Forbes' parakeet *(Cyanoramphus forbesi)* population on Mangere Island, Chatham Islands

T C Greene
Science & Research Unit
Science, Technology and Information Services
Department of Conservation
Private Bag 68-908
Newton
Auckland

Published by
Department of Conservation
Head Office, PO Box 10-420
Wellington, New Zealand

This report was commissioned by Wellington Conservancy.

ISSN 1171-9834

Reference to material in this report should be cited thus:

Greene, T.C., 2000.
Forbes' parakeet *(Cyanoramphus forbesi)* population on Mangere Island, Chatham Islands.
Conservation Advisory Science Notes No. 319, Department of Conservation, Wellington.

Keywords: Forbes' parakeet, *Cyanoramphus forbesi,* population monitoring, hybridisation, breeding, Chatham Islands.

This document should be read in conjunction with the Chatham Island Area Forbes' Parakeet Field Programme for the 1999/2000 season.

1. Population assessment and monitoring of Forbes' parakeet

Previous attempts at estimating the size of the Forbes' parakeet *(Cyanoramphus forbesi)* population have been based on relatively subjective estimates of the numbers of birds seen by observers as they move about Mangere Island. Such a casual approach has resulted in highly variable estimates and a great deal of confusion and uncertainty as to species status. Robust and sensitive population estimates of the Forbes' parakeet population of Mangere Island are clearly a priority if the effectiveness of the current management programme (e.g. periodic removal of hybrids and Chatham Island red-crowned parakeets *(C. novaezelandiae chathamensis),* provision of nest boxes, etc.) is to be accurately measured. Unfortunately such estimates are problematic given the species overall rarity, their significant variability in diurnal and seasonal conspicuousness (assuming they are anything like other species of the genus), the difficulties of quickly and accurately identifying birds as either Forbes', hybrid or Chatham Island red-crowned parakeets and the variety of habitats that they seem to occupy. Such problems are only exacerbated in forested (e.g. Robin Bush) or densely vegetated (e.g. Douglas Basin) areas where visibility and cletectability are often severely impaired.

Two main groups of census methods are usually used to census parrot populations. 'Look-clown' methods usually attempt to try and count every bird from a vantage point overlooking forest and have been used successfully on several rugged Caribbean Islands (Lambert 1983). Although numerous vantage points are available on Mangere Island the likelihood of actually seeing much from them (parakeets are small and green and most vantage points are quite high) is remote at best. Even if suitable vantage points were available, the method would only work where the birds habitually fly above the canopy and were rare enough to allow individual recognition - assumptions commonly violated on Mangere Island.

'Look-up' methods attempt to count birds from points or transects and can be divided into distance sampling methods and encounter rate methods (e.g. five minute counts) (Marsden 1999). Although the latter method is easy to execute, they do not cope particularly well (unlike distance methods) with differences in diurnal, seasonal or between habitat differences in detectability (Bibby et al. 1992, Buckland et al. 1993, Marsden 1999). Other major advantages of distance methods are that they allow estimates of density from which population estimates can be calculated, examination of responses to habitat change and meaningful measurement of population trends rather than simple and often misleading indices of abundance.

Alternative methods are also worth considering, given that a concerted effort is being made to catch and individually colour band as many birds as possible. Perhaps the most useful of these are mark/recapture models, where marked individuals are returned to the wider population from which the ratio of marked to unmarked birds observed within a given period is assessed and used to estimate population size (e.g. Lincoln estimates and Jolly-Saber models) (Nichols et al. 1981, Pollock 1981, Bibby et al. 1992).

Whatever method(s) is used, the long-term usefulness of such survey methods would benefit immensely from a pilot study. Such a preliminary study will provide rough estimates of encounter rates and variance as well as providing opportunities for assessing operational constraints, training of participants and insights into how best to meet important assumptions of the methods being used (Buckland et al. 1993).

2. Distance sampling

Numeric methods such as distance sampling provide an objective means of analysing population sampling data (where distance between a random point and object/animal of interest has been measured) to estimate the density and abundance of a given population (Buckland et al. 1993). As detectability usually decreases with increasing distance from the random point, a large proportion of the objects of interest may go undetected. However, the theory allows accurate estimates of density (or abundance) to be made with only mild assumptions (Buckland et al. 1993). Data are analysed using the program DISTANCE (Laake et al. 1994) which is capable of analysing distance sampling data derived from line transacts, point counts and cue counts. A variety of estimation models are available within the program and the `best' model is selected for the data set.

Application of distance sampling methods to the parakeet population of Mangere Island is problematic, particularly if accurate density and abundance figures are required. The identification of individual parakeets as either Forbes', hybrids or Chatham Island red-crowned parakeets is likely to be difficult if the birds are some distance from the observer, are in flight, or are in areas of dense vegetation. Difficulties such as these and a requirement for a minimum numbers of observations (approx. 80) of birds in each of the taxonomic groups being surveyed (particularly for point counts - Buckland et al. 1993) are likely to lead to significant biases in estimates for each of these groups and/or inaccurate analyses. Despite these drawbacks, distance sampling is still considered a potentially powerful tool for measuring total parakeet population trends over time on Mangere Island and should be tested as outlined below.

2.1 DISTANCE SAMPLING METHODOLOGY

Point counts v. transects

The choice between sampling designs based on transect counts or point counts is often a difficult one. Usually, if all things were equal, one would prefer line transect surveys to point counts, as more time is spent sampling in the former whereas more time is spent travelling between and locating points in the latter (Bollinger et al. 1988). In addition it is useful to wait several minutes prior to recording data to allow birds time to readjust to the disturbance generated by the observer approaching the sample point (Buckland et al. 1993, Marsden 1999). There are, however, a number of advantages to point counts. Birds (particularly parrots which can be very cryptic) are easier to locate and identify if the observer is standing still rather than trying to traverse difficult terrain in dense vegetation (e.g. Robin Bush). Ease of bird location is critical, as all animals close to the observer must be detected to comply with one of the major assumptions of distance sampling, i.e. probability of detection at the point g(0)=1. Point counts also tend to provide less biased estimates of density and abundance where habitat types vary within patchy environments (Marsden 1999) whereas it can be difficult to allocate line transects to allow efficient and unbiased density estimates by habitat (Buckland et al. 1993).

Layout of points

From a statistical point of view, points should be placed at random, but this is often impractical and can result in excessive travel times between points and/or some pairs of points being very close to one another (Buckland et al. 1993). An alternative approach is to establish points systematically at the intersections of a randomly placed grid. Distance between points needs to take into account the probability of double counting birds (individuals that are flushed from the vicinity of one point to another as opposed to the same stationary individual at two different stations) and the level of unnecessary walking between points. A compromise distance of 200 m is considered acceptable for most of the island with the exception of Robin Bush and parts of the Douglas Basin (see below).

