Swift Parrot *Ex Situ* Program Design Workshop

ZOOS VICTORIA Fighting Extinction

birdlife AUSTRALIA

IUCN SSC Species Survival Commission

CONSERVATION PLANNING SPECIALIST GROUP

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Content

Acronyms and abbreviations

ANU	AUSTRALIAN NATIONAL UNIVERSITY
BFD	BEAK AND FEATHER DISEASE
CPSG	CONSERVATION PLANNING SPECIALIST GROUP
CR	CRITICALLY ENDANGERED
DCCEEW	DEPARTMENT OF CLIMATE CHANGE, ENERGY, THE ENVIRONMENT AND WATER
DEECA	DEPARTMENT OF ENERGY, ENVIRONMENT AND CLIMATE ACTION (VIC)
DRA	DISEASE RISK ANALYSIS
EAZA	EUROPEAN ASSOCIATION OF ZOOS AND AQAURIUMS
GPS	GLOBAL POSITIONING SYSTEM
IUCN	INTERNATIONAL UNION FOR CONSERVATION OF NATURE
K	CARRYING CAPACITY
NE	GENETICALLY EFFECTIVE POPULATION SIZE
NSW	NEW SOUTH WALES
NZ	NEW ZEALAND
OBP	ORANGE-BELLIED PARROTS
OPA	ONE PLAN APPROACH
PMx	SOFTWARE PACKAGE FOR DEMOGRAPHIC AND GENETIC ANALYSIS
PVA	POPULATION VIABILITY ANALYSIS
RT	RECOVERY TEAM
SA	SOUTH AUSTRALIA
SMP	SPECIES MANAGEMENT PROGRAM
SNA	SPECIFIC NEEDS ASSESSMENT
SP	SWIFT PARROT
SPIBA	SWIFT PARROT IMPORTANT BREEDING AREAS
TO	TRADITIONAL OWNER
ZAA	ZOO AND AQUARIUM ASSOCIATION

Executive summary

Note: *This document aims to report on what was discussed and agreed by those who attended a three-day workshop in November 2024. It does not attempt to reflect wider views on this subject.*

Background

Swift Parrots (*Lathamus discolor*) are in accelerating decline due to habitat loss, particularly ongoing forest loss in the breeding range, nest predation by introduced gliders (*Petaurus breviceps*), and urban expansion. They are categorised as Critically Endangered by the IUCN (IUCN 2018) with recent population models predicting fewer than 100 birds surviving in the wild by 2031 (Heinsohn et al. 2015; Owens et al. 2023)[1][2].

Workshop context

In March 2022 the Swift Parrot Recovery Team endorsed the pursuit of an IUCN workshop process to evaluate the need for and scope of a conservation breeding program for the Swift Parrot. An analysis commissioned by Zoos Victoria and Birdlife Australia to assist the Swift Parrot National Recovery Team (see Recovery Plan Action 4.6 (DCCEEW 2024)) concluded that an *ex situ* breed for release program could improve the species' chances of persistence in the wild (Pritchard & Ferraro 2023). An *ex situ* population of Swift Parrots exists in ZAA institutions but has not been managed to support conservation efforts and as a result is not currently fit for this purpose. To create a design and preliminary plan for an *ex situ* program capable of supporting species recovery in this

Recommended first priorities in the event of a decision to proceed with an *ex situ* program:

1. Re-energise the Recovery Team: re-instate representation from key State and Federal agencies; create captive & translocation sub-groups.
2. Test tracker equipment *ex situ* on existing captive swift parrots.
3. Develop detailed plans and translocation proposals for:
    a. Short term tracker and release trials using select birds from the existing captive population to trial and refine release and monitoring methods; (Strategy 1)
    b. Establish a new long-term insurance and release population including acquisition of wild-caught founders. (Strategy 2)
4. Engage potential "first wave" institutions, raise resources and secure facilities for a long-term insurance and release population.
5. Audit the genetic quality of captive birds within and outside the ZAA population to identify and acquire potential "founders".
6. Establish health management protocols and release criteria.
7. Investigate causes of high early mortality in current captive swift parrots to inform facility design.
8. Refine estimates of maximum *ex situ* population growth rate to inform population size and release targets.
9. Align communications across *ex situ* and *in situ* program components clarifying that the role of the *ex situ* population is to support recovery in the wild, and that stronger action on threats *in situ* is required.

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[1] Note: at the time of the workshop there was no accurate census size estimate from field data. Olah (2024) estimated census population size of N=500 based on genetic data but see below.

[2] Post-workshop note: a rare opportunity to census the wild population in the field emerged in May 2025 after a mass roost event occurring over a number of weeks (peaking at 668 birds) was detected in Central Victoria. Assessment of numbers counted at the roost, in combination with discrete counts of birds detected elsewhere on the mainland during this time, has a minimum estimate of ~751 birds accounted for (Meney, unpublished data). Gauging age composition of the mass roost was not possible, and this estimate does not attempt to accommodate for individuals that went undetected during this period.

way, a workshop was held during November 6-8th 2024. All representatives on the Swift Parrot Recovery Team as at May 2024 were invited to participate in this workshop, in addition to a range of experts in *ex situ* management and husbandry, threatened species management and Swift parrot ecology. The workshop was attended by 23 stakeholders, including members of the Swift Parrot Recovery Team, representatives from more than 13 organisations, including zoos, research institutions, environmental NGOs, and State and Federal Governments. The workshop was hosted by Zoos Victoria and facilitated by the IUCN SSC Conservation Planning Specialist Group (CPSG).

Workshop process

In line with the IUCN's One Plan Approach (OPA), which promotes close integration of the conservation contributions of *in situ* and *ex situ* populations and sectors, the workshop used a multi-stakeholder participatory planning process based on CPSG's *Ex Situ* Conservation Assessment, which typically has five steps:

1) Review the threats and status of the wild population;
2) Define potential *ex situ* conservation role(s) in conserving or recovering the species;
3) Determine the characteristics of an *ex situ* program that would fulfil these potential conservation roles, and any *in situ* conditions required to support its success;
4) Determine the resources needed, risks, and feasibility;
5) Make a decision regarding whether an *ex situ* activity should be established and for what purpose.

Number 5) was out of scope for this workshop, which was not mandated to make a decision about whether or not an *ex situ* population would be integrated into the Recovery Program, only to inform that decision. It was agreed that costing the draft plans developed would be done as a separate exercise by a smaller team.

The workshop began with a series of presentations on the status and threats to wild Swift Parrots, the progress of conservation activities and research to date, the status of the current *ex situ* population, and the results of recent genetic analyses of wild and captive birds. A recap of the recent Specific Needs Assessment (Pritchard & Ferraro 2023) was also provided. The latter had discussed a breed for release role for an *ex situ* population of Swift Parrots and this was used as a starting point for discussions.

Informed by these presentations and a brief discussion of priority issues and challenges for any *ex situ* initiative for the species, participants collaborated on an aspirational description (vision) of a successful *ex situ* program (see page 16). This vision covers not only husbandry, demographic and genetic management but also the governance, communications and partnerships dimensions of a successful program, as well as potential contributions to *in situ* efforts beyond breed for release.

Equipped with a draft of this vision, participants formed three working groups to explore the practical implications of realising the vision and to agree *ex situ* roles, goals and strategies for moving towards it:

Working group 1. *In situ* factors: focussing on the *in situ* application of captive-bred birds to the wild population, the practical aspects of managing capture, release and post-release monitoring, and identifying the goals and the observational and behavioural markers of success post-release during the trial phase.

Working group 2. *Ex situ* factors: focussing on the care and management of *ex situ* birds, including: facility design; husbandry and health; retention of wild behaviours; and practical aspects of maintaining pedigree records and supporting demographic and genetic management recommendations.

Working group 3. Program-wide and integrated management: focussing on: program goals, targets and success indicators; mechanisms for integrated *in situ* and *ex situ* management; and governance.

On the final morning of the workshop, participants formed different working groups to discuss the following emergent or unresolved issues: 1) Founder collection strategy (number, sex-ratio, age-structure, location, timing); 2) Surplus birds (e.g. low priority breeders, those unsuitable for release); 3) *Ex situ* logistics of a wild-founded population (number of institutions, facility type, genetic and demographic management strategies); 4) Exit strategy and triggers; 5) An agreed workshop communiqué.

Throughout the workshop working groups reported back on their findings and absorbed input from other groups. The discrete outputs of the different working groups are synthesised in this report, which provides details of the deliberations that led to the following:

- An aspirational **vision** and six operational **goals** for an *ex situ* program able to support Swift Parrot conservation and recovery;
- Recommended **roles** for a Swift Parrot *ex situ* program;
- Two recommended **strategies** for deploying this program;
- Recommended **next steps** for implementation.

A summary of these is provided below.

Summary of outcomes

To establish an *ex situ* program consistently generating birds fit for release, the lead time is typically several years. It is assumed here that the best chance of success will involve releasing captive birds into the presence of wild flocks. Given estimated rates of decline in the wild it is also assumed the window for achieving that is closing. Therefore, the strategies recommended here are designed to shorten the lead time to releases, to improve overall chances of success.

Recommended goals for a successful *ex situ* program able to support conservation and recovery

Goals should be interpreted as desirable future conditions of the program that will allow it to thrive. Goals, along with associated targets, are used to measure progress. Roles, strategies and targets may shift during the course of the program in response to learning but the goals, and the vision on which they are based should remain relatively constant (see page 16 for more detail).

10-YEAR *EX SITU* PROGRAM GOALS

GOAL 1*:* *In situ* and *ex situ* populations of swift parrots are managed as a well-integrated meta-population.

GOAL 2: Demographic and genetic targets are met.

GOAL 3: Wild behaviours are retained.

GOAL 4: Good meta-population health is maintained.

GOAL 5: The *ex situ* program is growing support for threat mitigation in the wild.

GOAL 6: Science-based and evidence-led decision-making ensures effective and efficient management.

Recommended roles for an *ex situ* population

Roles here describe what we want the *ex situ* program to achieve for species conservation or recovery.

EX SITU **ROLES**

ROLE 1: Generate birds for release to the wild before threats are mitigated:

a. *to test and refine release protocols, monitoring methods and tracker equipment;*
b. *to keep wild flocks large enough to remain detectable for monitoring and information gathering;*
c. *for ongoing genetic rescue of a small wild population in decline;*
d. *to support retention of wild behaviours in captive-bred birds.*

ROLE 2: Provide long-term insurance against extinction (50 years).

ROLE 3: Generate birds for release to the wild after threats are mitigated:

a. *To support and accelerate species recovery in the wild.*

ROLE 4: To promote public support for in situ threat mitigation in specific areas.

Recommended strategies for fulfilling these roles

Participants recommended two complementary strategies which, operating concurrently, could expedite fulfilment of the roles identified.

