Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	27
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	Christmas Island - rehabilitation		
Hansard Page ECA:	110 (27/5/09)		

Senator SIEWERT asked:

Senator SIEWERT—Are you able to give us an update on the rehabilitation? It is some time since I have asked where the rehabilitation is up to, so I would appreciate an update.

…

Mr Cochrane—Yes. Secondary plantings are where we go back after a couple of years when the pioneer species have got to sufficient size and we plant a range of other species which need the shade to keep going. In total that is another 41 hectares all up.

Senator SIEWERT—Forty-one hectares all up and what percentage is that?

Mr Cochrane—What percentage of the task ahead?

Senator SIEWERT—Yes.

Mr Cochrane—The task ahead is a matter of judgement because we think a total of a couple of thousand hectares should be rehabilitated. However, there is not enough soil on the island to do that. We are much more likely to be able to rehabilitate perhaps up to 1,000 hectares, but it is dependent on the availability of soil, and that is where it intersects with what the mine does.

Senator SIEWERT—You probably can do 1,000 or is that how much you need to do? I misunderstood what you meant there.

Mr Cochrane—I would like to take that on notice, so I can give you a precise answer of what we would like to see as the target.

Senator SIEWERT—That would be appreciated.

Answers:

Approximately 3,150 hectares have been cleared on Christmas Island since settlement.

Under the rehabilitation program, Christmas Island National Park has prioritised 700 hectares of the cleared land with a high or medium priority status for future rehabilitation based on their proximity to Abbott's booby nest sites or other significant environmental areas such as high crab density.

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	28
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	Helicopter flights over Kakadu		
Hansard Page ECA:	116 (27/5/09)		

Senator TROETH/BIRMINGHAM asked:

Senator TROETH—Have any other dignitaries been provided with helicopter flights over Kakadu over the past year?
Mr Cochrane—Not to my knowledge, but can I take that on notice?
…
Senator BIRMINGHAM—Could you also take on notice any similar types of special treatment or experience in other national parks?
Mr Cochrane—Sure.

Answers:

No flights have been provided to other dignitaries over Kakadu or any other National Park.

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	29
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	National Landscapes - expenditure		
Hansard Page ECA:	117 (27/5/09)		

Senator MACDONALD asked:

Mr Cochrane—National Landscapes.
Senator IAN MACDONALD—Are there receipts of the expenditure for that program?
Mr Cochrane—I do separately identify it. Can I take it on notice? I did not bring those figures with me, but it is identified as an element within my budget.

Answer/s:

The following relates to expenditure by the Director of National Parks on the National Landscapes program (2008-09):

Employees	$320,518
Suppliers	$194,370
Total	**$514,888**

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	30
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	Red-footed boobies – North Keeling		
Hansard Page ECA:	120 (27/5/09)		

Senator SCULLION asked:

Senator SCULLION—… Would you be able to provide me with detailed maps showing where the transects are so we can have the full details? If there were transects there will be maps of transects. We would appreciate any copies of the field notes and also the rationale… Would you be able to provide me on notice with the rationale of the experiment: was it just a nest site survey? … Are you able to provide that material?
Mr Cochrane—Yes.

Answers:

A map containing the transects for the Red-footed boobies on North Keeling are provided at Attachment A. In this map the transect lines are marked with capital letters. Each dot on the map represents trees containing nests within quadrants. Each quadrant is 10m wide x20m long.

Field notes are currently hand written and would take extensive resources to photocopy and scan these. Given the low staff numbers on Cocos, it is impractical to provide all field notes. An example of the field data sheet is provided for reference (Attachment B).

The rationale and methodology for the surveys was developed by Ross Cunningham and Barry Baker in "Red-footed boobies on Pulu Keeling: a survey methodology to estimate the breeding population size", July 2001. A copy of the methodology is attached (Attachment C).

Further detail is provided in Baker, G.B., Cunningham, R. B. and Murray, W. 2004. Are red-footed boobies Sula sula at risk from harvesting by humans on Cocos (Keeling) Islands, Indian Ocean? *Biological Conservation* 119; 271-278. (Attachment D)

Current data for Red-footed boobies is collected and stored in a database, as recommended by Baker and Cunningham in “Data Analysis System for Red-footed Booby Program at Cocos (Keeling) Islands 2007” (Attachment E).

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Attachment A

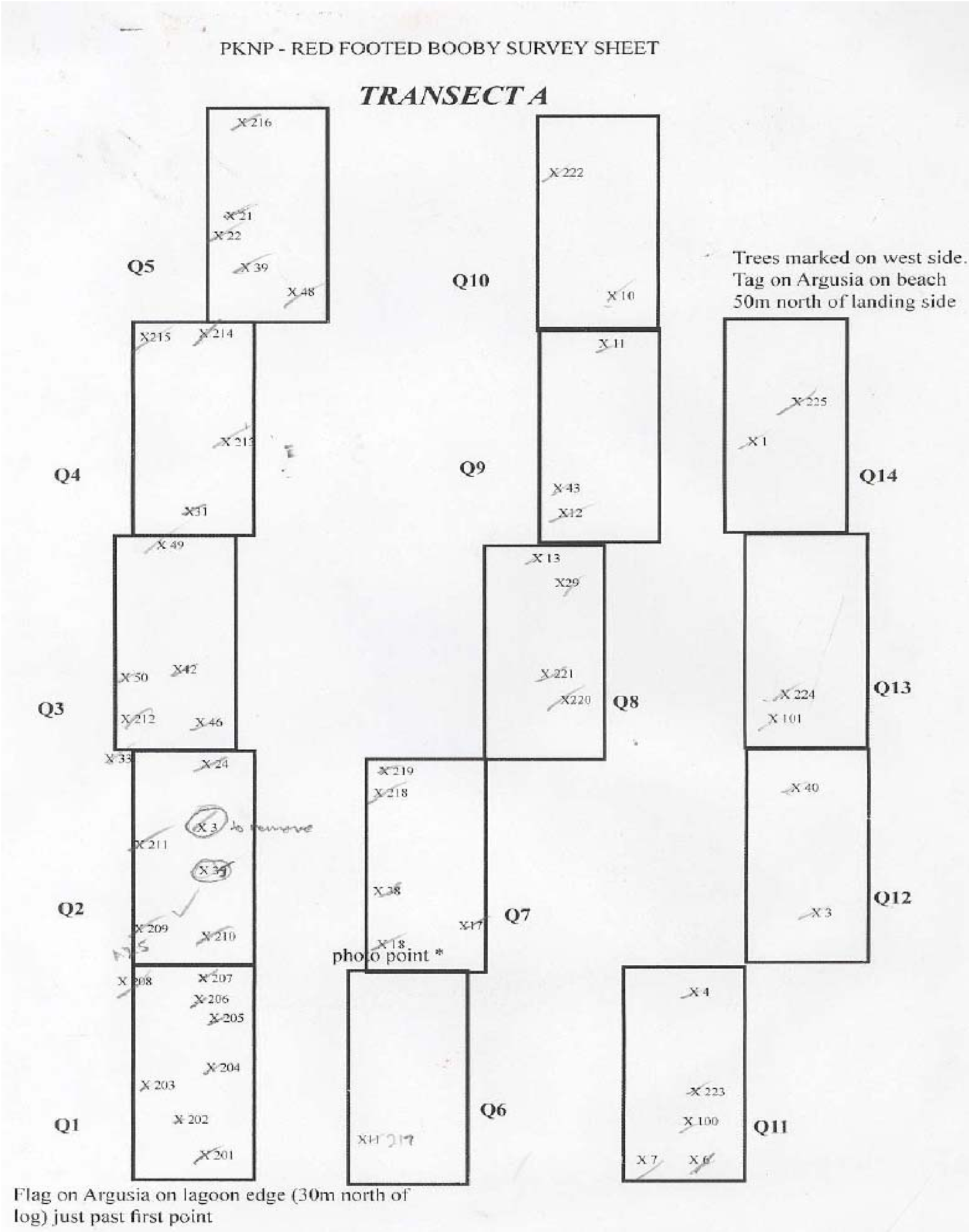
Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Attachment B



OBSERVER MSC WEATHER Partly Cloudy / sunny TIME 1030 DATE 08/02/05

RED-FOOTED BOOBY NESTING ACTIVITY - TRANSECT A

Transect and Quadrat	Tree No.	No. Nests / Chicks	Comments
A Q1	201	0	
	202*	6	
	203	4	
	204	0	
	205	0	
	206	0	
	207	0	
	208	0	
QUAD.	**TOTAL**	10	
A Q2	**25**	0	
	35	0	Re-growing
	209	0	
	210	0	
	211	1	
	24*	3	
	33	2	
QUAD.	**TOTAL**	6	
A Q3	46	2	
	212	3	
	50	1	
	42*	6	
	49	4	
QUAD.	**TOTAL**	16	
A Q4	**31***	24	
	213	2	
	214	0	Re-growing
	215	0	Re-growing
QUAD.	**TOTAL**	26	
A Q5	48	0	Re-growing
	39	5	
	21*	1	
	22	0	Re-growing
	216	1	
QUAD.	**TOTAL**	7	
A Q6	217	9	
QUAD.	**TOTAL**	9	
A Q7	**17***	7	
	18	7	
	38	5	
	218	2	
	219	5	
QUAD.	**TOTAL**	26	
A Q8	220	2	
	221	1	
	29*	7	
	13	0	
QUAD.	**TOTAL**	10	

Transect and Quadrat	Tree No.	No. Nests / Chicks	Comments
A Q9	**12**	0	Re-growing
	43	0	Check posn. re-growing
	11*	1	
QUAD.	**TOTAL**	1	
A Q10	**10***	9	
	222	4	
QUAD.	**TOTAL**	13	
A Q11	7	1	
	6	10	
	100	0	
	223	6	
	4*	16	
QUAD.	**TOTAL**	33	37
A Q12	**3***	7	
	40	1	
QUAD.	**TOTAL**	8	
A Q13	101*	1	
	224	0	Re-growing
QUAD.	**TOTAL**	1	
A Q14	1	6	
	225*	1	Check posn. OK
QUAD.	**TOTAL**	7	

TRANSECT A TOTAL – ~~172~~ 177

*** Monitor Breeding Success (next sheet)**

Red-footed boobies on Pulu Keeling: a survey methodology to estimate the breeding population size

A report to Environment Australia

Ross Cunningham and Barry Baker

July 2001

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background

StatWise Pty Ltd was contracted in May 2001 by Parks Australia (North) to provide an assessment of the methodology and statistical accuracy of annual red footed booby surveys on Pulu Keeling National Park. The terms of reference for the project were:

1. Assess current methodology of Booby Surveys and their accuracy in determining the sustainability of a future harvest (of varying or fixed size) by the residents of Cocos (Keeling) Islands.
2. Compare the methodology to that used in other areas in the Pacific, and make recommendations for revising methodology if required.
3. New methodology (if recommended) must not require more time than currently being spent, and must not require a stay on -island of more than 2 and 1/2 days for 3 people (this period usually the weather window of opportunity).
4. Examine the possibility of monitoring other bird species on Pulu Keeling using the recommended methodology
5. The Methodology is to be statistically sound.

Pulu Keeling National Park was proclaimed a national park under the *National Parks and Wildlife Conservation Act 1975* in 1995. Located 24 km to the north of the Cocos group of islands, a remote Australian External Territory in the western Indian Ocean, the Park contains significant populations of seabirds. By far the most abundant species is the red-footed booby, *Sula sula*. It has been estimated that approx. 30 000 pairs of red-footed boobies breed on Pulu Keeling (Stokes *et al.* 1984).

Red-footed boobies have been harvested by the inhabitants of Cocos (Keeling) since the Territory was first settled by the Clunies Ross family in 1827 and the subsequent occupation by Cocos Malay people. A review of the history of this harvest and the occupation of the Territory has been provided by Kentish *et al* 1996 and Reid 2000.

We visited Cocos (Keeling) 1-8 July 2001 to carry out this assignment. During this period we reviewed the current methodology with Parks Australia North staff Ms Wendy Murray, Mr Ismail Macrae, Mr. Robert ('Greenie') Thorn and Mr

Kenny Arklie.

Figure 1. Photograph of Pulu Keeling, Indian Ocean

We also visited Pulu Keeling from 3-5 July to carry out an on-ground reconnaissance and observe the vegetation structure, nesting locations, current field counting protocols and the logistical constraints imposed by island access and the habitats in which counts are conducted.

At the time of our visit Pulu Keeling had just been hit by Cyclone Walter, and the island vegetation had been severely modified. Approx. 14% of large trees and 60% of the canopy had been demolished and many birds killed (Wendy Murray personal communication). There was also evidence of extensive loss of breeding habitat, particularly in the Pisonia forest, with the forest floor littered with storm debris. Access to the existing transects was therefore difficult and it was apparent that this would impact on future counts for some time. It was also apparent to us, based upon our experiences in similar situations in the Coral Sea National Nature Reserves, that as recovery occurs there will be changes to the distribution of nesting habitat. This factor needs consideration in developing recommendations for ongoing monitoring and estimation of population levels.

We have read a comprehensive review by Kentish *et al* (1996) which elegantly reviews the literature pertaining to survey methodology and biology of red-footed booby. This report also assessed the program up to that time, and made recommendations for a new protocol which would permit an accurate estimate of the breeding population. Rather than repeat much of the information in Kentish *et al* (1996), we propose to examine each of their key recommendations and suggest modifications which we believe will enhance the proposed survey design.

Issues

Current survey methodology.

The current survey methodology was established by John Hicks in 1985 (reviewed in Reville 1987). Originally four transects were established and a further eight transects were added by Andrew Grant in 1987. Transects are a 20m wide strip and vary in length from 80-350m. Within these strip transects nesting trees are individually marked and their location has been mapped, with the distance from the start and end points of the transect recorded for each marked tree. Mapping of trees within transects assists observers locating them during counts. It will also permit disaggregation of transect counts back to either single or multiple tree units and, on the occasion they were established, to area based units or quadrats.

It is important to note that originally (1985) the study was established as an area-based survey, and all nest trees were marked, mapped and recorded. It appears that Kentish *et al* (1996) were not aware of the original basis of the study, believing that data could not be assigned to area-based units. This is understandable, because at some stage since 1985, birds used other trees within transects and these trees were not included in total nest counts of transects. Periodically, Park staff (e.g. during the time Paul Stephenson was at Cocos) re-assessed the trees being used for nesting within each transect and added these to the survey design; other trees have been lost due to natural causes such as wind damage and collapse. Details of exactly what took place in this regard will become apparent when we analyse data on a tree-by-tree basis, which will be provided in a supplementary report when data for 2001 become available.

Every month from March to October (where possible), observers count all nests within marked nesting trees, noting the stage of breeding. Stage of breeding is classified into 9 classes:

- NPL (nest apparently abandoned)
- NWT (nest without adult tenant, contents unknown)
- NA (nesting with sitting adult, nest contents unknown)
- 2W,5W,8W,11W,14W and 14W+ (nest with chick of designated age)

Method of observation varies among observers but always includes a thorough search of each tree. Some observers use optical aids (binoculars, monoculars), others use counters and/or multiple searches from varying positions around the base or each tree. Typically, observers conduct counts individually rather than in teams. Each observer is capable of completing a maximum of five transects in a day, and the party endeavours to conduct a complete count of all transects and trees within one day.

The number of transects, and hence the number of trees, counted has varied over the years (summarised in Kentish *et al* 1996). Following the visit of Kentish *et al* (1996), the number of transects was reduced from 13 to 10.

Current transects used are designated as: Transects A, B, C, D, F, I,J, K, L and P (see Figure 2);

Transects G, E and M were discarded.

In recent surveys it is important to note that, within transects, not all trees used for nesting have been marked and included in counts.

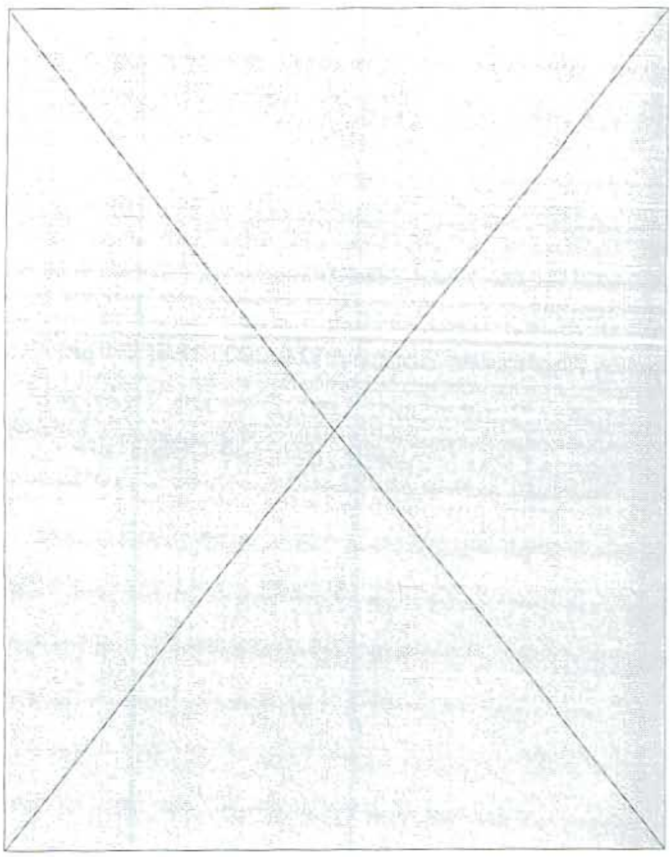

Figure 2. North Keeling Island, showing Red-footed Booby and Cocos Buff-banded Rail transect positions (after Royal Australian Survey Corp, Dept Defence, 1979, and Reid 2000). Note that the Cocos Buff-banded Rail transects, denoted CBBR, are note used for booby surveys.