Number of points

Having determined the pattern of the point placement and the required spacing, the number of points (or counts at points) required to achieve a useful level of estimate precision must be determined. This can only be done with any accuracy following a pilot study, so that some idea of the encounter rate and variance is known. For the purposes of a pilot study the points suggested in Fig. 1 should be an adequate start, provided that sufficient observations of birds are made in the three main habitat types into which Mangere Island can be coarsely divided - namely rank pasture grasses, tall plantings, and forest. Because Robin Bush is a very small area relative to the rest of the island, the likelihood of being able to count sufficient parakeets for useful analysis from relatively few points (at the standard 200 m spacing) is remote. For the purposes of a pilot study, point spacing of 100 m is suggested within Robin Bush and possibly parts of the Douglas Basin that are densely vegetated (see Fig. 1). In these areas counting should be concentrated within a 50 m radius of the

observer (see Appendix 1) to try and minimise the chance of birds that move being double-counted at adjacent points.

Length of counts

The longer the count period the more likely is the probability of detection at the point to reach g(0)=1. However, this advantage is also offset by an increasing likelihood of birds moving into the plot from the outside, or of the observer counting the bird more than once (Buckland et al. 1993, Marsden 1999). To minimise these problems and those caused by flushing birds when approaching points, the following is recommended:

- The approach to the point should be cautious, with any birds flushed (particularly those near the point) having their distance from the point recorded.

- On reaching the point, observers should leave an interval of two minutes before the count proper (10 minutes) commences.

- For the purposes of the pilot study an attempt should be made to determine the most efficient count period by recording all observations into two minute segments of the total 10 minute period.

- At the conclusion of the count, a short period should be spent moving about and searching the count area (particularly within 10 m of the census point) for parakeets that may have been missed (Buckland et al. 1993, Marsden 1999, R. Barraclough pers. comm.).

Measurement of distance

Although point counts only require an estimate of distance from observer to the object (transacts also require measurement of angle to the subject), distance estimates must be especially accurate, as errors in estimation are squared in density calculations (Marsden 1999). Any errors that do occur in measuring distance should be small and random. Every attempt should be made (at least for the pilot study) to measure distance to the nearest metre (distance intervals may be sufficient for future surveys and/or analysis). This invariably requires appropriate training for observers, with particular emphasis on distance estimation to aural cues. Permanent marks and electronic measuring devices such as laser rangefinders should also be used if possible, to reduce variation in distance estimates. Particular attention should be paid to the accurate estimation of distances relatively close to observers (0-50 m) particularly in Robin Bush (and possibly Douglas Basin), where points are only going to be 100 m apart. If at all possible, several observers trained in measuring distances and working in pairs should be used to minimise errors in distance estimation (Marsden 1999).

What should be counted?

All parakeets seen or heard from the point should be counted. However, careful note should be made of whether birds in flight during the count period are flying from within the census plot or over and/or into the plot. Inclusion

of aerial records without appropriate correction factors can significantly bias density estimate calculations (Buckland et al. 1993, Marsden 1999).

If parakeets occur in reasonably discrete definable clusters such as family parties or flocks (most likely following fledging), the recording unit should be the cluster rather than the individuals in it. Distance is measured from the point to the centre of the cluster rather than for each individual. Careful note is also made of the number of birds in each cluster (Buckland et al. 1993).

Although likely to be extremely difficult, every effort should be made to try and categorise all birds seen during the count period (at least during the pilot study) as either Forbes', hybrids, red-crowned parakeets (as per the scale below), or unknown.

Time of day and season

Every effort should also be made to standardise the time of day, time of year and the weather in which counts are conducted as well as the survey methodology so that meaningful comparisons over time are possible. In other *Cyanoramphus* species, diurnal conspicuousness is highly variable, with higher encounter rates in the morning and late afternoon (Calder & Deuss 1985). There is no reason to expect this to be different for parakeets on Mangere Island. As any significant reduction in the encounter rate (particularly close to the observer) will cause underestimation of density (Marsden 1999), the count period should commence at a standardised time (e.g. one hour after sunrise NZST) and finish no later than 1030 NZST or at a time prior to any significant decrease in detectability (possibly as late as 1200 NZST, T. Thurley pers. comm.).

Provided that sufficient resources are available, two distinct counts are seen as desirable. The first and most important count should be conducted prior to the breeding season (October/November) and should provide an estimate of the base population. A second count immediately following the breeding season (March/April) may provide a useful indication as to the success or otherwise of the preceding breeding season.

Weather has obvious and predictable impacts on both the conspicuousness of the birds and the counting abilities of recorders in a field situation, particularly on Mangere Island, which is highly exposed. Counts should only be considered if conditions are suitable - no rain, fog or other precipitation, light winds if at all possible (at least in the areas being surveyed), and reasonably mild temperatures.

Record sheet

Appendix 1 outlines the format of a suitable data sheet that could be used for estimating population size of Forbes' parakeet using distance sampling methods on Mangere Island.

3. Mark-recapture methods

Estimation of population size using mark-recapture methods is based on the assumption that marked individuals mix completely on return to the wider population. Therefore the ratio of marked individuals to unmarked at the second (or i th number of) sample(s) should be the same as that of the total number of marked individuals originally released to the whole population. An estimate of the size of the total population can then be made (Otis et al. 1978, Nichols et al. 1981, Pollock 1981, Bibby et al. 1992). This method of population estimation is particularly useful for species that are difficult to count in the field (Bibby et al. 1992). Although parakeets are not particularly difficult to see in field situations, identification of hybrid status for the parakeet population of Mangere Island clearly is. The intensive banding programme currently underway on Mangere Island is intended to identify the hybrid status of the parakeets captured and mark them individually so that breeding success and distribution can be monitored. This marking programme therefore provides an opportunity to assess population size using mark-recapture methods (as well as providing a comparative assessment of the appropriateness of the distance sampling estimates above), provided that recaptures and observations of marked birds are collected using standardised methods.

Mark-recapture methods are classified according to their requisite assumptions about population closure (Nichols et al. 1981, Bibby et al. 1992). Closed populations are those which are not influenced by mortality, recruitment, emigration and immigration throughout the investigation period. Open populations are those that do change throughout the investigation as a result of either mortality and emigration, recruitment and immigration, or both sets of factors (Nichols et al. 1981). Both types of models may be applied to the Mangere Island situation, but only if the underlying assumptions can be met. Closed population models could be applied to the number of parakeets captured during mist-netting operations over a short period of time, ensuring that violations of closure were negligible. Open models would be more suitable for examining seasonal trends (e.g. pre- and post-breeding) and between years. Appropriate design and the potential for violation of model assumptions need to be addressed prior to the adoption of mark-recapture methods as a long-term monitoring tool. For this reason a pilot study using the methods suggested below is strongly recommended.

