Chapter 3 Population demographics

INTRODUCTION

Knowledge of demographic parameters of natality, survival (mortality), emigration and immigration are fundamental to understanding the population dynamics of any taxon (Krebs 1978; Caughley and Sinclair 1994; Nichols *et al.* 2004). This knowledge underpins any decision making process to either increase, decrease, harvest or monitor wildlife populations (Caughley and Sinclair 1994). Management of threatened taxa is focussed on actions to alleviate factors preventing recovery (Jones 2004) and result in the increase of population size and/or individual survival, which in turn leads to an improved robustness of the population. An improved understanding of the demography of a threatened species may lead to the discovery of key weaknesses and strengths in a species' life history. Conservation actions can then be targeted to those areas having the greatest positive effect on the species.

A commonly used method to gather information on demographic parameters in bird populations is the use of colour bands to identify individuals at subsequent encounters (Gosler 2004). Since 1988 the Orange-bellied Parrot has been the subject of a colour banding program and intensive re-sighting effort to provide information on survivorship and other demographic parameters. This information is being used to assist with defining the conservation status and management of the species and to provide conservation managers with a means of assessing the effectiveness of recovery actions. While raw data have been presented to the Orange-bellied Parrot Recovery Team annually, this is the first time a complete description and analysis of the demographics of the Orange-bellied Parrot has been undertaken.

Since 1978, the Orange-bellied Parrot has been the subject of intensive conservation efforts, including monitoring of the main breeding population at Melaleuca in south west Tasmania (see Chapter 2). Early studies by Brown and Wilson (1980, 1981 and 1982) and the recovery plan resulting from these studies (Brown and Wilson 1984) concentrated mostly on locating the species and recommending protection of key sites. During the 1980s, population estimates and trends were based predominantly on counts of birds occupying key wintering habitats in Victoria and South Australia (Stephenson 1991).

METHODS

Study site

Melaleuca (as described in Chapter 2) has been the focus of population studies of the Orange-bellied Parrot since 1988. The site is recognised as a key breeding area for the species with most known and historic nests occurring within a 10km radius (Orange-bellied Parrot Recovery Team 2006). The reason for this concentration is not well understood; however, it is generally believed frequent burning of moorland vegetation in this area has produced favourable foraging habitat for the species (Brown and Wilson 1981).

Melaleuca has been the site of an alluvial tin mine for most of the 20^{th} century and is the only settlement within the Tasmanian southwest wilderness. It has an airstrip and field huts associated with the tin mine and bushwalking/tourism interests. This infrastructure is essential for access and accommodation for personnel involved in the national recovery program.

Supplementary feeding

The Orange-bellied Parrot has shown the capacity to utilise non-native food resources at Melaleuca. As early as the 1950s C. D. King observed Orange-bellied Parrots frequenting his garden at Melaleuca (Mattingley 2002). Brown and Wilson (1980) regularly observed the species feeding on a range of introduced plants in King's garden during their studies in 1979–80. As the Orange-bellied Parrot is a small (*c.* 45g, 22—25cm, Higgins 1999) ground-feeding species, it is difficult to observe without flushing, and prone to fly away when disturbed. This behaviour makes observation of colour bands problematic under normal circumstances, and close observation of this inconspicuous species is known to be difficult (Jarman 1965; Brown and Wilson 1980; Forshaw 2002). The ability to find and observe the species in un-tracked land within the breeding range, without disturbance, requires significant effort and most often fails to produce accurate observations. In an attempt to overcome this problem, supplementary seed was provided during the 1988/89 breeding season at a feed station in King's garden (Stephenson 1991). This proved to be very successful, with Orange-bellied Parrots quickly learning to utilise this new food source. King continued to provide seed under the direction of Peter Brown and in 1990/91 a coordinated monitoring program was established which continues to this day. This involves teams of volunteers observing colour banded and unbanded birds visiting a feed table throughout the breeding season (described below). The success of the observation program led to the development of a public observatory (The Deny King Memorial Hide) and interpretive display in 1991. The observatory provides volunteers with a comfortable viewing point and tourists with the opportunity to view the Orange-bellied Parrot in the wild (Stephenson 1991).

Supplementary dry seed is provided daily throughout the breeding season at two sites at Melaleuca—the main site adjacent to the observatory known as 'King's' and the other at Peter and Barbara Willson's residence known as 'Willson's'[4]. Initially, a variety of commercially available seed mixes containing barley, de-hulled oats, sunflower, panorama millet, Japanese millet, rape, linseed, white millet, niger and canary were provided. However, improved understanding of dietary requirements of the species in captivity resulted in this mix being refined to 50% plain canary, 25% red panicum 15% Japanese millet and 10% white millet. This, combined with limiting the amount of seed to *c.*200g/day, avoids potential harmful dietary consequences, such as obesity (Shephard 1994). Other conservation programs have used supplementary foods to positively influence aspects of a species' ecology such as increasing percentage of breeding birds, improvement of productivity and increasing survival of individuals (Jones 2004). The use of 'supplementary' seed within the Orange-bellied Parrot recovery program was not intended to achieve these outcomes and therefore the term is not strictly correct. The primary aim of the provision of the artificial food source was to aid observation, particularly of colour bands.

Hygiene protocols

The provision of seed at feed tables also attracts other granivorous birds, in particular Green Rosella *Platycercus caledonicus* and Beautiful Firetail *Stagonopleura bella*. Combined with the presence of large numbers of Orange-bellied Parrots, the presence of these species at the feed tables may increase the risk of disease transferral, particularly *Chlamydia psittaci* and *Coccidia spp.*, and endoparasites (*e.g.* roundworms *Ascaris spp.*) through faecal contamination of food (Shephard 1994). To date no signs of disease outbreaks have been detected at the study site; however, in order to minimise this risk, a hygiene protocol is implemented as follows.

1. When observations are not being conducted, there is no supplementary feeding. The frequency of this is variable and dependent on a number of factors including observer availability, time of year (*i.e.* observations are more focused early in the breeding season to observe returned individuals) and weather conditions (*i.e.* observations are less frequently conducted during inclement weather).

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[4] Peter and Barbara Willson own and operate Rallinga Mines Pty. Ltd., an alluvial tin (cassiterite) mine in the Southwest Conservation Area. This operation is licensed by Mineral Resources Tasmania and is a permitted activity under the *Parks and Reserve Act 2002.*

2. Seed is stored in a vermin proof container and replaced annually or whenever fungal/insect contamination is detected.
3. All uneaten seed and husks are removed from the feed table twice daily and, when observations are to continue, replaced with fresh seed.
4. The feed table is thoroughly scrubbed with proprietary sodium hypochlorite solution (20-42g/l) and rinsed with clean water daily[5]. Rubber mats (used to prevent seed blowing away) and stainless-steel trays are also washed down.
5. Observers are requested to note and report any signs of ailing birds.

In addition to managing disease risk, observers note the presence of any predators in the area, in particular Tiger Snake *Notechis ater,* Brown Goshawk *Accipiter fasciatus,* Collared Sparrowhawk *A. cirrhocephalus,* Peregrine Falcon *Falco peregrinus* and Spotted-tailed Quoll *Dasyurus maculatus*. In the case of Tiger Snakes and Spotted-tailed Quolls, the vegetation surrounding feed tables is kept low to reduce the cover afforded to these predators. Feed table legs are also coated in petroleum grease to prevent snake access. All predatory activity is recorded on daily observation sheets.

Monitoring the population

Banding

On the 27 February 1986, eight Orange-bellied Parrots were captured at Melaleuca as founder stock to establish a captive-breeding program. Two wild birds (both juveniles) also captured but not required as founder stock were opportunistically banded with Australian Bird and Bat Banding Scheme (ABBBS) stainless steel leg bands (*P*. Brown, unpublished report). These two birds were subsequently observed back at Melaleuca during the following breeding season and provided the impetus to

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[5] At the time of writing, disinfection has been changed to Virkon S™(Potassium perogymonosulohate, sodium chloride 1-2%) in accord with the recommendations within the draft disease hygiene protocols developed by G. Cross under the Psittacine Circoviral Disease Threat Abatement Plan (Department of Environment and Heritage 2005).

commence a banding program to provide information on survival and movements of individuals. Between the 1987/88 and 1990/91 breeding season, free-flying juveniles were mist-netted annually at the Melaleuca feed stations. From 1991/92 to 1993/94, nestlings retrieved from nest boxes (see Chapter 2) were banded in addition to mist-netted birds. In 1995, mist netting was discontinued because sufficient numbers of nestlings were available from nest boxes to undertake population studies. The ability to band nestlings also provided the capacity to determine natal nest location, siblings, parentage and site fidelity.

The process of banding nestlings involved the removal of the entire brood from the nest and processing on the ground. Nestlings were placed in a cotton bag within a rigid plastic bucket and carried down within a backpack by the tree climber. A cloth bung was placed in the entrance hole of nests to prevent parents from entering the nest while nestlings were being processed. This reduced the risk of desertions on discovery of an empty nest.