Strategy 1: (Roles 1a & 4).
Use existing captive birds immediately to:

- Trial tracker equipment *ex situ*.
- Trial release strategies, monitoring methods and tracker equipment *in situ*.
- Optimise these in advance of the release of birds from the newly established population of wild-founded birds (see Strategy 2).
- Wind-down after research goals are met.

ESTIMATED LEAD TIME TO RELEASES: 1-2 YEARS

Strategy 2: (Roles 1b, c, d, 2, 3, 4). Establish a new, long-term *ex situ* population that:

- Provides insurance against extinction for 50 years.
- Is genetically healthy and representative of the wild population:
  - i.e. founded on ≥ 30 wild birds
  - retains 95% wild source gene diversity for 50 years
  - with population mean inbreeding ≤ 0.125)
- Generates behaviourally competent birds for release to the wild over the long-term, as needed.

ESTIMATED LEAD TIME TO RELEASES: 3-5 YEARS

Recommended triggers for winding down an *ex situ* program

Triggers for moving between *ex situ* program phases (founder, maintenance, release, exit) were discussed in detail (see pages 43-45). Triggers for exiting an *ex situ* program could be based either on success or on failure:

1. Success:

- Swift Parrots are downlisted to Vulnerable, or;
- there is a stable and viable[3] population that matches the habitat's carrying capacity.

2. Failure:

A captive program of suitable quality cannot be established because (for example):

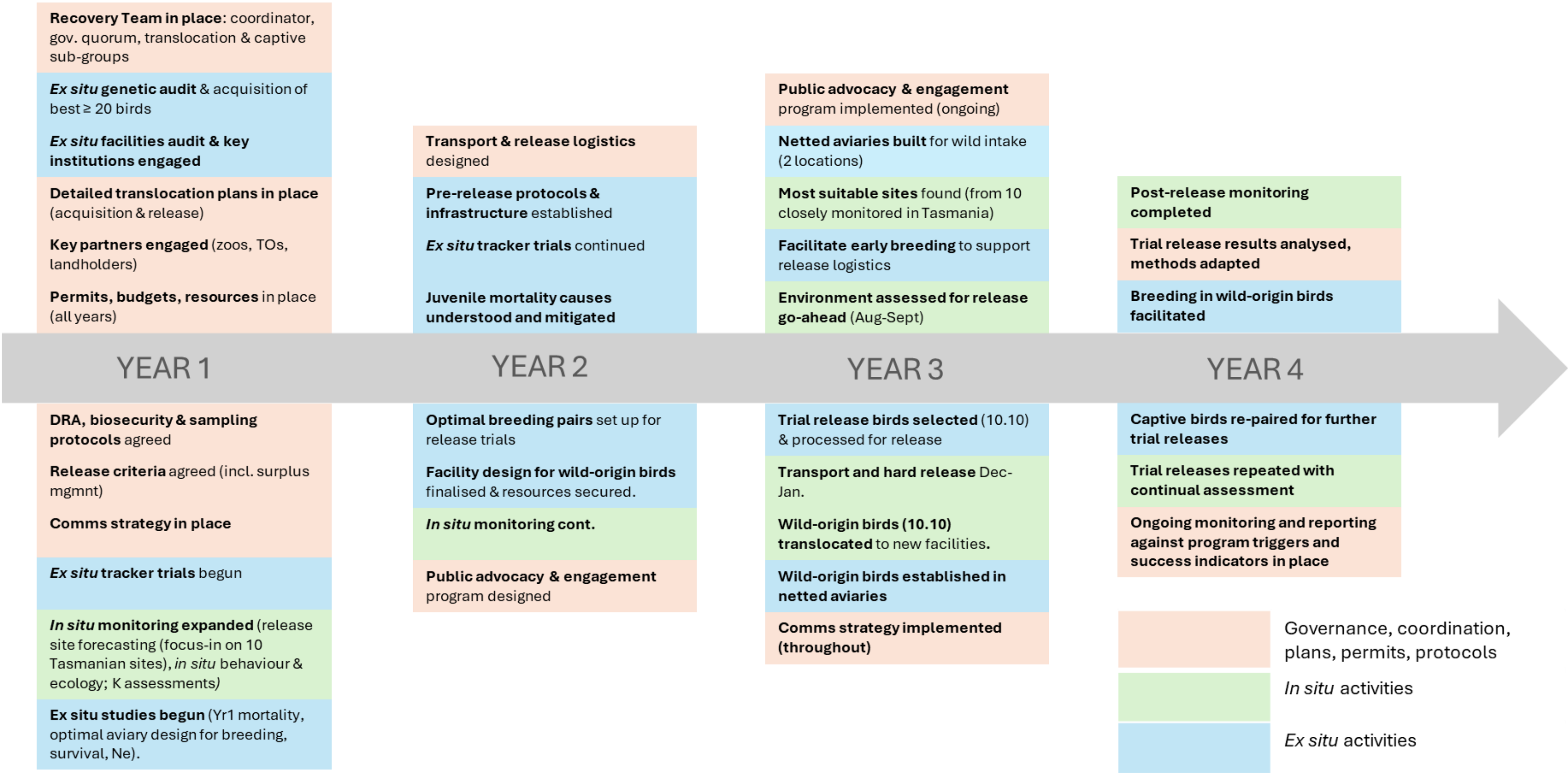
- founders cannot be acquired;
- mortality is irrevocably greater than recruitment.

Implementation and recommended timeline of activities

A draft timeline of recommended activities is shown below. Immediate priorities are highlighted on page 4 above. Individual and institutional responsibilities for the activities recommended are not comprehensively assigned in this document as no formal decision has been taken to proceed. However, the institutions represented at the workshop would be expected to take on much of the work required, assuming the necessary resources can be found.

[3] Suggested definition of viability: population viability analyses show zero extinction risk over 100 years.

Figure 1. Preliminary timeline for a dual strategy of immediate trial releases (using birds generated from the current ZAA *ex situ* population) and concurrent establishment of a new population built from wild-origin Swift Parrots. Activities beyond the 4 years shown will depend on the outcomes of release trials, the early survival and breeding results for wild-origin birds, and other factors that are currently uncertain.



Introduction

Ex situ breed for release programs: typical phases and common questions

When designing an *ex situ* program it can be helpful to think about it as a sequence of phases, each with its own targets and management needs. One of the principal roles outlined for a Swift Parrot *ex situ* program is breeding birds for release to the wild. Typical phases for this type of program and common questions that arise during their design, are shown in Figure 2.

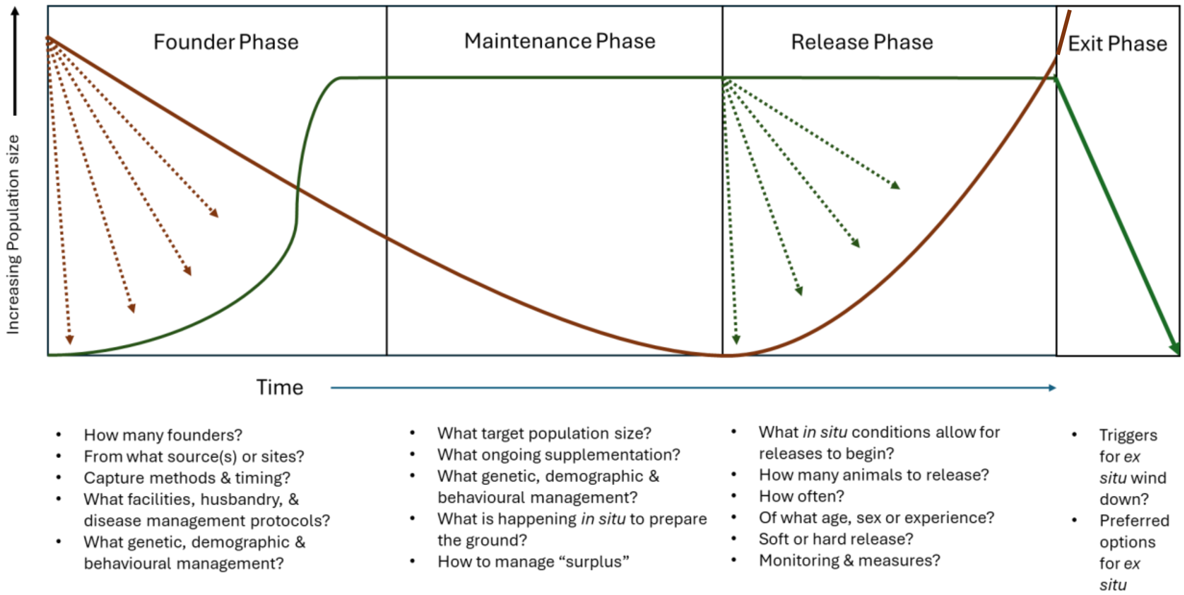


Figure 2: Generic phases of an *ex situ* program with a release component, and the types of questions commonly asked when designing each phase. *In situ* population (orange line); *ex situ population* (green line); translocations from one to the other (dotted lines).

Further details about each phase are given below. With some modifications and excepting the release phase, these descriptions are also relevant to *ex situ* insurance, advocacy and research programs. The following names and definitions are applied throughout this report:

Founder Phase [or Growth Phase]: in which founders are acquired and (ideally) breed prolifically and evenly to the target population size, minimising demographic stochasticity and gene diversity loss.

Maintenance Phase: in which breeding and sometimes mortality rates are managed, to sustain target population size while avoiding excess production, maximising gene diversity retention and other fitness characteristics (e.g. wild behaviours), and minimising the rate of inbreeding accumulation. In some programs, periodic supplementation from the wild may also occur.

Release Phase: in which suitable cohorts of birds are released to appropriate wild areas using agreed protocols for release and monitoring.

Exit Phase: in which the *ex situ* program is wound down and the remaining birds are managed according to the options agreed for the program.

Note: for an insurance program, if conservation action *in situ* is successful (or very unsuccessful), there may be no release phase. Similarly, where a program's main purpose is to provide birds for release and the wild situation is urgent, releases may begin during the founder phase, while the population is still growing.

Every program is different. In addition to the commonly raised questions described in Figure 2. there are likely to be additional species- and context-specific issues that will also require attention. It is useful to identify and address these before the program begins, to help ensure that all important elements are accounted for in the program's design and planning.