What is needed to determine a sustainable level of harvest?

Kentish *et al* (1996) reviewed the principles of harvesting outlined in Caughley (1977) and Caughley and Sinclair (1994), and concluded that, if a harvest was to proceed, it should be an unselective harvest, and not based on selective harvesting of age classes (first year birds), as recommended by Reville (1987). This principle is based on trying to achieve a compromise between an optimal harvesting strategy which seeks to take as many females as possible from those ages that contribute least to the population's potential rate of increase, and at the same time setting up the age distribution of the survivors to allow enough females to enter these age classes to provide the yield in following years (Caughley 1977). In practice, these conflicting objectives tend to cancel each other in an unselective harvest.

Whilst determining harvest levels can be as complex as you care to make it, Caughley and Sinclair note that most recreational or subsistence harvesting of wildlife is managed largely by trial and error. They state simple principles to manage this process:

> *The trick with managing a population for sustained yield is to play it safe. You estimate the maximum sustainable yield (MSY) on the information available (usually the trend of population indices under a known constant off-take or constant effort), refine the estimate of the MSY as often as you can or at least as often as your monitoring system allows, but keep the harvest well below the MSY. Make certain that the estimate of population size remains well above the estimate of N_{NSY}. Allow a wide margin of error....monitoring of population size will let you know in plenty of time when you need to ease off harvesting effort.*

As pointed out by Kentish *et al* (1996), to set a sustainable level of harvest it is necessary only to know the maximum population each year, which enables an estimate of the exponential rate of increase for that population to be calculated. The methodology we recommend will estimate the breeding population, but not the 'floaters' or unknown population of birds which do not breed. To estimate the 'floater' component of the population with precision would be extremely difficult, if not impossible, and we do not recommend that this be attempted. Therefore, the 'maximum population' estimated by the methodology proposed will be less than the actual population and hence lead to a conservative estimate of a sustainable harvest level. This accords with the approach recommended by Caughley and Sinclair (1994).and would be appropriate for determining a sustainable level of harvest for red-footed boobies on Cocos (Keeling).

Issues associated with current methodology & recommendations of Kentish et al *(1996)*

The current methodology, or variants of it, have been employed for a period of 12 years and, as such, provide a valuable baseline for assessment of the breeding population of Pulu Keeling over this period. However, data collected to date have not been comprehensively analysed and attracted criticism from Kentish *et al* (1996). Discussions with Park staff indicated that Kentish himself undertook some statistical analysis which is not described in Kentish *et al* (1996).

Their particular concerns, and our assessment of those concerns, are provided below:

> *Data collected from transects from 1986 - 1996 do not provide precise or accurate population estimates of the Red-footed Booby population on North Keeling Island.*

We believe that this comment refers to the fact that either Kentish failed to understand that data, although collected at the tree level, was originally designed to be analysed at a quadrat level as was done by Reville (1987), or that he was concerned that the survey methodology had degenerated solely to a tree based survey. Data as presented in Kentish *et al* (1996) are aggregated to the transect level and as far as we can determine, no attempt was made to estimate variability through disaggregating the data

> *The current methodology is inappropriate to meet the objectives of the survey. To meet the requirements for an index of the breeding population, it is strongly recommended that:*

the habitat be subdivided into suitable strata based on recognisable (on the ground and aerial photograph) features. The number of samples taken in each strata should be similar to the proportion occupied by that habitat. Canopy area should be recorded for each sample such that the data recorded are nest density (nests / ha);

the current methodology (i.e. tree transects) should be rejected as unsuitable to answer the main objective of the survey which is to estimate the population;

the proposed methodology uses fixed area quadrats of known size. The sample size and number would be a balance between variance and costs and:

sample size should be calculated for homogenous habitats and based on a known error (10%);

sampling should be stratfied random;

sampling should be without replacement;

an experimental approach be used to examine the cost and variance of different sampling strategies BEFORE any method is finally selected;

observers must understand the basic principles of sampling strategy and are able to implement these principles in the field;

where time and human resources are limited the surveys should be concentrated at a time (April to September) when there is the greatest breeding activity and nest density. There is little need to know the population density early or late in the breeding season unless climatic conditions affect the peak period for breeding; and

surveys are required to determine maximum breeding population for the year. If time permits it may be important to collect information on breeding success, longevity, recruitment and survivorship to add to the database of information on the population.

A sampling program is suggested based on randomly selected , fixed area quadrats. The need to estimate the area of breeding habitat is stressed. Sample number, placement and position are considered.

We agree with the principles espoused by Kentish *et al* (1996), however our suggested implementation of these concepts differs from their proposals. Since the vast majority of birds nest in *Pisonia* forest we suggest that effort be restricted to this vegetation type. Our observations reveal that within this vegetation type there are four sub-classes:

- *Pisonia* short
- *Pisonia* tall
- *Pisonia* / coconut mix
- *Pisonia* / ironwood mix

Rather than stratify these sub-classes at the design stage, we suggest that vegetation type in each sampling unit be initially recorded, and used in the analysis stage if considered important.

We propose that the current methodology (i.e. tree transects) should be phased out and replaced with an area based scheme, which will accord with the original intent of the survey (Reville 1987, Reville pers. comm.). As far as possible, information should be recorded at the tree level within each unit. This is the most practical method of initially recording data in the field, and will also permit a complete retrospective analysis of the data collected to date.

We believe the over-riding selection of a size of the survey is a practical one associated with the time and human resources available to carry out the task. Although the principles are laudable, power calculations are not relevant or helpful in this instance since the Terms of Reference (TofR 4) impose restrictions on the resources to be allocated to carry out surveys. Random sampling is completely impractical in the Pulu Keeling environment, where establishment and location of transects and quadrats is a major enterprise. Systematic sampling along strip transects has the advantage of ensuring wide coverage over the target habitat. The estimated variance associated with stratified sampling may lead to an underestimate of true variance. Statistical issues associated with non-random sampling can be dealt with through statistical modelling.

We concur that the surveys need only be concentrated when breeding activity and nest density are at their maximum. Further to Kentish *et al* (1996), we suggest that providing breeding stage can be assessed during other routine visits to Pulu Keeling through observation of nesting activity, or perhaps a limited survey of a few quadrats, the full survey effort can be further reduced to conducting only two surveys each year during peak breeding nesting. Ultimately the timing of these surveys is best assessed by field staff with experience of the red-footed booby breeding cycle on Pulu Keeling, noting that maximum counts obtained since 1993 occur when most nests contain nesting adults ie. birds are incubating.

Collection of information on breeding success, longevity, recruitment and survivorship is not important for obtaining an estimate each year of the breeding population. However, such data are useful for the development of demographic models and/or indicating a systematic trend in population parameters. For this reason we suggest that a subset of easily observed nests be selected each year for the purposes of tracking stage of nesting and ultimately providing an estimate of breeding success. A suggested sample size is c. 100 nests covering the range of habitat and conditions available.

We concur with the need to estimate the area of breeding habitat, which is fundamental to estimating total breeding population size. In the short term we will use existing rough vegetation maps (Figure 3) to obtain estimates of vegetation area. However, we are aware of new technologies, which should provide more precise estimates through enhanced satellite imagery, and propose to refine the vegetation estimates when the technology becomes available.

For our retrospective analysis, we may also require an estimate of the number of 'suitable' nesting trees for each habitat class. This will be obtained by estimating tree density in 2001 in survey units established as part of our proposed methodology.

Figure 3. Vegetation map of North Keeling Island.

It should be noted that, no attempt has been made to ensure that nests, trees or 'transects' were truly representative of the range of island habitats;

As stated above, we intend to target only *Pisonia* habitat since the vast majority of birds nest in *Pisonia* forest. Our observations indicate that the existing transects provide an excellent coverage of the *Pisonia* and mixed *Pisonia* habitats.

No attempt has been made to measure any variation in observer accuracy or precision;

During our visit to Pulu Keeling a trial was undertaken to provide data to quantify observer variability. Our evidence suggests that there is no extra variation beyond counting error with experienced observers and hence observer variability is not a problem. However, there was strong evidence that the performance of an observer inexperienced in the conditions encountered on Pulu Keeling was inconsistent with experienced observers. We therefore recommend that a training, and evaluation program be established to overcome this problem. Details of this study are provided at Attachment A.

Minimal attempt has been made to collect data suitable for a definitive answer to Stokes et al (1984) original question which related to the possibility of an over-harvest of the Red-footed Booby population on North Keeling Island.

The methodology we propose will provide an estimate of the number of nesting birds, together with an associated confident interval, for each year. From these data it will be possible to estimate rates of increase and associated confidence intervals for these rates. This information should provide a statistical basis for making decisions pertaining to the setting of harvesting levels and the subsequent impact on the breeding population.

proposed methodology

setting the framework

- It is necessary to define the objective of the surveys on Pulu Keeling before developing a design. Is the interest in providing an estimate of population size in a given year with an estimate of precision, or in designing a survey methodology to detect change? Whilst appearing similar, the survey methodology may be different to achieve these different aims. For example, if interest is in estimating number of breeding pairs, then it is necessary to predict populations or number of nests in areas not sampled for a given habitat type or strata. On the other hand, if interest is solely in quantifying change with high precision, then the important design consideration is to essentially re-sample or re-count the same transects/quadrats from one period of interest (year) to another.

- Re-sampling a set of quadrats increases precision of estimates when birds show high site fidelity. This is a reasonable assumption because biological data for red-footed boobies and other Sulids suggest that birds essentially re-use the same nesting sites from year to year, and also because there are few other options available on Pulu Keeling to support the current breeding population.
- Low precision or lack of precision of estimates is associated with a high spread or high variability of repeated estimates; small standard errors and hence tight confidence intervals lead to high precision. Bias refers to consistent divergence of sample estimates from true population parameters. Accuracy usually means bias but can refer to the sum of bias and variance. For example, Bibby et al (1992) define a precise and accurate estimate as one in which the results are closely spaced about the true value (see Bibby et al 1992, Box 2.5).
- Based on our discussions with park staff, we believe it is necessary to track population size from year to year. As a consequence we have chosen to focus on designing a survey principally for monitoring change, but with a secondary aim of estimating annual population size for Pulu Keeling.
- Although red-footed boobies are seasonal breeders on Pulu Keeling, the season is protracted. We aim to provide an estimate of the number of breeding pairs during the peak of the breeding season. It should be noted that at the time this count is taken, it is likely to underestimate the total number of breeding pairs in the population at that time, because some pairs will have already laid eggs and failed, whilst other pairs may not have commenced breeding. In our opinion this is not problematic if the main purpose of the project is to ultimately determine a sustainable yield, as the quota derived from the population estimate will be conservative.
- Taking the above point one step further, if harvesting is to proceed, then quotas or MSY should be based on the lower bound of an interval estimate of absolute population size. This will result in a very conservative estimate, which we believe is entirely appropriate for Pulu Keeling, a population which is important in the regional context, particularly if this estimate is to be used to determine an annual

harvest quota.

- In order to undertake a statistical analysis of historical data, the data needs to be dis-aggregated from a transect level to individual or multiple tree units. This is necessary because the survey has not been area-based for an indeterminate period of time. As stated above, this analysis will be provided in a supplementary report when data for 2001 become available, and will provide a summary of population trends.
- In considering the issues raised above, the design of the survey methodology is further constrained by the need to comply with the limit of resource specified in the Terms of Reference.

survey design

Our suggestions are based on some of our previous work on the design of surveys for monitoring seabird nesting on North East Herald Cay (see Baker et al, 2000; Welsh, Cunningham and Chambers, 1999; Cunningham and Welsh, 1996; Welsh et al, 2000), previous surveys on North Keeling (see Kentish et al, 1996) and information gleaned during our visit to Pulu Keeling in July, 2001.

A summary of the methodology we propose is:

- Select the area to be studied. In this case we suggest restricting the survey area to the *Pisonia* forest, which represents the major nesting area of the Island.
- Define a set of transects. In this case the 10 transects in current use seem appropriate. There is no clear heterogeneity in the *Pisonia* forest along transects, apart from some edge effects.
- Define area based survey units within strip transects of 10 m width. These should be marked quadrats of a given size – we suggest 10 metres wide by 20 m long. In most cases these will be contiguous, but may be non-contiguous segments along the strip transects.
- Within each quadrat we suggest that a convenient observational unit be a tree whose stem is within the quadrat. It is important that quadrats include as many trees previously counted as is possible, to assist in maintaining a continuity between the old and new survey methodologies. Protocols for selection of trees and other logistics associated with counting of nests to be finalised by Park staff. It is important that these protocols are well documented and understood by all staff.
- **It is also important to understand that trees simply facilitate counting in the field. This is a quadrat based methodology and a count of nests per quadrat is the fundamental data.**
- In the first year establish transects, quadrats and trees to be counted, ensuring that all markers are visible and are durable. Markers should be maintained every year. We commend the current practice of mapping all trees, (quadrats) and transects, and suggest that this is continued.

- Collect counts of boobies for all designated trees within quadrats and, in the first instance, record information on the vegetation types as stated above. Information on vegetation type may be important for the estimation of nesting abundance, since controlling for this in the statistical analysis may lead to a reduction in the standard error of abundance estimates.
- It is necessary to conduct at least two full counts of all trees (and hence quadrats) when breeding is considered at its peak. Note that whilst data are collected at the observational unit (tree) level, analysis of data will be aggregated and analysed at the survey unit (quadrat) level.
- As there is no evidence of extra-observer variability (see Attachment 1), it is not necessary to further quantify observer variability in counts. However, it is important that observers are trained and assessed by experienced observers before they participate as independent counters.
- Establish a subset (say 100) of clearly visible nests to provide an estimate of annual breeding success with adequate precision. Nests should be clearly marked, mapped and monitored throughout the breeding cycle to determine the fate of all eggs laid, and chicks which hatch, in those nests. This task is not essential to estimate the breeding population size, and should not impinge upon the main survey.

statistical analysis

It should be noted that survey units become the statistical population and will be counted each year. We believe the established transects provide a good coverage of the *Pisonia* nesting habitat and so provide a representative sample of the island's *Pisonia* forest.

Inferences relating to population size

If we wish to make inferences about the total population size in a given year, then quadrats should to be considered as random. In this case the standard error of the estimate of population size includes both variance due to counting as well as that due to sampling, and so we require estimates of variance components for quadrats (σ^2_q) and counting (σ^2).

Thus the variance of the mean number of nest per quadrat (density of nests) will be:

$$\mathrm{Var}(\overline{Y}) = \frac{1}{q}[\sigma_q^2+\sigma^2], \text{ where q is the total number of quadrats sampled.}$$

Inferences relating to change

Note that if we wish to make inferences about change in population size from year to year then quadrats can be considered as fixed. This improves the precision of estimates of change as the standard error is based only on variance associated with counting and not quadrat-to-quadrat variance (sampling variance) as well. In this case the variance component associated with quadrats does not contribute to the estimate of the standard error of the difference (change) and so the counting error is the only relevant variance term; we assume that this remains similar between months from one year to the next. Thus the variance of the mean number of nest per quadrat (density of nests) will be:

$$\mathrm{Var}(\overline{Y}) = \frac{1}{q}[\sigma^2], \text{ where q is the total number of quadrats sampled.}$$

For the purposes of monitoring abundance, and hence change, we can restrict inference to the sample ('statistical population') of quadrats and need not attempt to predict the total population size of the island. For the purposes of setting quotas we need an estimate of the total size of the breeding population of the island. In deriving this estimate from the sample, the precision is likely to be low and hence confidence intervals large. Typically, precision of population estimates in a given year will be much lower than precision of estimates of change in population based on the sample data.

We are also interested in studying the time profile of nest counts so that timing of the main survey can be determined.

Preliminary data analysis showed that the variance of counts was not independent of the mean count, nor were counts normally distributed. However we found that variance and distributional assumptions for our analysis were approximately met when data were transformed by square root (count). Thus our analysis will proceed either by transforming the data and carrying out a standard linear model analysis, or regarding the data as counts having a Poisson distribution and then modelling the data accordingly ie. as a GLM. This analysis will be undertaken when the 2001 data becomes available and will be described in detail in a supplementary report.

other birds

There are 11 seabird species, which breed on Pulu Keeling. For most of these species, an adaptation of this methodology is potentially suitable for monitoring populations and has been used by both us and others elsewhere (e.g. Baker *et al* 2000, Fullagar and Heyligers 2001).

However, unlike the situation which exists in other red-footed booby colonies elsewhere eg. Coral Sea (Baker *et al* 2000), Aldabra (Feare 1984), no other species nests extensively in the preferred red-footed booby habitat (*Pisonia*) on Pulu Keeling. To apply the methodology to other species would therefore require establishment of transects and quadrats specifically for the species in question. For some species (e.g. common noddy and sooty terns) the potential disturbance to the species may be too great to justify the level of impact, particularly if the work is not critical for current management issues. With other species such as the frigatebirds, the habitat used for nesting (*Pemphis*) is difficult to work in and surveys could potentially lead to habitat destruction or cause desertion of nests or loss of eggs and chicks as other conspecifics attempt to steal nesting material.

Should monitoring programs be required for other seabirds we recommend that specific designs be developed for those species.