All birds banded were fitted with uniquely numbered, ABBBS stainless steel bands (size 23, 0.7mm gauge, 4.0mm ID x 5.0mm H) applied to the tarsus (tarsometatarsus—below the tarsal joint) in accord with the banding procedures described by Lowe (1989). These bands were either untreated (silver) or colour powder-coated to indicate the year of banding. Colours were used on a rotational basis to avoid repeated combinations within life expectancy (*c.* 6 years). Up until 1999, either a single colour or bi-coloured plastic (Darvic®) band was fitted to the other tarsus to allow identification of individuals in combination with the year colour (Figure 3.1). The butt joint of the plastic bands was glued to minimise the potential for band loss.

During this study some of the plastic band colours changed over time thus causing problems with colour interpretation. In particular, light blue, light green, yellow and mauve as reported by Gosler (2004) were found to be variable in colour stability. From 2000 onwards the use of Darvic® bands was discontinued and replaced with Acraft™ aluminium, colour anodised bands with repeated engraved letters.

Figure 3.1. A banded female Orange-bellied Parrot at the King's feed table (in this case a returned captive-bred released individual) showing a blue powder-coated stainless steel band on the right leg and a black Darvic® band on the left leg (Photo M. Holdsworth).

Release of captive-bred birds

From 1991 to 1993, 38 captive-bred Orange-bellied Parrots were released at Melaleuca to test release methods and efficacy of reintroduction as a recovery technique (Orange-bellied Parrot Recovery Team 2006). Birds were held in a temporary release aviary for up to one month and 'soft' released as described by Brown *et al.* (1995). Each bird was individually colour-banded (as described above) and monitored as part of the observation program. While survival of released Orange-bellied Parrots over the first breeding season, immediately following release is high (*e.g.* 92% Brown *et al.* 1995), apparent survival to subsequent breeding seasons is lower (M. Holdsworth unpublished data). Experience elsewhere shows long-term survival of captive-bred birds can be compromised by several factors including predator naivety and inferior foraging skills (Wiley *et al.* 1992). In the case of migratory species such as the Orange-bellied Parrot, this potential is compounded. As a result of these complicating factors observations of captive-bred birds were excluded from the survival analysis.

Data collected at banding

For most banded birds the following details were recorded and entered in various databases[6].

- ABBBS band number
- left and right leg band colours
- date of banding
- sex (if known)
- banding location/nest name
- age at banding (estimated or known)
- sibling identification (for nestlings)
- parent identification (for nestlings if known)
- laying, hatching and/or fledging date (for nestlings if known)
- reproductive success (egg and nestling failures – see Chapter 2)
- blood and feather samples for DNA sexing

Observations of banded birds

The author, other researchers and a large team of volunteer observers conducted observations at the Melaleuca feed tables in each breeding season between 1990/91 and 2004/05 (Figure 3.2). Teams of 2–3 observers recorded details of birds visiting the feed table at the observatory during 1–2 hours each morning and evening as most

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[6] All data are now stored in a Filemaker Pro® v.3–7 relational database ' Orange-bellied Parrot Master.fp7'. Morphological characters of nestlings were measured, and blood and feather samples were collected for Psittacine Circoviral Disease from most individuals at the time of banding but not reported here.

feeding activity occurs during these periods (Kudrez 1996). Depending on weather conditions and the season (*i.e.* daylight hours), the morning observations were generally conducted between *c.*0600hrs and *c.*0900hrs, and evening observations between *c.*1530hrs and *c.*1800hrs. Observations were conducted continuously throughout the breeding period (Oct–Mar) with greatest effort focussed during October and November to detect birds returning from migration, and during late January to March to observe juvenile production. Peter and Barbara Willson conducted opportunistic observations of birds visiting their feed table and garden throughout the study period. Observations at both feeding stations were aided with spotting scopes (x25 Kowa™ TS-601, x25 Nikon™ and x30 Swarovski™ ST 80).

During observation periods the following details were recorded[7]:

- date and time of observation
- observer/s name
- location ('King's or 'Willson's)
- colour band details
- inter- and intra-specific behavioural notes (*i.e.* predatory attempts, breeding behaviour, *etc*)
- injuries and ailments

Throughout the study any leg injuries of banded and unbanded birds were recorded and reported to the study supervisors. The categories of leg injury symptoms were described as either transient lameness (favouring leg, swelling or bleeding) or permanent (fracture or band constriction). Leg injury rate was compared to total birds banded and types of band. The occurrence of leg injuries on banded birds was also compared to the occurrence of leg injuries to unbanded birds. Some individuals are

[7] Observers also recorded total numbers and banded:unbanded ratios of birds present at the feed table at five minute intervals. These data are not reported here.

known to visit the feed tables frequently throughout the breeding season (Kudrez 1996). Individuals were only recorded once per day rather than at every observation period. Resightings of individual colour-banded birds were entered into the relational database.

Figure 3.2. A volunteer undertakes observations of Orange-bellied Parrot visiting the feed table from 'King's observatory at Melaleuca. Nest boxes can be seen in the tree in the background (Photo M. Holdsworth).

Observations at natural nest sites and at nest boxes at the Melaleuca study site were conducted to identify parentage. These observations mostly occurred in January and February to maximise the opportunities to observe both parents as they visited nests to feed nestlings. Observers used spotting scopes (as described above) or 8.5 x 42 Swarovski binoculars during banding operations (occasionally adults would alight close to the tree climber). Parental pairs were determined by observation of pre-coital feeding, copulation, females incubating and/or both parents entering the nest to feed nestlings. Using these criteria, the maternity of nestlings is likely to be reasonably accurate; however, paternity may not necessarily be consistent with observed behaviour, as there is some evidence of polygamy (Holdsworth pers. obs.). Band status and details observed for each parent were recorded and entered into the relational database. The proportion of banded, unbanded and unknown band status (and the various combinations) for observed parents are presented.

Determining age at resighting

Age at resighting was determined by calculating the elapsed time between known hatching date and sighting date. Due to the small number of inspections made of nests during this study, few actual hatching dates were recorded. Where laying date was known the probable hatching date was calculated by adding the mean incubation time of 21 days (see Chapter 2) to the observed laying date. For individuals with no known hatching or laying date, the median hatching date calculated for each cohort during this study was assigned as the nominal hatching date to provide an estimated age in years at resighting.

Determining sex

At the time of banding all nestlings and free-flying juveniles, an effort was made to determine the sex of the individual based on plumage colour. In particular, as described by Higgins (1999), the extent and intensity of the orange patch on the belly (more extensive and intense in males) and the width and contrast of the frontal band (wider and distinctly two-toned blue in males) was used. For nestlings, this was not possible until feathers were grown at about three weeks of age. Between 1992/93 and 2000/01 the sex of some individuals was confirmed by examining sex-specific markers of molecular DNA as described by Griffiths *et al.* (1998). A 50μl blood sample was collected from the brachial vein of all banded birds. The vein was pierced with a sterile 0.5 x 16mm Thermo® single-use needle and drawn up by capillary action with Blaubrand® disposable micropipettes. These blood samples were stored in 1.0ml of Queen's lyses buffer solution (Seutin *et al.* 1991) and later sent to LaTrobe University, School of Genetics for DNA extraction, sex confirmation and storage. Various workers (*e.g.* N.D. Murray, H.B. Allen, M. Ivanyi and J. Baril unpublished data, Hristova 2001) provided results of these samples. However, a variety of laboratory problems, including unknown provenance of samples, missing samples and no DNA within some samples, resulted in an incomplete analysis (Hristova 2001). In addition, insufficient funds and availability of technical support between 2002 and 2005 prevented analysis of stored DNA samples and therefore the sex of juveniles failing to survive the first year during this period could not be confirmed[8]. However, individuals observed in subsequent years could be sexed either by plumage colour or by sex-specific behaviours. For males this included observation of copulation and courtship feeding with a confirmed female[9], and for females this included observation of copulation and courtship feeding by a confirmed male or incubation of eggs/nestlings. A comparison of the confirmed sexed birds with the observed sex at banding is provided to determine the accuracy of this method.

Productivity

The assessment of productivity of the Orange-bellied Parrot was limited to fecundity. The capacity to measure other productivity parameters (*i.e.* net reproductive rate, net recruitment rate, mean reproductive lifespan and mean generation length), all of which rely on tracking individual female and daughter reproduction over time (Krebs 1978), was constrained by the low level of observability of individuals away from feed tables. Many individuals use nest sites beyond the study site or use natural nests within the study area, which remain undetected. Furthermore, identification of parents at known nests was limited by the capacity to observe colour bands. Many nests are high in trees and observation opportunities (during feeding events) are limited to 2-3 minutes every 3-4 hours/day.

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[8] At the time of writing all DNA samples held at LaTrobe University were being transferred to the Australian National University for sex analysis and storage.

