in the extreme. The observations of Wood Jones (1909) suggested that the CBBR of the southern islands behaved in this manner. Small islands are renowned for their relatively simple ecology, and often there is only room (in terms of niche space) for a single species to fulfill a particular role (e.g. Rodda et al. 1998), which in this case would be that of a generalist, forest floor, 'chicken'. It seems quite possible that, in conjunction with the extensive habitat transformations and demise of the seabird colonies on the southern islands, the balance was tilted in favour of the protected (indeed actively encouraged), but largely free-ranging, feral chickens – the Red Junglefowls on all islands apart from West Island where the Green Junglefowl has flourished (Carter 1994). There would also have been the potential for interference competition, as the larger junglefowls may well have actively excluded the smaller rails from preferred feeding sites. The draft *Interim Recovery Strategy* (Anon 1999) also considers this possibility, and correctly asserts that it would be prudent to eradicate wild junglefowls from any islands selected for CBBR reintroduction. Junglefowls would be readily eradicated from islands, but any such campaign would need to be undertaken with the approval of the CKI community.

Decreased Productivity Hypothesis

I have raised the possibility in this document that, associated with the virtually total demise of seabird rookeries from the southern atoll, a vital input of organic matter and nutrients may have been lost to the terrestrial ecosystem. This in turn may have lowered the capacity of the CBBR to maintain sufficient body weight and breeding condition, or at least placed individuals at greater risk of predation if they were required to forage for longer periods and away from cover. The transformation of the original complex forest to simplified plantation mix and structure would only have exacerbated these effects.

If rails can be reintroduced to Horsburgh Island with the concomitant removal of all exotic vertebrates, then this would allow an interesting test of this hypothesis, particularly if the island's vegetation could be restored over time. Under this hypothesis a population on Horsburgh Island, free of predators and avian competitors, would not be expected to attain the same density as the population on NKI.

Vegetation Change

There is no likelihood of the anthropogenic transformation of the vegetation on NKI as occurred on the southern atoll during the early settlement phase, and so consideration is restricted to the role of this process in the southern population's extinction.

It is highly probable that the conversion of the southern atoll ecosystem from a diverse natural forest to a much simplified coconut plantation had some impact on the CBBR population. Indeed it is surprising that its demise took so long. I conclude that the CBBR must have been quite resilient to this extreme transformation in order to persist for as long as they did. It seems quite possible, therefore, that the population may have survived this impact if it had not been for the additional imposition of predation (by cats and rats) and perhaps competition (by junglefowls). Each process presumably played its part. However, it does not seem necessary to wait for Horsburgh Island to be fully revegetated before initiating reintroduction, provided that the feral predators and junglefowls are eradicated (preferably, or at least stringently controlled). The priority should be with the feral animal control programs rather than revegetation. The reasoning underpinning this argument is clear. Small populations, founding or otherwise, are at greatest risk from top-down forces, namely predation, and to a lesser extent interspecific competition for food. Bottom-up forces, such as insufficient production of food resources, are less likely to become an issue until the population begins to grow strongly when density-dependence limits to growth should become apparent.

Reintroduction Program – Captive Breeding or Direct Translocation?

Put bluntly by Rodda et al. (1998), the majority of translocation attempts with endangered birds have failed. Rodda et al. (1998) are equally critical of captive-breeding programs, when success is measured only by successful reintroduction (self-sustaining) from the captive-bred stock. However, captive breeding in accredited zoological institutions has often been successful in at least maintaining a critically-endangered species in existence. Should the