3.1 MARK-RECAPTURE METHODOLOGY

Study area

For the purposes of the proposed pilot study, assessment of population size using mark-recapture methods should be confined to Robin Bush, as much of the capture and banding effort to date has been concentrated in this relatively small area. This makes the chances of recapture or re-sighting of marked birds more likely, thereby increasing the sample size as well as avoiding violation of the assumptions that marked birds mix completely with the wider

population when released. Recent data, however, suggest that we may have to (at least initially) consider more open/robust models, as migration from Robin Bush seems to be much higher than anticipated. If the pilot study is successful, the application of the method to the rest of the island can then be considered, using simpler closed models.

Mist nets and sighting records

Data from recaptures of marked individuals in mist nets and from resightings can both be used to calculate population abundance, provided that the limitations of the methods are understood, accurate records are kept, and effort is standardised over time. For example, closed population models of analysis can be used, provided that the interval between capture and/or sighting (following initial capture, marking and release and between discrete sighting periods) sessions is large enough to permit sufficient mixing of the banded and unbanded populations (e.g. a minimum of 1-2 days) thus reducing the chances of assumption violation. If, however, these intervals are larger (seasonal or annual intervals) and assumptions for closed models are violated (e.g. assumptions of minimal migration), the population can be treated as fully or partially open and the appropriate alternative analysis models used.

It is therefore critical that accurate dates of capture and sighting sessions are recorded along with some measure of capture/sighting effort (e.g. time), and the identity of all birds captured (mist nets) or sighted as marked (individual colour combinations required) unmarked, or unknown (for sighting observations only). Accurate assessment of the proportion of birds thought to be hybrids will, however, only be possible using mark-recapture methods if the hybrid status of unmarked birds can be correctly identified. For the purposes of the proposed pilot study the following scale (after Nixon 1982) can be used:

1 = Forbes' parakeet (no red in the crown and red frontal band does not extend to the eye).

2 = Red band extends to the eye.

3 = Crown has red flecks or is orange.

4 = Crown red with yellow/orange margin, red marking in front and behind eye.

5 = Chatham Island red-crowned parakeet.

Time of day and season

For most *Cyanoramphus* species, detectability is highest between dawn and about 1030 (Calder & Deuss 1985). Recaptures based on sightings should therefore be completed within this time period to maximise the potential sample size as well as standardising the effort involved. A suitable time period for such observations would start about 1 hour after official sunrise and end no later than 1030 NZST (later times could be considered if detectability is still reasonable). Such standardisation of mist netting periods may not be

this easy, but every attempt should be made to standardise both the start time and the overall length of these capture attempts as well.

Like distance sampling, population mark-recapture estimates are possible over a number of time scales. Perhaps the most important of these is the pre-breeding survey tied in with seasonal mist netting activities (Oct. to Nov.). Every effort should also be made to try and extend the method to post-breeding surveys (Mar. to Apr.) as well particularly if further mist netting is planned.

Attempts should also be made to standardise other environmental variables such as the weather as outlined in the distance sampling section above.

Record sheet

Appendix 2 outlines the format of a suitable data sheet that could be used for estimating population size of Forbes' parakeet using mark-recapture methods on Mangere Island.

4. Breeding ecology

4.1 NEST BOXES

Number of nest boxes

The provision of nest boxes for parakeets on Mangere Island has been highly successful (in terms of the number used) particularly in the Douglas Basin plantings, where potential nest sites are few or absent. Given the attractiveness of these artificial sites in regenerating habitats (compared with Robin Bush) and the current wide distribution of parakeets on Mangere Island, consideration should now be given to their future use as a management tool. Provision of further nest boxes in regenerating or replanted areas other than the Douglas Basin would probably provide suitable nest sites where few currently exist. The southwestern end of Mangere Island has good areas of regenerating scrub (natural and planted) and good numbers of parakeets (pers. obs.) and is the obvious area in which to introduce a further 25 nest boxes provided that suitable sites can be found. The addition of further boxes in Robin Bush is likely to have little benefit in the next few years, as natural sites do not seem to be a limiting factor at present.

Other advantages of increasing the number of nest boxes include the ability to catch, mark and assess the hybrid status of specific breeding pairs of parakeets and the ability to more easily monitor the contents of artificial nests than natural sites.

Nest box design

Nest box dimensions appear to be adequate although the internal dimensions are somewhat cramped when compared with other boxes designed for

Cyanoramphus parakeets (Beggs et al. 1984). The addition of an internal ladder (internal parallel saw cuts in front board or small strip of wire netting) and increasing the amount of nesting material placed in each box is recommended. If possible, damp, powdered rotten wood and wood shavings to a depth of 8-10 cm should be used as most parakeets of the genus seem to like digging substantial depressions in such material prior to egg laying. An alternative to tying nest boxes to trees using thin wire is also needed, particularly if additional nest boxes are being contemplated. Long-term damage to the trees on which boxes are mounted may be less if the box is directly nailed to them (or some other method is used). Care is also required when siting boxes to ensure that their exposure to direct sun is minimal.

General monitoring of nest boxes

All nest boxes require adequate monitoring. A minimum interval of 3-4 days between inspections is preferred, with a smaller sample being monitored in greater detail (see below) providing there are adequate resources available. Such monitoring is critical, as evidence to date suggests that, although nest box occupancy is higher, breeding success is significantly lower in Douglas Basin than in Robin Bush (14.8% cf. 52.9% of fledged chicks to eggs laid respectively during the 1998/99 season. Data for the 1999-2000 year show much less disparity - 23% cf. 30%). The reasons for such a difference are not yet known although higher-than-expected egg infertility has been implicated.At least 53% of eggs laid in nest boxes in Douglas Basin were judged infertile compared with only 22% of eggs laid in nest boxes in Robin Bush (Thurley 2000).

Baseline monitoring should aim to record clutch size, egg fertility, hatching success, fledging success and date as well as the hybrid status of adult birds using the box as per the 1999/00 work plan. Accidental disturbance (boxes being opened and torches/mirrors inserted into boxes when birds are inside) and even intentional disturbance (trapping birds at the nest) will occur during such monitoring. However, Forbes' parakeets appear very robust to these sorts of brief intrusions, and no discernible impact on nesting birds has yet been recorded.

Detailed monitoring of five pairs of Forbes' parakeets

There is little point in detailed monitoring (for 12-hour periods) of five pairs of Forbes' parakeets breeding in nest boxes to try and determine daily nest occupancy, as little or no pattern usually exists (Greene in prep.). Incubation stints are highly variable and largely dependent on the vagaries of male birds returning to nests following foraging forays. As a result, lengthy waits for the opportunity to investigate the contents of a given nest often occur and should not be surprising. This has obvious impacts on the number of nests that can be checked in a given period, and appropriate allowance should be made for this.