[9] Some homosexual copulation and mutual feeding by males was occasionally observed by the author during this study.

Fecundity

Fecundity rate, defined as the mean number of female fledglings produced by a breeding female per year (Krebs 1978; Caughley and Sinclair 1994), was determined for the Orange-bellied Parrot at Melaleuca. This was calculated for breeding females for 12 breeding seasons from 1993/1994 to 2004/05. It was not possible to calculate fecundity from female hatchlings per female, because of the difficulty in confirming the sex of desiccated nestlings at the time of nest inspections. However, the result is unlikely to be significantly different from the fecundity rate from fledglings because of the relatively low level of nestling mortality observed throughout the study (see Chapter 2). To overcome the problems of identifying the sex of individuals not resighted post-fledging, and in the absence of molecular DNA analysis to confirm sex for many of these individuals, an estimated number of female fledglings was derived from the observed ratio of females resighted in the following year. This assumed there was no difference in survival between sexes.

Mean lifespan and longevity

The mean lifespan and longevity of Orange-bellied Parrots was calculated from observational records of all fledglings and juveniles colour-banded from 1991/92 to 2003/04. These records also included observation of individuals outside the breeding range contained in Birds Australia's Orange-bellied Parrot winter database.

The probability of observing colour banded individuals at Melaleuca is generally very high and therefore it is reasonable to assume that individuals not re-sighted after several breeding seasons have in fact died. However, the fate of most individuals is unknown and since it is unlikely individuals die immediately after last sighting, the actual date of death is unknown. This problem is compounded with the Orange-bellied Parrot because of the species' mobility and the difficulties of observing individuals on migration and throughout their extensive wintering range. Incidental observations of cause and timing of death are reported in this study. Where actual date of death is not known, but death is presumed to have occurred, a calculated death date was assigned by finding the mid-point between the date of last sighting of an individual and the date of first return of banded birds to Melaleuca in the subsequent breeding season.

Data management and survival estimation

Observational data from this study were exported from the Orange-bellied Parrot relational database into Excel® worksheets and converted into a series of capture histories using Pivot Tables to produce '.inp' files (White and Burnham 1999; Cooch and White 2001). Estimation of survival (S) and recapture probability (p) was conducted by analysing the capture histories using program MARK 4.1 software (Gary C. White, Colorado State University). MARK 4.1 computes these parameter estimates via numerical maximum likelihood techniques (White and Burnham 1999; Cooch and White 2001) using a range of models. The models were based on the basic Cormack-Jolly-Seber (CJS) model (Cormack 1964; Jolly 1965; Seber 1965) which allows the calculation of time-specific survival and recapture probabilities. Models considered survival and recapture separately for each sex (males, females, unknown), age class (juveniles and adults, or juveniles and adults aged 1, 2 and >3 years), time (annual periods of interest) and capture method at banding (banded at nest as a nestling or captured in mist nets post-fledging). Assumptions underlying the models for a given sampling location and period are as follows:

- all marked birds have the same probability of recapture and survival,
- birds behave independently with respect to survival and recapture,
- no bands are lost over time, and
- sampling is instantaneous.

Models were ranked using Akaike's Information Criterion (AICc) (Akaike 1973), and models with the lowest AICc value were considered to be the best on the basis of parsimony and quality of fit to the data. This method of model selection is useful as it works well when data generally meet standard mark-recapture assumptions, and also when these assumptions are violated (Burnham *et al.* 1995; Burnham and Anderson 1998). Analysis was restricted to wild-caught birds only — released captive-bred birds were not included as survival and probability of resighting is known to be less than wild birds and would therefore skew the models. The models fitted to the data are shown in Table A9 (Appendix 6).

Where parameter estimates are non-identifiable because of problems in the data, this will often be characterised by estimates of 0 or 1 and standard errors that are extremely small or large (Cooch and White 2001). Other authors (Rothery and Prince 1990; Lebretton *et al.* 1992) suggest the first two years, but particularly the last year of a mark-recapture analysis, are the least reliable estimates. Where this occurs, and when there is reasonable grounds to doubt the result, they recommend these estimates be ignored. Consistent with this convention, estimates for the last year (2004/05) were excluded from the results, as were other model estimates as appropriate. Parameter estimates of survival (Phi) and probability of recapture (p) were calculated for all cohorts from 1990/91[10].

Migration

Records of first and last observations of Orange-bellied Parrots at Melaleuca were used to determine the approximate dates of arrival and departure at Melaleuca. It was not possible to determine the actual time of arrival/departure and therefore the data presented are treated as indicative of migratory behaviour. The dates of first and last

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[10] Parameter estimates were not conducted on the 1997/98 cohort because consistent observation effort did not commence until 1991/92.

sighting are presented for 34 breeding seasons during the period 1959/1960 to 2004/2005. These data are derived from King's diary records for 17 breeding seasons between 1959/1960 and 1978/1979 (Brown and Wilson 1980); records for three breeding seasons between 1979/1980 and 1982/1983 (Brown and Wilson 1980 and 1981); and 14 breeding seasons of observations at the feed tables between 1991/1992 and 2004/2005 (this study). The mean arrival and departure dates are calculated. Observations at the feed tables were also used as the basis for determining the arrival dates. The dates of first observation (presumed first arrival) of each banded, known-sex bird were combined for each year into 5-day intervals from 29th September until the 16th December (the median laying date reported in Chapter 2). A comparison of arrival dates between 1st year birds and 2nd year + birds, and both sexes is presented.

RESULTS

The banded population

A total of 810 wild caught Orange-bellied Parrots were banded since 1986/87. Of these, 786 were fitted with individually unique colour bands at Melaleuca between 1987/88 and 2004/05. Of these, 15 did not survive to fledging, three were known to have died shortly after fledging and eight were banded as unknown-aged adults (1+ years). The remaining 760 birds were of known age juveniles (banded either at nest or in mist nets post-fledging) and were known to be alive prior to their first northern migration. The numbers of each of these 16 cohorts, method of capture and the year colour code are shown in Table 3.1.

Table 3.1. Year colour and capture method of 760 juvenile Orange-bellied Parrots colour-banded at nest or in mist nets post-fledgling at Melaleuca in each of 16 cohorts for the period 1987/88– 2004/05. NB Banding was not conducted during 1989/90.

Cohort	Year colour code	Banded in mist nets	Banded at nest	Total
1987/88	silver	20	-	20
1990/91	red	32	-	32
1991/92	dark blue	44	-	44
1992/93	yellow	36	11	47
1993/94	pale blue	30	29	59
1994/95	black	-	37	37
1995/96	pink	-	37	37
1996/97	green	5	41	46
1997/98	orange	-	55	55
1998/99	red	-	52	52
1999/00	silver	-	53	53
2000/01	dark blue	-	40	40
2001/02	yellow	-	71	71
2002/03	black	-	56	56
2003/04	pink	-	60	60
2004/05	green	-	51	51
Total		167	593	760

A total of 327 observers (248 individuals) recorded 27,324 sightings of the colour-banded birds at the Melaleuca feed tables on 1895 days between 1991/92 and 2004/05. Observation effort for each year is detailed in Table A10 (Appendix 7).

Leg injuries

The details of leg injuries to birds observed at Melaleuca throughout the study are detailed in Table A11 (Appendix 8). A total of 13 individuals (10 banded and three unbanded) were observed to have leg injuries. Of the 10 banded individuals, four were transient lameness, four were permanent injuries, one had an otherwise transient leg injury but with additional major body injuries (*e.g.* feather damage and head wound) and probably died, and another had an otherwise transient leg injury but was not resighted again. Only one of the banded birds was injured (transient) on the left leg carrying the ABBBS stainless steel band. This represents 0.12% of 810 individuals banded with stainless steel bands. All other band associated injuries (n =

9) were on the right leg with either Darvic® (*n* = *3*) or Acraft™ (*n* = 6) bands. This represents 1.19% of the 759 individuals fitted with Darvic® or Acraft™ bands. Half of the Acraft™ injuries (*n* = 3) were on nine adults that had their Darvic® bands opportunistically replaced with Acraft™ bands as part of a separate radio telemetry study in December 1999. These bands were subsequently found to be 0.6mm higher (6.1mm) than the ABBBS stainless steel bands. It is speculated that the higher band resulted in difficulty for the individuals to clean sloughing skin from beneath the band resulting in constriction-related injury. The height of Acraft™ bands was corrected for the 1999/2000 cohort onwards. Even if we ignore these injuries associated with incorrect sized band, Acraft™ banded birds still have a higher rate of associated leg injury of 1.04% (*n* = 3) of 287 individuals with Acraft™ bands compared to 0.63% (*n* = 3) of 472 individuals with Darvic® bands. More males (*n* = 7) had injuries than females (*n* = 2); however, this difference was not significant (Fisher's Exact test *P* = 0.14).