PKNP population of CBBR plummet suddenly below 100-200 or otherwise move into the Critically Endangered category, captive breeding may be the only recourse for the bird's survival. Buff-banded Rails are readily maintained and bred in captivity, and so provided a sufficient number could be captured from the wild in the first place, this option appears feasible, as discussed previously. Currently though, this course of action does not seem warranted. What is problematic is whether a population should be reintroduced to the southern atoll directly when the site is prepared or whether a larger population should be bred in captivity beforehand. A variant of these alternatives would be to consider a combined strategy, i.e. when the time comes, reintroduce birds from both sources (bet-hedging). Under this strategy there would be truly wild birds, presumably with a greater chance of faring readily in a strange but similar environment, buffered from demographic stochasticity through the addition of captive-bred stock which, although naive to an extent, would have their experienced wild cousins to learn from. Current reintroduction biology opinion favours direct translocations over the alternatives involving the intermediate step of captive breeding (Appendix B: Melody 1994), provided sufficient numbers of animals can be caught (P.B. Copley, SA Department of Environment & Heritage, *personal communication*).

Despite the cautionary tone expressed by Rodda et al. (1998), techniques for reintroduction have been honed in recent years to engender a mild degree of optimism for future attempts, particularly if the lessons and experience gained from previous work are shared and heeded (Saunders 1994; Burbidge 1999). Much of this recent success stems from New Zealand efforts using offshore islands (Saunders 1994; Clout & Craig 1995; Clout 1999), but there are heartening developments in Australia as well, again mainly on offshore islands (A.A. Burbidge, *personal communication*). Success is usually contingent on removal or amelioration of the threatening processes, i.e. securing the site (Dr N. Mazur, ANU, *personal communication*), particularly eradication of feral predators (Saunders 1994; Burbidge 1999), in addition to minimising the stress to the animals during translocation.

There is a draft ANZECC statement currently under review that deals with translocations of threatened Australian animals (A.A. Burbidge & P.B. Copley, *personal communication*). It is uncertain whether it will be prescriptive (a 'policy' statement) or advisory (a 'guidelines' statement). However, similar guidelines and policies are in routine use within South Australia and Western Australia. In addition, the *IUCN position statement on translocation of living organisms* (IUCN 1987) and the *IUCN guidelines for re-introductions* (IUCN 1998) should also be referred to, when planning translocations and reintroductions. Translocation in this context includes the reintroduction of animals bred in captivity, whereas in this report I prefer to distinguish between 'direct translocations' and 'captive-bred reintroductions' as used earlier. The guidelines in all these documents advise on sensible and comprehensive documentation of all aspects of any reintroduction attempt. Under the existing *Endangered Species Protection Act* (1992) and the imminent *Environmental Protection and Biodiversity Conservation Act* (to take effect from July 2000), there are various permits required to trap and transport endangered animals when this action is being contemplated on Commonwealth land.

The major problems with captive breeding are the financial costs involved, risk of disease and parasites, and loss of wildness in the captive-bred population. If these obstacles can be overcome and quality-assurance provided with respect to health risks, then having a captive population provides as strong protection against extinction as is possible. Furthermore, under the 'combined strategy' outlined above, it provides a convenient larger population for reintroduction attempts than might otherwise be possible. I would not rule out the captive-breeding option, especially if a suitable institution offered a fully-resourced program (see guidelines in next section). Additional benefits that ought to flow from a captive-breeding colony include wider community education, opportunities to gain detailed biological knowledge of the species, and immediate protection is secured by establishing a second population. However, the provision of external resources is unlikely, and so if a modest reintroduction budget is envisaged direct translocation becomes the preferred option, subject to several riders. These are that a) a suitable number of animals can be caught in a short period, without b) causing undue disturbance to the NKI population, or more generally to the NKI environment and its particular wildlife values, and c) without significantly further endangering the viability of the NKI CBBR population itself.