Detailed monitoring of Forbes' nests in boxes should concentrate on trying to learn more about the species breeding biology, particularly their productivity. The following protocol is proposed for a seasonal maximum of five nests:

- After identification of a Forbes' parakeet pair's interest in a nest box (e.g. female seen entering) the box is to be checked daily until the first egg is laid.

- Daily nest checks are continued until the clutch is complete. As each egg is laid it should be marked sequentially with a soft pencil. If lay dates are uncertain the nest can be checked at 3-4 day intervals until the clutch is complete.

- Five days after the last egg is laid, all eggs should be candled and fertility determined. If fertility is uncertain (some uncertainty is expected particularly if the clutch size is large, as eggs are produced asynchronously) leave for a further five days.

- Ten days after the last egg was laid, fertility should be checked again and any infertile eggs removed for autopsy/preservation.

- Nest checks of 3-4 days are sufficient from clutch completion until 17-19 clays after the first two eggs were laid after which nest checks should be daily until the last egg hatches.

- Following the hatching of the last egg (this will take several days depending on clutch size) all other eggs should be removed from the nest and autopsied and/or preserved. If possible chicks should be marked so that their growth and development can be monitored. Marks may include patches of indelible ink or pieces of coloured wool/wire tied loosely around the legs. If the marks are robust enough (don't rub or come off) nest checks can be at 3-4 clay intervals; otherwise daily checks to re-mark will be necessary.

- Chicks should be banded with appropriate colour band combination at about 30 days old.

- Daily monitoring should recommence just prior to anticipated fledge date until all chicks have fledged.

4.2 NATURAL NESTS

As many natural nests as possible should be located, marked, mapped and their physical parameters and seasonal occupancy measured. If at all possible, the same sort of breeding parameters recorded for parakeets using nest boxes (ii and iii above) should be recorded for up to 20 natural sites. Because many natural sites are difficult/impossible to get access to, serious consideration must be given to the use of technology such as fibrescopes (at a minimum) or nest modification allowing physical access. This level of access is particularly important, given the current unexplained differences in breeding success between parakeets breeding in nest boxes in the Douglas Basin and Robin Bush. Examination of all Forbes' x red-crowned parakeet and F1 hybrid pairs, the number of progeny they produce, and the physical and genetic make-up of these Fl hybrids is also crucial, irrespective of whether they are using boxes or natural sites.

4.3 HOME RANGE

Accurate estimates of home range are highly dependent on the number of sightings of marked individuals. Sightings of individually marked parakeets on Mangere Island are likely to be too few (bands difficult to see, dense vegetation in areas, etc.) for accurate estimates of home range, but should still be noted to provide information on longevity, the way individuals utilise various habitats, dispersal of juveniles, and the maximum distance travelled from point of capture.

4.4 DIET

If possible, attempts should be made to record the diet of foraging parakeets seen on Mangere Island using a simple "first food" method (Greene 1998). Only the first item of food (food type and species) an individual parakeet is seen to eat is recorded along with details of time, date, habitat, height above ground and species/hybrid status. This method has inherent biases toward foods that are taken often but in small amounts, have long handling times, and are in conspicuous feeding stations. A minimum of 100 feeding observations needs to be collected every month from each of the major habitat types to make the exercise worthwhile.

5. Hybridisation

Central to the research programme is the assessment of the extent and nature of hybridisation between Forbes' and Chatham Island red-crowned parakeets. Analysis of nuclear DNA and comparison with morphometric measurements will provide information crucial to the future management of both parakeet species. It is therefore imperative that such measurements are accurate, recorded in highly standardised fashion and numerous enough for useful analysis.

5.1 DNA SAMPLING

Blood and/or feather samples from a minimum of 10 parakeets (provided that no harmful effects are observed) across the range of identifiable plumage phenotypes exhibited on Mangere Island should be collected according to the appropriate protocols and strictures imposed by the Recovery Group and current operation plan. Adequate supplies of collection equipment and suitably trained staff should be readily available throughout the field season to ensure that samples are able to be taken from all parakeets captured at mist nets or at nests. Appropriate storage of samples prior to shipment to Victoria University for analysis is also required.

5.2 COMPARATIVE BREEDING PERFORMANCE OF MANGERE ISLAND PARAKEETS

As outlined elsewhere, assessment of hybrid status for unmarked parakeets is often difficult even when birds are at nests and more easily observed. Every effort should therefore be made to try and capture known breeding pairs so that a more objective evaluation of their hybrid status (i.e. genetics, morphometrics and plumage diagnostics) can be correlated to various indicators of breeding success (e.g. choice of nest sites, clutch size, fertility and fledging success, etc.) as well as the genetic and physical appearance of any offspring.

The only efficient way of targeting breeding pairs of parakeets is to trap them (using mist nets or other traps) at their nests during the breeding season. To minimise disturbance and the risk of nest desertion, adult parakeets should only be trapped at the nest some 10-12 days after the eggs have hatched.

5.3 PLUMAGE DIAGNOSTICS

The links made between genotype and readily observable phenotypes will have important consequences for the management of the Mangere Island parakeet population. It is therefore vital that measurements of plumage characteristics are recorded as accurately as possible.

Nixon (1982) analysed plumage characteristics of 224 preserved specimens, 9 live birds and 87 skins of Chatham Island parakeets (of which only 14 were Forbes' parakeets). Four features of head plumage received particular attention as "obvious indicators of specific affinity". An arbitrary five-point hybrid scale was derived from this and has since formed the basis for identification of hybrids and subsequent management decisions concerning which birds should be culled (i.e. all hybrids and red-crowned parakeets). It is worth noting here that even Nixon had some difficulty using his hybrid scale in the field "because of the inability to get a clear view of facial plumage" (p.25). Although there are other plumage characters which seem typical of Forbes' or Forbes'-like parakeets (ventral plumage yellowish, outer primary a greener shade of blue, etc) these are not as obvious or as readily interpretable. Objective measurements of these types of patterns are only possible using very expensive equipment such as spectro-radiometers and associated highly complex analysis methods (R. Heinsohn pers. comm.).

Direct comparison of data collected during this programme with those collected by Nixon (1982) is considered highly desirable. To achieve this, data on plumage characteristics should be collected in a similar fashion to those in Nixon (1982) and recorded on to each capture sheet.

Hybrid Index -The hybrid phenotype of each parakeet captured shall be scored using four head plumage characters and associated hybrid phenotype score. This score can be derived from the sum of the character states and diagrams showing the range of hybrid scores as they apply to phenotypes (see Nixon 1982, p. 26-27 for details).

