Assessment of Methodology and Statistical Accuracy of Annual Red Footed Booby Surveys on Pulu Keeling National Park

A report to Environment Australia

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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 Palu 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 and Mr. Robert ('Greenie') Thorn. We also visited

Palu Keeling from 3-5 July to carry out an on-ground reconaisance 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 Palu 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 needed to be considered in developing recommendations for ongoing monitoring and estimation of population levels.

We have read a comprehensive review by Kentish *et al* (1996) which elegantly reviewing the literature pertaining to survey methodology and biology of red-footed booby, assessed the existing 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 XXXX in XXXX. It consists a set of transects which include a number of nesting trees within a 20m wide strip. Transects vary in length from 130 to 250 m (check). 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. It is important to note that originally (year? 1993) all nest trees were marked, mapped and recorded, but since then, birds have used other trees within transects and these trees have not been included. 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.

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 XXX classes:

- NA
- NWT
- LIST CLASSES

Method of observation varies among observers but typically 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 trees, counted has varied over the years. Summarise from 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 1);

Transects G, E and M were discarded.

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 Palu Keeling over this period. However, data collected to date have not been comprehensively analysed and attracted criticism from 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. An analysis of some

transect data demonstrates that the population is in decline (1987 -1996) and the overall the rate of increase is negative. The reason for the negative rate of increase is unknown.

We believe that this comment refers to the fact that the existing tree based methodology does not allow prediction of population size because the number of trees on the island is unknown. 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, as 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. 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. Random sampling is completely impractical in the Palu 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. The 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 Palu 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 Palu 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 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. WENDY – DETAILS PLEASE

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

- *it should be noted that, no attempt has been made to ensure that nests, trees or 'transects' were truely 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 Palu 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 variablitiy is not a problem. However, there was strong evidence that the performance of an observer inexperienced in the conditions encountered on Palu 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 overharvest 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

- What is the objective? Is the interest in providing an estimate of population size in a given year, or in designing a survey methodology to detect change? Whilst appearing similar, the survey methodology is 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.
- Define accuracy and precision, with examples
- 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 Palu Keeling.
- 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 Palu Keeling, an population which is important in the regional context.
- In terms of estimating an annual harvest quota, this is not problematic
- Data needs to be dis-aggregated

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 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 Palu 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 a convenient observational unit is a tree of minimum height 5 metres and 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.
- 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 under Section XXX above. Information on information on vegetation type may be important for the estimation of nesting abundance, since controlling for this is likely to 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 throught 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 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.

PUT IN SE FORMULAS Calculation of SE of change is according to the following formula blah blah blah where

Inferences relating to population size

On the other hand 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 includes both variance due to counting as well as that due to sampling. Typically, precision of population estimates in a given year will be much higher than precision in estimates of population change.

PUT IN SE FORMULAS Calculation of SE of popn size is according to the following formula blah blah blah where

For the purposes of monitoring abundance, and hence change, we can restrict inference to the '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 'statistical population', the precision will be low and hence confidence intervals large.

other birds *this secton needs work*

There are 11 seabird species which breed on Palu Keeling. For xxx of these species, an adaptation of this methodology is potentially suitable for monitoring populations and has been used by both us and others elsewhere (refs). These species are:

XXX

- No other species nests extensively in the target red-footed booby habitat (Pisonia), unlike the situation which exists in other red-footed booby colonies elsewhere eg. in the Coral Sea (Baker *et al* 2000), Aldabra (Feare 1978).
- Potential disturbance is too great and the work is not critical for current management issues
- The habitat that some of these species use for nesting is difficult to work in and could potentially lead to habitat destruction (pemphis) or cause desertion of nests or loss of eggs and chicks as other conspecifics attempt to steal nesting material (frigatebirds).
- Should monitoring programs be required for other seabirds we recommend that specific designs be developed for those species. However, as a rule of thumb:
    - White terns – nested in low densities within the Pisonia and could be recorded at the same time that red-footed booby counts were being conducted. However, an appropriate time for conducting counts for white terns would need to be determined and may not coincide with the timing of booby counts.
    - Masked booby – total counts would be appropriate as the colony size is limited and visibility is high;
    - Brown booby - total count may be appropriate, although the species is sensitive to disturbance
    - Sooty terns

- Common noddy
- White-tailed tropicbirds
- Great and least frigatebirds
- Wedge-tailed shearwater – counts of burrow nesting species are usually area based but require the use of specialised equipment such as burrowscopes to determine occupancy rates and stage of breeding (Dyer et al XXX)
- Round Island petrel

Future directions

The proposed methodology should be immediately implemented if possible 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 Palu 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 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.
5. 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.
6. 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.
7. 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.
8. A report should be prepared each year to maintain continuity and provide feedback for all stakeholders. The 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.
9. The survey methodology proposed to count red-footed boobies on Palu 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
10. 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 clearly marked, mapped and monitored

throught 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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- It is not necessary to conduct a complete survey every month, recording detailed information on the stage of nesting as well as counts. Analysis of the past data indicates that the modal class of such data is 'NA – nest with sitting adult', and the existing data on age of chicks is very limited and doesn't assist in determing optimal survey time. Further, the maximum counts invariable occur between April and August (note that in 1999, when maximum counts were recorded in october, no counts were carried out during the period April to August). On this basis, we suggest that full nest counts only be conducted in each of these months to ensure the maximum nesting count is captured, thus reducing counts 5 counts per year.
- In one year, we note that a double peak in breeding occurred. If this becomes apparent, we suggest that at least one other full survey be carried out to coincide with the second peak of nesting activity. If there is a major climatic event which alters typical breeding patterns it may be necessary to carry out additional surveys to capture the impacts of the event. This will be up to the judgement of local staff who are in the best position to assess the situation.
- Early on in the first survey (April), a number of clearly visible nests (say 100) should be identified, for intensive monitoring to determine/ estimating nesting success. These nests should be selected across the full range of nesting habitats to ensure coverage which is representative of habitat usage across the Palu Keeling. These nests should be continuously monitored until the fate of the nesting attempt is determined. Collection of these data are not essential for the purposes of estimating bird abundance or maximum sustainable harvesting yields, but would significantly improve our knowledge of nesting success for this important population. It may also be useful for development of population models in the future.