Our recent experiences suggest that large numbers of rails will be difficult to trap in a short period, but I consider it to be possible. A combined strategy of many mist nets (10+) and many baited traps (20+) and a large taskforce (6 personnel) would be required. A period of free-feeding inside open traps prior to the capture date to habituate the population to entering and feeding from cages is recommended. The nets would best be placed at the edge of the fringing vegetation around the lagoon shore, and an ambush tactic then used to scare birds into nets after they had ventured onto the shoreline. Some of the personnel would need to be experienced in safe bird handling and bird transport. It ought to be practicable to capture 20-40 birds in this manner over a 2-4 day period, after preliminary trials including free-feeding. It is unlikely that the captured birds will be able to be sexed at the time, but all birds should have blood samples taken (along with standard morphological measurements) so that the sex structure and genetic variability within the founding population can be ascertained retrospectively. All translocated birds should be banded, colour-banded individually and fitted with small radio-tracking transmitters, so that their immediate fate on Horsburgh Island can be followed. It ought to be possible to conduct an intensive and extensive trapping program on NKI without serious detriment to the welfare of the CBBR population or other seabirds. Provided that an intensive census prior to the translocation exercise reveals the population to be at close to its current size (500+), an off-take of a maximum of 40 birds (< 10%) should not prejudice the population's viability in the short or longer term.

Captive Breeding Program – Its Potential Use and Requirements

I am required to recommend actions to be taken if a captive breeding program is pursued for the CBBR and identify suitable procedures and institutions for establishing a captive colony. However, as discussed above a captive breeding program may not be necessary. I have also been advised (G. Slater, Zoological Parks Board of Victoria, *personal communication*) that national procedures have been established that means the choice of the most appropriate institution should be made in consultation with an expert ('Taxon Advisory Group') committee. Therefore I can only advise on what might be the desirable attributes to look for in a zoo or similar facility in terms of skills, expertise and geographic location. Climatically, a northern Australian institution would be more appropriate than a cool temperate location. The Taxon Advisory Group for Birds (Acting Chair, Liz Romer, Sydney) could advise on institutions that have demonstrated their willingness to work cooperatively with state and federal wildlife agencies in aiming to achieve recovery of endangered birds in the wild through captive breeding. Candidates include Corrumben, Taronga (Sydney), Perth Zoo, Territory Wildlife Park (Berri Springs), and Desert Wildlife Park (Alice Springs).

Were a captive breeding program to be initiated a detailed planning process would need to be worked through first, guided by specialist input from the Regional Zoos Association, the Taxon Advisory Group, and Commonwealth wildlife experts. However, by way of preliminary advice on appropriate procedures, the following advice is offered (based on material provided by G. Slater, *personal communication*). The most affordable option for a dedicated captive breeding program would be to remove eggs from a range of rail's nests on NKI, and to have them brooded by a suitable foster rail in the institution. This is most likely to be the mainland form of the Buff-banded Rail which is an easily managed zoo animal, but particular care would need to be taken to separate all juvenile independent *andrewsi* from their foster parents to prevent interbreeding. A range of nests should be sourced to increase the scope for genetic variability. Translocating birds from North Keeling to an institution poses additional risks to the birds (transportation of eggs is easier). The practice of hand-rearing either parentless juveniles or eggs at the institution by humans is labour and costs expensive. These two options are not preferred. There is a need to ensure that the chosen foster taxon will accept a foreign clutch of eggs, but this is unlikely to be a problem with rails. The foster parents would need to be in reproductive mode. In 1999 G. Slater advised that start up costs for a 25-pen aviary complex for sole use to such a project might be in the order of $25,000. It would be worthwhile for PAN to canvass the potential for obtaining this kind of monetary support, and preliminary discussions with the Regional Zoos Association (and the Taxon Advisory Group) are recommended.

Recommendations

1. Monitoring of the CBBR population on NKI should be initiated on a quarterly basis through 2000 and 2001 at the completion of which a review of the program should be undertaken. The review would need a statistical component.

2. Any apparent crash in the population should signal alarm, and trigger an immediate intensive study to determine the (likely) cause(s) of the decline and to assess the need for establishing a captive population at a secure site – crisis response. The establishment of feral cats on NKI should also trigger a 'crisis response'. The establishment of rats on NKI or a direct hit by a cyclone should trigger more intensive population monitoring to determine whether translocation is required in the short term.