Plumage Measurements - In addition to the five-point hybrid scale outlined above, a number of plumage measurements should be taken for every bird captured. These are outlined in detail with an accompanying diagram in Nixon (1982 p. 115-117) and include frontal band depth, crown length, crown width, ear covert length and width (if present) and lores. In addition the distance between the intersection of crown and frontal band to the eye should be measured so that the proportion of the lores without markings can be determined.

Photographic Record - Every bird captured should also be photographed in a standardised fashion (see Fig. 2.). A minimum of four photographs is required. These include:

- Head frontal - taken at a fixed distance (to be determined by camera gear used), centred and at a right angle to the medial line of the frontal band.

- Head lateral - taken at a fixed distance, centred and at right angles to the eye. A picture of both sides of the head should be taken if there are significant differences.

- Underside of wing - photograph of whole underside of one wing extended from body.

- Flank - photograph illustrating lateral flank of body from trailing edge of wing to rump.

The current photographic equipment being used to record plumage is inadequate to record the level of detail that is required. This equipment should be replaced with a good quality SLR camera body,TTL flash, a 50 mm lens and a set of supplementary magnifying lenses that can be attached to the main lens. Quality second-hand equipment such as an Olympus OM-10 or OM-20 camera with Zuiko 50 mm lens, Olympus T-32 flash and set of magnifying lenses would cost around $700 and produce excellent large sharp images. Once the supplementary lens for appropriate magnification is chosen, camera settings could be fixed to standardise image size and exposure. All photographs should be taken under shade using TTL flash with an 18% A4 sized mid-tone card (Kodak) as a background. The subject should be recorded as large as possible in the frame (dependent on minimum camera to subject distance allowed by equipment) and efforts should be made to eliminate distracting colours of people's clothing through judicious use of the grey background card.

Appropriate film stock is problematic. Ideally, transparency slide film (100 ASA) should be used if consistency in comparisons of colour and tone are desired. Print film, although cheaper and easier to view, will not deliver such consistency (because of the development process) unless all films are developed at once as a batch. Slides can also be stored more easily and prints made from them if so desired. Slide film can also be purchased in bulk rolls of 30 metres at greatly reduced cost. If slide film is used, the need to make multiple copies should also be reconsidered as this is likely to be a significant additional cost.

Analysis of photographs will simply involve overlaying individual images with associated genetics analyses then looking at the resulting phenotype/genotype frequencies along a continuum.

A separate protocol detailing the camera settings, operation, appropriate angles, distance to parakeets and size of image can only be prepared following the purchase of the appropriate photographic equipment and relevant tests.

5.4 CAPTURE AND MORPHOMETRICS

Capture using mist nets

As many parakeets as possible should be captured using mist nets and given individual leg band combinations. Pre and post breeding periods of intensive mist netting effort should be continued,but the areas in which it is conducted (mainly Robin Bush at present) should be broadened. More effort is clearly needed to capture birds in the Douglas Basin to assess patterns of habitat use and the degree of migration between Robin Bush and elsewhere on the island. However, the requirement to capture and mark birds should not occur at a cost to the vegetation in which it is being conducted. Clearance of vegetation should be minimised by using naturally open sites and tying back (where possible) rather than cutting impinging branches.

Capture using other traps

Where practical, other means of trapping parakeets should also be used, particularly those birds known to be nesting. A suitable trap has been designed to be fitted over nest entrances while adult birds are inside. This is a very effective and highly targeted means of catching specific individuals when they emerge, and causes the minimum of stress. It also appears to be the only practical and efficient means of establishing the exact hybrid status of the breeding adults in relation to their productivity and appearance of their offspring. If this method is adopted, care will be required to minimise disturbance and the potential for nest desertion. For this reason, trapping at nest should only be done following an assessment that the eggs are either infertile or dead or the continuous brooding of chicks by the female has ceased (10-14 days). At this point both male and female parents will begin entering the nest at intervals to feed chicks and will be able to be captured.

Morphological measurements

Standard morphological measurements of external characters should be recorded for all parakeets captured. These measurements include wing length, tail length, tarsus length, bill length, bill width and weight. All measurements should follow the description and illustrations provided by Nixon (1982 p. 110-112) so that direct comparisons with his data can be made. Additional measurements are not considered necessary. Moult or the presence of broken feathers that could affect measurements should also be recorded.

Individual identification

The current banding scheme in use on Mangere Island (one metal band on one leg and two cut down colour bands on the other leg) does not provide sufficient individual colour band combinations for the purposes of the study. A minimum increase in the number of colour bands to three (colour-coated metal band and two plastic colour bands) or preferably four (four plastic colour bands and no metal bands) is required.

6. Culling of hybrid and Chatham Island red-crowned parakeets

There is little doubt that the programme of culling all hybrid and Chatham Island red-crowned parakeets on Mangere Island was an urgent and necessary measure for the survival of Forbes' parakeets. However, the long-term advisability of such a management strategy is rather less clear, particularly when our understanding of Chatham Island parakeet ecology is far from complete. The most significant gap is our poor understanding of Forbes' parakeet breeding biology. Although this is critical to our understanding of the hybridisation that has occurred we have only a rudimentary idea of what morphological variation exists within Forbes' parakeets, what F1 hybrids actually look like, differences (if any) in Forbes' and hybrid fertility and productivity and whether positive assortative mating is a significant feature in the observed hybrid system.

The small amount of information that does exist suggests that F1 hybrid offspring resulting from Forbes' and red-crowned parakeet pairings tend to (a) look like red-crowned parakeets (hybrid category three), (b) be difficult to separate from the latter in the field and (c) associate socially with red-crowned parakeets rather than Forbes' parakeets (Nixon 1982). If these tendencies are typical for F1 hybrids, back-crosses are most likely to be with red-crowned parakeets (positive assortative mating - see Thurley 2000). Those hybrids closely resembling Forbes' parakeets are likely to have been produced by much back-crossing with that species and their genomes are likely to be dominated by Forbes' alleles (Nixon 1982, Rhymer & Simberloff 1996).

This has obvious and important ramifications for the management of parakeets on Mangere Island. If this pattern of gene flow is found to be typical within the hybrid system, efforts to cull phenotypically Forbes'-like hybrids may be unnecessary or even counter-productive (Rhymer & Simberloff 1996). Forbes-like hybrid parakeets may in fact represent an important genetic resource (Nixon 1982). Additionally, the effect of heterosis from the introgression of red-crowned parakeet genes could have also strengthened the Forbes' genome against environmental changes or congenital weakness in individuals (Nixon 1982, Rhymer & Simberloff 1996). However, given recent observations of low fertility in Forbes' and Forbes'-like hybrids, suggestions

of such potential positive effects of hybridisation should be viewed with caution. Care should also be exercised when evaluating the value of hybrids resembling red-crowned parakeets. Depending on the complexity of the inheritance system involved, the genome of these hybrids may comprise 50-75% Forbes' parakeet genes.