Future directions

If possible, he proposed methodology should be immediately implemented to permit data collection for the 2001 breeding season. As part of this contract we are prepared undertake an analysis of both past data and that collected this year. A report on the outputs of this analysis will be provided as a supplement to this report

To assist with future analysis, we will provide details of the necessary computations to estimate relevant statistics. We can provide assistance in future analysis if required.

In order to maintain continuity and provide feedback for all stakeholders, it is advisable for a small report to be prepared at the end of each breeding season. Such a report should include a control chart, which graphs the trend in bird abundance, a population estimate, and an estimate of breeding success, all with confidence intervals, together with interpretation of the trends observed.

recommendations

1. We recommend that yearly surveys be conducted at Pulu Keeling to provide high quality data to permit both estimation of population size and detection of change.
2. Past data should be analysed to obtain a summary of retrospective trends in annual breeding population density, together with some measure of statistical uncertainty eg. confidence intervals. This will be provided as a supplement to this report once data have been collated and entered into an electronic format.
3. It is necessary to enhance the existing methodology to provide high quality data, which will permit future estimation of population size as well as the detection of change in the population. We recommend that this be done by implementing a revised survey methodology, which is area-based rather than tree-based.
4. The revised survey methodology will provide annual estimates of the total breeding population and the rate of increase of the population, which will permit the setting of harvest quotas if so desired.
5. The focus of the survey should be on *Pisonia* and mixed *Pisonia* habitats since the vast majority of birds nest in these habitats. Our observations indicate that the existing transects provide an excellent coverage of these habitats.
6. We recommend that quadrats of 10 m X 20 m be established along the existing transect lines, incorporating as far as possible as many of the existing survey trees to maintain continuity between the old and new survey methodologies. In these quadrats all trees assessed as being suitable nesting trees should be individually marked with a durable marking system and their locations mapped.
7. We recommend each year that at least two complete counts of all quadrats be undertaken at the time of peak breeding. This should be determined on site by Park staff using incidental data and limited counting at a sub-set of sites.

Normally, we envisage that this will occur when most breeding birds are incubating eggs.

8. As there was no evidence of large observer variance in existing tree-based counts it is not necessary to carry out repeat counts for each survey.
9. Each year prior to or during the first survey, every quadrat should be searched to identify:
   - marked trees which have fallen over or been lost; and
   - unmarked trees which contain nests.
10. A report should be prepared each year to maintain continuity and provide feedback for all stakeholders. The report should include graphs which displays the trend in bird abundance, population estimates, and estimates of breeding success, all with confidence intervals, together with interpretation of the trends observed.
11. The survey methodology proposed to count red-footed boobies on Pulu Keeling has been developed specifically to meet the specified objectives, taking into account relevant biology, distribution of nests and logistical considerations. If other species are to be monitored, it would be more appropriate to develop a specific program for those species. For some species it may be possible to adapt the methodology we have developed to suit the objectives of any proposed study and the biology of the species concerned. However, we recommend that if such survey work is required, a specialist expert(s) be consulted to design and develop a purpose-specific methodology to meet the stated objectives of the project
12. It is not essential to record stage of breeding (as is currently done) to estimate the size of the breeding population. However, information on breeding success and other reproductive parameters may be useful for other purposes. We suggest that data on breeding success be obtained by establishing a subset of clearly visible nests. Nests should be marked in the field, mapped and monitored throughout the breeding cycle to determine the fate of all eggs laid and chicks which hatch in those nests. This task should not impinge upon the main survey.

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ATTACHMENT A: Observer variability in nest counts of Red-footed Booby on Pulu Keeling.

During our visit to Pulu Keeling a small experiment was designed to enable assessment of observer effects in nest counts of Red-footed boobies. The five observers who participated in this study were: – four observers from Parks Australia North - Wendy, Ismail, Greenie and Kenny - and Barry, who has had extensive experience in counting red-footed booby nests in low Pisonia forest elsewhere but not in Pulu Keeling. Each observer independently counted four (sub)transects of five trees each over four half-hour periods during the morning. Assignment of the regular(local Parks staff) observers to transects and periods was at random in a latin square arrangement; Barry conducted his counts at the same time with Kenny. This designed ensured that all observers counted all trees and all the effects – transect, period and observers - were balanced with respect to each other.

There were large differences in the mean counts per tree between Transects and a suggestion of a difference between Observers (Table 1).

Table 1. Mean nests per tree classified by Observer and Transect.

Transect	Barry	Greenie	Ismail	Kenny	Wendy	Mean
A	4.4	5.6	7.0	7.2	5.2	5.9
B	3.6	4.8	5.4	5.2	4.2	4.6
K	5.0	6.8	6.0	5.4	5.6	5.8
L	2.6	3.6	4.2	3.4	4.6	3.7
Mean	3.9	5.2	5.7	5.3	4.9	5.0

Table 2 shows analysis of variance of the aggregated data - transect level data expressed as mean counts per tree - for (a) is for all observers and (b) with excluded. As there was no - extra variance due to the random factor Period, this has been omitted from the analysis.

Table 2. Analysis of variance of the mean number of nests per tree.

(a) All Observers

***** Analysis of variance *****

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRANSECT stratum	3	16.1180	5.3727	12.71	
TRANSECT.*Units* stratum					
OBSERVER	4	7.0880	1.7720	4.19	0.024
Residual	12	5.0720	0.4227		
Total	19	28.2780			

(b) Barry Excluded

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRANSECT stratum	3	13.2075	4.4025	8.35	
TRANSECT.*Units* stratum					
OBSERVER	3	1.1475	0.3825	0.73	0.562
Residual	9	4.7425	0.5269		
Total	15	19.0975			

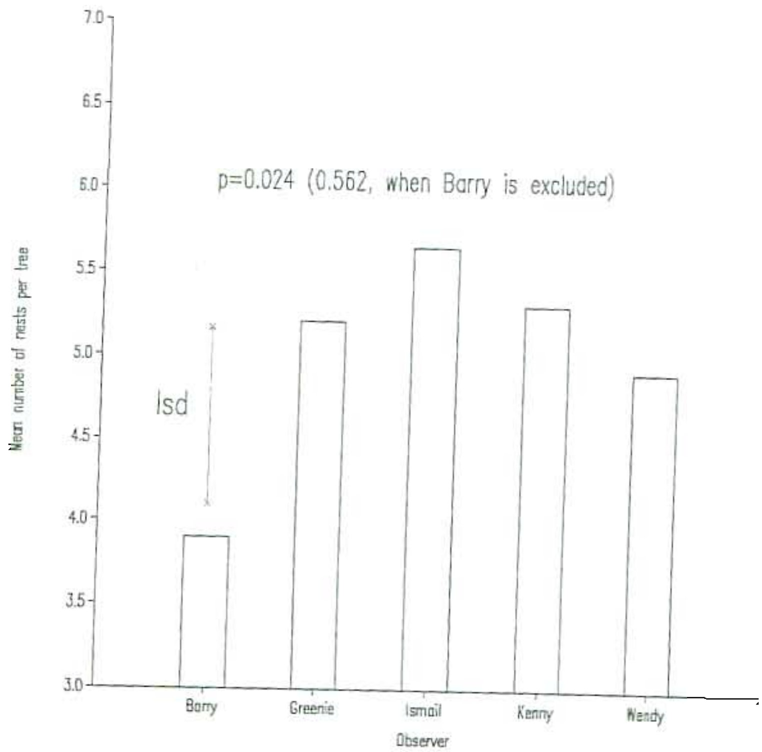

Figure 1. Graph of observer means

There was no evidence of a difference in mean counts between the four regular observers and hence of large observer variability in counting nests. However there was evidence (Figure 1 and ANOVA Table) that Barry's count was systematically lower than counts recorded by local Parks staff.

It should emphasised here that there IS underlying counting error, but there is no evidence of systematic (or random) differences among observers. This counting error will be a component of the total error in the estimates the population size and change in population from one year to the next; the other component of error in the estimate of population size will be sampling error.

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Are red-footed boobies *Sula sula* at risk from harvesting by humans on Cocos (Keeling) Islands, Indian Ocean?

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Abstract

The red-footed booby, *Sula sula*, has been hunted in the Cocos (Keeling) Islands, eastern Indian Ocean, since first settlement in 1827. Formerly present throughout the islands, an estimated 30,000 pairs now breed only on isolated and uninhabited North Keeling Island. Despite legislative protection, illegal hunting for food remains a major conservation threat. Informants estimated that 2000–3000 birds are killed in most years and possibly as many as 10,000 in some years. Analysis of nest count data collected between 1985 and 2002 to assess long-term population trends showed no evidence of decline in nesting density. There was large inter-annual variation with substantial fluctuations which tended to be greater following significant cyclonic events. These results indicate that the level of illegal harvest during the study period has not negatively impacted the booby nesting population. Future management of seabird harvesting requires improved knowledge on the population's capacity to sustain harvesting, together with increased enforcement activity to control illegal harvest, and enhanced education programs to encourage change in community attitudes.

Keywords: Red-footed booby; *Sula sula*; Seabird harvesting; Cocos (Keeling) islands; Indian ocean

1. Introduction

The red-footed booby, *Sula sula*, is a large, long-lived seabird belonging to the Sulidae. The smallest of the sulids, it has an extensive pan-tropical distribution, and is arguably the world's most abundant booby (Nelson, 1978). Throughout its range the species has been persecuted by man, often with devastating effect. For example, of 16 breeding colonies known to have existed in the western Indian Ocean within the last 100 years, 12 were extinct by the late 20th century (Feare, 1978, 1984). The demise of these colonies was almost entirely due to hunting for food by indigenous people.

The Cocos (Keeling) Islands were settled in 1827 by the Clunies Ross family, which established coconut plantations and brought a number of Malay workers to the islands to work in the plantations. These workers are the ancestors of the Cocos Malay people who are now the main inhabitants of the islands. Red-footed boobies probably occupied most of the 27 islands in the group, but by the early 20th century they had been extirpated from the southern Cocos atoll, and now only breed on the isolated and uninhabited North Keeling Island, located about 24 km north of the Cocos group. The significant population of about 23,000 pairs (B. Reville, in litt.) that remains on North Keeling Island is now the largest remaining red-footed booby colony in the Indian Ocean.

Red-footed boobies have been hunted since humans first colonised the Cocos Islands. For many years hunting was unregulated, although the Clunies Ross family (who held title to the Islands) exerted some control over harvesting and access to guns until 1978, when the family sold their interests to the Australian Government. Between 1978 and 1986 hunting of red-footed boobies was uncontrolled and large numbers were harvested each year. J. Hicks and C. Campbell (in

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litt.) considered that between 3000 and 10,000 birds were taken annually from 1981 to 1985.

In late 1986, an agreement on seabird hunting was made between the Cocos Malay community and the Australian government. This agreement established formal hunting seasons and quotas on the Cocos (Keeling) Islands (Environment Australia, 1999). At the same time, a research program for red-footed boobies was established on North Keeling Island to monitor bird abundance, measure breeding parameters, and assess the feasibility of controlled harvesting and hence set quotas as appropriate. Legal harvesting commenced in 1987 but the declaration of annual open seasons was disrupted after tropical cyclone 'John' hit North Keeling Island in 1989, resulting in the death of many birds and severe damage to the booby's breeding habitat. As a result, the Cocos Malay people agreed to stop harvests and allow the population to recover (Australian Nature Conservation Agency, in litt.). A formal hunting season has only been declared twice since that time, in 1996 and 1997 (Australian Nature Conservation Agency, in litt.), although extensive poaching has occurred in both the southern atoll and at North Keeling (J. Barry, in litt.).

The Cocos Malay people view hunting of boobies as an important tradition. Seabird flesh is served on occasions such as Hari Raya, weddings, circumcision ceremonies, social ceremonies involving important visitors (J. Hicks and C. Campbell, in litt.), and is also eaten in a non-ceremonial context (Environment Australia, 1999). Birds were traditionally captured by using a pole with a red flag at the top to attract them, and subsequently brought to the ground using a flail (a 6 m long bamboo pole with a chain or metal wire attached) (J. Hicks and C. Campbell, in litt.). Most birds are now killed with a shotgun (J. Barry, in litt.) and the community has sought approval for the use of guns in future legal harvests. However, the two official harvests sanctioned in the 1990s required that birds could only be taken by use of the flail, with hunting restricted to Horsburgh Island in the southern Atoll, where boobies often roost during the non-breeding season. The imposition of these conditions may have been unacceptable as no members of the Cocos Malay community participated in the official harvest, although they were well publicised (Julian Barry, unpublished).

Illegal hunting occurs in the southern atoll throughout the year, but the isolation of North Keeling and unsuitable landing sites preclude access to the breeding colony when sea conditions outside the atoll are rough. This restricts access to North Keeling between October and April, when the inter-tropical front moves as far south as Cocos during the cyclone season, bringing little wind and calm seas (Environment Australia, 1999).

Efforts by the Australian government to reduce poaching have been largely unsuccessful, although some hunters have been prosecuted. Law enforcement resources in the region are limited and community networks can warn would-be offenders when enforcement activities are taking place. The government is regularly pressured by the Cocos community to approve annual harvests between 1500 and 2000 birds, but open seasons have not been declared in recent years for a number of reasons: (1) changes to wildlife legislation have cast doubt on the basis for declaring open seasons for protected species; (2) the levels of illegal take are unquantified, and it is unclear what effect this harvesting has had on the breeding population; and (3) uncertainty exists as to whether additive mortality through an additional level of harvest can be sustained. Attempts to resolve some of these issues have been hampered by irregularities in the methods used in the survey program, particularly in assessing the level of illegal hunting. It is clearly important to resolve these issues so that appropriate conservation and management strategies for the red-footed booby population on the Cocos (Keeling) Islands can be developed.

In this paper, we examine existing data to determine if they are informative in assessing long-term trends in the Cocos (Keeling) red-footed booby population. We also try to assess the level of illegal harvest to determine if these activities are impacting the population, and discuss the scientific and political implications of resuming legal harvesting.

2. Methods

2.1. Site description

The Cocos (Keeling) Islands (12° 12′S, 96° 54′E) are located in the eastern Indian Ocean. The island group comprises two separate atolls, the southern inhabited atoll of 26 islands and the northern atoll (North Keeling Island), which is a single horseshoe-shaped island located 24 km to the north of the main group. North Keeling was proclaimed a national park in 1995 (Environment Australia, 1999).

North Keeling Island is 2.0 km long and 1.3 km wide, with its long axis bearing north-east. It is low and flat, 3–5 m in height. A large, shallow lagoon occupies the greater part of the interior. Unlike the southern atoll, North Keeling Island has not been continuously inhabited and is in a natural state. Much of the island is dominated by closed Pisonia forest (*Pisonia grandis*), mixed in many areas with coconut (*Cocos nucifera*) and ironwood (*Cordia subcordata*) (Environment Australia, 1999). Most red-footed boobies nest in high (15–20 m) Pisonia forest and Pisonia/coconut or Pisonia/ironwood mixed forest along the western shoreline of the island. The physical characteristics of North Keeling Island are described in more detail in Environment Australia (1999).

Mean annual rainfall is 1976 mm (Environment Australia, 1999), and temperatures are relatively uniform, rarely falling below 20 °C or exceeding 30 °C. Relatively strong and constant south–east trade winds blow for much of the year. From January to May the Cocos (Keeling) Islands are subject to the north-west monsoons and, during this period, tropical cyclones may occur. Two tropical cyclones occurred during the period of this study "John" (1989) and "Walter" (2001). On both occasions these caused extensive loss of breeding habitat, particularly in the Pisonia forest, with 14% of large trees being felled and many birds killed (W. Murray, unpublished).

2.2. Survey methodology

A survey method to estimate breeding density on North Keeling Island was established in 1985 (J. Hicks and C. Campbell, in litt.; B. Reville, in litt.). Originally, four strip transects were established (J. Hicks and C. Campbell, in litt.) with a further 10 transects added in 1987 (A. Grant, in litt.). Transects were 20 m wide and varied in length from 80 to 350 m. Within transects all trees containing nests were individually marked and their location mapped to assist observers locating them during counts. Transects were not random but systematically selected to ensure wide coverage of the major breeding areas on the western section of the island (J. Hicks and C. Campbell, in litt.).

Each year, nesting trees were assessed on transects, with new trees being used added to the population, and those that had been lost due to natural causes removed. The survey was designed to allow nesting densities to be calculated and extrapolations made island-wide to estimate the number of annual breeding pairs (B. Reville, unpublished). The number of transects, and hence number of trees, counted has varied over the years but at least 10 transects have been used continuously since 1987 (Transects A–D, F, I–L and P, Fig. 1).

Following recommendations by R.Cunningham and G.B. Baker (in litt.), transects were re-established in 2001 and partitioned into 20 × 10 m quadrats to ensure that quadrats became the basic unit for future analyses. This change was intended to provide data permitting estimation of population size, unlike the situation that had developed in earlier studies (see below).

In most years from 1987 to 2002, counts of nesting trees were carried out each month during the red-footed booby breeding period (March–October). Counts were not conducted in 1990, 1991, 1992 and 1998 because of difficulties of access. In each count all nest trees were inspected and the number of active nests present recorded. As there was no evidence of large observer variance in tree-based counts it was not necessary to carry out repeat counts for each monthly survey (R. Cunningham and G.B. Baker, in litt.).