3. **Maintaining the security of NKI is the foremost requirement for persistence of the CBBR in the shorter and medium term**; PAN recognises this already; I can recommend nothing further here; I commend current policy concerning, and management of, PKNP – continual vigilance is required.

4. A molecular survey of the CBBR in the context of the wider species should be commissioned by PAN so that its likely origins and systematics can be better understood. Provided DNA-bearing tissues can be obtained from a minimum of five individuals from the CBBR (*andrewsi*) and the Australian subspecies (*mellori*, *tounelieri*), the Flores subspecies (*wilkinsoni*), Timor population (*philippensis*) and several other near-Pacific island populations, a modest grant of <= $10,000 would be sufficient for this project (e.g. graduate Honours study). The Environmental Biology Unit at the South Australian Museum would be an appropriate and qualified institution.

5. **The establishment of a second, geographically separate, population is the crucial action needed to improve the survival prospects of the CBBR in the medium to longer term.** Greater financial investment and strategic planning are required to advance this objective.

6. Attempts to secure a viable site on the southern atoll should intensify and greater urgency be given to a reintroduction program. Horsburgh Island is already identified, and action to eradicate feral animals should be initiated as a priority. Eradication of cats, rats and

chickens should take precedence over revegetation in terms of securing the site. Revegetation has commenced and it can continue, but the point is that it can proceed satisfactorily after a reintroduction occurs, whereas the eradication of feral animals must be completed prior to any reintroduction attempt. **The imperative rests with establishing a second population, sooner than later.** Removal of most of the island's interior coconuts should facilitate feral animal control and revegetation programs.

7. Eradication of cats and rats from Horsburgh Island (*ca* 120 ha) will be difficult but should be feasible with dedication and persistence. Recent Western Australian experiences (A.A. Burbidge, CALM) should inform this program.

8. Provided the NKI population remains at current levels (500+), a reintroduction strategy involving direct translocation of wild birds is preferred to establishing a captive-breeding colony; a target of 40 birds should be aimed for, with a minimum figure set at 20. This is extremely unlikely to affect the NKI population's viability.

9. Notwithstanding Recommendation 8, the establishment of a captive-breeding colony would be desirable if external funds were forthcoming. Provided safeguards and protocols were strictly observed, a successful captive-breeding program would substantially reduce the immediate risks of extinction. There is the potential for far-reaching community education benefits as well as the provisioning of birds to augment the reintroduction program. Discussions with the Regional Zoos Association of Australia (and their bird Taxon Advisory Group) are recommended.

In conclusion, the priorities for enhancing the recovery of the Cocos Buff-banded Rail are:

1. **Undertake rail surveys on North Keeling Island four times a year for the next two years to establish a baseline.**
2. **Initiate work on rat, cat and feral chicken eradication on Horsburgh Island, pending approval from the Cocos (Keeling) Islands Council and external funding support.**
3. **Prepare a crisis strategy that covers stochastic disasters and the accidental introduction of feral animals to Pulu Keeling National Park.**
4. **Prepare a captive-breeding plan and obtain the necessary approvals/agreements; implementation following either a crisis event or sufficient funding.**
5. **Conduct an annual (or twice yearly) survey of rail daytime activity patterns.**
6. **Commission a genetic study of the Buff-banded Rail to clarify the taxonomic and systematic relationships of the Cocos subspecies.**

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[Several references enclosed in square brackets have not been formally cited in the body of the report.]