Two of the injured birds were not resighted in a subsequent breeding season whereas two others survived for one and four subsequent seasons respectively. The latter bird was alive in 2004/2005 and is the only injured bird confirmed to have successfully bred (sire in 2001/2002 and 2003/2004). One bird (ABBBS no. 230-13462) lost its Darvic® band in its second year without any observed injury.

Mortalities

Throughout the study, a total of 17 fledged Orange-bellied Parrots were found dead, or sustained injuries which probably led to their death soon after observation. Three juveniles died as a result of being mist-netted, one each in 1992/93, 1993/94 and 1994/95. In April 1992, an unbanded juvenile was observed to be unwell for several days at the 'King's feed table and was captured for treatment but subsequently died. This bird was under-weight (35g); however, the cause of death could not be determined (P. Brown pers. comm.). Four adults were found dead in parental nest boxes from unknown causes (one female in each season 1994/1995 (one year old), 1995/1996 (one year old), 2002/2003 (two years old) and one male in 1995/1996 (five years old). Three were found dead directly beneath structures or were observed to collide with structures. One of these (an unbanded adult male) was found beneath the Willson's wind generator tower in 2000/2001. Subsequently, the Willson's have only operated the generator at night or during the non-breeding months. The other two had collided with the observatory windows—an adult male (one year old) in 1995/1996 and a juvenile in 2000/2001. A further three adults were observed sick or traumatised at the feed tables and not observed again thereafter—presumed dead—in 1995/1996, 1999/2000 and 2003/2004. The remains of one other adult was found at Kings but no obvious cause for its death could be determined. Bird-eating raptors (*i.e.* falcons and goshawks) were observed infrequently near the gardens and feed table areas, and no successful predatory attempt was noted. On two occasions (one observed by the author and another by Peter and Barbara Willson) a Peregrine Falcon *Falco peregrinus* made a concerted but unsuccessful attempt to take Orange-bellied Parrots flying from the feed table.

Survivorship and lifespan

Of the 760 known-age banded birds, a total of 740 capture histories were available for analysis, comprising of 231 males, 187 females and 322 birds where the sex was not determined for 15 cohorts between 1990/91 and 2004/05. Parameter estimates of survival (Phi) and recapture probability (p) for these were calculated against 39 models. An AICc for each model is presented in Table A12 (Appendix 9).

The best (lowest AICc) model was one where survival was age (juvenile, adult), sex (male, female, unsexed) and time dependent, with recapture probability age and sex dependent. Parameter estimates for Model 1 are shown in Table A13 (Appendix 9).

Annual estimates calculated from Model 1 show the mean annual juvenile survival was females 64% (± 5.7 s.e), males 66% (± 5.7 s.e) and unknown sexed birds 33% (± 4.5 s.e). While there was no significant difference between the mean survival of juvenile females and juvenile males, mean survival of unsexed juvenile birds was markedly lower. In contrast, there was no significant difference in mean survival of any of the three adult sex classes using this model — 63% (± 5.8 s.e) for females, 66% (± 5.2 s.e) for males and 58% (± 7.7 s.e) for unsexed birds. The similarity in survival between juveniles and adults was considered implausible and caused by the bias imposed by the inclusion of unsexed juveniles in the analysis of juvenile survival — juveniles that could not be sexed at banding remain unsexed if they are not resighted as adults. Consequently the survival of juvenile males and females is biased high while juvenile unsexed birds is biased low. Therefore it is only appropriate to compare juvenile and adult survival for birds if sex was ignored as a dependent variable. On this basis no further consideration was made of any model that included sex-dependency for either survival or recapture probability. Accordingly, Models 22, 24, 27 and 31 were considered, with Model 22 selected on the basis of lowest AICc. This shows a more biologically plausible mean survival of 55% (± 3.2 s.e) for juveniles (Table A14, Appendix 9). A comparison of juvenile and adult survival derived from these two models is shown in Figure 3.3.

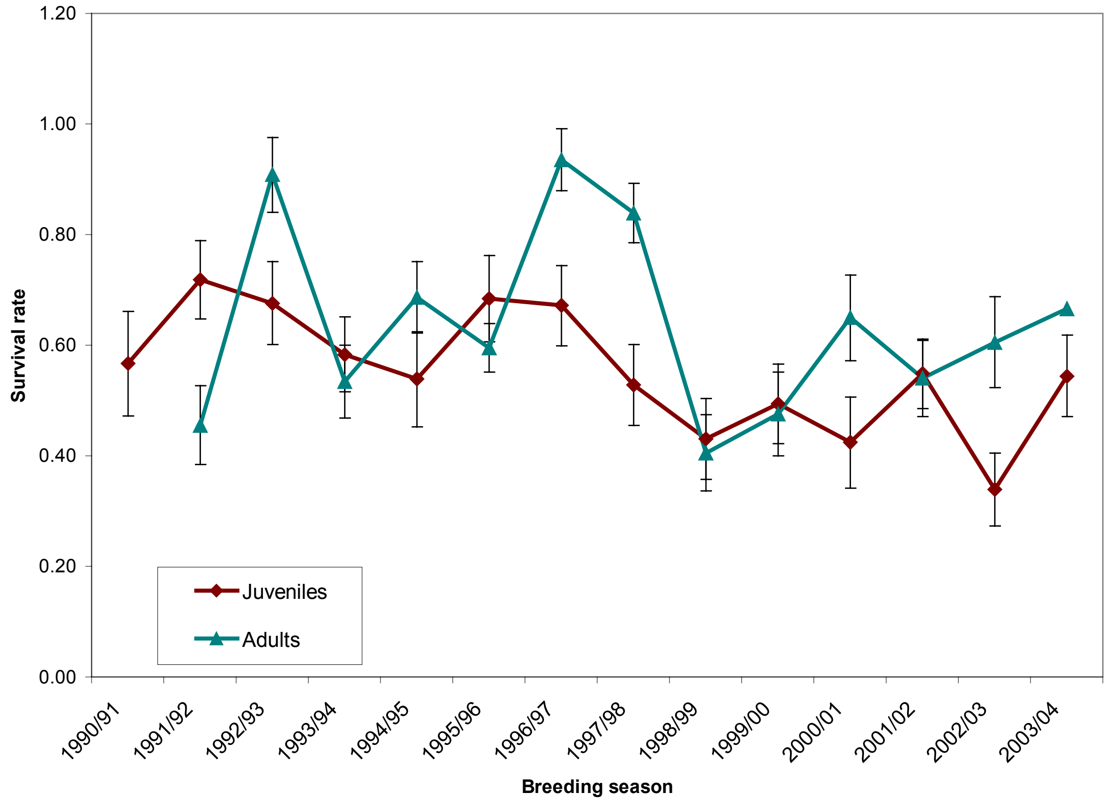

Figure 3.3. Mean annual survival of Orange-bellied Parrots observed at Melaleuca between 1990/91 and 2004/05. Survival estimates are derived from Model 22 (Table A14, Appendix 9). Error bars are +s.e for each category.

The 1991/92 cohort had the highest juvenile survivorship of 72% (±7.0 s.e) and the lowest was the 2002/03 cohort with 34% (±6.6 s.e). The mean survival of juveniles was 62% (± 2.6 s.e) up until 1997/98, then it declined to 45% (±3.5 s.e) from 1998/99 to 2002/03 (Figure 3.3). The mean survival estimate for adults was 63.6% (± 2.0 s.e). The highest survival estimates for adults was 94% (± 4.4 s.e) in 1996/97 and the lowest of 41% (± 5.4 s.e) in 1998/99. Adults also showed a decline in mean survival after 1997/98, from 71% (± 7.2 s.e) to 54% (± 4.4 s.e) (Figure 3.3). The mean survival of juveniles and adults over the study declined for both groups. However, the decline was more pronounced for juveniles ($r^2 = 0.4331$) compared to adults ($r^2 = 0.0198$).

The survival of juveniles (birds surviving to the first breeding season) was compared to four different adult age classes (*i.e.* year 1, year 2, year >=2, year >=3). The best AICc was Model 28 and therefore this model was selected over models 35, 36 and 37. The survival estimates are shown in Table A15 (Appendix 9) and illustrated in Figure 3.4. The mean survival of juveniles was 56% (± 3.1 s.e) compared to 66% (± 6.2 s.e) for Year 1 birds and 59% (± 19 s.e) for Year >=2 birds. The results show lower survival occurs in the first (juvenile) year of life, and maximum survival to the third year of life.