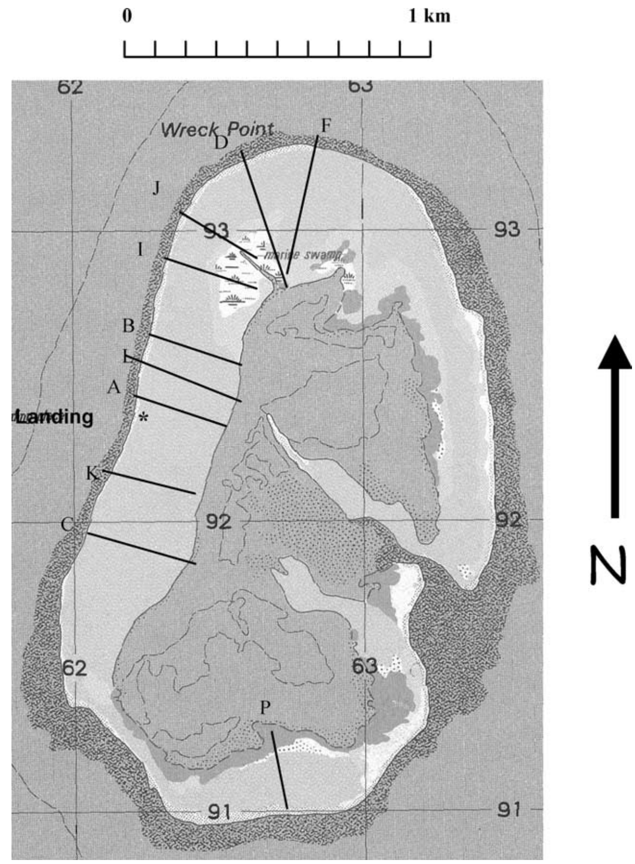

Fig. 1. North Keeling Island, showing red-footed booby transect positions.

Counts for each transect were summed, and only the highest monthly count, representing the peak of breeding activity in a year, was used in further analysis. However, maximum annual counts may underestimate the total number of breeding pairs in a season since it is possible that birds that fail early in a season may have re-laid later.

2.3. Modelling temporal patterns in nest counts

Unfortunately, the intent of the original survey design was misunderstood, leading to the belief that surveys were tree based, rather than area-based, counts (B.Kentish et al., in litt.; R. Cunningham and G.B. Baker, in litt.). As a result, at some stage after 1987 new nesting trees within transects were not routinely added to the survey design and included in total nest counts, although this did occur periodically. For this reason, it was necessary to analyse data on a tree-by-tree basis rather than using area based units to determine longitudinal patterns of nesting density.

For each year the month of peak breeding activity (maximum monthly count) was identified and used to determine an annual maximum nest density. Maximum counts occurred when most nests contained incubating adults and were, for 1987: May, 1988: June, 1989: August, 1993: June, 1994: June, 1995: August, 1996: May, 1997: April, 1999: October, 2000: August, 2001: August, and 2002: July.

For each transect, plots comprising groups of three roughly adjacent trees were selected from trees that had been counted continuously for all years of the survey. We considered the use of more (four and five) trees in plots but found that this reduced the number of sampling units for study. Data selected for formal statistical analysis consisted of nest counts for 12 years on 41 three-tree plots distributed along eight transects. These data have both a spatial and temporal dimension. The spatial component is hierarchical in that three-tree plots are nested within transects. It seems reasonable to assume that counts between transects are independent but that there may be some spatial correlation between plots within transects. Preliminary data analysis showed that nest counts of plots within transects were correlated, but that the spatial correlation did not depend on the distance between plots within transects. On the other hand, there was strong evidence of serial correlation between counts from one year to the next. This serial dependence was modelled by a simple exponential decay process, which is equivalent to an auto-regressive process of order 1, when data are equally spaced. It was assumed that temporal dependence between years was the same within all three-tree plots.

As the focus here is on temporal trends we have chosen to model overall year effects as a fixed effect. An alternative formulation is to model year as a random effect. However, because data were complete and fully balanced these alternative formulations gave similar results.

The statistical model described above is known as a general linear mixed model. The estimation of year effects is by weighted least squares, and transect and residual components of variance and the serial correlation parameter were estimated by restricted maximum likelihood, done simultaneously. As aggregate nest counts were skewed, a logarithmic transformation of the raw data was required before analysis. Further preliminary analyses of the data showed that the pattern of variation between years was approximately consistent from transect to transect (Fig. 2). Thus, our additive model for log counts seemed reasonable (Fig. 3).

2.4. Assessment of levels of illegal harvesting

In July 2001 interviews were conducted with three members of the Cocos Malay community to assess the nature of illegal hunting activities. They were questioned on their involvement in illegal activities, the methods used to take birds, and the number of birds that they estimated were taken each year.

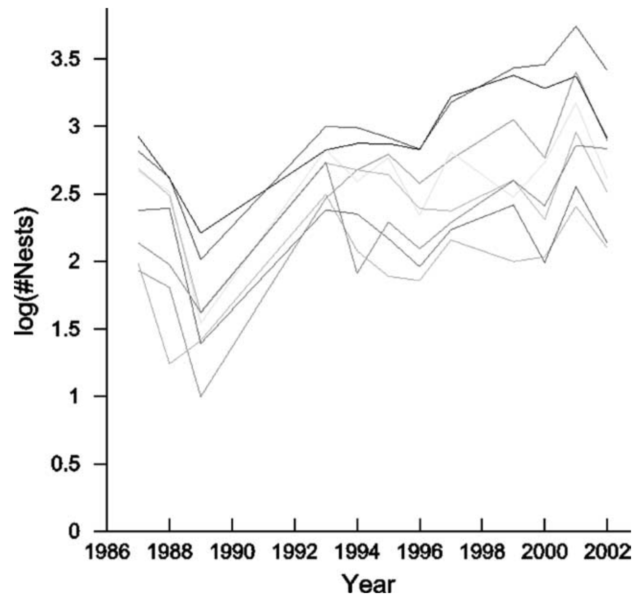

Fig. 2. Log (counts) of red-footed booby nests in three-tree plots located along eight transects, derived from maximum annual counts for the period 1987–2002.

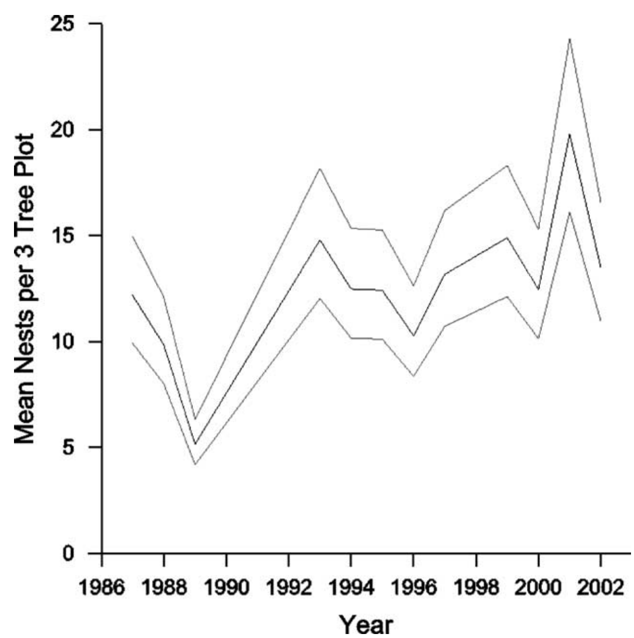

Fig. 3. Predicted mean density of red-footed booby nests in three-tree plots ($n = 41$), with 85% confidence intervals, derived from maximum annual counts for the period 1987–2002. Significant cyclone events occurred in January 1989 and April 2001.

3. Results

3.1. Population trends

The predicted mean density of nests derived from three-tree plots, where data were available from all years that surveys were conducted (Fig. 3), shows no evidence of general decline in nesting density. There was large inter-annual variation with substantial fluctuations which tended to be greater following the significant cyclonic events of 1989 and 2001. The inter-annual variance is of similar magnitude as the sampling variance, providing confidence in the survey methods and data as a tool for detecting long-term changes in the population. Such results indicate that the level of illegal harvest sustained during the study period has not impacted negatively on the nesting population of red-footed boobies on North Keeling Island.

We were unable to estimate the number of birds nesting annually on North Keeling every year. However, in 2002 the mean nesting density along transects (1.96 ha) during the peak of the breeding season was 606.1 nests per ha in the major inland and shoreline breeding habitat. After digitising the boundaries of this habitat defined on air photos by J. Hicks and C. Campbell (in litt.), we calculated the area of this habitat by using the Geographic Information System software ArcInfo Version 7. The resulting estimate of 52.6 ha figure was rounded down to 50.0 ha to account for spatial error associated with data interpretation and the inaccuracies inherent in the datasets. Multiplying the mean density along transects by the estimated area of major habitat extrapolates to an estimated 30,306 nests (or breeding pairs). This estimate is conservative, and does not include birds nesting in 15.9 ha of poorer quality breeding habitat on North Keeling Island (J. Hicks and C. Campbell, in litt.; B.Reville, in litt.).

3.2. Illegal harvesting

All three men interviewed acknowledged that illegal harvesting of birds was a common practice and two admitted that they had taken birds illegally at some time in the past. 'Informant A' reported that in the southern atoll birds were hunted either from land or boats, and most commonly were shot as they flew within shotgun range. Typically, when boats are used there may be one or more vessels involved, and the number of birds taken on each hunting expedition may be as high as 80–100. Hunting in the southern atoll is more easily detected by law enforcement staff and is, therefore, carried out with greater discretion. 'Informant A' stated that when hunting expeditions were undertaken to North Keeling usually two or three vessels are involved for safety reasons. Boats used are small (c. 4 to 4.5 m length) aluminium dinghies, and hunters usually land on the island and may take up to 200 birds per boat. The number of trips each year to North Keeling Island is unknown, but may be as many as eight. He believed that the annual take for both the southern atoll and North Keeling probably did not exceed 3000 birds.

'Informant B' confirmed that hunting expeditions to North Keeling always involved two or three vessels. Hunters usually landed on the island and took up to five bags of birds per boat, each bag holding 80–100 birds. 'Informant B' was unable to say how many trips were made each year, but agreed that eight trips, as reported by 'Informant A', was a reasonable estimate. He believed that 2000–3000 birds were killed each year.

'Informant C' stated that although most birds were now killed with a shotgun, the flail was still used on occasions, taking mainly juveniles because they are naïve and readily attracted to the flag and pole. Harvesting by shotguns in the southern atoll is less selective, and both adults and young birds were taken in this manner. He stated that annual harvest rates were about 1000 birds.

4. Discussion

4.1. Population trends

There was clear evidence of inter-annual variation in the mean density of nests for the three-tree plots, but there was no evidence of decline in nesting density over the 15 years of this study. Given that poaching has occurred at reportedly high levels over this time (J. Barry, in litt.), it would be expected that negative population growth would be apparent by now if both natural and human-induced mortality exceeded births and/or immigration.

Cyclonic activity is a regular but stochastic event in the tropical eastern Indian Ocean and 15 cyclones with a minimum central pressure less than 1000 hecto-pascals were recorded passing within 100 km of the Cocos (Keeling) Islands during the period of the study (Environment Australia, 1999). Peaks in population growth occurred immediately following the cyclones of 1989 and 2002 which directly hit North Keeling Island. Both these events occurred when breeding had either largely finished (January) or was just commencing (April). Nonetheless, the extensive damage to the canopy of the major breeding habitat caused destruction of many nests and the deaths of large numbers of birds (P. Stevenson and W. Murray, unpublished). We interpret the observed increase in breeding activity following these events as evidence of a density-dependent response, indicating a population containing many non-breeding birds limited by nest site availability in most years. We have no empirical data to explain the mechanism of this density-dependent response. However, it may be that severe canopy defoliation provides additional nesting sites and an abundance of nesting material, thus enabling birds that may not have normally bred the opportunity to do so (G.B. Baker, unpublished).

4.2. What is the current level of poaching?

Quantification of any illegal activity is difficult, but the information provided goes some way to developing an understanding of the magnitude of the illegal harvest over the last 20 years. All three informants interviewed agreed that at least 1000 birds are harvested illegally each year, and two stated that a figure of 2000–3000 was more likely. An application submitted by the Cocos community in October 2002 stated that annual harvesting levels at North Keeling Island had exceeded 17,000 birds in the past (Adam, 2002). Clearly the annual take is large, probably involving 2000–3000 birds in most years, and may be as high as 10,000 in some years, although it is difficult to accept that a harvest toward the higher end of this range could be sustained for many years before a negative population response became apparent.

Our estimates of the level of illegal take concord with those of J. Hicks and C. Campbell (in litt.). They concluded that probably between 3000 and 10,000 birds were taken each year from 1981 to 1985, and that higher levels of seabird harvesting had occurred intermittently during the previous 70 years. Hicks and Campbell (in litt.) also believed that the hunting methods used at the time of their review (flag and flail) selected for the more inquisitive juvenile birds.

4.3. Consequences for management

The Cocos Malay community continues to press for a resumption of an annual hunting season (Adam, 2002). A decision by the Australian government to allow this to proceed requires resolution of a number of legal and scientific issues.

The *Environment Protection and Biodiversity Conservation Act*, 1999 (EPBC Act) is the Australian government's primary instrument for the protection of wildlife. The red-footed booby is listed under the EPBC Act as a 'migratory species' in recognition of Australia's obligation to protect migratory birds in accordance with the Japan–Australia Migratory Birds Agreement. Animals listed as migratory species under the EPBC Act are considered to be a matter of national environmental significance and are therefore fully protected. A person proposing to conduct an activity which will impact upon a listed species must first refer the matter to the Minister for the Environment for approval. It is doubtful that an approval will be granted to hunt red-footed boobies unless the Cocos Malay community can demonstrate that the harvest is sustainable and unlikely to have a significant impact on the population.

Illegal harvesting is likely to continue for a number of sociological reasons: (1) seabirds are highly valued for ceremonies which occur at all times of the year; (2) open seasons are likely to be restricted to a few weeks each year, outside the main breeding season; and (3) recreational opportunities at Cocos are limited and hunting is a popular social activity.

At present there is no empirical evidence to suggest that current levels of illegal harvesting are negatively affecting the population. Data examined here indicate that this level, whatever it might be, is currently sustainable. However, it is not possible to infer with any precision what level of harvest can be sustained. This requires consideration of a number of factors including the population size at the time of harvest and the level of illegal hunting.

Following the recommendations of Kentish et al. (in litt.), the Australian Nature Conservation Agency (in litt.) prescribed a harvest of 1000 birds per year for a three year period, with ongoing population monitoring. As a result, formal hunting seasons were declared in 1996 and 1997, but the Cocos Malay community chose not to participate. The reason for this is unclear, but may have been because of objections to the hunting conditions imposed, or because the harvest was declared during Ramadan, a period of fasting.

It is likely that pressure for a legal harvest of red-footed boobies will continue in the foreseeable future, despite uncertainty as to the level of illegal harvest and the capacity of the population to sustain it. Dealing with uncertainty is a familiar situation in many wildlife harvest operations and many strategies have been developed to deal with it. Although harvesting theory is well established in the literature, with the exception of B. Kentish et al. (in litt.), it has not been applied to this particular issue. Harvesting theory provides guidance for adaptive management responses to ensure sustainability in the face of uncertainty (Caughley, 1977; Caughley and Sinclair, 1994).

Central is the need to closely monitor harvested populations, harvest below the estimated maximum sustainable yield, and adjust off-take levels as appropriate if monitoring data indicates such a need. The current monitoring program (R. Cunningham and G.B. Baker, in litt.) aims to provide an estimate of the density of breeding pairs during the peak of the breeding season and to track these estimates over time. Population estimates derived from this monitoring are likely to underestimate population size, because some pairs will have already laid eggs and failed, whilst others may not have commenced breeding at the time of the peak count. Use of these data for determining a sustainable yield will therefore be conservative.

If a legal harvest is to be sanctioned, we advocate maintenance of the monitoring program (R. Cunningham and G.B. Baker, in litt.). This will provide critical data to assess whether the level of harvest (both legal and illegal) is too high, providing adequate opportunity to adjust management strategies as appropriate. As suggested by B. Kentish et al. (in litt.), a non age-specific harvest would be practical to implement and most likely the best strategy to adopt (see Caughley (1977)). However, it should be noted that there is substantial discussion in the literature demonstrating that seabird population growth rates are sensitive to small changes in adult survival (Russell, 1999).

An alternative approach to establishing quotas, and one frequently adopted in many commercial fisheries, would be to control harvesting effort. However, given that it has been impossible to control poaching effort effectively in the past, such an approach is unlikely to succeed.

4.4. Conclusion

The North Keeling Island population of red-footed booby has increased since 1985, but its future cannot be considered secure while the species is subject to largely uncontrolled hunting pressure. Boobies can be readily hunted to extinction, as evidenced by the short time taken to exterminate them from the southern Cocos atoll (Forbes, 1885) and elsewhere in the Indian Ocean (Feare, 1978, 1984). And, while there has been an active program to control harvest pressure, the North Keeling breeding population has probably thrived more through luck than good management. As found elsewhere in the Indian Ocean (Feare, 1978), physical barriers to hunters such as the difficult landing on North Keeling Island and rough sea conditions for much of the year have probably proven more effective in conserving the population than active management approaches.

The EPBC Act provides strong legislative protection for red-footed boobies but its effectiveness is limited by the difficulty of enforcement in this remote area. For the last decade the Australian government has had three conservation officers located in the Territory. Their office and housing is located on West Island but, for historical and cultural reasons, the Cocos Malay community live on Home Island, 10 km to the east. The isolation of the community provides an effective barrier to enforcement activities, with poachers generally safe from detection and prosecution. Despite regular enforcement patrols by conservation officers, the departure of an official government vessel from West Island is usually immediately reported to would-be offenders, providing adequate opportunity to cease activities or dispose of evidence.