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Appendix 1. Raw Data: Transect Counts of Cocos Buff-banded Rails

Transect RFB-I 9/11/99 0710-0720 300m W Obs:JR

#	Meth	Habitat	Ddist	PDist
1	S	Lagoon	-	-
2	H	Cordia	-	30
2	HS	Pg-Coc	12	2
1	H	Pg-Coc	-	25
1	H	Pg-Coc	-	35

Transect RFB-B 9/11/99 0725-0735 300m E Obs:JR

#	Meth	Habitat	Ddist	PDist
1	S	Pg	10	0
1	H	Pg	-	30
1	S	Pg	6	5
1	S	Pg	30	8
1	HS	Pg	15	15
1	H	Pg-Coc	50	5
1	HS	Pg-Coc	50	15
1	S	Pg-Coc	30	30
1	H	Pg-Coc	40	40
1	H	Cordia	12	10
1	S	Lagoon	30	30

Transect RFB-L 9/11/99 0745-0800 300m W Obs:JR

#	Meth	Habitat	Ddist	PDist
1	H	Pg	15	0
1	S	Pg	35	30
1	S	Pg	30	20
1	HS	Pg	35	30
1	S	Pg	15	10
1	H	Pg	-	40
1	HS	Pg-Coc	10	0
1	H	Pg-Coc	-	20
1	H	Pg-Coc	-	30

Transect RFB-A 9/11/99 0820-0835 300m E Obs:JR

#	Meth	Habitat	Ddist	PDist
1	H	Pg-Coc	-	10
1	HS	Pg	15	3
1	HS	Pg	10	10
1	HS	Pg	5	2
1	H	Pg	-	10
1	H	Pg	-	40
2	H	Pg	30	15
1	H	Pg	-	10

Transect CBBR-1 9/11/99 0850-0905 300m W Obs:JR

#	Meth	Habitat	Ddist	PDist
1	S	Lagoon	-	0
2	S	Pg	15	5
1	H	Pg	-	20
2	HS	Pg	40	15
1	S	Pg	30	15
1	H	Pg	-	30
1	H	Pg	-	20
1	HS	Pg	15	15
3	S	Pg-Coc	7	0
1	HS	Pg-Coc	10	5
1	H	Pg-Coc	-	30
1	H	Pg-Coc	-	30

Transect RFB-C 9/11/99 0925-0935 300m E Obs:JR

#	Meth	Habitat	Ddist	PDist
1	H	Pg	-	40
1	HS	Pg	25	15
1	H	Pg	-	0
1	HS	Pg	40	7
1	S	Pg	35	15
1	H	Pg	-	30
1	S	Pg	5	5
1	HS	Pg	45	35
1	S	Pg	20	0
1	H	Cordia	-	10
1	H	Cordia	-	20

Veg Transect Y 9/11/99 0950-0955 100m SW Obs:JR

#	Meth	Habitat	Ddist	PDist
1	H	Pemphis	-	15

Transect RFB-P 9/11/99 1000-1005 200m N Obs:JR

#	Meth	Habitat	Ddist	PDist
1	HS	Pg ecotone	20	12
1	HS	Pg ecotone	15	10
2	S	Pg	25	10
1	H	Pemphis	-	15

Transect CBBR-2 9/11/99 1020-1025 200m N Obs:JR

#	Meth	Habitat	Ddist	PDist
1	S	Argusia	10	5
1	H	Arg-Pg	-	20
2	S	Cocos	15	10
1	H	Cord-Cocos	-	10
1	S	Cordia	5	3
1	H	Cordia	-	0
1	H	Pemphis	-	10

PAN Staff

Transect RFB-J 10/11/99 0715-0725 200m NW Obs:JR

#	Meth	Habitat	Ddist	PDist
1	H	Pg	-	35
1	H	Pg	-	20
1	HS	Pg	40	30
1	H	Pg-Cocos	-	25
1	H	Pg-Cocos	-	20

Transect CBBR-3 10/11/99 0730-0740 200m ENE Obs:JR

#	Meth	Habitat	Ddist	PDist
1	HS	Pg-Cocos	30	20
1	H	Pg-Cocos	-	35
1	HS	Pg-Cocos	20	20
1	H	Pg-Cocos	-	5
1	H	Pg-Cocos	-	15
1	H	Pg-Cocos	-	10