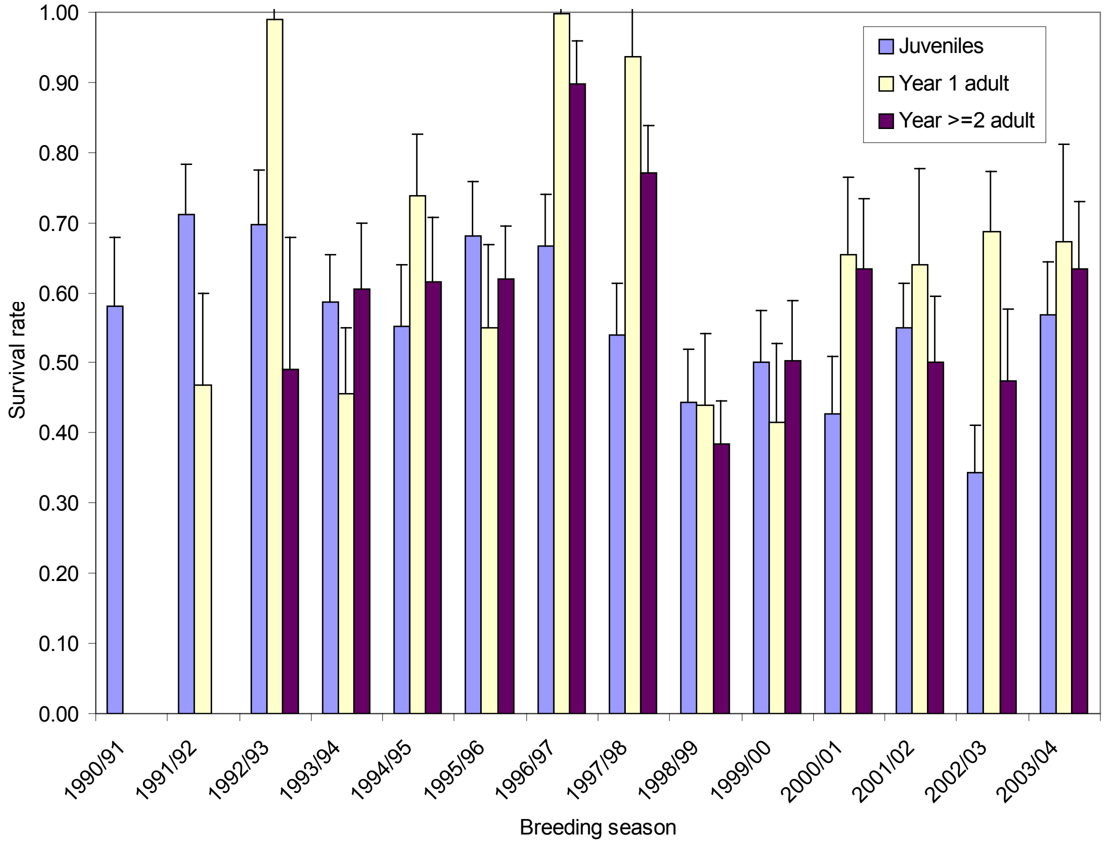

Figure 3.4. Mean annual survival of Orange-bellied Parrots by three age classes derived from Model 28 (Table A15, Appendix 9) . Error bars are + s.e for each category.

Lifespan

A comparison of mean and median lifespan and longevity of Orange-bellied Parrots observed during this study was limited to the period 1991/92—1999/00 because at the time of writing significant numbers of individuals were still alive in each cohort post this period. Mean lifespan for 693 individuals were assessed for the 1987/88—2003/04. For all individuals (sexed and unsexed combined), the mean lifespan was 2.22 years (± 0.074 s.e, range = 0.37–11.70). The mean lifespan of known sex birds was 2.71 years (± 0.097 s.e, range = 0.18–11.70, *n* = 429). There was no difference between the mean lifespan of male and female Orange-bellied Parrots. Males lived on average for 2.75 years (± 0.127 s.e, range = 0.43–11.70, *n* = 240) and females lived on average for 2.67 years (± 0.141 s.e , range = 0.18–10.41, *n* = 189). The median lifespan ranged from a high of 3.16 years in the 1991/92 cohort to a low of 1.13 years in the 1997/98 cohort (Table 3.2). The longevity ranged from 4.47 years in the 1994/95 cohort to 11.70 years in the 1990/91 cohort (Table 3.2).

Table 3.2. Mean, median and maximum lifespan of 10 Orange-bellied Parrot cohorts at Melaleuca between 1990/91 and 1999/00.

Cohort	Number of colour banded fledglings	Mean lifespan (years)	Median lifespan (years)	Longevity (years)
1990/91	32	3.26	1.86	11.70
1991/92	44	3.86	3.16	7.40
1992/93	47	3.12	2.05	7.41
1993/94	59	2.82	1.92	7.36
1994/95	37	2.34	2.09	4.47
1995/96	37*	4.01	3.10	9.37
1996/97	46	2.47	2.11	6.67
1997/98	55	1.57	1.13	4.44
1998/99	52	1.58	1.21	6.29
1999/00	53	1.81	2.08	5.53

* The 1995/96 cohort was the only year that still has one individual alive at the time of writing.

The oldest male recorded was 11.70 years of age at last sighting (28/08/2002 at Swan Island, Victoria). The oldest female recorded was 10.41 years of age at last sighting (29/01/2000 at Melaleuca). This bird was banded as an unknown aged adult (presumed to be one year old) in March 1991 but may have been older than assumed. Only one female observed at Melaleuca on 5/01/2005 that was 9.37 years of age could possibly live longer. The longevity of wild Orange-bellied Parrots is less than that recorded for the current captive population. The oldest captive male and female were

12.7 and 11.7 years of age respectively—both of which were still alive as of 1st October 2005 (J. Hockley pers. comm). However, these individuals are no longer reproductively successful. The oldest reproductively successful captive male and female was 10.9 and 11 years respectively (J. Hockley pers. comm). This compares with an 8.9 year-old male and a 9.0 year-old female confirmed breeding in the wild population.

Sex ratios

A comparison between the sex observed at the time of banding with confirmed sex through either molecular DNA analysis or sex-specific behaviours observed in subsequent years, reveals that sexing at banding is reasonably accurate. Of 802 Orange-bellied Parrots banded as juveniles since 1987/88, 324 were assumed to be male, 269 female and 209 were not sexed. Thirty males were incorrectly sexed as females and 31 females incorrectly sexed as males. The combined sexing accuracy was 92% (741/802). Identification of males was 91% (321/351) accurate and females 89% (240/271) accurate.

A total of 675 individuals were sexed either by molecular DNA analysis or sex-specific behaviours. Of these, 56% (n = 378) were males and 44% (n = 297) were females. The sex of 127 individuals remains unknown. The ratio of males to females measured over the study was 1:0.79 (range =1:0.34—1:1.58). The numbers of each sex confirmed in each cohort are shown in Figure 3.5.

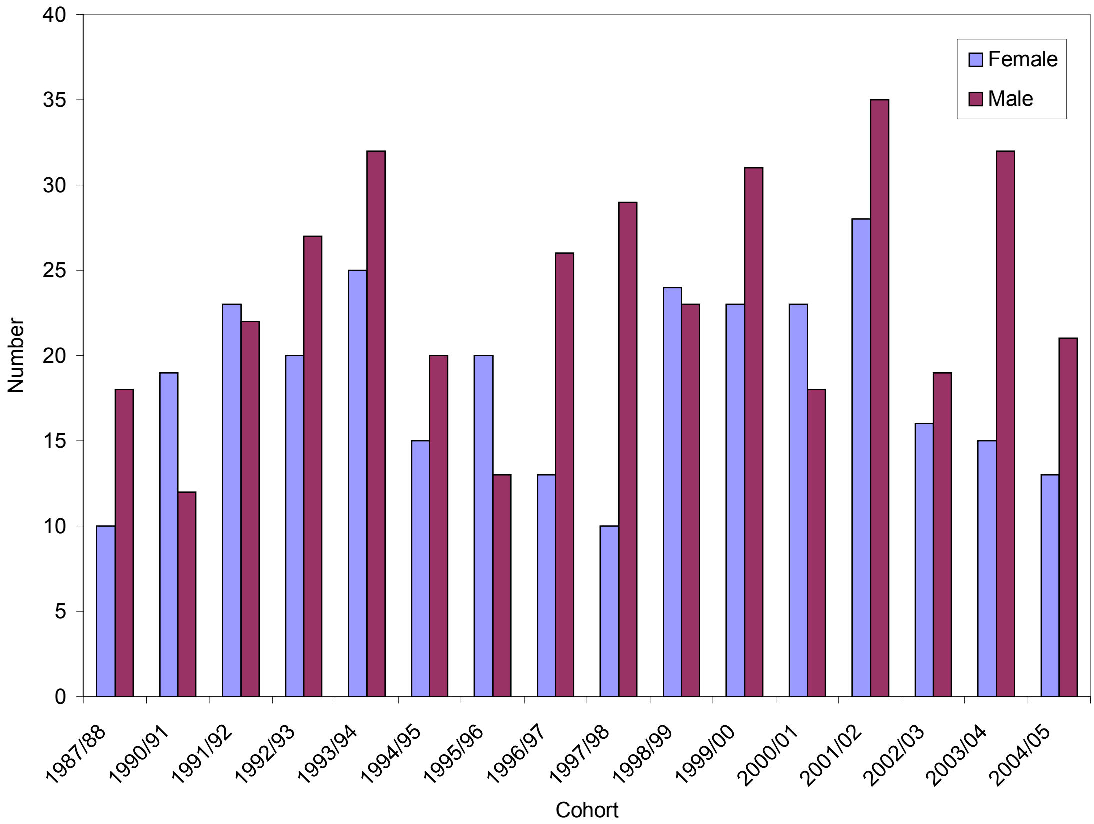

Figure 3.5. The number confirmed sex, based on molecular DNA analysis and plumage characteristics of nestling and juvenile Orange-bellied Parrots banded at Melaleuca in 16 cohorts for the period 1987/88–2004/05 (N = 675, male n = 378, female n = 297). Error bars are ± 7.8% for males and ± 6.6% for females.