Restrictions on firearm ownership are also essential. Australia's firearm legislation has been revised over the last decade, requiring a person to have a legitimate reason to possess a gun. Whilst recreational hunting is generally not recognised as legitimate reason for firearm possession (except under very strict conditions), ownership of firearms for target shooting is an acceptable purpose. In 2000 a formal gun club was established on the Cocos (Keeling) Islands, leading to an increase in legal gun ownership. Increased gun ownership coincided with detection of increased poaching incidents (W. Murray, unpublished). Effective gun control on the southern atoll is considered to be a key factor in reducing the level of poaching (Environment Australia, in litt.).

The Cocos Malay people view hunting of seabirds as an important tradition and believe that they are entitled to harvest birds because they have done so 'traditionally' for 150 years. However, there is no legislative basis to this claim. While Australian indigenous people and traditions such as hunting are exempted from certain aspects of the EPBC Act, the Cocos Malay community are not recognised under the Act as indigenous people. This situation is no different than that which exists for other Australians whose ancestors colonised Australia within the last two centuries and who have a tradition of hunting, such as those who actively hunt native waterfowl.

The positive growth rate of the North Keeling population of red-footed booby provides evidence that it could undoubtedly support some level of harvest. However, there is little to suggest that an official harvest would lead to a cessation in illegal activities. A commitment by the community to cease illegal harvesting should be an essential prerequisite to the declaration of a legal harvest. It is unlikely that a legal harvest of the order being sought over the last few years (c. 1500 birds per year), in addition to an annual illegal harvest of 2000–3000 birds would be sustainable over a longer period.

Of concern is the fact that there appears to be no acknowledgement by the Cocos Malay community that unrestricted hunting of red-footed boobies is unsustainable, despite implementation of an environmental education program over the last 10 years (W. Murray, unpublished). There is also little evidence of social disapproval of illegal hunting; indeed the opposite is the case. Between 1997 and 2002 there were at least four successful prosecutions of residents who had killed more than 20 birds each. In another incident (in 2000) two hunters were apprehended on North Keeling with 71 birds in their possession. In some cases, those apprehended for wildlife offences were respected members of the community, whose good-standing was not impaired by prosecution and conviction.

Management of seabird harvesting on Cocos (Keeling) Islands is therefore likely to remain problematic for some time. The solution requires both improved biological knowledge on the capacity of the population to sustain harvesting, and resolution of associated social issues. It is likely that a range of management approaches will be necessary, with particular emphasis placed on maintaining or increasing enforcement activity to control illegal harvest, and enhanced education programs to further encourage a change in community attitudes.

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Barry Reville and John Hicks established the early methods for the monitoring program and provided useful background information and insights into the history of harvesting. Barry Kentish and Julian Reid provided background to their research on Cocos and copies of their unpublished reports. Much of the data were collected by Australian government conservators and support staff on Cocos during the period 1987–2002. These included Andrew Grant, Tony Stokes, Theo Hooy, Jeff Tranter, Paul Stevenson, Ismail Macrae, Robert (Greenie) Thorn, and Kenny Arkrie. Ismail Macrae and Nor-Dianna Hajat assisted in data compilation. Jason Passioura and Craig Richardson calculated the area of the major breeding habitat. We are particularly grateful to three members of the Cocos Malay community who provided information on illegal hunting practices. Thanks also to David Carter, Ian Norman, Graham Robertson, Geoff Tuck and an anonymous referee for reviewing drafts and providing suggestions which greatly improved the manuscript.

Many of the references in this paper are unpublished reports that are not widely available. They are available from the senior author as electronic (pdf) files on request.

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Data Analysis System for Red-footed Booby Program at Cocos (Keeling) Islands 2007

Draft Report prepared for

Department of Environment & Water Resources
RS39

by Barry Baker & Ross Cunningham

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Introduction

The red-footed booby, Sula sula, is a large, long-lived seabird with an extensive pan-tropical distribution. It is arguably the world's most abundant booby (Nelson, 1978). Throughout its range the species has been persecuted by man, often with devastating effect. For example, of 16 breeding colonies known to have existed in the western Indian Ocean within the last 100 years, 12 were extinct by the late 20th century (Feare, 1978, 1984). The demise of these colonies was almost entirely due to hunting for food by indigenous peoples.

The Cocos (Keeling) Islands, located in the north-east Indian Ocean, consists of 27 islands in the group. Red-footed boobies probably occupied most of the these islands, but by the early 20th century they had been extirpated from the southern Cocos atoll, and now only breed on the isolated and uninhabited North Keeling Island, located about 24 km north of the Cocos group. The significant population of about 30,000 pairs (Baker et al., 2004) that remains on North Keeling Island is now the largest remaining red-footed booby colony in the Indian Ocean.

Red-footed boobies have been hunted since humans first colonised the Cocos Islands. The history of this harvest has been summarised in Baker et al. (2004). While hunting has at times been sanctioned by the Australian Government, a formal hunting season has not been declared since 1997, although extensive poaching has occurred in both the southern atoll and at North Keeling (J. Barry, in litt.).

Hunting of boobies remains an important tradition amongst the Cocos-Malay people and in 2006 a draft Community Management Plan for harvesting boobies was prepared by consultants Brydie Hill and Julian Reid, working with the Cocos Congress (Hill and Adam, 2006). The aim of this plan was to ensure the long-term conservation of the red-footed booby in the Cocos (Keeling) Islands and allow sustainable harvests of boobies for the Coco Malay. This plan did not state a desired harvest level, but Hill and Reid (2006) considered 3,000 birds would constitute a safe, conservative annual human harvest for this population. Although calculations provide some information on population status and projected scenarios as the basis for this proposal, in our assessment this harvest figure does not have any rigorous scientific support.

In July 2001 we were commissioned by the Australian Government to provide an assessment of the methodology and statistical accuracy of annual red footed booby surveys on Pulu Keeling National Park (Cunningham and Baker 2001). Following the development of the Community Management Plan, Latitude 42 Environmental Consultants Pty Ltd has been asked to re-examine existing data to determine if they are informative in assessing long-term trends in the Cocos (Keeling) red-footed booby population. Specifically, we have been commissioned to:

1. Develop an electronic data management system that permits efficient storage and management of survey data collected to estimate the breeding population trend of the red-footed booby at Pulu Keeling.
2. Populate the database with all relevant data collected to date.

3. Analyse the data collected to estimate population trend for the Pulu Keeling red-footed booby breeding population, using statistical approaches that can be readily implemented in the future. Determine the population trajectory for the period 1987 to 2006.

Develop a population model to examine the impacts of an annual recreational harvest of red-footed boobies. Ideally, the model should utilise software that is readily available and easily operated by a person with basic biological expertise.

4. Report on the work undertaken. Products sought are:
   - a populated database;
   - statistical analysis framework to estimate future population trajectories;
   - an analysis of the current population trend;
   - a population model;
   - recommendations for a sustainable harvest level in 2007; and
   - clear instructions on how to undertake statistical analyses and use the population model.

This report is provided in fulfilment of our contractual obligations.

Assignment 1 and 2

Develop an electronic data management system that permits efficient storage and management of survey data collected to estimate the breeding population trend of the red-footed booby at Pulu Keeling. Populate the database with all relevant data collected to date.

1. Database structure

No database software specification was specified for this project. We have chosen Microsoft Excel for the construction of the Cocos (Keeling) red-footed booby database since this software is readily available and widely used and understood by most people familiar with data entry, storage, management and analysis. The data collected under the existing survey methodology has a simple structure, and therefore requires nothing more sophisticated than a flat file for storage and rapid access purposes. They can be easily exported into more complex database formats if so desired.

The Excel or Database file contains three Worksheets:

<**Metadata**> — Provides all associated background information relating to the design of the study, the data collection protocols, database structure and how to analyse the dataset.
<**Database**> — Contains 11 fields in which the data collected in the field are stored for subsequent analysis.

<**Data entry template**> — Contains duplicate fields to the <Database> worksheet, to facilitate data entry prior to incorporation into the <Database> worksheet at a later stage.

The structure of the <Database> worksheet prepared for this study are described below.

Column Code	**Field/ Column**	**Contents**
A	Transect	Contains an Alpha transect identifier. There are currently 10 transects used — A, B, C, D, F, I, J, K, L and P. Four other transects — E, G, L and M — have been used for a number of years but are now discarded.
B	Quadrat	Contains a numeric code for each 20 X 10 metre quadrat
C	Tree Number	Contains the unique quadrat-specific numeric code that is given to all trees that fall within a quadrat and have been used for nesting at some stage.
D	Tree OK	Records if a tree used for nesting at any time since the survey commenced is still extant (Y or N)
E	Distance	Records the distance of a nesting tree from the start of

		the transect. Relevant mainly for assisting field personnel in locating a particular tree during field work, but also used in the post-hoc establishment of the 3-Tree Plots.
F	Number	The number of nests within a tree at the time of a count
G	3 Tree Plot No.	Contains a numeric code assigned to groups of three adjacent trees along transects by Baker & Cunningham (2001) to permit analysis of change in nesting density over time. There were 41 3-Tree Plots in 2001, comprising trees that had been used continuously for breeding since the survey commenced in 1987.
H	Day	The day of the year that a count was undertaken
I	Month	The month of the year that a count was undertaken
J	Year	The year that a count was undertaken
K	Comments	Any comments made either in the field or during data entry that may provide additional information relevant to analysis of the data by others

The populated database includes information on all maximum-monthly counts for every year from 1987 to 2002 where counts were carried out, and all counts conducted since that time. Metadata are provided in a separate Worksheet ***Metadata*** stored within the Excel database file ***North Keeling database_V2.*** This provides a detailed description of data collection protocols, together with survey design history, to facilitate understanding of the development of the program and ensure the basis for the survey is maintained.

Assignment 3

Analyse the data collected to estimate population trend for the Pulu Keeling red-footed booby breeding population, using statistical approaches that can be readily implemented in the future. Determine the population trajectory for the period 1987 to 2006.

1 Summary of Survey methodology

Cunningham and Baker (2001) and Baker et al (2004) previously reviewed and modified the survey methodology for estimating breeding population density and, in particular, for tracking change in population density. Provided below is a summary of previously employed methodologies that have led to the survey program in place today.

A survey method to estimate breeding density on North Keeling Island was established in 1985 (Hicks and Campbell, 1985; Reville, 1987.). Originally, four strip transects were established with a further ten transects added in 1987 (A. Grant, 1989). Transects were 20 m wide and varied in length from 80-350 m. Within transects all trees containing nests were individually marked and their location mapped to assist observers locating them during counts. Transects were not random but systematically selected to ensure wide coverage of the major breeding areas on the western section of the island (Hicks and Campbell, 1985).

Each year, nesting trees were assessed on transects, with new trees being used added to the population, and those that had been lost due to natural causes removed. The survey was designed to allow nesting densities to be calculated and extrapolations made island-wide to estimate the number of annual breeding pairs (B. Reville, unpublished). The number of transects, and hence number of trees, counted has varied over the years but at least ten transects have been used continuously since 1987 (Transects A-D, F, I-L and P).

Unfortunately, the intent of the original survey design was misunderstood, leading to the belief that surveys were tree based, rather than area-based, counts (Kentish et al., 1996; Cunningham and Baker, 2001). As a result, at some stage after 1987 new nesting trees within transects were not routinely added to the survey design and included in total nest counts, although this did occur periodically. This meant that the survey ceased to be area based, which constrained the ability to extrapolate data to develop total population estimates. However, analysis of longitudinal patterns of nesting density was still possible using plots of three trees that were roughly adjacent to each other (referred to as '3 Tree Plots' in the database).

Following recommendations by Cunningham and Baker (2001), transects were re-established in 2001 and partitioned into 20 X 10 m quadrats to ensure that quadrats became the basic unit for future analyses. This change was intended to provide data permitting estimation of population size, unlike the situation that had developed in earlier years.

Counts of nesting trees were carried out each month during the red-footed booby breeding period (March to October) in most years from 1987 to 2002. Counts were not conducted in 1990, 1991, 1992 and 1998 because of difficulties of access. There were also access difficulties in 2005 and 2006, although at least one count was conducted in these years. In each count all nest trees were inspected and the number of active nests present recorded. As there was no evidence of large observer variance in tree-based counts it was not necessary to carry out repeat counts for each monthly survey (Cunningham and Baker, 2001). Counts for each transect were summed, and only the highest monthly count, representing the peak of breeding activity in a year, was used in further analysis. This procedure was followed in the years 2002 to 2006. It should be noted that maximum annual counts may underestimate the total number of breeding pairs in a season since it is possible that birds that fail early in a season may have re-layed later.

We do not support any radical change to the methodology outlined in Cunningham and Baker (2001) and Baker et al (2004), as proposed by Hill and Reid (2006). In any monitoring program designed to facilitate or manage a harvest, the fundamental issue to be addressed is tracking changes in population with high precision, not necessarily that of estimating population size with high precision. Statistical arguments on this point are clearly discussed in Cunningham and Baker (2001), Annex 2. To radically move away from the well-established methodology that is providing high-quality data permitting tracking of the population would ignore the retrospective power derived from 20 years of survey effort. Any alternative methodology needs to be statistically efficient and logistically feasible. The changes outlined in Hill and Reid (2006) does not fulfil these requirements. Although an alternate method may provide precise and unbiased estimates for population size, it will be some years before these are useful for tracking change. Random selection of quadrats is not essential for monitoring change. Further non-random aspects of a survey design can now be readily modelled using current statistical methodology (see below); inferences will then be model-based rather than design-based.

2. Modelling temporal patterns in nest counts

Because the intent of the original survey design was misunderstood, Cunningham and Baker (2001) found it necessary to analyse data up to 2001 on a tree-by-tree basis rather than using area based units to assess longitudinal patterns of nesting density. To continue to maintain a long-term picture, we have retained this approach for all data from 1987 to 2006. However concurrent quadrat based data is also available from 2001, which has meant that it is possible to analyse area-based data as well as continue the log term tree based analysis. Quadrat data now provides relevant information for scaling tree-based data to give approximate population totals of breeding pairs on North Keeling.

For each year the month of peak breeding activity (maximum monthly count) was identified and used to determine an annual maximum nest density. Maximum counts occurred when most nests contained incubating adults and were, for 1987 – May, 1988 – June, 1989 – August, 1993 – June, 1994 – June, 1995 – August, 1996 – May, 1997 – April, 1999 – October, 2000 – August, 2001 – July, 2002 – June, 2003 – July, 2004 – November, 2005 and August, 2006.

For each transect, plots comprising groups of three roughly-adjacent trees were selected from trees that had been counted continuously for all years of the survey. We considered the use of more (four and five) trees in plots but found this reduced the number of sampling units for study. Data selected for formal statistical analysis consisted of nest counts for 16 years on 39 three-tree plots distributed along 8 transects. These data have both a spatial and temporal dimension. The spatial component is hierarchical in that three-tree plots are nested within transects. It seems reasonable to assume counts between transects are independent but that there may be some spatial correlation between plots within transects. Preliminary data analysis showed that nest counts of plots within transect were correlated, but that the spatial correlation did not depend on the distance between plots within transects. On the other hand there was strong evidence of serial correlation between 3 tree- plot based counts from one year to the next. This serial dependence was modelled by a simple exponential decay process, which is equivalent to an autoregressive process of order 1, when data are equally spaced. It was assumed that temporal dependence between years was the same within all three-tree plots.

Similar properties were found for the quadrat based data and so an analysis using the same model was undertaken for these data.

As the focus here is on temporal trends we have chosen to model overall year effects as a fixed effect. The statistical model described above is known as a general linear mixed model. The estimation of year effects is by weighted least squares, and transect/plot and residual components of variance and the serial correlation parameter were estimated by restricted maximum likelihood, done simultaneously (Galwey, 2006). As nest counts were skewed, a square root transformation of the raw plot/ quadrat data was required before analysis (earlier data were analysed on a log scale but a thorough re-analysis with additional data showed the square root transformation was slightly preferable). Further preliminary analyses of both plot and quadrat data showed that the pattern of variation between years was approximately consistent from transect to transect. Thus our additive model for square root (counts) seemed reasonable.

3. Results of data analysis

The predicted mean square root of the number of nests per 3 tree plot where data were available from 1987-2006 shows some evidence of general increase in nesting density (Fig. 1), However there was large inter-annual variation with substantial fluctuations which tended to be greater following the significant cyclonic events of 1989 and 2001. Such results indicate that the level of illegal harvest sustained during the study period has not impacted negatively on the nesting population of red-footed booby.