It is therefore crucial that phenotypic variation for a reasonable number of Forbes' parakeets, F1 hybrids and their various back-crosses are described and documented alongside the proposed genetic research. Whether sufficient F1 hybrids can be identified on Mangere Island is, however, uncertain, given the current low numbers of red-crowned parakeets. If this situation persists, controlled captive studies will have to be considered. Future visits to Little Mangere should also be used to gather as much information as possible about the baseline variability of the resident Forbes' parakeet population.

Although the case for shooting all hybrids no matter how marginal seems difficult to sanction based on the information to hand, limited culling of red-crowned parakeets and red-crowned-like hybrids (hybrid index score 9-12??) can probably be justified if their numbers are considered high (20-30%??) relative to the population of Forbes' parakeets. If such culls are to occur, steps must be taken to maximise the information that can be gained from such operations. All birds shot should be measured, photographed and assessed for hybrid status (as detailed above) and the location recorded. Samples suitable for genetic analysis (feathers, blood, internal organs) should also be collected using the relevant protocols.

7. References

Beggs, J., Bowen, A., Flux, J., Gibbs, N. and Ruarus, S. 1984. Nest boxes for parakeet and kaka. Report of Ecology Division, DSIR, Lower Hutt, New Zealand.

Bibby, C.J., Burgess, N.D. and Hill, D.A. 1992. *Bird census techniques.* Academic Press Limited, London.

Bollinger, E.K., Gavin,TA. and McIntyre, D.C. 1988. Comparison of transects and circular-plots for estimating bobolink densities. *Journal of Wildlife Management* 52: 777-786.

Buckland, S.T,Anderson, D.R., Burnham, K.P and Laake J.L. 1993. *Distance sampling: estimating abundance of biological populations.* Chapman and Hall, London.

Calder, B. and Deuss, E 1985. The effect of 1080 poisoning on bird populations in Motere, Pureora Forest Park, winter 1984. New Zealand Forest Service, Auckland.

Greene, T.C. 1998. Foraging ecology of the red-crowned parakeet *(Cyanoramphus novaezelandiae novaezelandiae)* and yellow-crowned parakeet *(C. auriceps auriceps)* on Little Barrier Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology* 22(2): 161-171.

Laake, J.L., Buckland, ST., Anderson, D. R. and Burnham, K. P. 1994. DISTANCE users guide V2.1. Colorado Co-operative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO.

Lambert, F. 1983. Survey of the status of the St. Vincent Parrot *Amazona guildingii* in 1982. *ICBP Study Report No. 3.* International Council for Bird Preservation, Cambridge.

Marsden, S.J. 1999. Estimation of parrot and hornbill densities using a point count distance sampling method. *Ibis* 141: 377-390.

Nichols, J.D., Noon, B.R., Stokes, S.L. and Hines, J.E. 1981. Remarks on the use of mark-recapture methodology in estimating avian population size. *Studies in Avian Biology* 6:121-136.

Nixon,A.J. 1982. Aspects of the ecology and morphology of *Cyanoramphus* parakeets and hybrids from Mangere Island, Chatham Islands. Unpublished PhD thesis, Victoria University of Wellington, N.Z.

Otis, D.L., Burnham, K.P., White, G.C. and Anderson, D.R. 1978. Statistical inference from capture data on closed animal populations. *Wildlife Monographs* 62: 135pp

Pollock, K.H. 1981. Capture-recapture models: a review of current methods, assumptions and experimental design. *Studies in Avian Biology* 6: 426-435.

Rhymer, J.M., and Simberloff, D. 1996. Extinction by hybridisation and introgression. *Annual Review of Ecology and Systematics* 27:83-109.

Thurley,T. 2000. Mangere Island parakeets: October 1999 - February 2000. Report to Chatham Island Area Office, Department of Conservation, Chatham Island.