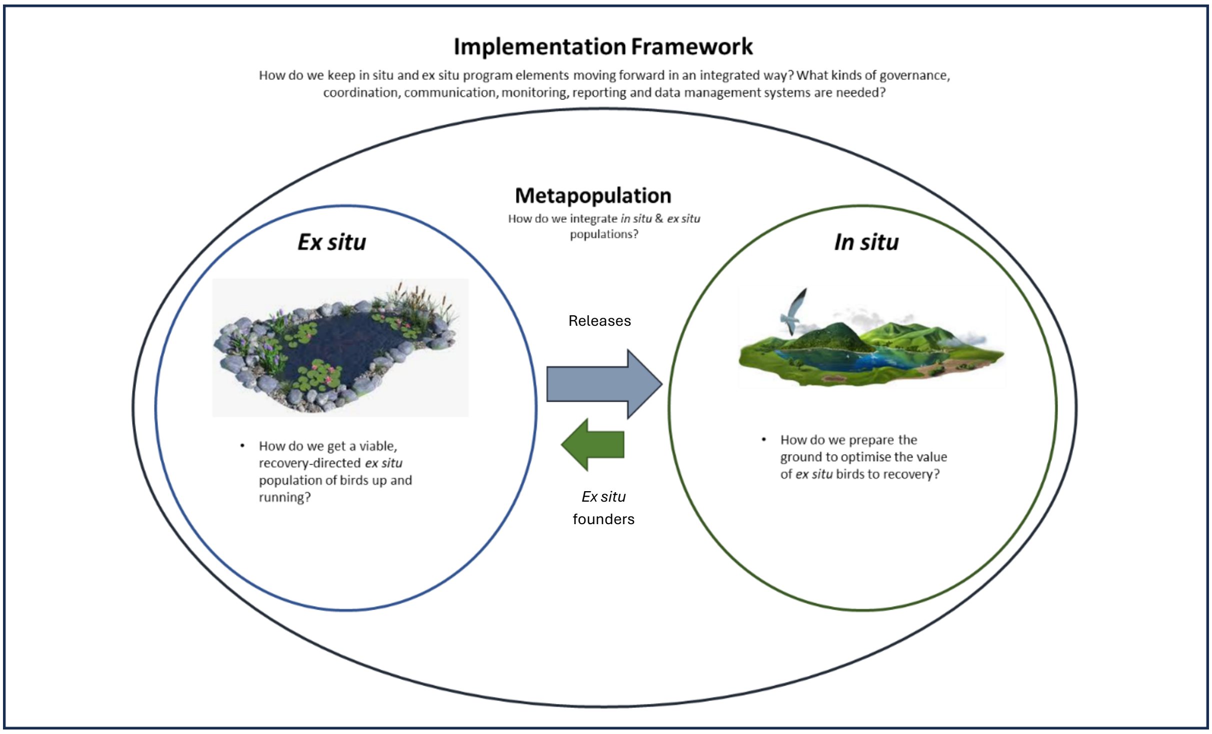
The IUCN One Plan Approach

As shown in Figure 2, in each typical phase of a program there are challenges to be addressed *ex situ* and *in situ*, for the program to proceed smoothly. This benefits from the close integration of *in situ* and *ex situ* efforts so that they remain closely aligned and mutually supportive. To support this, the IUCN advocates a "One Plan Approach" (OPA) to planning the conservation of threatened species, which is defined as:

"Integrated conservation planning for species both inside and outside their natural range and under all conditions of management, with all responsible parties and available resources engaged, to produce a single, comprehensive conservation plan for the species."

The One Plan Approach is about breaking down barriers between disciplines and aligning goals, activities and organisational structures to create more effective multi-disciplinary programs. Among other advantages, this can help bridge the gap between planning for species in the wild and planning for them in captivity, which are often done as independent exercises by non-overlapping groups of people. Swift Parrot conservation in the wild is already the subject of a recovery plan (DCCEEW 2024), which includes an action to assess the need to establish an *ex situ* Swift Parrot population to guard against extinction in the wild and to allow for reintroductions. Although the focus of the workshop was *ex situ* program design, all efforts were made to ensure effective integration of *in situ* and *ex situ* program components, through a combination of the workshop structure and the participation of experts from across this spectrum (see Figure 3).

Figure 3. Typical components and challenges involved in a breed for release program that the One Plan Approach is designed to address.



To support a One Plan Approach, the main working groups during the workshop were aligned with the major components of an integrated program as illustrated in Figure 3: **Working group 1. *In situ* factors; Working group 2. *Ex situ* factors; Working group 3. Program-wide and integrated management.**

Key issues for consideration

In addition to the typical challenges and issues described in Figures 2 & 3, there are species and context-specific issues that need to be factored into program design for Swift Parrots. Those that were front of mind for participants were captured at the start of the workshop to help direct the discussions that followed. Participants were invited to describe issues that they would like to make sure were discussed. The resulting themes were as follows:

- **Ensuring support for threat mitigation in the wild:** how do we ensure that an *ex situ* program would not detract from or dilute the commitment and resourcing for conservation in the wild? How do we avoid a situation in which we are just adding captive-born birds to a wild environment in which threats are not being addressed?
- **Addressing the urgency:** genetic diversity and demographic stability are being eroded rapidly in the wild. How can we account for the potential consequences of delayed intervention?
- **Meta-population management:** how would *in situ* and *ex situ* program elements remain aligned?
- **Success indicators and an exit strategy:** what would success or failure look like in the context of running an *ex situ* program for Swift Parrot recovery? What are sensible indicators of this? What should the triggers be for exiting the program?
- **Maximising learning opportunities:** how could we maximise the opportunities provided by captive birds for improving release and monitoring strategies?

- **Optimising the use of molecular genetics analyses:** can molecular genetics analysis help us understand the conservation value of captive birds currently held in zoos and in private aviculture? What is the ongoing role of molecular genetics analysis?
- **Learning from other programs:** given the expertise of those present, what can we learn from the Regent Honeyeater, Plains-wanderer, Orange-bellied Parrot and other *ex situ* programs with a release component?
- **Health status of birds in captivity and in the wild:** how would we establish this early on in the program? What are the avian influenza implications (i.e. High Pathogenic AI (H5N1 clade 2.3.4.4b).
- **Managing birds that are surplus to the program:** in particular those that do not meet release criteria.
- **Qualities of captive birds:** how do we resolve current unknown pedigree and improve future records? What are the most important wild behaviours and how do we retain them in a captive population? How do we support the welfare of a migratory parrot?
- **Ensuring effective deployment:** how do we navigate known policy, political and other more nuanced barriers to getting the resources needed for effective deployment of an *ex situ* program? How do we ensure good governance and an ability to meet legislative requirements for collection and release of wild birds?
- **Use of population models:** what can we learn from models about how we expect the program to perform against any targets set? How fast can an *ex situ* population grow? How many birds should we be able to release sustainably? What will it take to retain an acceptable amount of gene diversity over the period of the program?

These were folded into working group and plenary sessions.

What could an *ex situ* program do for Swift Parrots?

In order to design an effective *ex situ* program it is important first to be clear about what the role or roles of the population are, that is, what it will do for species' conservation or recovery. This requires an understanding of the main threatening processes for the species, what actions could help address them, how and whether *ex situ* populations and tools can help, and whether the required action can be set in place quickly and effectively enough to conserve or recover the species successfully.

Once roles (if any) are identified, these guide decisions about the number and source of founders, how large the population needs to be, program length, intensity of genetic and demographic management, and in some cases the preferred location of animals.

Due to the focus of the Specific Needs Assessment, the workshop began with an assumption that breed for release would be the main role. Additional roles were recommended during workshop discussions and these are presented below, with associated justification and assumptions.

Recommended roles

The following roles were recommended for an *ex situ* program:

ROLE 1: To generate birds for release to the wild <u>before</u> threats are mitigated:

- *To test and refine release protocols, monitoring methods and tracker equipment;*
- *To keep flocks large enough to remain detectable for monitoring and information gathering;*
- *For ongoing genetic rescue of a small wild population in decline;*
- *To support retention of wild behaviours in captive-bred birds*.

ROLE 2: To provide insurance against extinction.

ROLE 3: To generate birds for release to the wild <u>after</u> threats are mitigated:

- *To support and accelerate species recovery in the wild*.

ROLE 4: To advocate for and promote public support for *in situ* threat mitigation in specific areas.

Justification and assumptions

The following justification and assumptions underpinned the recommended roles:

1) The wild population has experienced significant declines, and these are set to continue. The required commitments and methods for effective threat abatement in the wild are not in place and the timeframe for achieving this is uncertain. Releasing birds into the presence of known threats is not the preferred approach but is thought to be warranted in this case as:
    - Releases from captivity into sites with wild flocks are expected to have a better chance of success as birds can forage, move and migrate alongside wild conspecifics. The window for this is closing as the wild population declines;

- If wild flocks continue to decline at current rates, they may become difficult to detect, which will increase the difficulty of much needed conservation-directed research and monitoring, as well as of released birds mingling and interacting with wild counterparts;
- A well-founded release program at this point could provide ongoing genetic rescue to support resilience in the wild population while it is small.

2) An *ex situ* population founded on wild-origin birds, as well as being the ideal source of birds for longer-term breed for release once threats have been mitigated, can provide a helpful back-stop, suspending extinction for a period and buying time for effective *in situ* action.
3) It is critically important that establishing an *ex situ* program of this kind does not reduce the impetus to mitigate threats in the wild and, ideally, should be designed to increase it.
4) Genetically and behaviourally suitable birds from a well-managed *ex situ* population recently founded from wild-origin birds would be the ideal source population for releases. However, the lead time to successfully establishing such a population is too uncertain, and the situation too urgent, for this to be an adequate sole response.
5) Early releases with *ex situ* birds can provide a useful supporting strategy towards a more successful long-term outcome. Although these birds may be less genetically or behaviourally ideal than birds sourced from a new *ex situ* population founded on wild-origin birds, using the best available existing birds offers the advantage of expediting the testing of tracker equipment and development of release protocols.
6) Early releases with immediately available though less genetically or behaviourally ideal captive birds, can provide a useful supporting strategy towards a more successful long-term outcome. Specifically, by using birds *ex situ* and *in situ*, to test tracker equipment and develop release protocols.

Defining success: a vision for an *ex situ* program supporting recovery

Multi-institution *ex situ* programs are complex, often facing a combination of biological, technical, operational, financial and sometimes political challenges. To help visualise a pathway to success, participants were asked to describe the key characteristics of a future, high-performing, *ex situ* program for Swift Parrots.

In this exercise, participants first developed their own ideas about what program success could look like, and then shared and synthesised their ideas with those of an increasingly large group of others. This resulted in three draft statements. Participants reviewed these statements as a group and identified what major themes emerged. These themes formed the basis for six long-term operational goals which were further developed by a working group (see below). The visioning timeframe was kept short (10 years) to maintain the focus on establishing a high-performing *ex situ* program rather than on benefits to the wild population that could accrue over a longer period. The three descriptions of success were consolidated into the vision statement shown below. Subsequent discussions by the three Working Groups described earlier were aimed at operationalising this vision.

Vision

By 2034 we envision an *ex situ* program where:

Conservation breeding is a catalyst for increased investment in wild recovery. The ex situ program has a direct, positive impact on species status in the wild, engaging communities to support threat mitigation and policy change, insuring against extinction and helping to accelerate recovery.