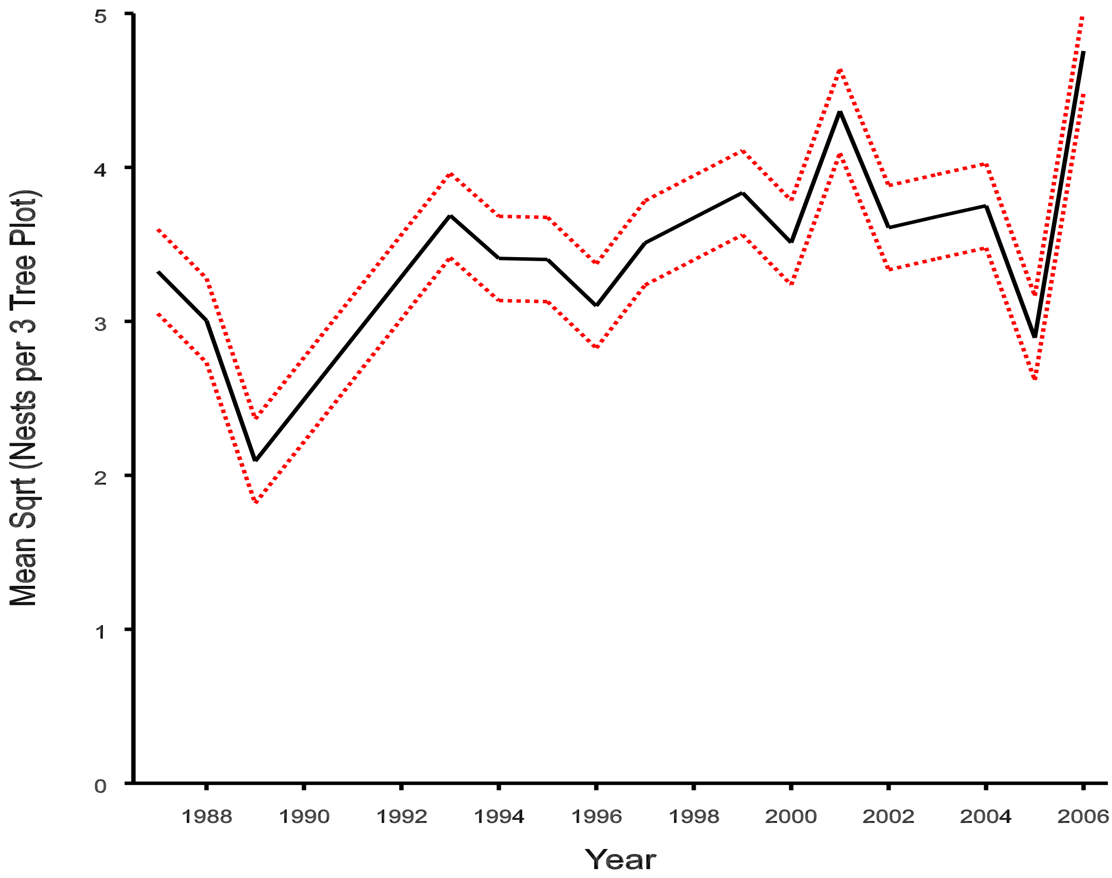

Fig. 1. Predicted mean density of red-footed booby nests in three-tree plots (*n=39*), with 85% confidence intervals, derived from maximum annual counts for the period 1987–2006. Significant cyclone events occurred in January 1989 and April 2001.

The matching quadrat based data for the years 2002 – 2006 shows a year-to-year pattern similar to the 3 tree-plot data (Fig 2)

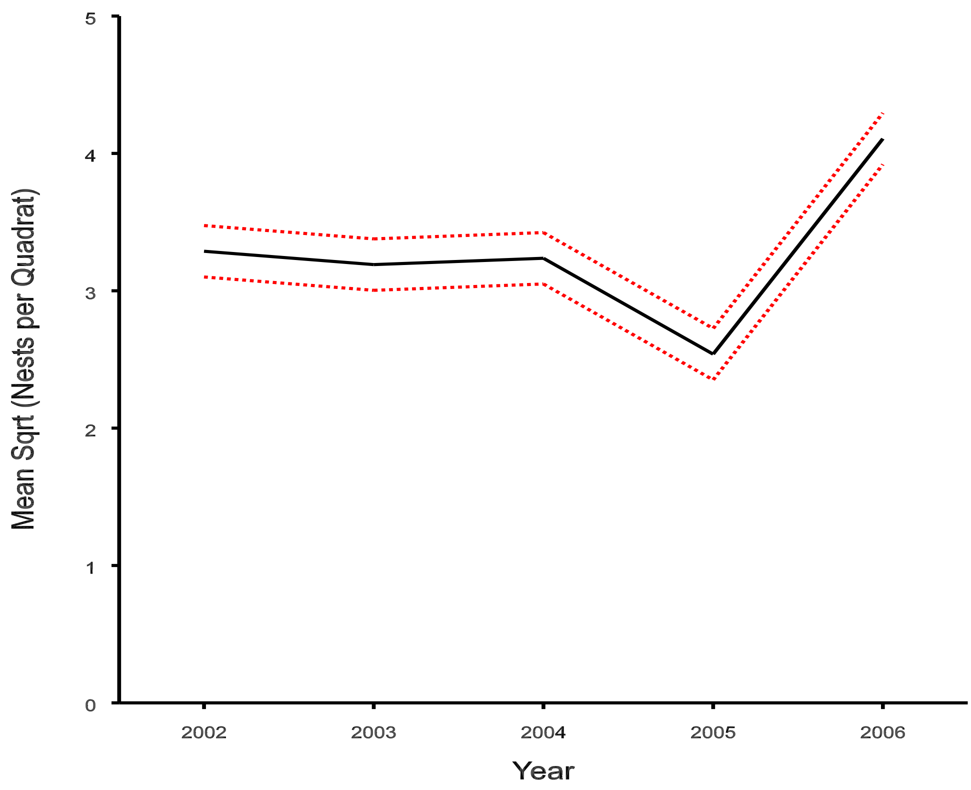

Fig.2. Predicted mean density of red-footed booby nests in 20×10 m quadrat (*n=99*), with 85% confidence intervals, derived from maximum annual counts for the period 2002–2006.

We are now able to obtain approximate estimates of the number of birds nesting annually on North Keeling every year using both the quadrat and 3-tree plot based data. The ratio statistics for the years 2002 to 2006 for scaling 3 –tree plot data to an areal based measure are given in the Table below.

Year	Quadrat/3 Tree-plot
2002	0.8390
2003	0.7705
2004	0.7675
2005	0.7973
2006	0.7675

As can be seen there is a high degree of consistency in this ratio between years and so we have used the mean, 0.791, as the scaling factor. After digitising the boundaries of this habitat defined on air photos by Hicks (1985), we calculated the area of this habitat by using the Geographic Information System software ArcInfo Version 7. The resulting estimate of 52.6 ha figure was rounded down to 50.0 ha to account for spatial error associated with data interpretation and the inaccuracies inherent in the data. Multiplying the mean density by the estimated area of major habitat we estimate the approximate number of breeding pairs. These are shown in Figure 3 together with a smoothed trend line. The smoothed curve was obtained by fitting a smoothing spline of order 3 (i.e. 3 d.f. — Hastie and Tibshirani, 1990). The overall mean from 1993 to 2006, a period for which the linear trend was not significantly different from zero, was estimated to be 30,000 nests or breeding pairs, rounded to the nearest 1000. This estimate is conservative, and does not include birds nesting in 15.9 ha of poorer quality breeding habitat on North Keeling Island (Hicks and Campbell, 1985).

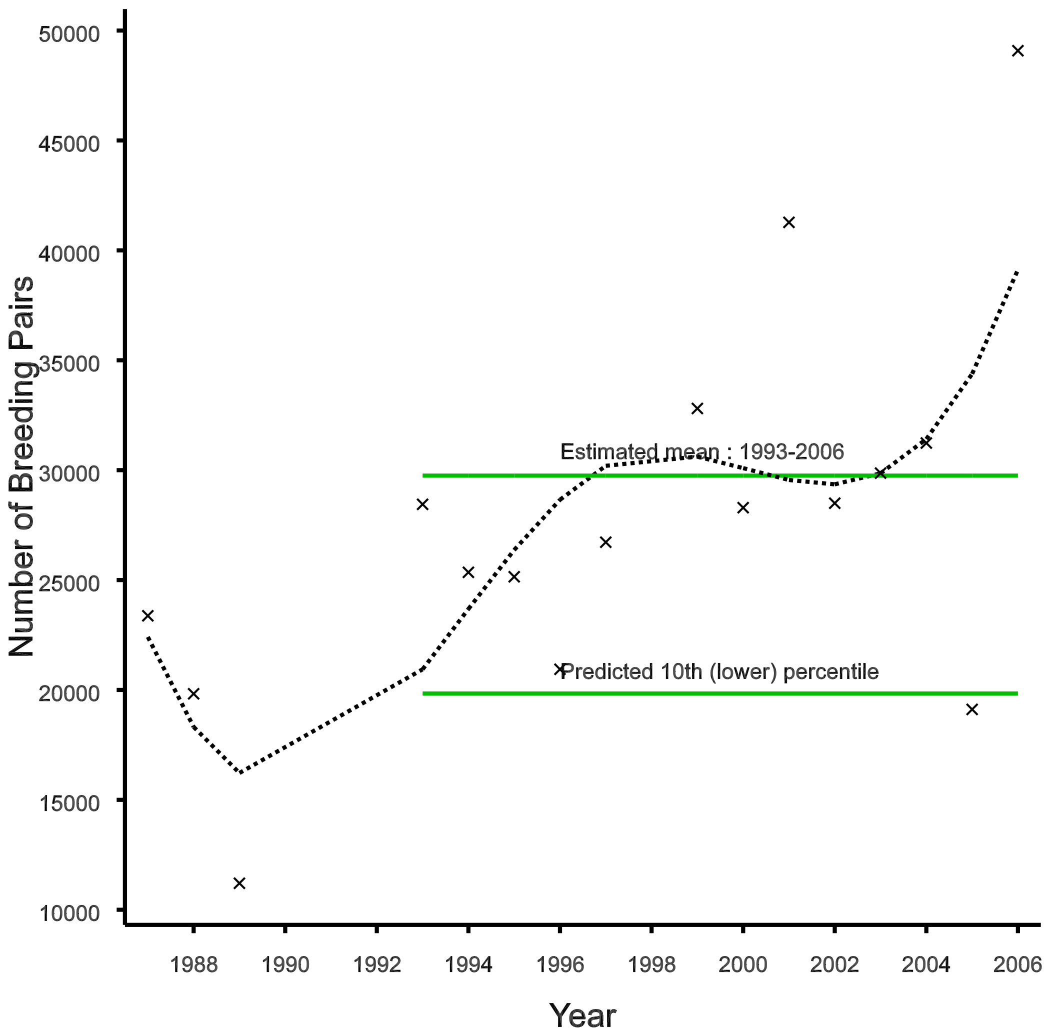

Fig. 3. Observed and a smoothed estimate of from 1987 to 2006. Also included is the predicted number of breeding pairs based on the data from 1993 to 2006, together with a lower 10% bound.

If we assume ‘year’ to be random rather than fixed as assumed in the previous analysis we can obtain a simple model for predicting the annual number of breeding pairs. For this model we assume a Normal distribution for annual nest counts (not unreasonable for aggregate count - Central Limit Theorem - and supported by model diagnostics) with mean equal to the mean (30,000) for the period 1993 -2006 and a standard deviation of 7746. This standard deviation reflects both the inter-annual variability plus sampling error. Using this simple model we obtain a prediction the lower limit (e.g. 10^{th} percentile) of total number of annual breeding pairs per year ie 20,000 breeding pairs (Figure 3). This number may be useful as a conservative estimate of population size upon which a harvest can be based.

5. Recommendations for future analysis

We have used a combination of Generalised Linear Mixed Models and General Linear Mixed Models to analyse the data collected on red-footed boobies. Statistical computation was carried out using the software program GenStat.

The level of sophistication employed in the data analysis is high, and it is not possible to write a prescription to permit a thorough analysis of these data by non-statistical experts. However, to carry out these analyses by an expert will require only a few days work in future, provided the data are digitised as recommended in this report. For this reason, we recommend that consideration be given to funding ongoing analysis of the data on an annual or biennial basis, rather than attempting to do these analyses using non-experts. The costs of carrying out such an analysis, together with an assessment of the impact of harvesting are likely to be less than $5,000.

If data analysis by Parks Australia staff is considered essential, it is suggested a simple analysis be undertaken each year by local staff. This would involve calculating the total number of nests on the 3 tree plots (n=39) and the quadrats (n=99), confirming the scaling factor, and then calculating the total number of breeding pairs. This number can then be plotted as an additional point on the temporal profile graph, and the number used as a parameter input for a demographic model.

Assignment 4

Develop a population model to examine the impacts of an annual recreational harvest of red-footed boobies. Ideally, the model should utilise software that is readily available and easily operated by a person with basic biological expertise.

1. Introduction

Population viability analysis (PVA) is widely used in conservation biology to predict extinction probabilities for threatened species and, in particular, to assess the likely impact of current and future threats (e.g., Hamilton and Moller 1995; Brook et al. 1997a, b; 1999, 2000). PVA is a risk assessment process that can be used to:

- Predict the probability of extinction
- Predict how management/disturbance such as a annual harvest might affect persistence over time
- Estimate the size of a viable population (Minimum Viable Population)
- Estimate habitat requirements
- Identify vulnerable aspects of natural history (sensitivity analysis), and
- Determine what additional data need to be collected to ensure appropriate management of populations.

The first two of these capabilities are employed here to predict the likelihood of a significant impact on the Cocos (Keeling) red-footed booby population should an annual harvest by the Cocos-Malay community proceed.

The following analysis is comparative and, although an attempt was made to input realistic life history information, the models do not do not necessarily reflect the future prospects of the population. Rather, they predict the likely change in probability of persistence of the population that a proposed harvest will cause.

PVAs were generated using the VORTEX computer simulation model (Version 9.51, Lacy et al. 2003; http://www.vortex9.org/vortex.html); this is one of the most widely used and realistic of PVA software packages (e.g., Lindenmayer et al. 1995; Brook et al. 1997a, 1999, 2002). VORTEX was written by Dr Robert Lacy, Department of Conservation Biology, Chicago Zoological Society and is available as freeware. It is also supported by a downloadable manual (Miller and Lacy 2003) that is easy to follow, together with a list-server that handles questions from users (vortex@listhost.uchicago.edu). It complies with the project brief of being software that is readily available and easily operated by a person with basic biological expertise, although training in its use by experienced operators will certainly benefit the user. We are able to assist in this regard, if necessary.

It should be noted that the version of VORTEX we have used (V9.51) is not the most current — V9.72 can currently be downloaded but this is not supported by the manual. The differences between the two versions are inconsequential for the purposes of this assignment, and we felt the use of a manual would be beneficial for inexperienced users.

2. Model Parameters

Unfortunately, there are no long-term studies of red-footed booby that provide appropriate estimates of vital rates for input into a PVA, but data from shorter-term studies of this species and other Sulids have been used here. Unless stated to the contrary, these have been obtained from a recent review of the Pelecaniformes (Nelson, 2005) and discussions with Dr D. Anderson, who has a long-term dataset on Nazca boobies. Where parameters were not known they were estimated from available information on boobies and other long-lived seabirds, a practice that is widely used when modelling populations where input data are unavailable (e.g., Hamilton and Moller 1995; Baker and Wise 2005). Life history parameters used to derive the VORTEX inputs used in the baseline model (Model 1) are summarised in Annex 2.

On the grounds that the population appears to have been more-or-less stable since 1993, the parameters were adjusted to ensure that they predicted persistence of the population in the long-term with minimal population growth rate. These adjusted values were used as assumptions in the baseline PVA. VORTEX is a stochastic model that imposes variability based on standard deviations (SD). The standard deviations used in the baseline model (Model 1) are also indicated in Appendix 1.

We have assumed this population has only one extant breeding colony, located on North Keeling Island, which has been monitored since the late 1980s. The population estimates we have used are described in Section 3 of this report. To be conservative, we have based our modelling on an initial population size of 20,000 annual breeding pairs, or 120,000 individuals, assuming a stable-age distribution.

Quasi-extinction is defined as 50% of initial population size. This level has been selected because we anticipate that management action would be implemented well before the population approached biological extinction. Cyclones are a frequent occurrence in the North-east Indian Ocean. Between 1980 to 2006 two cyclone events caused extensive damage to breeding habitat on North Keeling and killed many breeding birds during at least one of these events (Paul Stephenson, pers. comm). We have therefore assumed that a serious cyclone event can be expected to occur every 12 years.

VORTEX is limited to the size of population it can model. This means that we have modelled a smaller population here to ensure the Program ran smoothly. The initial population size was set at 4,700 individuals, 10% of the conservative estimate of population size (47,000 birds). In assessing harvesting scenarios, models therefore divided the number of birds to be harvested under each scenario by 10.

All models did not include a term for density dependence, as there are no data for any Sulid that could provide guidance on this parameter. In fact, evidence for density dependence in any seabird species is limited. Density dependence would undoubtedly exist, however, and will most likely be expressed by the proportion of birds breeding in any year. As populations decline, it would be reasonable to assume that birds would commence breeding at an earlier age, and the proportion of birds skipping a year would decline. The increase in breeding numbers recorded immediately after the 1989 and 2002 cyclones provides evidence of density dependence in Cocos (Keeling) red-footed boobies. Baker et al. (2004) postulated that severe canopy defoliation provides additional nesting sites and an abundance of nesting material, thus enabling birds that would have not normally bred the opportunity to do so.

3. Harvest Scenarios

Vortex provides the opportunity to remove birds from a population, as would occur in a harvest situation. Scenarios can be set up to simulate harvesting in one or more years, and to take birds from any age class. While an annual harvest would most likely lead to random selection of individuals for killing, we have assumed that most of the birds taken would be younger, naïve individuals, and there would be no sex bias in the take. The age proportions used in all harvest scenarios were:

Age 1	50%
Age 2	20%
Age 3	10%
Age 4	6%
Age 5	14%

We investigated the following harvest scenarios:

Scenario	Scenario Description
1	No harvest
2	Harvest 1500 birds once
3	Harvest 1,500 birds each year
4	Harvest 1,000 birds each year
5	Harvest 500 birds each

After running 2000 simulations of each scenario, all harvesting options reduced population growth to negative values, with the exception of Scenario 2.