The ratios of males to females deviated from expected values (1:1) for all years. Chi-square tests were used to determine whether the observed deviations from unity were significant for each season (Table 3.3). Three cohorts (1996/97, 1997/98 and 2003/04) showed a significant deviation from parity with a bias to males ($X^2_1 = 2.17$, P = 0.037; $X^2_1 = 4.63$, P = 0.002; $X^2_1 = 3.07$, P = 0.013 respectively). However, there was no significant difference between sexes when all cohorts were combined across the study period ($X^2_{15} = 23.07$, P = 0.083).

Table 3.3. Chi-square test for male and female Orange-bellied Parrots confirmed in each of 16 cohorts banded at Melaleuca.

Cohort	Female	Male	Chi-square	P
1987/88	10	18	$X^2_1 = 1.14$	0.131
1990/91	19	12	$X^2_1 = 0.79$	0.209
1991/92	23	22	$X^2_1 = 0.01$	0.881
1992/93	20	27	$X^2_1 = 0.52$	0.307
1993/94	25	32	$X^2_1 = 0.43$	0.354
1994/95	15	20	$X^2_1 = 0.36$	0.398
1995/96	20	13	$X^2_1 = 0.74$	0.223
1996/97	13	26	$X^2_1 = 2.17$	0.037
1997/98	10	29	$X^2_1 = 4.63$	0.002
1998/99	24	23	$X^2_1 = 0.01$	0.884
1999/00	23	31	$X^2_1 = 0.59$	0.276
2000/01	23	18	$X^2_1 = 0.30$	0.435
2001/02	28	35	$X^2_1 = 0.39$	0.378
2002/03	16	19	$X^2_1 = 0.13$	0.612
2003/04	15	32	$X^2_1 = 3.07$	0.013
2004/05	13	21	$X^2_1 = 0.94$	0.170

Mate and site fidelity

Of 165 nests observed at Melaleuca between 1992/93 and 2004/05, 129 parents were banded (72 males and 57 females), 107 (48 males and 59 females) were unbanded and 94 (45 males and 49 females) were of unknown band status. The band status of both parents at 105 nests (63.6% of all nests) was confirmed. Twenty-nine (17.8%) had both parents banded, 24 (14.5%) had both parents unbanded, 20 (12.1%) had a banded female and an unbanded male and 32 (19.4%) had an unbanded female and a banded male. A total of 60 nests (36.4%) had one or both parents with unknown band status. Thirty-four (20.6%) had both parents as unknown identity, 8 (4.8%) had a banded female and an unknown male, 11 (6.7%) had an unknown female and a banded male, 3 (1.8%) had an unbanded female and an unknown male and 4 (2.4%) had an unknown female and an unbanded male.

Of 43 males whose identity was confirmed from 63 nesting attempts, 13 (30.2%) were confirmed to breed in two or more seasons (range = 2—4). However, of these only one male was observed to use the same nest more than once (230-17197 in 'Hut 5' in 2002/03 and 2003/04). When all nests are combined for the Melaleuca and Pandora zones (see Figures 2.2 and 2.3, Chapter 2), seven males used nests in the same zone and six males used nests in both zones. The results for females were similar to those observed for males. Of 42 females whose identity was confirmed from 50 nesting attempts, seven (16.6%) were observed to nest more than twice (range = 2—3). Only one female was observed to reuse the same nest more than once (230-15743 in a natural nest at Celery Top Islands in 2002/03 and 2003/04). When all nests are combined for the Melaleuca and Pandora zones, four females used nests in the same zone and three females used nests in both zones.

Fecundity

The mean fecundity rate calculated from females in each of 12 breeding seasons between 1993/94 and 2004/05 was 1.62 (± 0.13 s.e) female fledglings per female. This ranged from a low of 0.87 in 1998/99 to a high of 2.34 in 2001/02 (Table 3.4).

Table 3.4. Fecundity of female Orange-bellied Parrots at Melaleuca for 12 breeding seasons between 1993/94 and 2004/05. The numbers of female fledglings produced by each productive female is used as the measure of fecundity.

Breeding season	Females producing fledglings	Number fledged	Proportion of females in population	Estimated female fledglings	Estimated fecundity
1993/94	8	32	0.43	13.6	1.70
1994/95	11	37	0.44	16.2	1.48
1995/96	10	39	0.43	16.7	1.67
1996/97	10	37	0.61	22.4	2.24
1997/98	16	58	0.33	19.3	1.21
1998/99	17	58	0.26	14.9	0.87
1999/00	14	54	0.51	27.6	1.97
2000/01	12	41	0.43	17.5	1.46
2001/02	17	71	0.56	39.8	2.34
2002/03	15	57	0.44	25.3	1.69
2003/04	17	63	0.46	28.8	1.69
2004/05	16	55	0.32	17.6	1.10
Total	163	602		248.7	

Migration

First arrivals and last departures

The dates of first arrival and last departure of Orange-bellied Parrots recorded for 34 breeding seasons since 1959/60 at Melaleuca are shown in Table A16 (Appendix 10). The mean date of first arrival for all years was the 7th October (± 6.8 days s.d). The mean arrival date since 1991/92 (14 breeding seasons), when coordinated observations were commenced, was the 2nd October (± 5.1 days s.d). In comparison, the mean date of arrival recorded for 20 breeding seasons between 1959/60 and 1982/83 (principally by C.D. King) was the 10th October (± 6.0 days s.d). It is likely the earlier arrival recorded during the coordinated observation period when compared to the incidental records is due to birds being attracted to the feed tables, and therefore more likely to be observed.

The mean date of last departure for the 14 breeding seasons between 1991/92 and 2004/05 was 5th April (± 11.1 days s.d). The higher degree of variability of departure of the last birds compared with arrival is probably influenced by the fact that these are juvenile (inexperienced) birds.

Arrival of banded birds

The first observation of 699 banded, known age Orange-bellied Parrots visiting the Melaleuca feed tables was recorded for the period 1991—2004. The results of these observations clearly show those individuals in their second year of life or older return 13 days before the first, first-year birds arrive (Figure 3.6). The median arrival date for birds in their second year or older was the 23rd October compared to 9th November for first-year birds. Older birds begin to arrive late in September and increase to a peak arrival in the five-day period between (14—18 Oct). Conversely, the first first-year birds to be sighted were on the 11th October, and the peak arrival is during the period 29 Oct — 2 Nov.