Within the program there is strong collaboration and communication between* in situ *and* ex situ *stakeholders and between multiple jurisdictions and agencies. All are united behind shared and well-integrated goals for the species and have a clear understanding of the roles they play in achieving them.

Good, standardised husbandry and management consistently deliver birds that are genetically and behaviourally equivalent to wild counterparts and capable of thriving in the wild, and disease management and vigilance in situ and ex situ mitigate against population-level disease impacts.

A clear exit strategy is in place and progress is monitored and measured. Well-integrated research ensures key knowledge gaps are filled and information from post-release monitoring is helping to increase release success.

Long-term funding is secure, supporting partner agencies and institutions to work effectively and efficiently.

Working Group 1: *in situ* considerations

Members: Nikki Anderson (DCCEEW); Dan Harley (Zoos Victoria), Chris Hartnett (Zoos Victoria); Rob Heinsohn (ANU); Glen Johnson (independent); Beau Meney (Birdlife Australia); Michael Magrath (Zoos Victoria); Leanne Wicker (independent).

This group discussed *in situ* management issues including release to the wild and *in situ* monitoring and data collection. It was tasked with addressing these overarching questions**: 1) If a thriving captive population capable of generating suitable birds for release was in place, how would it be used *in situ*? And 2) What would be the indicative timelines and milestones for such a project?**

To assist this, the group worked through a set of smaller questions initially, which were a combination of pre-set questions, those raised by the larger group on DAY 1, and additional ones that emerged during their discussions. Outputs are summarised below.

Recommended *in situ* application of captive-bred Swift Parrots

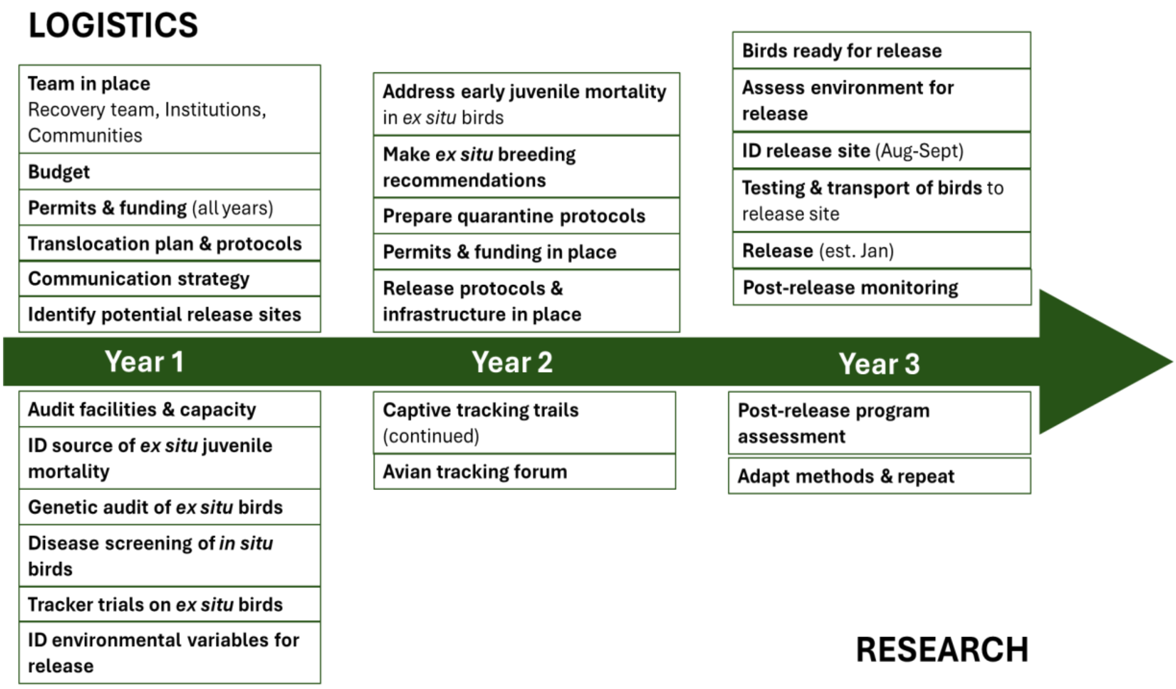


Figure 4. Timeline and milestones for a program aimed at accelerating the development or refinement of methods for the release and monitoring of captive-bred Swift Parrots, using those already available in captivity.

The group recommended a "rapid plan" for an initial program of trial releases to gather information and refine release strategies. Depending on the outcomes of this and the situation on the ground at the time, this would be followed by larger-scale, systematic releases.

A summary of what was recommended is provide below, with specific elements described in more detail beneath.

Justification and assumptions

Swift Parrots are hard to study in the wild and there remain many information gaps that could hinder the success of a release program.

Individuals cannot be tracked easily and what we know is mostly surmised from demographic data and genetic tools. We do have 15 years of data on their general spatial and habitat use[4] but we cannot accurately predict their breeding or foraging locations. Our ability to learn more is dependent to some extent on tracking technology but we cannot necessarily afford to wait for the technology to become sufficiently small and light. Technologies used for the similarly sized migratory Orange-bellied Parrots (OBPs) are likely to offer learnings that can be applied to the Swift Parrot. For example, fixed receivers as part of the Motus Wildlife Tracking systems were used to track OBP migration on the Victorian and Tasmanian coasts, coded VHF tags are being used to track OBPs on their migration, and a variety of GPS tags and attachment methods are also being trialled on captive birds. There are GPS tags light enough for OBPs, but they still on the heavier end of the allowable weight limit (~3% of body weight), are archival (store data on board) and need to be attached in a different way to VHF tags. Retrieval will be harder for Swift Parrots as they don't return to the same breeding spot every year as OBPs do. There is already good technology for local tracking but not necessarily for migrations (though noting that migrations are being tracked for OBPs).

Several tracking technologies should be trialled (with initial expectations carefully managed). Tracking attachments could initially be trialled on birds in captive institutions, however there is much we do not know about fitness and behaviour that cannot be determined from captive studies alone. Developing release techniques takes time (figuring out tracking attachment devices, refining field tracking techniques, transportation and release techniques). An efficient use of time and resources would be to employ existing *ex situ* birds to refine release and tracking techniques while a breed-for-release and insurance population is developed and before the situation in the wild deteriorates further.

It was agreed that a series of tracking trials should be planned:

- Using *ex situ* birds in tracker trials and monitored releases to the wild.
- Running both in Tasmania and in Victoria (it was agreed trial releases would ideally be in Tasmania, but Victoria was not to be ruled out if that was the only option available and birds were ready.)
- Ensuring the approach is not setting birds up to fail.
- Designed to maximise learning towards future, larger-scale systematic releases.

Wild releases: when, where and how

In the first instance, any releases will require the presence of a captive population that is producing enough suitable birds. However, to avoid prejudicing success there are other conditions that need to be in place before releases go ahead. For example, in a year like 2024, with little Tasmanian Blue Gum (*Eucalyptus globulus*) flowering, it would probably not have been a good breeding season. The wild population is highly dispersed, with limited resources (i.e. food and hollows). If birds were released this year (2024) it might have a negative impact on the wild population due to competition for resources.

[4] The 15 year dataset refers to the continuous data started by two ANU students, Dejan Stojanovic in 2010 (nesting success, glider predation) and Matt Webb slightly earlier but formalised in 2010 (surveys and location of parrots across the eastern seaboard).

Further, it was agreed that the best chance for released juveniles to migrate successfully is to connect with a wild cohort, which is harder in years where the birds are sparsely distributed.

In making a decision to release birds it will be important always to release into a suitable situation, accounting for:

- The carrying capacity of the wild habitat at the time (i.e. flowering or food resources, and nesting hollows where relevant).
- The presence of wild flocks into which released birds can integrate.
- The accessibility or logistical requirements of the site for people and equipment.
- State legislative requirements.

Because conditions on the ground vary there will need to be flexibility in the locations and timing of release. For example, when release conditions are not optimal in Tasmania there may still be suitable mainland sites (noting that most mainland sightings typically emanate from Victoria) and in some years it may not be possible to release at all and alternative arrangements will be needed for release birds. This must be communicated to *ex situ* partners from the outset of the program so that solutions can be agreed in advance.

Habitat suitability varies temporally and spatially across the range. Nevertheless, it should be possible to anticipate which sites would be suitable in a given year. For example, if we know Yellow Gum (*Eucalyptus leucoxylon)* is going to be flowering well in a given area, available data should help anticipate whether the habitat will attract a wild cohort and releases can be planned accordingly. Lerp availability is an important resource, but its occurrence and extent of availability cannot be accurately predicted. Anecdotally, some eucalypt species such as Yellow Gum do seem to more reliably support the species when flowering productively compared to other key feed tree species across the mainland range.

Tasmania is a good focus for release sites as there are more predictive models and more is known about the Swift Parrots breeding season. Though still temporally and spatially variable, the breeding range is quite well known, the distribution of suitable habitat is more concentrated in comparison to the mainland, and it is expected that birds will return to previously used nests in years when local conditions are suitable for breeding.

A 15-year Australian National University dataset[5] indicates most nesting sites occur in State production forests. There was a suggestion that this could be a biased evaluation because areas used in research projects are often chosen for accessibility (e.g. roads, thus favouring forestry areas and national parks). However, researchers confirmed the techniques used to inform this conclusion excluded land tenure bias (Heinsohn pers. comm and see Owens *et al*. 2025)

In the first instance it was agreed that planning for 5-8 years of annual releases would be reasonable, accepting that it may be necessary to suspend a release due to poor conditions.

[5] The 15 year dataset refers to the continuous data started by two ANU students, Dejan Stojanovic in 2010 (nesting success, glider predation) and Matt Webb slightly earlier but formalised in 2010 (surveys and location of parrots across the eastern seaboard).

Release protocols

Releases in Tasmania would be in January or earlier and would be prioritised, with mainland (Vic) releases from March-April onwards (birds typically start arriving from March-April, but conditions are likely to be more suitable for release after April, particularly as more birds arrive on the mainland and flocks become more reliable at productive sites). There would need to be flexibility regarding the timing of release of captive-bred juveniles, because when they can be released depends on when they breed in captivity in a given season. Some captive bred birds might not be old enough for release until February for example depending on when eggs are laid and hatched.

It was agreed that release trials should include both adults and juveniles when available, to test for differences in performance. However, juveniles are more prone to window strikes and car collisions, which could affect the number of successes. On the other hand, older release birds will have spent longer being shaped by captivity which may prejudice their survival, however these birds may be bigger and able to be fitted with larger transmitters so could be useful for tracking travel across the Bass Strait.

Information from the Orange-bellied Parrot program. Captive-bred adults are released at Melaleuca in spring to increase the number of breeding pairs and wild-born young. Management is intensive and threats minimal at Melaleuca, so they survive well there. However, the captive-bred adults that we release generally have low migration survival (<10% annual survival, vs ~60% for wild-born adults). So, the adults released at the start of the breeding season contribute to the population through producing progeny that have similar survival to wild parented birds, but the released birds rarely survive the return migration.