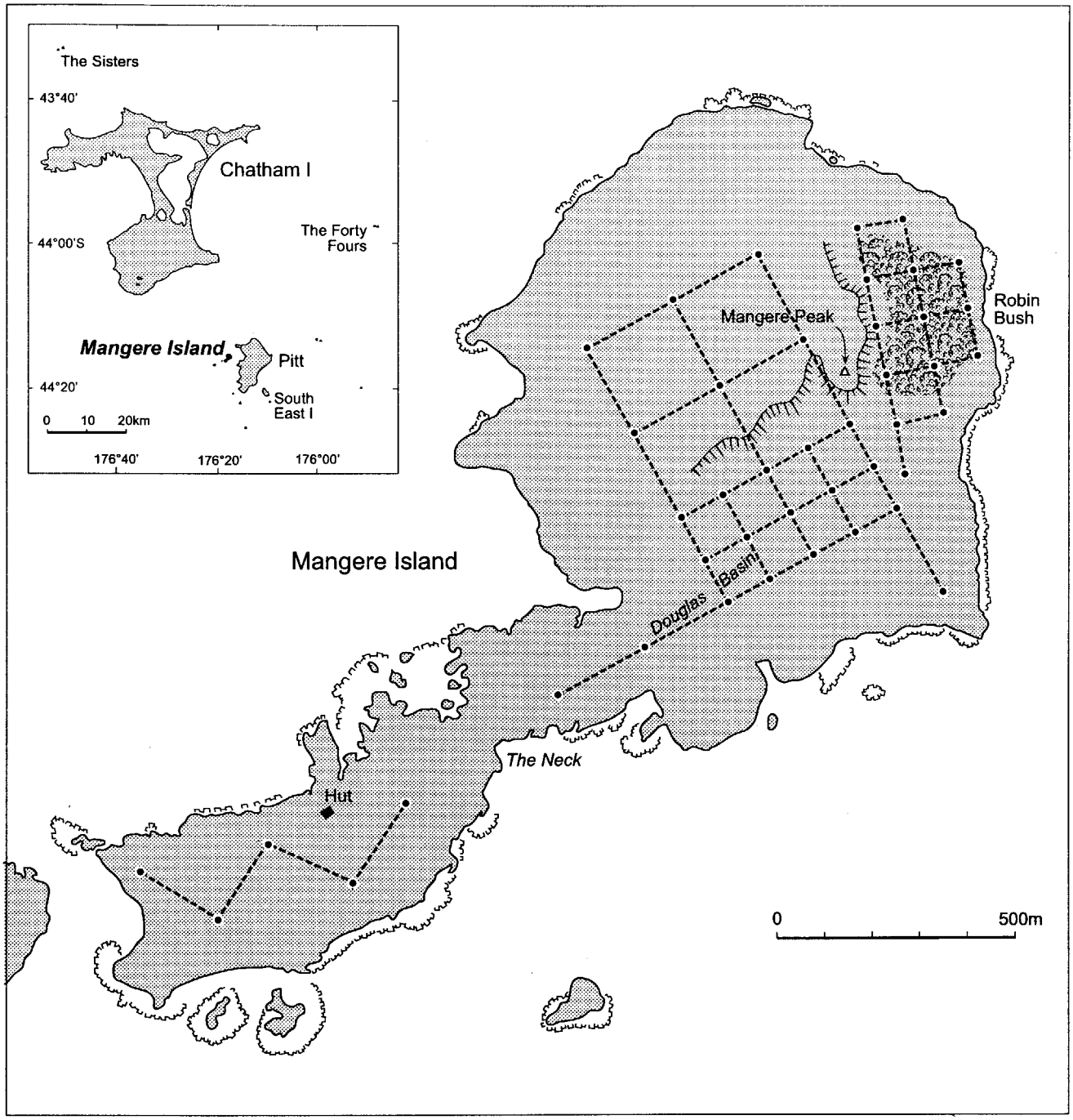
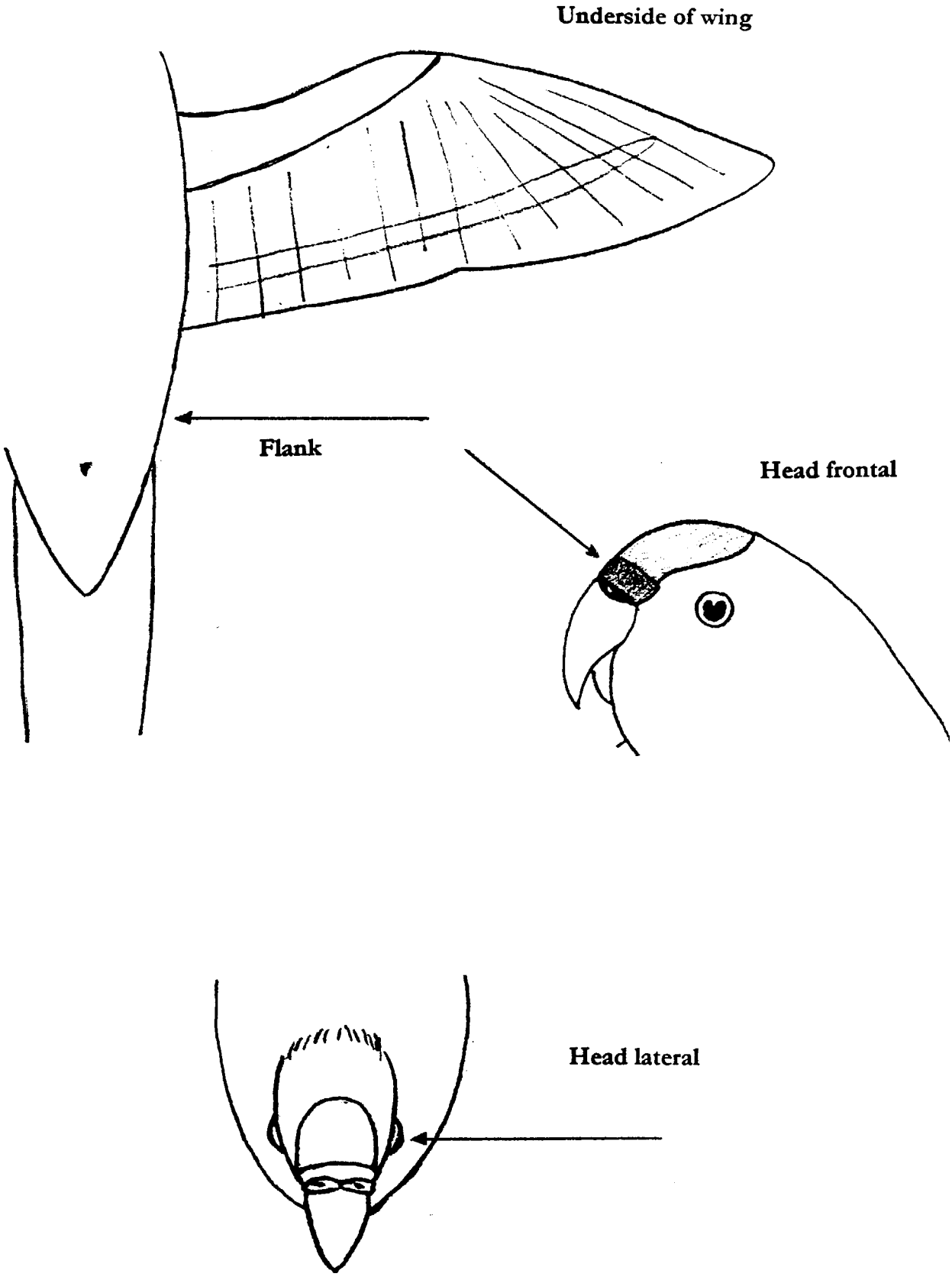


Figure 1. Mangere Island and proposed positions of point counts.

Fig. 2. Guide to standardised photographs to be taken for all parakeets captured on Mangere Island.



Appendix 1

Distance sampling - Survey method summary and example data sheet

- If possible counts should be conducted prior to (Oct./Nov.) and after (Mar./Apr.) each breeding season.

- Time of day counts should be standardised. Suggested start time is no later than one hour after official sunrise (CIST) and no later than 1200 (CIST).

- Counts should only be considered if the weather is suitable, i.e. no rain, fog or other precipitation, but light winds and mild temperatures.

- A systematic design using points placed at the intersections of randomly placed grids of 200 m and 100 m is to be used. Point count location is suggested in Fig. 1.

- Prior to survey all points need to be located and permanently marked in such a way that they can be easily found again.

- Points in places that are difficult to access, present unwarranted hazards to observers, or are atypical of the habitat being surveyed (e.g. extensive areas of grass when supposed to be surveying forest habitats) should be discarded.

- If possible, fixed distances from each point should be measured and marked to provide visual references when estimating distances during count periods.

- If a point is near the edge of a cliff or on the boundary of a given habitat type the effective survey area must be noted. For example, if the entire area surrounding a point can be surveyed then survey area equals one. If a cliff or habitat boundary means that only half the possible area can be surveyed then survey area = 0.5.

- Caution is required when approaching points to try and minimise the chances of birds being flushed. If the recorder flushes birds then their distance from the point prior to being flushed must be recorded. If such records are ignored, density will be underestimated.

- On reaching the point the recorder(s) should wait a minimum of two minutes before commencing the count proper. Such an interval reduces disturbance effects and gives recorders information prior to the count as to where birds are.