Scenarios 2000 simulations	Popn growth rate r	SD	No. Popns reaching quasi-extinction	Mean final popn size	Mean time to quasi-extinction for populations going extinct (years)
Start population size				120,000	
1. No harvest - base scenario	0.0046	0.0407	0	131,307	
2. Harvest 1,500 birds, once only	0.0042	0.0406	0	130,390	
3. Harvest 1,500 birds each year	-0.0089	0.0416	151	93,625	24.9

4. Harvest 1,000 birds each year	-0.0037	0.0413	34	108,870	24.4
5. Harvest 500 birds each year	0.0003	0.0410	8	120,544	27.1

Summary

Bearing in mind that we have used a conservative estimate of population size, modelling suggests that the population could sustain a limited annual harvest of between 500 to 1,000 birds per year. A one-off harvest of 1,000 birds in 2007 would certainly be sustainable.

The 20 years of data available have allowed us to provide precise estimates of both the inter-annual component of variance as well as the inherent sampling components of variance. We have used these estimate to construct a lower bound (10th percentile) for a predicted number of breeding pairs (and hence the derived estimate of total birds in the population) in a future year. By using this estimate we can use these numbers as the basis for recommending a safe harvest bound.

The argument in support of this is that in 9 years in 10, we expect the number of breeding pairs will exceed this lower bound. We still favour the use of this figure, noting that there is large inter-annual variation, as well as inherent sampling error, as evidenced by the confidence intervals, in the mean values. However, there may be criticism of this approach as being too conservative. We can certainly model additional scenarios for example, using the mean estimate of population size as a basis, if required.

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ANNEX 1. Extract from Cunningham and Baker (2001) — Statistical inferences relating to population size versus changes in population

Inferences relating to population size

If we wish to make inferences about the total population size in a given year, then quadrats should to be considered as random. In this case the standard error of the estimate of population size includes both variance due to counting as well as that due to sampling, and so we require estimates of variance components for quadrats (σ_q^2) and counting (σ^2).

Thus the variance of the mean number of nest per quadrat (density of nests) will be:

$$\textbf{Var}(\overline{Y}) = \frac{1}{q}[\sigma_q^2 + \sigma^2], \text{ where q is the total number of quadrats sampled.}$$

Inferences relating to change

Note that if we wish to make inferences about change in population size from year to year then quadrats can be considered as fixed. This improves the precision of estimates of change as the standard error is based only on variance associated with counting and not quadrat-to-quadrat variance (sampling variance) as well.

In this case the variance component associated with quadrats does not contribute to the estimate of the standard error of the difference (change) and so the counting error is the only relevant variance term; we assume that this remains similar between months from one year to the next. Thus the variance of the mean number of nest per quadrat (density of nests) will be:

$$\textbf{Var}(\overline{Y}) = \frac{1}{q}[\sigma^2], \text{ where q is the total number of quadrats sampled.}$$

For the purposes of monitoring abundance, and hence change, we can restrict inference to the sample ('statistical population') of quadrats and need not attempt to predict the total population size of the island. For the purposes of setting quotas we need an estimate of the total size of the breeding population of the island. In deriving this estimate from the sample, the precision is likely to be low and hence confidence intervals large. Typically, precision of population estimates in a given year will be much lower than precision of estimates of change in population based on the sample data.

ANNEX 2. Summary of relevant life history and parameters used in baseline PVA for the Red-footed Booby

Breeding system	• Monogamous	Nelson 1971; 2005
Age of first breeding Median age at first breeding	• 3 years • 5 years	Nelson 2005 Derived from long-term data for Nazca booby, D.Anderson pers.comm.
Maximum age of reproduction	• 25 years	No data, assumption
Maximum no. of progeny per year	1 chick	Nelson 1971, 2005
Sex ratio at birth – in males	• 50%	No data; assumption based on data for Nazca booby, D.Anderson pers.comm
Density dependent reproduction	• No	Density dependence would undoubtedly exist but mechanism unknown
% females breeding each year	• 90% (SD 2%) i.e. 10 females skip breeding in a year	No data exists. Assumption based on data for Nazca booby, D.Anderson pers.comm
No. of chicks fledged annually per breeding female	• 0.8 • 0.7 (SD 0.05)	Woodward 1972, in Nelson 2005 Value selected for modelling, based on Verner 1961, in Nelson 2005
Mortality – year 1	• 55% (SD 5%)	Nelson 2005
Mortality – adult	• 7% all adult age classes (SD 1%) • 10% following cyclone	Nelson 2005 Assumption
Cyclones frequency	• 8% - 1 severe cyclonic event every 12 years	Paul Stephenson pers.comm.
Life expectancy (max longevity)	• 25 years	Assumption based on Nelson 2005
Current annual breeding population	• 20,000 pairs, equivalent to 120,000 individuals • input value for model 12,000 individuals	This study See text
Carrying capacity (K) of North Keeling	• 150,000 individuals • input value for model 15,000 individuals	See text

Nestling sex ratio	• 1:1	Assumption

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	31
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	Red-footed boobies – North Keeling – survey data		
Hansard Page ECA:	120 (27/5/09)		

Senator SCULLION asked:

Mr Cochrane—Yes. I have a number of documents which relate to the monitoring program. We have had a number of pieces of advice on ensuring that it is robust and that the population estimates that come from that transect data are reliable and statistically reliable in particular. I am happy to provide an outline of the methodology of the surveys. We have survey data going back to 1986. Surveys were not possible in a few years when because of bad weather we were unable to gain access to the island. We have survey data that goes back to at least 1985 and most years thereafter. I noticed that you asked at the last estimates for the last five years worth of survey data but for some reason it did not end up in the written questions that came to us.

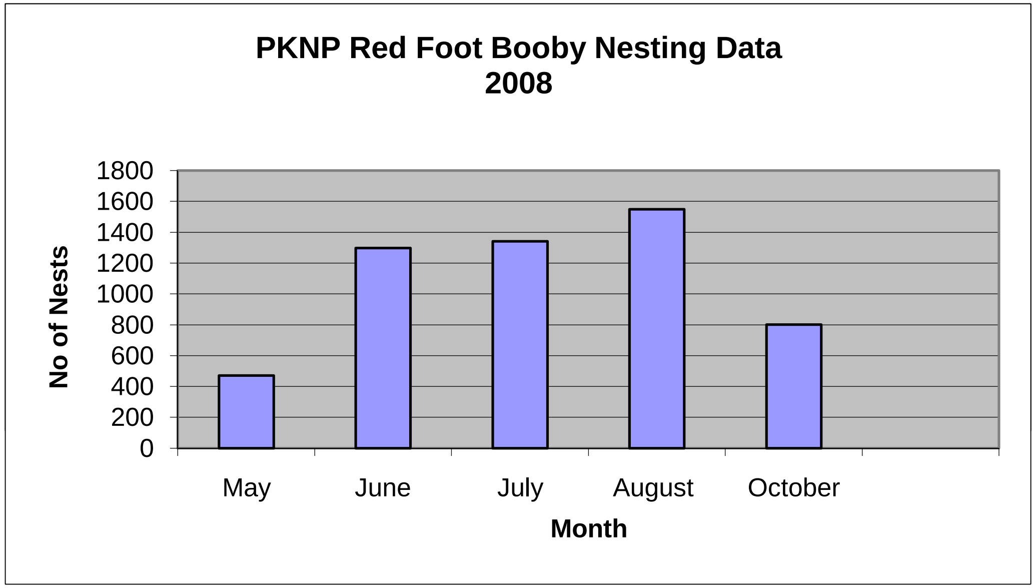
Senator SCULLION—I did indeed. You have provided some aspect of that, but could you provide me with copies of the entire reports that were provided?

Answers:

Survey data was recorded in our database, written reports were not produced. Copies of the survey data for the last 5 years are attached (Attachments A-E).

Month	No. Nests
May	471
June	1297
July	1341
August	1549
October	802

August is max nesting month therefore



Quadrat		No. of Nests	Total nests per transect	Calc mean sqrt nests per quadrat
A	1	13		3.606
	2	4		2.000
	3	14		3.742
	4	33		5.745
	5	16		4.000
	6	9		3.000
	7	34		5.831
	8	15		3.873
	9	1		1.000
	10	16		4.000
	11	12		3.464
	12	7		2.646
	13	2		1.414
	14	10	186	3.162
B	1	5		2.236
	2	14		3.742
	3	15		3.873
	4	7		2.646
	5	38		6.164
	6	22		4.690
	7	7		2.646
	8	32		5.657
	9	21		4.583
	10	18		4.243
	11	3		1.732
	12	19		4.359
	13	9	210	3.000
C	1	1		1.000
	2	0		0.000
	3	27		5.196
	4	11		3.317
	5	13		3.606
	6	21		4.583
	7	57		7.550
	8	2		1.414
	9	63		7.937
	10	44		6.633
	11	5		2.236
	12	6		2.449
	13	18		4.243
	14	10	278	3.162
D	1	14		3.742
	2	17		4.123
	3	47		6.856
	4	11		3.317
	5	41		6.403
	6	34		5.831
	7	15		3.873
	8	42		6.481
	9	29		5.385
	10	32		5.657
	11	14		3.742
	12	13		3.606
	13	7		2.646
	14	9		3.000
	15	10	335	3.162
F	1	21		4.583
	2	11		3.317
	3	18		4.243
	4	22		4.690
	5	36		6.000
	6	20		4.472
	7	28		5.292
	8	17		4.123
	9	9		3.000
	10	15		3.873
	11	16		4.000
	12	15	228	3.873
I	1	5		2.236
	2	19		4.359
	3	23		4.796
	4	23		4.796
	5	29		5.385
	6	18		4.243
	7	11	128	3.317
J	1	19		4.359
	2	5		2.236
	3	39		6.245
	4	46		6.782
	5	32		5.657
	6	2		1.414
	7	5		2.236
	8	12	160	3.464
K	1	13		3.606
	2	2		1.414
	3	1		1.000
	4	28		5.292
	5	12		3.464
	6	30		5.477
	7	10		3.162
	8	21		4.583
	9	25		5.000
	10	27		5.196
	11	31		5.568
	12	27	227	5.196

Quadrat	3 tree plot no.	No of nests	Calc mean sqrt nests per 3 tree plot
A	1	17	4.123
A	2	13	3.606
A	3	28	5.292
A	4	15	3.873
A	5	37	6.083
B	6	26	5.099
B	7	30	5.477
B	8	25	5.000
B	9	19	4.359
B	10	13	3.606
C	11	44	6.633
C	12	112	10.583
D	13	12	3.464
D	14	6	2.449
D	15	20	4.472
D	16	35	5.916
D	17	26	5.099
D	18	46	6.782
D	19	21	4.583
F	20	21	4.583
F	21	14	3.742
F	22	8	2.828
F	23	5	2.236
F	24	47	6.856
F	25	21	4.583
F	26	31	5.568
F	27	12	3.464
F	28	2	1.414
F	29	14	3.742
I	30	19	4.359
I	31	19	4.359
I	32	16	4.000
I	33	8	2.828
I	34	15	3.873
J	35	19	4.359
J	36	20	4.472
J	37	45	6.708
J	38	10	3.162
K	39	18	4.243
K	40	51	7.141
K	41	42	6.481
Sum		**1002**	**191.50**
	/n	**24.44**	**4.671**
	sqrt	**4.94**	

Column1		85% confidence limits	
Mean	4.675398	5.051637	4.299158
Standard Error	0.256343		
Median	4.358899		
Mode	4.358899		
Standard Deviation	1.641394		
Sample Variance	2.694174		
Kurtosis	2.998531		
Skewness	1.090681		
Range	9.168792		
Minimum	1.414214		
Maximum	10.58301		
Sum	191.6913		
Count	41		
Confidence Level(85.0%)	0.376239		

P	1	26		5.099
	2	26		5.099
	3	15		3.873
	4	14	81	3.742
Sum		**1833**	**1833**	**397.96**
		18.5	/n	4.020
		4.3		

Quadrat/3 tree plot 0.8606

Column1			
		85% confidence	
Mean	4.015939001	4.241436	3.790442
Standard Error	0.155418574		
Median	3.872983346		
Mode	3.872983346		
Standard Deviation	1.546395282		
Sample Variance	2.391338369		
Kurtosis	-0.068154147		
Skewness	-0.028364594		
Range	7.937253933		
Minimum	0		
Maximum	7.937253933		
Sum	397.5779611		
Count	99		
Confidence Level(85.0%)	0.225497446		

Quadrat		No. of Nests	Total nests per transect	Calc mean sqrt nests per quadrat
A	1	8		2.828
	2	1		1.000
	3	18		4.243
	4	27		5.196
	5	14		3.742
	6	9		3.000
	7	35		5.916
	8	14		3.742
	9	6		2.449
	10	15		3.873
	11	36		6.000
	12	5		2.236
	13	2		1.414
	14	15	205	3.873
B	1	5		2.236
	2	6		2.449
	3	18		4.243
	4	6		2.449
	5	36		6.000
	6	26		5.099
	7	3		1.732
	8	43		6.557
	9	19		4.359
	10	20		4.472
	11	5		2.236
	12	15		3.873
	13	7	209	2.646
C	1	2		1.414
	2	2		1.414
	3	24		4.899
	4	16		4.000
	5	12		3.464
	6	15		3.873
	7	47		6.856
	8	5		2.236
	9	62		7.874
	10	38		6.164
	11	6		2.449
	12	14		3.742
	13	17		4.123
	14	10	270	3.162
D	1	8		2.828
	2	21		4.583
	3	47		6.856
	4	12		3.464
	5	30		5.477
	6	39		6.245
	7	20		4.472
	8	50		7.071
	9	28		5.292
	10	31		5.568
	11	10		3.162
	12	11		3.317
	13	8		2.828
	14	5		2.236
	15	7	327	2.646
F	1	24		4.899
	2	12		3.464
	3	26		5.099
	4	24		4.899
	5	27		5.196
	6	26		5.099
	7	21		4.583
	8	25		5.000
	9	10		3.162
	10	21		4.583
	11	17		4.123
	12	12	245	3.464
I	1	11		3.317
	2	22		4.690
	3	20		4.472
	4	23		4.796
	5	31		5.568
	6	21		4.583
	7	12	140	3.464
J	1	33		5.745
	2	10		3.162
	3	53		7.280
	4	45		6.708
	5	30		5.477
	6	1		1.000
	7	4		2.000
	8	18	194	4.243
K	1	9		3.000
	2	3		1.732
	3	0		0.000
	4	31		5.568
	5	14		3.742
	6	24		4.899
	7	6		2.449
	8	14		3.742
	9	29		5.385
	10	17		4.123
	11	39		6.245
	12	28	214	5.292

Quadrat	3 tree plot no.	No of nests	Calc mean sqrt nests per 3 tree plot
A	1	39	6.245
A	2	11	3.317
A	3	30	5.477
A	4	12	3.464
A	5	34	5.831
B	6	21	4.583
B	7	27	5.196
B	8	36	6.000
B	9	15	3.873
B	10	15	3.873
C	11	40	6.325
C	12	95	9.747
D	13	6	2.449
D	14	6	2.449
D	15	25	5.000
D	16	38	6.164
D	17	28	5.292
D	18	39	6.245
D	19	20	4.472
F	20	24	4.899
F	21	16	4.000
F	22	13	3.606
F	23	5	2.236
F	24	33	5.745
F	25	20	4.472
F	26	30	5.477
F	27	18	4.243
F	28	3	1.732
F	29	17	4.123
I	30	24	4.899
I	31	17	4.123
I	32	15	3.873
I	33	11	3.317
I	34	15	3.873
J	35	33	5.745
J	36	28	5.292
J	37	44	6.633
J	38	17	4.123
K	39	20	4.472
K	40	44	6.633
K	41	44	6.633
Sum		**1028**	**196.15**
	/n	**25.07**	**4.784**
	sqrt	**5.01**	

Column1		85% confidence limits	
Mean	4.675398	5.051637	4.2991582
Standard Error	0.256343		
Median	4.358899		
Mode	4.358899		
Standard Deviation	1.641394		
Sample Variance	2.694174		
Kurtosis	2.998531		
Skewness	1.090681		
Range	9.168792		
Minimum	1.414214		
Maximum	10.58301		
Sum	191.6913		
Count	41		
Confidence Level(85.0%)	0.376239		

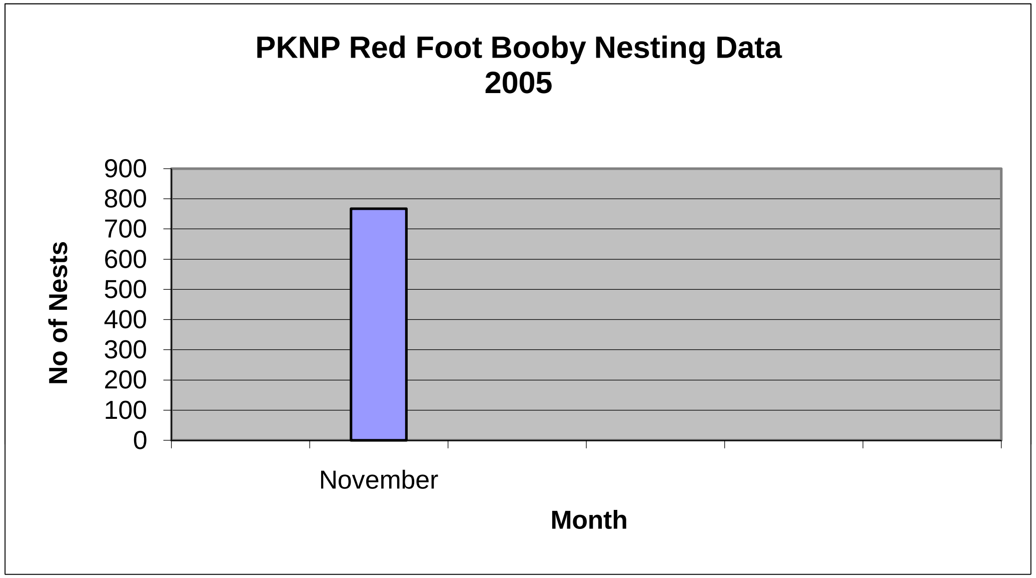
P	1	27		5.196
	2	31		5.568
	3	19		4.359
	4	33	110	5.745
Sum		**1914**	**1914**	**406.70**
		19.3	/n	4.108
		4.4		