When we release captive-bred adults away from Melaleuca, either at the start of the breeding season or over winter, at sites where OBPs are absent or in low numbers, translocation survival rates are very variable and typically lower than releases at Melaleuca. We assume this is due to released birds learning from conspecifics.

We also release captive-bred juveniles at Melaleuca at the end of breeding, around the same time wild nests fledge. These birds have extremely high (>95%) survival to the end of the season to migrate, and migration survival rates similar to wild juveniles (20% - 40%). Once they've migrated once, OBPs usually go on to successfully migrate in subsequent years, and so these birds contribute to the population for multiple years (from Shannon Troy, provided on request post-workshop)

The size of release cohorts was discussed. Outcomes might be better with a large release cohort because a) this is a social species that may perform better in larger numbers and b) there may be significant losses early on in the trials. However, it was noted that releasing large numbers of birds and losing a lot of them could prove politically unpalatable. Alternatively, releases could be of few individuals initially. Ten could be a good *minimum* release number, all with trackers, though twenty would be much better. Releasing between 100-250 birds over the course of the 5-8 year trial phase was considered reasonable.

Hard release of juveniles was recommended, with a day or two of acclimatisation in soft holding tents (as for Regent Honeyeaters). Supplementary feeding was not recommended as, realistically, it might simply be feeding gliders (where present).

It was noted that released Regent Honeyeaters have attracted wild conspecifics on occasions. Swift Parrots, which are loud and colourful birds, may do likewise and so the requirement for releasing into wild flocks may not prove essential. However, presence of wild flocks at or near the release site does indicate that conditions are suitable for supporting Swift Parrots.

When birds are released in Tasmania earlier in the breeding season, they will presumably have access to more resources and learning. When they are released later, they will have fewer learning opportunities but should have better body condition retained from captivity so may be better equipped for migration. This is another aspect to test in the trials.

The wild sex-ratio is male-biased. An even sex-ratio was recommended for the trials.

Ideally release birds would be selected for behavioural characteristics that equip them for life in the wild. It is assumed that keepers will get to know "normal" and "abnormal" behaviours. There may be capacity for pre-release predator avoidance training in captivity if deemed necessary. Though some birds may be deemed unsuitable for release on welfare grounds (established by a veterinarian), some variation in the physical condition of birds will be useful for the trials. Similarly, details of microbiomes and stress hormone levels are good information to collect pre-release. A 'stressy' bird could do well in the wild – fear can be good for survival.

Pre-release handling and disturbance should be minimised. For example, trackers should be attached during the health check. It was noted that for parrots there is much concern about Beak and Feather Disease (BFD). Though this needs to be included in a pre-screening welfare and health check, there is no evidence of it posing a population-level problem for wild Swift Parrots (though it is present there) and its significance should not be overstated (L. Wicker pers.comm.).

Indicators of success or failure

Success and failure indicators will change over the course of the program.

For the trials, short-term signals of success would include birds surviving in the wild (requiring a means to measure mortality/survival), foraging and behaving like wild birds, and integrating into wild flocks. Longer-term signals would be returning from migration, followed by successful breeding and eventually some indication that the population has stabilised. Beyond that the program can move to full-scale releases as long as available habitat and threat mitigation allow for it.

It was considered better not to set firm targets for the release program before the trial phase but instead to develop them using the results of the trials.

It was agreed that failure to meet success criteria does not mean stop, it means *adapt*. Failure was described as consistently not meeting success requirements and being unable to adapt. The success/failure rate is likely to fluctuate. It is not necessary to get better every year and there should be efforts to manage any expectations that there will be consistent improvement or scaling-up in the trial phase. Perseverance is important in the first 5-8 years of trials even if there is high mortality or other issues.

Monitoring equipment

The purpose of running a trial release phase is to create an opportunity for adaptive learning and management. The challenges and opportunities for monitoring both short- and long-term outcomes for this species were discussed.

Monitoring using leg bands will be of limited value. They are hard to see as the species legs are short causing bands to commonly be concealed by plumage, making the task of viewing bands on birds high up in the canopy, exceedingly difficult. However, as the numbers of captive-bred birds in the wild increases, bands could begin to provide more feedback about long-term survivability.

Local VHF trackers will allow tracking of whether released birds survive the first few weeks and integrate with the wild flock. For long-term monitoring further technical innovations will be needed. Satellite trackers are very effective and trials in captivity could be started immediately. They can be used to assess, for example, whether there is an impact on breeding behaviour.

Ongoing resources will be needed to support the monitoring work. This will need to include monitoring floral resources to predict sites with suitable habitat, for which a Citizen Science based monitoring program could be considered.

Translocation sub-group

A translocation sub-group of the Recovery Team was recommended, which should include the Recovery Team co-ordinator and the appropriate expertise. This group could be responsible for determining the appropriate environmental variables that would support a decision to release. At a macro level this might include extreme weather events such as bush fires etc. The micro-level is more challenging, requiring expert on-ground knowledge. Conditions would have to be poor to cancel the release as juveniles would then have to wait another year. Again, the existing 15-year data set could provide information on past performance of areas under certain conditions.

Steps

The following provides a more detailed account of the first three years of a trial phase.

Year 1:

- Undertake a genetic audit of captive birds inside and outside ZAA and identify most genetically suitable (ideally at least 20 with an equal sex-ratio).
- Develop permit applications and a translocation plan (including a post-release monitoring plan).
- Engage Traditional Owners (Tasmania and mainland).
- Complete a disease risk analysis and develop biosecurity protocols.
- Form a translocation sub-group of the Recovery Team to support decisions.
- Secure resourcing for annual breeding monitoring including personnel and a team coordinator.
- Start monitoring to identify or forecast ten likely release sites.
- Engage landholders and secure their endorsement and the necessary permits.
- Engage with *ex situ* collaborators and start tracking equipment trials on birds not destined for release (e.g. Adelaide Zoo).

Year 2

- Design logistics of transport and release.
- Establish pre-release protocols and infrastructure.
- Continue *ex situ* transmitter attachment trials.

Year 3

- Ramp up resource monitoring to identify which of the 10 sites are suitable.
- Assess environment for release go-ahead (August-September).
- Release in December-January.
- Complete post-release monitoring.
- Assess results to adapt methods for future releases.
- Repeat with continual re-assessment.

Working Group 2: *ex situ* considerations

This section covers the work of three groups: one that worked on Day 2 and two on the morning of Day 3. Some of the items discussed overlapped with those of the in situ group. Some of the direct duplication has been removed but as the same issues were often discussed from slightly different angles most has been retained.

These groups covered *ex situ* management issues including: founder selection and acquisition (from *ex situ* and *in situ* sources); facility design; husbandry and health; retention of wild behaviours; and practical aspects of maintaining pedigree records and supporting demographic and genetic management recommendations.

Members (DAY 2): Rachel Pritchard (facilitator); Chad Crittle (ZAA Bird TAG co-convenor, Zoos SA); Gael Glassock (ZAA); Ashley Herrod (Zoos Vic); Tanya Paul (Zoos Vic); Jarrad Prangell (Symbio Wildlife Park); Kate Pearce (Zoos Vic); Tia Scott (Zoos Vic, Recorder), Monique Van Sluys (Taronga Conservation Society, Australia).

Members (DAY 3): Caroline Lees (facilitator); Chad Crittle (ZAA Bird TAG co-convenor, Zoos SA); Gael Glassock (ZAA); Chris Hartnett (Zoos Vic); Ash Herrod (Zoos Vic); Kat Selwood (Zoos Vic); Monique Van Sluys (Taronga Conservation Society, Australia).

Members (DAY 3) [wild founder collection group]: Anne Wignall (facilitator); Nikki Anderson (DCCEEW); Dan Harley (Zoos Vic); Mark Holdsworth (Independent); Glen Johnson (Independent); Beau Meney (Birdlife Australia); Michael McGrath (Zoos Vic).

Potential sources for founding a recovery-directed *ex situ* program

A single *ex situ* program able to achieve all of the roles described previously would ideally be built from a genetically, demographically and behaviourally representative group of founders. Three options for founding birds for a recovery-directed *ex situ* program were discussed: birds in ZAA institutions; birds outside ZAA institutions and in private aviculture; and wild birds. The advantages and disadvantages of each were considered. It was acknowledged that the program could be built from a combination of the birds from the three groups listed, depending on additional genotyping of unsampled birds in ZAA institutions, and some sampling of birds from private aviculture. Further genotyping of the current *ex situ* population (within and external to ZAA institutions) would be valuable for determining the genetic value of these birds.

ZAA population

A small population of Swift Parrots resides in ZAA member institutions. This is now the focus of a program coordinated by Ashley Herrod, Zoos Victoria. The population has been in captivity for multiple generations. Initial analyses of 25 birds from four institutions (see Appendix III) indicate some genetically important birds. Overall, the analyses indicated low population gene diversity and a high proportion of inter-related birds. However most birds sampled (N = 16; 67%) were from Adelaide Zoo, which has been a closed population since 2009. Additional genetic analysis of the entire ZAA population (N=64) will shed more light on the genetic health and value of the broader ZAA population.

There may be a few wild-sourced birds in the population that were brought into captivity as injured individuals. There has been a recent influx of birds from private aviculture and these birds have not yet been genotyped. It was noted that the population currently shows relatively high first-year mortality.

Population outside ZAA institutions

300-400 Swift Parrots are held outside ZAA institutions and in private aviculture. The genetic, demographic and behavioural qualities of these birds are unknown. It is unlikely that any of the current living birds in private aviculture are wild-caught, as wild trapping of Swift Parrots is not legal and no longer occurs given their ease of breeding in captivity, relatively low price, and licensing requirements. It is possible however, that some individual birds may derive from lineages not currently represented in the ZAA population. It may be possible to acquire high value birds for the ZAA Species Management Program via purchase or exchange.

Wild-origin birds

Wild-caught birds are expected to provide the most ideal genetic and behavioural qualities sought for founding the recovery directed *ex situ* program, however, bringing in wild birds to found a new program always brings challenges, both expected and unexpected, that take time to work through. For example, for wild-caught Swift Parrots, a high likelihood of mortality due to enclosure collisions is anticipated and participants agreed there are no facilities currently available to the program that are suitable for housing a wild-caught group without some form of modification. Existing facilities would need to be modified or new ones built, requiring new resources and time (though note that some institutions can be relatively nimble, for example Symbio might be able to construct appropriate facilities within 3-6months). Securing the necessary translocation permissions will take time.

The information presented at the workshop indicates that Swift Parrots are in steep decline in the wild and may already number fewer than N=500[6] (close to the total number estimated in *ex situ* populations). Participants noted that the smaller the population becomes, the greater the need for an *ex situ* program but the harder the decision to remove birds from the wild. The latter is especially true if the mortality risk in captivity is considered high or highly uncertain, or if the chance of successful release downstream is considered low or highly uncertain.