- Estimation of distance from point to object should be to the nearest metre. In areas where there is a 200 m grid any bird greater than 100 m from the point can be pooled into a distance class 100+ m.Where there is a 100 m grid any bird more than 50 m from the point can be pooled into a distance class 50+ m.

- If birds are in family groups or in flocks, distance should be measured to the centre of the cluster. The number of birds in each cluster should also be recorded.

- Particular care in estimating distances out to 50 m is required for all points.

- Care is required when recording flying parakeets. Particular attention should be paid to discerning the difference between birds flying out of the point area and those flying into or over the point area.

- Every attempt must be made to ensure that birds are recorded only once at each point.

- Following the 10 minute period, several minutes should be spent actively searching the area within 10 m of the point to try and ensure all birds close to g(0) have been detected.

- If possible the hybrid status of each parakeet seen from a point should be recorded according to the scale on the data collection sheet.

- All data should be recorded on the appropriate data sheets.

Mangere Island Parakeet Survey Sheet - Distance Sampling

Location	Date	Observer(s)	Official Sunrise (NZST)
Habitat	Weather		Sheet

Point #	Start time	Period	Distance to indiv.	Distance to clust.	# in clust.	# Seen	# Heard	Perched	Fly out	Flying in or over	Age Ad/Juv	Hybrid Status 1	2	3	4	5	6	Comment

Hybrid Status:
1 = Forbes Parakeet - no red in crown & band does not extend to eye
2 = Red band extends to eye
3 = Crown flecked with red or is orange
4 = Crown red/margin yellow, red in front of and behind eye
5 = Chatham Island Red-crowned Parakeet
6 = Unknown

Appendix 2

Mark-recapture survey method summary and example data sheets

- If possible, mark-recapture estimates using both mist nets and visual sightings should be conducted prior to (Oct./Nov.) and after (Mar./Apr.) each breeding season.

Mist net captures-recaptures

- Initially mark-recapture estimates should be confined to Robin Bush, where most mist-netting activity has occurred previously.

- Dates and time spent trying to capture parakeets must be recorded accurately. If possible, the time spent catching should be standardised in terms of start time (e.g. one hour after official sunrise CIST) and duration (hours per day).

- Accurate records must be kept of marked birds recaptured (record identity) and number of unmarked birds captured for the first time.

- Weather conditions should be chosen to be as standardised as possible for all capture efforts.

Sighting-based estimation

- For the purposes of the proposed pilot study, mark-recapture estimates should be confined to Robin Bush, where most mist-netting activity has occurred previously.

- Time of day, duration of sighting-based recapture periods as well as the approximate area surveyed (e.g. a set survey route) should be standardised. Suggested start time is no later than one hour after official sunrise (CIST) and no later than 1030 (CIST) when detectability is highest.

- Accurate records of date relative to previous capture attempts must be kept.

- All parakeets (marked and unmarked) seen during the sighting-based recapture period must be recorded. Marked birds must have individual identity recorded. Birds of uncertain identity should be recorded as such.

- Hybrid status of all parakeets should be assessed using the scale on the data sheet.

- Counts should only be considered if the weather is suitable, i.e. no rain, fog or other precipitation, but light winds and mild temperatures.

Mangere Island Parakeet Survey Sheet - Mark-Recapture Mist-nets

Net site	Location	Date	Operators

Weather	**Mist, Rain, Hail, Snow**	**0** - nil, **1** - dripping foliage, **2** - drizzle, **3** - light, **4** - mod., **5** - heavy	
	Sun:	Sunny	Partly cloudy	**Overcast**
	Wind:	**0** - none, **1** - leaves rustle, **2** - branchlets move, **3** - branches move, **4** - tree moves	

Time Start (NZCI)	Total New Parakeets	Total Recaptured	Habitat
Time Finish (NZCI)			

New Parakeets Captured			
Bird No.	Bands	Hybrid Score	

Recaptured Parakeets			dist. from
Bird No.	Bands	Hybrid Score	first capt.

Comment

Mangere Island Parakeet Survey Sheet - Mark-Recapture Sightings

Location	Date	Observer	Habitat

Weather	**Mist, Rain, Hail, Snow**	**0** - nil, **1** - dripping foliage, **2** - drizzle, **3** - light, **4** - mod., **5** - heavy
	Sun: Sunny	**Partly cloudy** **Overcast**
	Wind:	**0** - none, **1** - leaves rustle, **2** - branchlets move, **3** - branches move, **4** - tree moves

Time Start	Total Marked	Total Unmarked	Total Unkown ID
Time Finish			

Survey Section	Time Start	Time Finish	ID of Marked Birds		Hybrid Status	Date 1st Capture	Location	Unmarked Birds Seen	Hybrid Status	Birds ofUnkown ID Seen	
			Bird No.	Bands							

Hybrid Status:	1 = Forbes Parakeet - no red in crown & band does not extend to eye	4 = Crown margin red/yellow, red in front of and behind eye
	2 = Red band extends to eye	5 = Chatham Island Red-crowned Parakeet
	3 = Crown flecked with red or is orange	6 = Unknown

Appendix 3

First food method summary and example data sheet

- Feeding observations should be collected throughout the field season on Mangere Island.
- A minimum of 100 observations is required for every month.
- Effort should be made to ensure independence of observations. For example, equal observational effort in various habitat types, recording only one observation of foraging when a group of birds is foraging on the same food item in close proximity, etc.
- Appropriate record sheets should be used and any unusual behaviour noted.

First Food Diet Records

Date	Time (CIST)	Sex Male Female Unkn.	Age (if known) adult sub-ad juv	Hybrid Status
Observer	Location Grid Ref.		Vege Type (Circle one) Forest Plantings Scrub Rank Grass Herb Bare Other	
Canopy Height	Food Species Eaten			

Food Type (Circle one)

FRT = Fruit **FLW** = Flowers **NEC** = Nectar
SDS = Seeds **BRK** = Bark **LWI** = Live Wood Invert
DWI = Dead Wood Invert **SGI** = Surface Gleaning Invert
LVS = Leaves **VEG** = Other Vegetative Growth **SAP** = Sap Feeding

Foraging Level (Circle one)

ABC = Above Canopy **EME** = Emergent Leaves
USC = Unshaded Canopy **SHC** = Shaded Canopy
UUN = Upper Understory **LUN** = Lower Understory
GRO = Ground

Comments

Hybrid Status:

1 = Forbes Parakeet - no red in crown & band does not extend to eye
2 = Red band extends to eye
3 = Crown flecked with red or is orange
4 = Crown red/margin yellow, red in front of and behind eye
5 = Chatham Island Red-crowned Parakeet
6 = Unknown