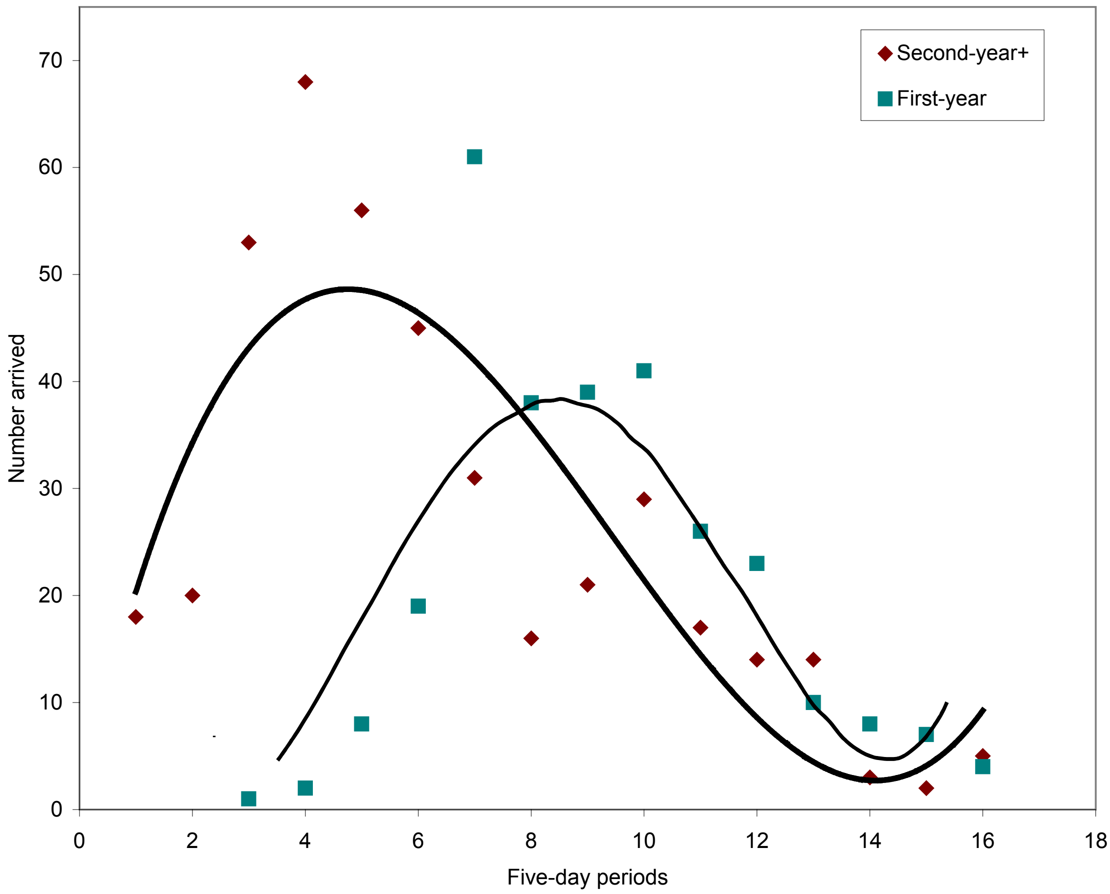

Figure 3.6. Frequency of arrival of first-year and second-year+ Orange-bellied Parrots at Melaleuca. Arrival dates are categorised into 5-day intervals from 29th September to 16th December for all breeding seasons for the period 1991—2004. Least square polynomial trendlines are fitted.

The frequency of arrival of second-year+ declined from the fourth, five-day period until the eighth, five-day period (3—7 Nov), with 74.5% (307/412) being observed at this point. There was a slight increase in arrivals during the ninth and tenth, five-day periods (8—17 Nov). Most birds (97.5%, 402/412) had been observed by the thirteen, 5-day period (28 Nov — 2 Dec).

For 694 observations of first arrival of banded Orange-bellied Parrots at Melaleuca (irrespective of age), 406 were male and 288 were female. Both sexes were observed during the first, five-day period (19 Sept — 3 Oct) (Figure 3.7). Male arrival peaked during the fourth, seventh and tenth five-day period (14—18 Oct, 29 Oct — 2 Nov and 13—17 Nov respectively), with 82.2% (334/406) returning by that date. Females showed less dramatic fluctuations in sightings with a gradual decline from a peak in the seventh, five-day period (52.1%, 150/288 of arrivals).

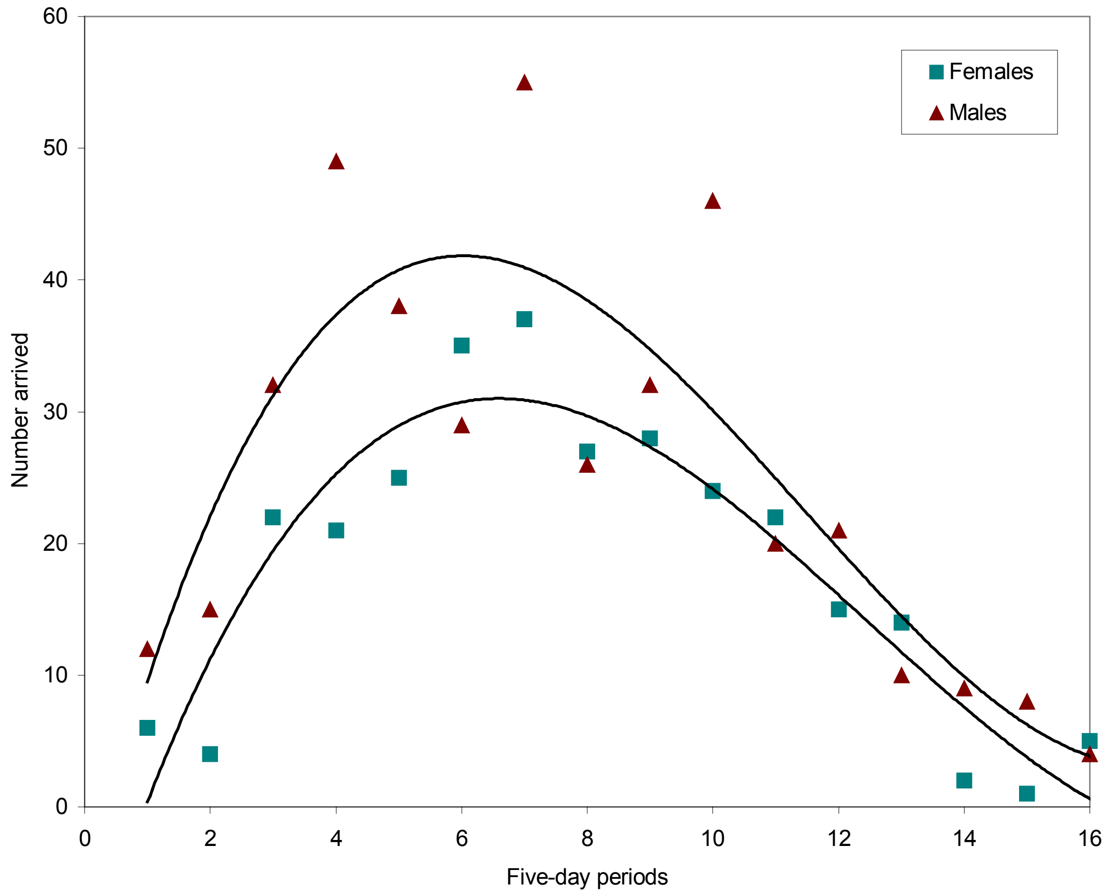

Figure 3.7. Frequency of arrival of male and female Orange-bellied Parrots at Melaleuca. Arrival dates are categorised into 5-day intervals from 29th September to 16th December for all breeding seasons for the period 1991—2004. Least square polynomial trendlines are fitted.

DISCUSSION

Banding and observation

The use of colour-bands to study the Orange-bellied Parrot demography has not been attempted to such a level for any other species of parrot in Australia. From its inception, in 1990/91, the observation of banded Orange-bellied Parrots relied heavily on the assistance of volunteers. A total of 1895 days of effort was contributed by volunteers to observe birds visiting the feed tables at Melaleuca. The financial value of this effort is significant, equating to $A303,200 (@ $A160/day, not including expenses) of in-kind support. While this contribution is significant, the use of volunteers to undertake observations caused some problems during the study. The quality of observations varied between different observers and some records were discarded because they were deemed to be unreliable. The cause of these inaccuracies mostly related to interpretation of colours, particular the Darvic® bi-coloured bands. Wherever possible, colour-band information recorded by volunteers was checked with results obtained by Peter and Barbara Wilson who provided a constant standard with which to compare. In addition, volunteers who had previously assisted with observations were favoured over new volunteers, as their experience would reduce the degree of errors. Nevertheless, the survival estimates and other demographic parameters reported here may still contain some biases through observer error. Further analysis of the data is required to determine the level of any such errors by comparing estimates derived from observations by 'reliable observers' with those from the wider data. Such an exercise will further improve the accuracy of these estimates.

While the use of colour bands to study the Orange-bellied Parrot resulted in a low level of leg injury, this was four times higher than the occurrence of leg injuries observed in the unbanded population. The overall impact of banding and consequential injury on the population is unknown. There are few detailed accounts of band induced leg injuries and no agreed acceptable level of injury (Berggren and Low 2004). Nonetheless, any human induced injury to a species as rare as the Orange-bellied Parrot should be treated as significant. These results show the stainless steel ABBBS bands were less likely to cause injury than either plastic or aluminium bands. Further work is required to determine the cause of this difference and, if possible, develop new bands to minimise the amount of leg injury. The colour-banding program and supplementary feeding will be reviewed annually (Orange-bellied Parrot Recovery Team 2006). It is recommended that if an increase in leg injuries, or negative affects from supplementary feeding, is detected then these should be discontinued to avoid further impact on the population.

Survivorship and longevity

This study provides various results on the demographic parameters of 760 individually banded birds, including detailed capture histories of 740 individuals based on at least 27324 observations. There are no published data with which to compare the results of these observations with those from other species of *Neophema.* The banding details presented by Higgins (1999) and records from the Australian Bird and Bat Banding Scheme (D. Drynan pers. comm.) show no other species of *Neophema* has had comparable banding and observation (recapture) effort to establish any of the demographic parameters presented here. The banding and recoveries for closely related species are Budgerigar *Melopsitticus undulatus* 374/1, Bourke's Parrot *Neopsephotus bourkii* 25/2, Elegant Parrot *Neophema elegans* 163/3, Turquoise Parrot *N. pulchella* 213/6 and Ground Parrot *Pezoporus wallicus* 215/50 (D. Drynan pers. comm). Only the Ground Parrot recoveries provide a reasonable sample to determine a mean lifespan of 1.11 years and longevity of 6.13 years. Furthermore, there are no other studies of similar sized, granivorous psittacids elsewhere with which to compare these results. The only other studies that have sufficient data to determine survivorship have been from the large flightless species Kakapo *Strigops habroptilus.*

However, the Kakapo is a large (1.6—4.0 kg, Powlesland *et al.*), flightless parrot known to be long-lived to at least 30 years and possibly as old as 100 years (Clout 2006). This, combined with infrequent (K-selected) breeding makes a comparison with the Orange-bellied Parrot difficult.