Discussion of these and other challenges and opportunities led the groups to converge on a two-pronged strategy for founding an *ex situ* program comprising:

1) An immediate program using existing *ex situ* resources for research and development. This would be aimed at developing, testing and refining the methods, and equipment needed for successful release and monitoring of captive-bred birds.
2) More gradual establishment of a long-term program for release and insurance using new founder birds from the wild and purpose-built facilities.

[6] Though see note from Beau Meney on Page 4 which estimates at least 751 from a post-workshop survey opportunity.

Strategy 1. Short-term tracker and release trials

Rationale

As described previously, optimal strategies, methods and equipment for releasing captive birds and for monitoring the success or failure of those releases are not yet developed for Swift Parrots. There is an opportunity to make use of existing captive birds and facilities within the ZAA program, for this purpose. If successful, the knowledge gained from these trials will reduce some of the uncertainty around how best to release birds on a larger-scale, from a wild-founded population.

Note: it is acknowledged that birds in the current ZAA-managed population may not be ideal candidates for release. As a result, where trials perform poorly it may be difficult in some cases to discern whether this is due to the strategies applied or to the quality of the birds. However, it was agreed there would be enough opportunities for learning for it to be worth pursuing this strategy.

Aims

- To accelerate the development and refinement of methods for the release and monitoring of captive-bred birds.
- To mobilise immediately the existing captive birds, facilities and resources to support species conservation:
    - by providing birds for *ex situ* tracker and other trials as needed;
    - by providing birds for *in situ* release trials and other key research posing no population-level risks to wild birds;
    - by supporting a coordinated program of advocacy and fund-raising promoting stronger *in situ* action.

Strategy 2. Long-term insurance and release

Rationale

Current captive birds and facilities are not suitable for building a large enough, genetically and behaviourally representative *ex situ* population for the purpose of insurance and large-scale releases. While several hundred birds remain in the wild, there is an opportunity to capture a number of individuals to found a new *ex situ* population with the necessary genetic, demographic and behavioural characteristics, housed in purpose-built facilities designed to mitigate physical risks to the birds and promote wild behaviour. This new *ex situ* population would provide a long-term, high-quality resource to support recovery efforts.

Aims

To build a large, genetically and behaviourally representative population of Swift Parrots capable of:

- Insuring against extinction for 50 years;
- Retaining at least 95% of wild source gene diversity for this period;
- Maintaining population mean inbreeding below F=0.125;
- Generating a harvest of birds for wild release that:
    - are capable of thriving in the wild;
    - pose no population-level risk to the health of wild birds.

Steps

Table 1. Summarises the approach recommended for implementing both strategies concurrently.

Year	Strategy 1: Short-term tracker and release trials	Strategy 2: Long-term insurance and release	Strategy 1 & 2
Year 1	• Secure government support and permits for trial release of *ex situ* birds. • Audit captive facilities and engage key institutions (likely early partners: Adelaide Zoo for tracker trials). • Start tracker trials.	• Investigate causes for the high mortality of juveniles in captivity and refine estimates of capacity and release potential. • Study past performance of flocking aviaries versus pair-wise breeding aviaries (re early mortality and genetically effective population size) to refine netted facility design for wild-origin birds. • Audit the genetic profiles of untested captive birds inside and outside ZAA facilities to identify founder candidates for the new program(s). • Secure government support and permits for translocations and all other work. • Audit captive facilities and engage key institutions (likely early partners - Symbio Wildlife Park & Zoos Victoria Kyabram Fauna Park for receiving wild-origin birds).	• Recovery Team to develop and deliver a clear communications strategy about the *ex situ* program and the critical importance of threat mitigation in the wild. • Establish a Swift Parrot captive management group with representation on the Recovery Team (via new RT Coordinator). To include key institutions, husbandry experts, zoo vets, Wildlife Health Australia, government and other relevant parties. • Establish release criteria and protocols for pre-release welfare and health testing (new Captive Management Group). • Disease testing of wild birds to provide a benchmark for testing captive birds. • Prepare a budget and agreement about who pays for what. • Establish a position statement on what happens to birds not needed or not suitable for release; • Confirm an exit strategy. • Secure program resources for all strategies.
Year 2	• Make breeding recommendations to create genetically suitable trial release birds. • Facilitate earlier breeding to support release logistics (e.g. avoid release in hot weather). • Continue *ex situ* transmitter attachment trials.	• Understand and mitigate causes of juvenile mortality (e.g. reduce by 50%). • Finalise design for netted flocking facilities for wild-origin founders (informed by studies).	

Year	Strategy 1: Short-term tracker and release trials	Strategy 2: Long-term insurance and release	Strategy 1 & 2
Year 3	• Identify at least 10.10 suitable birds from multiple facilities for trial release; • Leave young with parents until ready for release or consider flocking together (tbd); • Handle once for health screening, tracker attachment and transport to release site; • Hard release together.	• Build netted flocking facilities (ideally at two locations) for first intake of wild-origin founders; • Receive first intake of wild-origin birds into new facilities.	

Discussion and justification

Immediate use of the existing population [Strategy 1]

An urgent genetic audit of birds is needed – both of those outside the ZAA population and of any birds within the ZAA population not already accounted for in the last analysis. This may locate some genetically valuable birds that could be used for an immediate program of breeding for release. The most suitable 20-30 birds should be used as a basis for this trial release program.

Tracker trials could be based at Adelaide Zoo using the existing birds there. Adelaide holds a reasonable number of birds whose genetic profile would not suit them for release.

Founding a new wild-origin population (discussed on Day 3) [Strategy 2]

The earliest opportunity for capturing founders would be winter 2025 on the mainland, or in Tasmania in February 2026.

The group discussed the pros and cons of founding a population on: adults; post-fledge juveniles (3-4 weeks); pre-fledge juveniles; a mix of adults and juveniles. Adults with dependent young and eggs were ruled out. "Fixes" were suggested for the cons identified. A summary is provided below.

Table 2. Summary of pros, cons and fixes relating to the sexes and age-classes of wild-origin founders.

PROS	CONS	FIXES
ADULTS		
• Wild fitness (behaviour). • Can sex in the field. • Ready to breed. • Wider captive window on mainland (March-Sept). • Tasmania - more predictable location.	• Difficult adjustment to captivity. • Unknown age. • Narrow capture window (Tasmania – Feb-March only to avoid adults with young). • More value to wild population. • Uncertain time to maturity.	• Reduce stress myopathy with Vitamin E; prevent enclosure collisions – soft perches, double mesh, circular design; soft transport boxes with managed temperature; house communally. • Staged collection & release after 2-3 years (replace with new birds).
POST-FLEDGE JUVENILES		
• Easier adjustment to captivity. • Tasmania – more predictable location. • Less value to wild population. • Easier to catch.	• Can't sex in the field. • Reduced wild fitness (behaviour). • Additional uncertainty about relatedness.	• Sexing: health checks for incoming birds incl. DNA; collect extras to get 50:50 sex-ratio; balance sex-ratio across years. • Fitness – enclosures to provide foraging, perching & enrichment opportunities. • Minimise time in captivity or release birds. • Relatedness: collect from Tas and mainland; repeated collections; start releasing quickly. • DNA testing & management.
PRE-FLEDGE JUVENILES		

• Can target dispersed nests (to control relatedness). • Accessibility. • Tasmania – more predictable location. • Less value to wild population. • Easier adjustment to captivity.	• Captive rearing challenges. • No foraging experience. • Harder to catch. (unpredictability & scale (nest boxes in hollows?). • No socialization in wild flock.	• Rearing: ramp-up keeper expertise.
ADULTS & JUVENILES		
• Mentors available. • Mimics mixed wild flock. • More chance of some birds breeding. • Some birds available for release very quickly. • Can test comparison of adults and juveniles in captivity. • Easier to catch.	• Multiple collection trips needed (at least 2). • Others as above.	• As above.

Removal of eggs or pre-fledged birds would have the least impact on the wild population as mortality is greatest in these age-classes. However, the chances are low of successfully cross-fostering eggs or of successfully rearing behaviourally competent birds taken this young.

We should avoid taking eggs or nestling juveniles from hollows as we want post provisioning and some socialisation behaviour already developed, with some skills already learnt from the parents. This strategy has shown some success for Regent Honeyeaters.

Post-capture mortality (especially due to collisions in enclosures) poses a significant risk for adults, less so for fledged juveniles. Further, unlike fledged juveniles, adults will be of unknown age and some may be close to the end of their breeding life. However, ongoing proximity to wild adults is considered important for fledged juveniles to ensure they develop or retain important social, foraging and (where relevant) migratory behaviours. A combination of fledged juveniles and adults is therefore recommended for recruitment to the captive population.

Initial cohorts should be brought into two different institutions, if possible, to manage the risks of having all birds at a single site. There are also benefits to bringing all birds into one institution i.e. the benefits of working with a lot of birds. This requires further discussion and resolution.

The population should be founded on at least 30 effective founders in total (expected wild source gene diversity captured = 98.3%). As some birds will fail to breed in captivity this may require the capture of more birds than this. To allow for iterative learning it was recommended that founders be acquired in small batches. Initial cohorts of 10-12 adults and 8-10 juveniles are recommended. For Year 1, collecting 10 adults and 10 juveniles was suggested. For Year 2 and onwards, it was suggested that collections should start to skew more towards juveniles (depending on results of Year 1).

Facilities and management for a new wild origin population (Strategy 2)

Within ZAA institutions the current *ex situ* capacity is estimated at 110 birds (with 64 birds currently held) which are kept in walkthrough aviaries (estimated at 70%). It was agreed that there are currently no facilities immediately suitable for accommodating wild-origin birds. This will take resources, and accessing these will take time.

It was considered important that any new program for Swift Parrots does not encroach on existing conservation breeding program space for other species.

The ideal facility would support wild social breeding behaviour in a way that allows close genetic management. It should be user-friendly for keepers and provide for high individual welfare with low mortality. Participants considered the pros and cons of flocking aviaries versus pair-wise breeding aviaries (see Table 3.).

Table 3. Summary of pros and cons of flock-breeding versus pair-wise aviaries for Swift Parrots.

Enclosure system	Pros	Cons
Flock breeding	• Faster to set-up and to scale-up. • Cheaper set-up & ongoing costs. • Maintains more natural mate choice and social behaviours. • Husbandry is simpler. • Maintains physical fitness. • Intra- and inter-specific interactions are good for resilience. • Increased immunological competence.	• Cost of parentage testing (cannot rely on observation/management). • Disease outbreak risk. • Little control over which birds pair . • Catching-up individuals is hard and disruptive.
Pair-wise aviaries	• More control over which birds pair-up (may lead to better genetic outcomes if successful) . • Parentage is easily tracked. • May have better breeding and rearing success. • Lower risk of disease outbreak. • Disease screening is easier & cheaper. • Less chance of injury (aviaries too small to build up speed). • More control over environmental variables.	• More expensive set-up & ongoing costs. • Disrupts natural mate choice and social behaviours. • Husbandry is more intensive. • Slower to set-up and to scale-up. • Less effective at maintaining. physical fitness and immunological competence. • Less opportunity for building resilience to inter- and intra-specific interactions.