Quadrat/3 tree plot 0.8587

Column1			
		85% confidence	
Mean	4.015939001	4.241436	3.790442
Standard Error	0.155418574		
Median	3.872983346		
Mode	3.872983346		
Standard Deviation	1.546395282		
Sample Variance	2.391338369		
Kurtosis	-0.068154147		
Skewness	-0.028364594		
Range	7.937253933		
Minimum	0		
Maximum	7.937253933		
Sum	397.5779611		
Count	99		
Confidence Level(85.0%)	0.225497446		

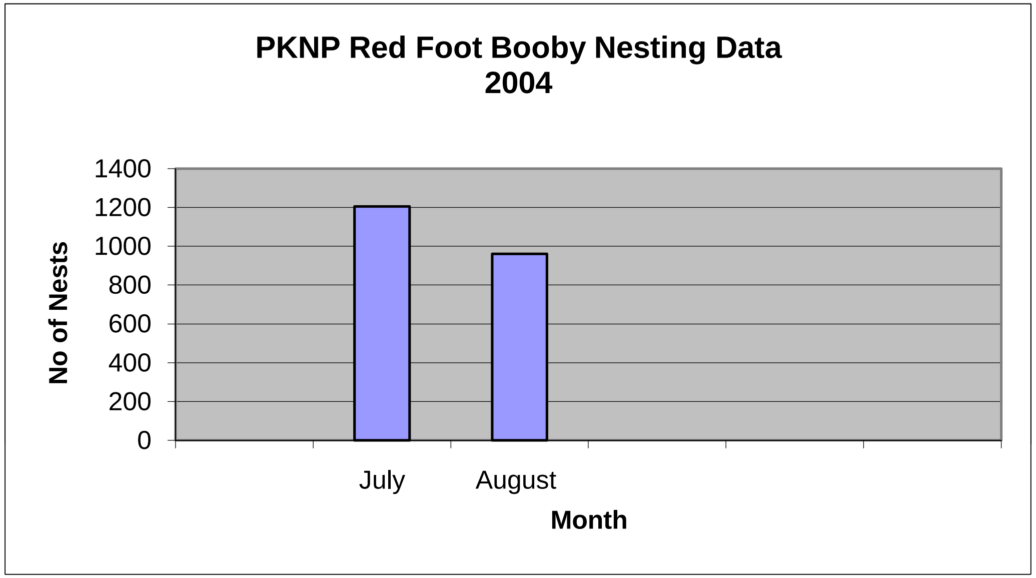
Month	No. Nests
November	767

Nov is max nesting month therefore



Month	No. Nests
July	1205
August	961

July is max nesting month therefore



Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	32
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	Harvesting of red-footed boobies - Community Management plan		
Hansard Page ECA:	121 (27/5/09)		

Senator SCULLION asked:

Senator SCULLION—I understand, Mr Cochrane, you helped out with the tender process to select the people who would do that. Is that correct?
Mr Cochrane—It is, and I think, due to our good nature, we funded it as well.
Senator SCULLION—I think that is just terrific. I understand from your answers that the tenders were assessed against criteria outlined in the terms of reference for the consultancy. I will get to the report in a moment. I have not seen the terms of reference for the tender, but you may wish to provide those to me on notice. Was one of the terms of reference or were some of the requirements about a history of providing advice on sustainable use?
Mr Cochrane—You are correct—I do not have that information—but I could certainly provide you with the terms of reference.

Answers:

The Terms of Reference are provided at Attachment A. Through the tender assessment the tenderer's experience were assessed against the following criteria:

1. Contract material provided (approach, personnel, price, timeline, ABN/GST registered, public liability).
2. Previous experience – communication (community consultation, communication in cross cultural environment, any experience with Cocos/Malay, consultation involving ecological principles and/or legal framework, written reports and presentation of data).
3. Previous experience – scientific disciplines (biology/ecology qualifications and/or experience relevant to project (eg research & interpretation of data)).
4. Previous experience – legal framework (experience working with EPBC Act or similar legislation and/or environmental assessment processes).
5. Proposal – approach (understanding and adequacy of consultation process, understanding and adequacy of research review, draft and final report process, other).
6. Proposal - timeline and deliverables.
7. Fees (hourly rate, total hours, travel, accommodation, total costs, invoice arrangements)
8. Value for money – overall assessment.

Attachment A

RS37 Production of a Cocos (Keeling) Islands Red Footed Bobby Community Management Plan and Preliminary Information for a referral to the Department of the Environment and Heritage.

Terms of Reference and Information for Quotes

Objectives

The objective of the consultancy is to develop a community management plan for the Cocos Community for the protection and sustainable harvest of red-footed boobies (*Sula sula*) in the Cocos (Keeling) Islands. The plan will comprise the bulk of the preliminary information requested by the Department of the Environment and Heritage (DEH) in relation to the referral, under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Background

About 30, 000 pairs of red-footed boobies (*Sula sula)*, a listed migratory and marine species under the EPBC Act, breed on North Keeling Island, the terrestrial component of Pulu Keeling National Park. The red-footed booby is also listed under the Japan Australia Migratory Birds Agreement (JAMBA) and the China Australia Migratory Birds Agreement (CAMBA).

The Cocos-Malay residents of the Cocos (Keeling) Islands have been hunting boobies for consumption from the time of settlement of the islands in the 1820s until the birds became protected under Commonwealth laws in the early 1990s. When the atoll was first settled all twenty-seven islands were reported as seabird rookeries. Hunting combined with habitat destruction, primarily for coconut plantations, has resulted in seabirds now breeding only on North Keeling Island, which is only 1.2 km^2 in area, with a few birds venturing to Horsburgh Island, a relatively isolated island of the southern atoll.

The red-footed booby became a protected animal in 1992 under the National Parks and Wildlife Regulations. A management program approved under those regulations in 1997 allowed for some restricted harvesting by traditional flail of red-footed boobies on or near Horsburgh Island. When the EPBC Act commenced in July 2000, replacing the National Parks and Wildlife Regulations, the red-footed booby was listed under Part 13 as both a migratory and marine species. The EPBC Act provides for an approved management program that would allow any harvesting as a condition of approval under Part 9. Since July 2000, therefore, harvesting under an approved management program has not been possible, though there is evidence that illegal poaching has frequently occurred. Harvesting of red-footed boobies in the Cocos (Keeling) Islands could now only occur without contravening Part 13 of the EPBC Act if it was provided for and carried out in accordance with an approval issued under Part 9 of the EPBC Act.

On 23 October 2002, the Cocos (Keeling) Congress referred a proposal to the Minister for the Environment and Heritage a proposal for a harvest of up to 10-15 red-footed boobies per household per season. On 20 November 2002 the proposed harvest was declared a controlled action with the controlling provisions being Sections 16 & 17B (Wetlands of international importance), Sections 20 & 20A (Listed migratory species) and Sections 26 & 27A (Protection of the environment from actions involving Commonwealth land) of the EPBC Act.

DEH subsequently informed the Cocos (Keeling) Congress of the controlled action decision and requested the submission of preliminary information as the basis for determining the level of assessment. That information has yet to be provided.

Harvesting within Pulu Keeling National Park is not currently permitted as it is not provided for in the park's management plan and would therefore contravene Section 354(1) (a) of the EPBC Act. The option remains open, however, for the Minister for the Environment and Heritage to approve a program to manage the sustainable harvest on or near Horsburgh Island, outside the park and well away from the birds' breeding area. The program would be a requirement of conditions of approval under Part 9 of the EPBC Act. Such an arrangement would be consistent with the moratorium on seabird hunting on Pulu Keeling Island reached with the Cocos-Malay people in 1986.

The Project

A) The successful consultant will be required to develop a community management plan for the protection and sustainable harvest of red-footed boobies in the Cocos (Keeling) Islands with the members of the Cocos (Keeling) Congress. The management plan should include detailed information about bird population data, recruitment rates, mechanisms for managing take, estimates of illegal take and proposed mechanisms for monitoring and audits.

A significant amount of research data on red-footed booby populations and recruitment rates has been accumulated over a twenty-year period and would be made available to the consultant to determine yearly maximum sustainable harvests. Further research in that area would not be necessary.

B) The successful consultant will also be required to respond on behalf of the community to the request for Preliminary Information. The aforementioned community management plan should form the bulk of the Preliminary Information; however, the successful consultant is encouraged to follow the Preliminary Information Guide to ensure that the requested information is provided in the required format and is consistent with the requirements under part 1 of Schedule 3 of the EPBC Regulations.

The successful consultant is encouraged to liaise with the Great Barrier Reef Marine Park Authority on its management regime for the traditional use of marine resources, which facilitates an active role for Aboriginal and Torres Strait Islander communities in monitoring a sustainable level of take of marine resources whilst maintaining their living maritime cultures, customs, and traditions. Not everything the GBRMPA does will apply, as Cocos Malays are not Traditional Owners for the purposes of the EPBC Act, nor do they have a spiritual relationship with the environment. PAN and Cocos Congress will assist the consultant to determine which aspects of the GBRMPA management regime do not apply to Cocos.

The project will need to be completed in the following stages:

Stage 1

Review available research on populations and recruitment rates of red-footed boobies in a range of conditions, including in response to major disruption events such as cyclones. This stage of the project will provide the information necessary for Parks Australia North (PAN) to determine the yearly maximum sustainable harvest for red-footed boobies in the Territory of Cocos (Keeling) Islands.

Stage 2

Support members of Cocos (Keeling) Congress to develop a community management plan for the protection and sustainable harvest of red-footed boobies in the Territory of Cocos (Keeling) Islands. The plan should include appropriate mechanisms for effectively managing the take of the birds in line with the yearly maximum sustainable harvest determined in Stage 1, a process for sanctions against individuals for illegal take, and mechanisms for effective survey and monitoring of bird populations.

Stage 3

Prepare draft Preliminary Information, including the community management plan, for comment by Cocos (Keeling) Congress and staff of PAN on Cocos (Keeling) Islands and in Darwin.

Stage 4

Consider all comments received during stage three. Finalise the community management plan and prepare the finalised Preliminary Information in accordance with the Preliminary Information Guide, and undertake the submission by/on behalf of the Cocos (Keeling) Congress as proponents.

Timelines

Quotes must take into account the following restrictions in planning to provide the services:

- Stage one must occur before visiting the Cocos (Keeling) Islands.
- Stage two should be undertaken during a single visit to the Cocos (Keeling) Islands.
- Stage three must occur within two months of the visit to the Cocos (Keeling) Islands.
- Stage four must occur within three months of the visit to the Cocos (Keeling) Islands.
- Finalised Preliminary Information must be submitted to DEH within four months of the visit to the Cocos (Keeling) Islands.

Deliverables

Milestone 1

Within two months of the visit to the Cocos (Keeling) Islands, submit draft Preliminary Information to members of the Cocos (Keeling) Congress and staff of Parks Australia North (PAN) on Cocos (Keeling) Islands and in Darwin for their comment.

Milestone 2

Within four months of the visit to the Cocos (Keeling) Islands, submit the completed Preliminary Information Form to the Approvals and Wildlife Division of DEH.

Staged payments

Payments will be made in four stages. On signing of the consultancy by both parties, on consultant's arrival on Cocos (Keeling) Islands, on receipt of draft plan and information, and on successful completion of consultancy.

Assistance from PAN Cocos.

Staff on Cocos (Keeling) Islands will provide transport if required to Pulu Keeling National Park and red footed booby research data. The Cocos (Keeling) Congress (or Parks Australia) will provide transport to locations not serviced by public transport and basic office facilities while the consultant is on-island.

Other requirements

The consultant shall have 10 million dollars public liability insurance. It is recommended the consultant have an ABN and be registered for GST. The consultant will be required to sign a consultancy agreement with the Director of National Parks.

Proposal

The consultant shall submit a detailed proposal in their quote. This shall include:-

a) Approach
How the consultant intends to approach the task

b) Personnel
Personnel who will be carrying out the consultation with stakeholders and writing the Preliminary Information, including the community management plan, need to be specified in the response to the tender documents.

c) Consultancy Price
The prices submitted by consultants must be GST inclusive. The Director of National Parks will pay the GST inclusive amount on receipt of a correctly rendered tax invoice.

The prices submitted by the consultant must show a breakdown of costs including travel, accommodation and fees.
The prices submitted must also clearly show the amount of GST included in the price (for example, 'the total price is $XX,XXX ($AA,AAA + $B,BBB in GST)') and be fully inclusive for completing the work.

d) Timeline
The quote should include a proposed timeline for execution of the work including how long the consultant intends to spend on the Islands.

QUOTES CLOSING DATE

Submissions must be received by 2.00pm CST on Thursday 23 March 2006 at

Postal address
The Tender Box
Parks Australia North
GPO Box 1260
Darwin NT 0801

Street address
The Tender Box
Parks Australia North
Department of the Environment and Heritage
Cnr Pedersen Road and Fenton Court
Darwin Airport
Marara NT 0812

Submissions may be faxed to arrive by the closing date, but must be closely followed by an original document.

Fax 08 89 201 315

Contacts

Contact for Cocos (Keeling) Congress

Haji Adam (Rabuhu Anthoney)
(08) 9162 7709 Email: cocos_congress@kampong.cc

Contact for Government Conservator Cocos (Keeling) Islands

Ms Wendy Murray
Government Conservator
Parks Australia North
PO Box 1043
Cocos (Keeling) Islands
Indian Ocean 6799 tel (08) 9162 6678 fax (08) 9162 6680

Email: wendy.murray@deh.gov.au

Some References for Information Only. The list is not exhaustive and Parks Australia does not warrant commercial websites are true and correct.

DEH Pulu Keeling National Park Website
http://www.deh.gov.au/parks/cocos/index.html

DEH Pulu Keeling National Park Management Plan
http://www.deh.gov.au/parks/publications/pulu-mp.html

DEH Referral of a Proposed Action Factsheet Website
http://www.deh.gov.au/epbc/publications/referral.html

Cocos Tourism Website
http://www.cocos-tourism.cc/

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome: 1 **Question No:** 33

Program: 1.1

Division/Agency: Parks Australia Division

Topic: Pulu Keeling National Park– patrols

Hansard Page ECA: 122 (27/5/09)

Senator SCULLION asked:

Senator SCULLION—I asked some other questions about the management of Pulu Keeling National Park itself. I note again that in your national park management plan is says, 'Surveillance and patrols of the marine zone of the park will be carried out.' Would you be able to tell me how many patrols of the marine park were carried out this year?
Mr Cochrane—I would have to take that on notice. I do not have that information with me.
Senator SCULLION—Perhaps when you are taking that on notice you could go back for the last five years and tell me how many patrols there were. I would prefer it if you did not come back next time and say, 'Look, I am sorry; other patrols were conducted by the federal police.' I am aware of that. In the spirit of the arrangement, is it possible to reflect that partnership about who does the work for you on the island?
Mr Cochrane—Yes.
Senator SCULLION—The total patrols conducted by yourself under their auspices as well?
Mr Cochrane—Yes.

Answers:

Surveillance Patrols are outlined below. The reduced surveys in 2008-09 are a reflection of the introduction of gun controls and the reduced use of illegal fire arms for poaching.

2009	2008	2007	2006	2005
15 (to date)	29	70	61	69

Of these patrols our records indicate that 1 patrol in 2008 and 2 patrols in 2006 were undertaken with Australian Federal Police (AFP) officers. The AFP does not carry out patrols within the Park without Park staff in attendance.

Senate Standing Committee on Environment, Communications and The Arts Legislation Committee

Answers to questions on notice

Environment, Water, Heritage and the Arts portfolio

Budget Estimates, May 2009

Outcome:	1	**Question No:**	34
Program:	1.1		
Division/Agency:	Parks Australia Division		
Topic:	National Reserve System - purchases		
Hansard Page ECA:	Written Question on Notice		

Senator SIEWERT asked:

1. What quantum of NRS grants for new protected areas purchases have been contracted in this 08-09 FY?
2. How many hectares of land has or will be purchased with those grants?
3. What proportion of the dollar quantum of grants is for purchases in the high priority less than 2% reserved bioregions identified in Caring for Our Country business plan p45?
4. What proportion of the area of purchases falls in the high priority less than 2% reserved bioregions identified in Caring for Our Country business plan p45?
5. How many purchase contracts been entered into respectively with the State of Queensland, the Northern Territory government or the Government of Western Australia?

Answers:

1. Eleven grants comprising 16 properties were contracted in 2008-09.
2. The grants purchased 146,858 hectares
3. 20.1%
4. 44.6%
5. None.