Transect RFB-F 10/11/99 0750-0810 400m S Obs:JR

#	Meth	Habitat	Ddist	PDist
1	S	Pg-Cocos	3	0
1	H	Pg-Cocos	-	35
1	S	Pg	10	0
1	S	Pg	20	0
1	H	Pg	-	30
1	H	Cordia	30	20
1	S	Pg-Cordia	20	18
1	HS	Pg-Cordia	35	10
1	S	Pg-Cordia	40	5
1	S	Pg-Cordia	35	20
1	S	Pg-Cordia	40	25
2	S	Pg	20	15
1	HS	Pg	20	10
2	H	Pg	-	5
1	H	Pg	-	30
2	S	Lagoon	-	-

Transect CBBR-4 10/11/99 0830-0845 400m ENE Obs:JR

#	Meth	Habitat	Ddist	PDist
1	H	Pemphis	-	15
2	H	Cordia	-	15
1	H	Cordia	-	20
2	S	Cordia	10	0
1	S	Pg-Cordia	15	5
1	S	Pg-Cocos	40	20
1	H	Pg-Cocos	-	25
1	H	Pg-Cocos	-	20
1	H	Cocos	-	30

Transect RFB-K 24/11/99 0900-0915 300m E Obs:WM

#	Meth	Habitat	Ddist	PDist
1	S	Pg-Cocos	10	0
1	H	Pg-Cocos	40	30
1	H	Pg-Cocos	30	10
1	S	Pg-Cocos	25	20
1	S	Pg	10	0
1	H	Pg	20	20
1	S	Pg	30	20
1	H	Pg	40	0
1	H	Pg	40	30

Transect RFB-C 24/11/99 0930-0945 300m W Obs:WM

#	Meth	Habitat	Ddist	PDist
2	HS	Pg	30	10
1	H	Pg	40	40
1	H	Pg	40	30
1	H	Pg	30	30
1	HS	Pg	20	20
1	HS	Pg-Cocos	20	20
1	HS	Pg-Cocos	40	30
1	S	Pg-Cocos	40	35
1	H	Pg-Cocos	30	30

Transect RFB-B 24/11/99 0900-0915 300m W Obs:IM

#	Meth	Habitat	Ddist	PDist
1	H	Pg-Cordia	30	30
1	S	Pg	25	20
1	H	Pg	35	15
1	S	Pg	4	4

Transect RFB-A 24/11/99 0930-0945 300m E Obs:IM

#	Meth	Habitat	Ddist	PDist
1	S	Pg	18	14
1	HS	Pg	6	3
1	S	Pg	20	0
1	HS	Pg	7	5
1	H	Pg	30	30

Transect RFB-D 24/11/99 0855-0915 400m NNW Obs:RT

#	Meth	Habitat	Ddist	PDist
1	H	Pg	20	10
1	H	Pg	30	20
1	S	Pg	30	0
1	H	Pg	30	20
1	S	Pg	40	30
1	S	Pg-Cocos	25	25
1	S	Cocos	5	5

Transect RFB-F 24/11/99 0930-0945 300m S Obs:RT

#	Meth	Habitat	Ddist	PDist
1	H	Cocos	20	20
1	SH	Pg	20	20
1	S	Pg	20	20
1	S	Pg	30	20

Appendix 2. Modified Transect Sheet for Cocos Buff-banded Rail Monitoring

Date: / / Transect ID: Weather: Bearing:

Start: Finish: Observer: Tran Length:

No.	Meth[1]	Habitat[2]	Ddist[3]	Pdist[4]	?[5]	Notes
Tot						

[1] **H**: heard only; **S**: seen without being heard first
HS: heard first then seen

[2] **Habitats** (used so far)
Pg – Pisonia grandis
Pg-Cocos
Cocos
Cordia
Pemphis
Argusia
Hab1/Hab2 – ecotone between 2 habitats

[3] Direct distance between bird and observer

[4] Perpendicular distance from bird to transect line

[5] acute angle between bird and transect line