Netted flocking aviaries can be established relative quickly and inexpensively and are readily scalable. They support wild flocking behaviours and may lead to more birds breeding, which is particularly important during the founder phase. See previous section on additional recommended design features to reduce collisions and support wild behaviour.

Pair-wise breeding aviaries are more costly and will take longer to establish. Nevertheless, they should become more important as the program progresses and the population is at or nearing capacity, for close genetic management of priority genetic lines as needed (e.g. to amplify the contributions of new wild-origin birds).

A mix of the two systems was also discussed, in which birds mostly spend time in flocking aviaries and move into pair-wise aviaries during the breeding season, while egg management in the flocking aviary ensures there is no unwanted breeding. This has the potential to neutralise some of the disadvantages of both systems (though not the cost issues).

It was noted that in the wild, birds may be several hundred metres away from the flock when breeding – though still able to hear other birds. In the flocking aviaries described, birds would be breeding in closer proximity. Further, lower nest success for females has been observed in the wild, where there are multiple males involved, suggesting harassment may be an issue. It is not clear whether these factors could reduce performance in captivity by leading to higher early mortality than pair-wise breeding in separate aviaries. This needs to be established before a final decision is made about the design of new facilities. Visual barriers were suggested to help reduce aggression/stress.

Comparing the effective population size of flocking aviaries versus an equivalent number of pair-wise aviaries would also be useful information in determining the best approach to aviary design. A preliminary study of this could be carried out using the studbook if the pedigree data were complete. Molecular data may be able to assist with this.

Molecular genetic analysis will be required to confirm the parentage of all birds bred in flocking aviaries. This will need to be done at the end of each breeding season to ensure complete pedigree records are maintained.

A key focus should be on natural, complex habitats. Where a concrete floor is required for biosecurity, potted plants can be introduced. Long flight paths provide for fitness, though because this can allow birds to build up enough speed to injure themselves, soft-sided aviaries are preferable, especially for wild-origin birds.

A 50:50 sex-ratio of founders is recommended and in general sex-ratios should be kept even. In the wild, half the clutches have two fathers (probably due to the male-biased sex-ratio) and birds there breed in pairs or trios. Weighting towards males can increase harassment of females and result in fewer chicks generated overall.

Birds within the program should be given the opportunity to interact with other species to build resilience to competitors. Some form of predator awareness training may also be possible. It was suggested that the period spent in the captive environment could be used to habituate birds to glider proof boxes so that when they are released they defer to them.

Maintaining migratory behaviour (Strategy 2)

Maintaining migratory behaviours was considered the main challenge to retaining wild fitness. It was acknowledged that little could be done in the captive environment to support this.

In OBPs, the release of captive juveniles to flock with recently fledged wild juveniles produces the best migration success for released birds. In OBPs the adults leave the breeding site first, and the captive and wild born juveniles flock together and then move off together and have comparable migration survival.

Recommended approaches to retaining migratory behaviour were:

a) Releasing captive birds close to wild flocks to encourage them to integrate into them and follow their natural movements and migration patterns; and

b) Releasing young captive birds with older, well-represented wild-origin founders to act as "guides". It was acknowledged that the latter could present some difficulties, especially if wild-origin founders are in short supply.

In general, minimising the number of generations of birds in captivity (to reduce selection for captive traits), maintaining a flow of wild-origin birds through captive flocks, and maintaining a close connection between captive-bred release birds and wild counterparts, were considered important. It was recommended that releases be routinely accompanied by capturing new founders, to keep birds cycling through the wild and captive populations. The benefits of this would be to maintain the behavioural integrity of captive birds as well as maintaining high levels of gene diversity.

Genetic and demographic management (Strategy 2)

Parentage information is hard to track in social breeding species and without close genetic management of pairings the gene diversity and inbreeding targets are harder to achieve.

In this case, it was assumed that annual molecular testing of all offspring in breeding flocks would be required, to confirm parentage. Even where active management of pairings is not practised (for example, where wild-origin birds are brought in and left to choose their own mates) molecular testing will allow ongoing measurement of effective population size, gene diversity loss and inbreeding accumulation, and to select less related birds for release as needed.

Management by mean kinship is the approach usually used for genetic management (see Appendix IV). This can be implemented very intensively (by calculating the number of offspring needed to meet program goals and selecting only the requisite number of high-value pairs) or less intensively (e.g. by ranking the value of the pairs that the birds themselves have chosen and replacing with dummy eggs the eggs of the lowest value pairs). An overarching Maximal Avoidance of Inbreeding scheme, which creates some within-population groupings between which there is reduced flow of individuals, can be a helpful way to support the management of social species (see Appendix. IV).

Equalising founder representation should be attempted wherever it does not put viability at risk. Successful and consistent breeding is a priority while the population is small. As the population grows and becomes more demographically secure, and provided breeding is reliable and consistent, it may be possible and beneficial to start releasing birds before target size is reached. Releasing birds from over-represented lines will benefit the captive population by correcting founder skew. Additional corrections can be made by identifying priority pairings (using mean kinship values) and supporting these in pair-wise breeding aviaries.

Capacity and release targets (Strategy 2)

The amount of aviary capacity required is highly dependent on achievable population growth rate and on the ongoing availability of wild-origin birds.

For example:

- A breed for release program with a continual influx of new founders will require a smaller population than an insurance population with little or no ongoing supplementation from the wild.

- An insurance population that has grown rapidly and evenly from the initial founders will retain more gene diversity at a smaller final population size than a population that has grown more slowly and unevenly.
- To generate a particular number of birds for annual release, a fast-growing population will require a smaller overall population size than a slow-growing one.

Maximum achievable growth rate and availability of wild-origin birds are currently uncertain quantities. Maximum achievable growth rate (λ) is currently estimated at λ=1.2 (or 20% per year) based on past performance of the ZAA population. However, this observed growth is likely to have been influenced by management and by the apparently high first-year mortality rates, especially pre-fledge mortality (75% of total year 1 deaths). Improvements in first-year mortality may allow goals to be met with a smaller population and a better understanding of factors driving high first-year mortality is a priority. (Note that growth rates of λ=1.5 and 1.7 are also considered in Appendix V. models, based on reported OBP rates).

The following working targets were set for discussion purposes, based on the identified needs of the *in situ* working group and what is likely to be possible based on preliminary PMx and Vortex models (see Appendices IV & V for details),

- Capacity= 200 – 300 birds;
- Release cohorts= 20-50 birds,

Further work is needed to refine these as described in Appendix V and in the section on Working Group 3 Goal 2 (page 38).

Disease risk management [Strategies 1 and 2]

While the importance of maintaining adequate biodiversity standards was acknowledged, it was recognised that biosecurity measures can be prohibitively difficult and expensive. If those required for OBPs were applied to Swift Parrots, it would significantly reduce holding capacity. Many OBPs fail the biosecurity screening, placing pressure on holding capacity in the *ex situ* program. A holistic assessment of risks and benefits was recommended, accounting both for the urgency of releases, realistic threats from diseases and based on an acceptable level of risk that is well understood by all. Biosecurity protocols should be developed early so that they can be factored into new facility design.

Criteria for release [Strategies 1 and 2]

Criteria for release are likely to include health, welfare, genetic and behavioural considerations. To support management decisions these should be established and communicated at the outset of the program (e.g. by the proposed captive sub-group).

Testing and transport [Strategies 1 and 2]

The best time for releasing Swift Parrots in Tasmania was considered to be when there are maximum food resources. December to January was recommended though there was discussion about whether January would be too late. In January/February the heat and welfare implications are harder to manage. December could be preferable. Black Gum flowers earlier than Blue Gum and earlier releases would give access to this food resource too. An earlier release also means allowing released birds more time to associate with other birds. Another consideration is the potential release of two separate cohorts (e.g. of ten birds each) to make use of birds fledging earlier versus later and provide an opportunity to address problems observed with the initial releases in time for the second cohort.

Pre-release monitoring/trials could help test these ideas and inform the appropriate release time and strategy.

The implications for the *ex situ* program are that earlier breeding might be beneficial, to facilitate the logistics for transport, the availability of testing facilities over the Christmas period, and any preference for a December release if pre-release trials prescribe it.

It was considered unlikely that birds would go straight from their parents to the release site and that instead, release cohorts from different institutions might need to be crèched together before release and transported together. This is done for Regent Honeyeaters and helps with the issue of asynchronous breeding across facilities (though note that for Regents, pre-release transfers are more linked to giving the birds the opportunity to live in large multispecies aviaries and to release logistics and health testing rather than directed at 'creching' the fledgings (M. Van Sluys pers. comm.). This is an additional consideration for costs, facility construction and collaborating institutions.

Governance and stakeholder representation (Strategy 1&2]

A stakeholder analysis of institutions within and outside ZAA was recommended, to identify key institutions, current or potential facilities, and resources. Further, a captive management sub-group for the Recovery Team was recommended, to support a One Plan Approach by bringing together key institutions and expertise (including veterinary and government) to advise the Recovery Team on important issues related to *ex situ* management. Private aviculture would be represented on this group.

Private aviculture holds a significant number of Swift Parrots, and their expertise was acknowledged. They could also provide support by housing surplus birds. There should be a strategic approach for engaging and working with private aviculturists

[Private aviculturists were not represented at the workshop. Several had been invited but were unable to attend].

Government buy-in and resourcing (Strategy 2]

No purpose-built facilities will be possible without first securing the necessary permits, which in-turn require in-principle agreement from State government agencies potentially via the Recovery Team.

Communications

There should be a communications plan to ensure the purpose of the program is clear to the public. It is important that recovery partners have clear and consistent messaging around the purpose for the *ex situ* program, especially in the context of wild threats.

Communications and press releases should be designed wherever possible to support all partners. From an *ex situ* holders' perspective it is important to acknowledge those holding bachelor groups, program surplus etc. as well as the higher profile breeding facilities, as these are all essential components of a functioning program.

Risks

Captive adaptations embedded transmitted to wild populations: orange-bellied Parrots now breed at a lower rate than previous records indicate – both in captivity and in the wild. It was suggested that this population characteristic may have developed in captivity and now affects wild rates due to the large proportion of captive-origin birds present (S. Troy pers. comm.). This kind of effect should be guarded against if possible. One of the best chances for avoiding this in Swift Parrots is to release into a substantially larger wild population. This again argues for urgently moving to a breed for release program as in five years there will be fewer birds on the ground.