Mean annual survivorship of adult male and female Orange-bellied Parrots were similar (66% ± 5.2 s.e male, 63% ± 5.8 s.e female). This result is not surprising as there is no difference in morphology between the sexes (Higgins 1999) and both are thought to contribute equally to reproduction and care of offspring. Furthermore there appears to be no difference in the utilisation of food resources, with males and females being recorded feeding together throughout the species' range.

The survival of fledglings through the first year of life (juvenile) to adulthood showed the expected pattern where survival of early life stages are typically lower than later life stages (Krebs 1978). The mean survival of juveniles was 56% (± 3.1 s.e) and is lower than adults (*i.e.* those that attain one year or older). However, mean adult survival did not show a robustness expected of mature birds. This suggests the primary causes of mortality within the non-breeding range have a similar effect on the species regardless of age. The marginally higher survival of adults is likely to be attributable to familiarity with feeding resources and predator behaviour within the migratory and winter range. Overall the survival rate of the Orange-bellied Parrot is consistent with a Type II survival where there is a constant probability of death which is not uncommon in other small species of birds (Deevey 1947).

It is therefore suggested most mortality of juveniles occurs at the beginning of the northern migration, when individuals are inexperienced compared to those that survive to the southern (spring) migration. Further effort is required to identify colour-banded individuals within the migratory and winter range to build a clearer picture of the survivorship of individuals over this period.

The trend of decline in mean annual survival of the Orange-bellied Parrots at Melaleuca in recent years is of concern. However, applying these estimates with the fecundity values reported here in a simple density-independent life table model, all deterministic simulations examined produced populations exhibiting positive population growth (B. Baker unpublished data) and therefore, neither survival nor fecundity appears to be currently inhibiting population growth. This conclusion is surprising, but these estimates match or exceed those used by Drechsler *et al.* (1998) in their Population Viability Analysis (PVA) for the species. At the time of preparing the Drechsler PVA, there was greater uncertainty surrounding estimation of parameters, which further supports the results obtained here. A possible cause of the positive population growth observed in the deterministic simulations is the influence of sex ratio and/or numbers of females attempting to breed. The models run thus far show greatest sensitivity to these two variables. It is therefore important that molecular DNA sexing is completed for each year and that more effort is made to determine the numbers of females attempting to breed.

The scope of the survival analysis and sex ratios was constrained because analysis of molecular DNA to determine sex of all nestlings banded since 2000 was not available to the author at the time of writing. Furthermore, a variety of problems encountered in the La Trobe University laboratory resulted in inaccurate records. This included missing blood/DNA samples, incorrect/illegible accession numbers and inadequate extraction of DNA from blood samples (Hristova 2001). At the time of writing, all samples held by La Trobe University have been transferred to the Australian National University for reanalysis and to consolidate the database. Future work on refining survival estimates should therefore concentrate on examining differences in survival of sexes, through the use of data derived from molecular sexing of nestlings.

Some of the assumptions in the Drechsler *et al.* (1998) PVA require further testing. In particular, the assumption all females of breeding age breed every year may not be valid. This is an unusual situation in most vertebrates, and for Orange-bellied Parrots it seems likely some females of breeding age do not breed every year, either through, for example, lack of fitness, incompatible males and/or shortage of suitable nesting sites. There is a need to also test for the effect of the hatching order of chicks on survival. This is relevant to the selection of chicks for future founder work in the captive-breeding program.

Parrots are generally assumed to live for long periods with some authors reporting longevity of mythical proportions (Brouwer *et al.* 2000). However, this is usually based on anecdotal evidence from aviculturists and biased toward captive-bred birds and larger species, which generally tend to have a longer life expectancy. There are no studies of similar sized, granivorous parrots in the wild with which to compare the mean lifespan and longevity of this species. In the wild the mean lifespan of known sex Orange-bellied Parrot was 2.71 years and the maximum reproductive lifespan was 10 years of age. The longevity of wild birds was similar to captive-bred birds. Long-term studies of reproductive performance in bird populations in the wild indicate that individuals rarely survive beyond reproductive active years (Curio 1989), whereas captive-bred birds will often live well beyond reproductive active years (Brouwer *et al.* 2000). This is the case with the Orange-bellied Parrot; however, at the time of writing the Healesville Sanctuary databases were not able to differentiate individuals that have bred or not to calculate mean reproductive lifespan of the captive population (J. Hockley pers. comm.). It is important that these data be analysed further so a comparison can be made with the wild population.

Extreme longevity in parrots is reported to have evolved through species-specific diet, habitat and behaviours that influence extrinsic mortality (Munshi-South 2006). In particular, granivorous communal roosting species that are confined to islands were shown to live significantly longer than frugivorous, solitary species on mainland situations. According to these findings the Orange-bellied Parrot (a granivorous, communal roosting, island species) should be long lived. However, the results of this study do not reflect this hypothesis. The possible cause of this lower longevity than that predicted may be due to the species' obligatory migratory behaviour, effectively making it a mainland species. This, combined with reduced population size and therefore fragmentation of communal roosting opportunities acts to increase extrinsic mortality such as predation, reduced capacity to locate scarce/dispersed food resources in the wintering area and associated reduced immune system fitness to fight diseases. It has been presumed that winter habitat resources is limiting (Orange-bellied Parrot Recovery Team 2006); however, the influence of a migratory behaviour leading to reduced flocks may have a stronger influence than previously thought. A possible solution to this problem is to use captive-bred birds to bolster flock numbers at key winter range sites at critical periods. While further work is required to determine the efficacy of this proposal, the successful release of captive-bred birds at Point Wilson in 2004 (R. Loyn pers. comm.) provides some confidence in its potential.

Sex ratio

This study has shown the confirmed sex ratio in the population has had a slight but not significant bias to males across all years. There was a decrease in the number of females in 1996/97 (X^2_1 = 2.17, P = 0.037), 1997/98 (X^2_1 = 4.63, P = 0.002) and 2003/04 (X^2_1 = 3.07, P = 0.013). The significant decrease in females in 1997/98 may be an aberration because in that cohort the sex of 16 individuals remains unknown. Further analysis of molecular DNA to determine sex (see above) will resolve this issue.

Mate and site fidelity

The results suggest the Orange-bellied Parrot does not have a strong fidelity to mates, nest site or nesting zone, and this is contrary to previous assumptions by other authors (*e.g.* Brown and Wilson 1981, Higgins 1999). The species is presumed to be monogamous (Brown and Wilson 1980) and thus the number of males or females in the population further limits the breeding capacity, whichever is smaller (Drechsler *et al.* 1998). In the case of the Orange-bellied Parrot, this appears to be the female in most years. Observations conducted during this study show an undetermined level of polygamy in the wild population and therefore males may be maximising the genetic input. If this is the case, then genetic drift will be minimised. Further analysis of genetic material is required to determine the level of polygamy over time.

Fecundity

The estimated mean fecundity of 1.62, calculated as the number of females produced by each egg laying female per year was sufficient in all but one year (1998/99) to replace the population. This finding is consistent with the views expressed by Drechsler *et al.* (1998) and Menkhorst *et al.* (1990) that reproduction is less important than survival of individuals (post-fledging). Not withstanding this, the capacity to measure the fecundity (and other reproductive success parameters see Chapter 2) serve as critical indicators as to the reproductive health of the population. Measurement of other productivity parameters (*i.e.* net reproductive rate, net recruitment rate, mean reproductive lifespan and mean generation length) was not possible during this study because all of these parameters rely on tracking individual female and daughter reproduction over time (Krebs 1978). The collection of such data will greatly improve the understanding of the demographic dynamics of the population. The ability to collect data with which to measure these parameters will require refocussing of observer effort and a higher level of skill/training of staff and volunteers.

Migration

This study has shown the arrival of the first Orange-bellied Parrots at the breeding area usually occurs in late September to early October and this has been consistent since records began in 1959. In addition to this trend, there is also a significant earlier arrival of second year or older birds compared to those in their first year. This result suggests competition for nest sites could be important with older (experienced) birds returning more rapidly to the breeding area to secure nest sites. Conversely, birds in their first year of life do not appear to be under the same pressure to return, possibly due to their lack of breeding experience or delay in reaching sexual maturity. The earlier return of older birds may also indicate a high level of competition for high quality nest sites. If this is the case then natural nest sites may in fact be a limiting factor on the population. Further work is required to determine the quantity, quality and availability of natural nest hollows in the region.