Competition for OBP captive space: current understanding is that the facilities for OBPs and those required for SPs are not interchangeable, at least in the first few years.

Challenges of having two Swift Parrot programs running concurrently: the initial program of trial releases has a finite life (5-8 years) after which the current population could be slowly phased out through reduced breeding and natural attrition and replaced with excess birds from the wild-origin program (see Appendix V for initial estimates of time to natural attrition).

Data gaps

Swift Parrots have been managed and bred successfully in zoos and in private aviculture for decades, though not with the intent to return them to the wild. To inform facility design and management for a breed for release program we need more information about the seasonal and throughout life needs of the species in the wild as well as a better understanding of the species' response to captive environments. The following data gaps were identified by the working group. Rob Heinsohn added additional insights during the review process:

- Is there seasonality in flocking behaviour? [Note from Rob Heinsohn: This is a flocking species. I don't think there is much seasonality i.e. they prefer to nest in the same location and they migrate in flocks].
- What is the natural sex-ratio – is the current male bias the result of female predation by gliders? [RH: We have calculated the bias that must be there due to predation on females. It is fairly safe to assume that the natural sex ratio is roughly 50:50 maybe with a small male bias].
- How does *ex situ* and wild nutrition differ? Do *ex situ* diets affect fitness, behaviour, fertility, sex ratios etc?
- What is the minimum group size for successful reproduction?
- What level of fitness needs to exist in the *ex situ* population for a good chance of wild survival? [RH: It is unclear how fitness would be measured here. Ultimately finding out how they go upon release and relating this back to conditions in captivity is the only way to get data on this].
- What aviary sizes will work for breeding?
- How do flocking and pair-wise aviaries compare in terms of breeding success and genetically effective population sizes?

Working Group 3: program-wide and integrated management

Members: Gemma Cadd (Scribe), Michelle Cooper (DEECCA), Lainie Berry (Birdlife), Kat Selwood (Zoos Victoria), Monique Van Sluys (Taronga Conservation Society Australia), Shannon Troy (NRE Tas), Mark Holdsworth (Independent, Tas), Garry Peterson (Zoos Victoria), George Olah (ANU), Caroline Lees (CPSG Facilitator).

The focus of this group was the overarching program goals, targets and success indicators; mechanisms for integrated *in situ* and *ex situ* management; and governance.

Based on the draft vision statement and incorporating feedback from the other two groups, Working Group 3 developed six operational goals for establishing a successful, integrated program of *in situ* and *ex situ* work able to fulfil the roles proposed. For each goal, targets and/or next steps were recommended.

Goal 1. *In situ* and *ex situ* populations of Swift Parrots are managed as a well-integrated metapopulation:

Wild and captive Swift Parrots are managed as a metapopulation with well-integrated targets and close collaboration among stakeholders.

A well-functioning and coordinated Recovery Team, with representation from multiple States and Federal agencies, is essential to ensuring that the *in situ* and *ex situ* recovery actions for the Swift Parrot are congruous and that the species can be managed as a well-integrated metapopulation. In particular, the following tasks were considered important for the Recovery Team to undertake, potentially with the support of a new Recovery Team coordinator:

1. Add translocation and captive management sub-groups (with representation on the latter from key institutions including private aviculture, husbandry experts, zoo vets, Wildlife Health Australia and government) to the Recovery Team.
2. Coordinate or otherwise support the development of detailed plans and translocation proposals for:
    a. releasing select captive birds from the existing population to trial and refine release and monitoring methods;
    b. acquiring wild-caught founders for a long-term insurance and release program.
3. Facilitate representation to State Governments to secure in-principle support for an *ex situ* initiative (without which no investment in new facilities can be made).
4. Ensure avenues for continued information sharing with other programs such as the Plains-wanderer, Regent Honeyeater and Orange-bellied Parrot programs (as this had proved valuable during the workshop).
5. Initiate discussions about population targets for wild populations towards a fully integrated metapopulation approach to conserving the species.

Goal 2. Demographic and genetic targets are met:

High levels of gene diversity are retained, population-level inbreeding accumulation is managed, and the breeding and survival rates of populations are supported or managed to maintain viability, and (ex situ) to reduce surplus and provide for release where required.

The scope of the workshop was designing an *ex situ* program. Only aspects of *in situ* management that would assist the successful application of *ex situ* resources were considered in detail. However, participants recommended that in-keeping with the One Plan Approach it could be useful to apply a similar approach to target setting for the wild population and for the meta-population. This will be a matter for the Recovery Team.

Ex situ genetic and demographic targets may change over time as different program roles or management strategies become more relevant. For the dual strategies discussed at the 2024 workshop the following targets were recommended:

Strategy 1: Short-term tracker and release trials

Table 4. Preliminary genetic and demographic targets for a short-term *ex situ* program aimed at trialling equipment and developing release and monitoring protocols.

Program length:	5-8 years (1-2 yrs to first releases)
Gene diversity retention target:	Not applicable
Maximum population inbreeding threshold:	F=0.125
Initial founders (to be selected as a result of the proposed genetic audit of captive birds):	20 (10.10) most suitable individuals available to the program from the current *ex situ* population in Australia.
Ongoing supplementation with wild-origin birds:	Not applicable
Target production:	Generate 10-20 birds per year
Target *ex situ* capacity:	10-15 breeding pairs plus offspring

Strategy 2: Long-term insurance and release

Table 5. Preliminary genetic and demographic targets for a long-term *ex situ* program fulfilling both insurance and breed for release roles.

Program length:	50 years (3-5 yrs to first releases)
Gene diversity retention target:	≥ 95%
Maximum population inbreeding threshold:	F=0.125
Initial number of wild-origin founders:	≥ 30 (15.15)*
Ongoing supplementation with wild-origin birds:	≥ 2 (1.1) every 4 years*
Target population growth capability:	Estimated λ = 1.1 – 1.3 (preliminary)
Target *ex situ* capacity:	Estimated 200 birds (preliminary)

* effective founders – that is, that breed adequately in the population.

Additional notes: retaining 90% wild source gene diversity is typically set as a target for *ex situ* programs. This 90% value was originally conceived for 200-year, speculative, *ex situ* insurance programs (Soulé et al 1986). This is a lot of gene diversity to lose. For shorter-term recovery contexts such as the Swift Parrot, more ambitious targets are appropriate and participants recommended ≥ 95%. Based on experience with similar programs in

Australia, a fifty-year timeframe was recommended. An average population-level inbreeding coefficient (F) of no more than 0.125 was recommended based on the standard used in zoo programs around the world. To achieve this the program is expected to require at least 30 effective founders (capturing approximately 98.3% wild source gene diversity and, ideally, ongoing supplementation of at least four additional wild-origin birds each generation (4 years). It is assumed that to achieve the target of 30 or more effective founders, more than this number will need to be brought into the program to account for birds that fail to breed. The target number of birds for release may vary over time and in the first instance 10-20 birds per year was recommended for trial releases, with 20-50 birds recommended for subsequent, longer-term releases. Targets for growth and capacity hinge on accurate estimates of maximum potential population growth rate. This is currently unknown. More analysis of past population growth in captivity along with analysis of the causes of first year mortality are needed to refine these parameters. (See Appendix III for further details).

ZAA has recently appointed Ashley Herrod (Zoos Victoria) as Studbook Keeper and Species Coordinator for Swift Parrots. The purview of this role includes investigating first year mortality factors as well as meeting genetic and demographic targets and other population management and reporting activities.

Next steps: Further investigate past growth rates achieved in the captive population. Investigate first year mortality in captive swift parrots, particularly in the pre-fledge stage. Compare performance of flocking versus pairwise aviaries. Re-evaluate targets with the information gleaned using PMx (and Vortex models if needed).

Goal 3. Wild behaviours are retained:

Ex situ *husbandry and management support the seasonal and throughout-life behaviours of the species and released birds can forage, migrate and breed normally.*

Breed for release is the main role identified for an *ex situ* Swift Parrot population. Concerns were raised at the workshop about the difficulty of maintaining key wild behaviours that will allow captive-bred birds to thrive in the wild. [It was noted that there is a large *ex situ* population of Orange-bellied Parrots (OBPs) (N≥600) in which many birds are unsuitable for release and are therefore surplus to the program].

Key behaviours were agreed to be those associated with:

- Wild survivorship;
- Successful integration into wild flocks;
- Normal foraging behaviour (i.e. similar to wild birds);
- Normal migratory behaviour (i.e. similar to wild birds).

Next steps: Begin tracker and release trials as soon as possible, to test and refine release strategies for captive-bred birds. Agree initial criteria for releasing birds.

Goal 4. Good metapopulation health is maintained:

A holistic analysis of the population-level significance of health issues in captive and wild Swift Parrots guides and supports conservation outcomes for the species.

Health and disease management were discussed at various points in the meeting. Ensuring that population viability (*in situ* and *ex situ*) is not compromised by disease issues is critical to success. Also critical to success is the ability of the program to generate immunologically resilient and behaviourally competent individuals for release, both of which may involve a level of disease risk. The right balance needs to be struck. The following approach and next steps were recommended:

1. Understand any evidence of significant disease issues in the captive and wild populations.
2. If there is something – determine whether it can be screened for or mitigated.
3. Assess the population-level consequences of health issues.
4. Use that to inform biosecurity and health assessment protocols.
5. Integrate disease risk into an overall assessment of risks to conservation outcomes of the program.

A detailed health assessment of all birds as they come into the program is recommended:

a) To identify any diseases or potential health concern.
b) To establish baseline health parameters (blood reference ranges, microbiome information, parasite diversity, etc).
c) To identify other species of potential conservation value that might be present (it is important to acknowledge that all living creatures carry a diversity of other organisms with them, some which may be host specific and thereby also under conservation risk).
d) To bank material for testing at a later date.

Next steps: (possibly Zoos Victoria to lead these):

- Review ZIMS records for health issues in captive Swift Parrots (likely to be similar to those affecting OBPs (e.g. ascarids (gut worms), mycobacterial infections).

- Obtain relevant information from the OBP program, including advice from the OBP Vet Technical Reference Group and the OBP Disease Risk Assessment, in order to inform a disease risk assessment for the Swift parrot.

- Develop a pre-release health check and protocol for ensuring a single handling event prior to release.

Potential outcomes of disease screening and investigations were not pre-empted in the workshop as this will form part of a planned disease risk analysis. The DRA will also entail formulation of contingency plans (e.g. a halt to or pause of releases) if a significant disease risk is identified."

Goal 5. The *ex situ* program grows support for threat mitigation in the wild:

Community awareness and advocacy programs delivered consistently across ex situ partners and in key areas drive support for in situ threat mitigation.

Recommended action. Develop and deliver a community conservation campaign with partner institutions. Potentially including:

- Ability to donate to the program at *ex situ* locations;
- Swift Parrot trackers near foraging locations;
- Citizen Science programs identifying flowering trees etc.

Goal 6. Science-based and evidence-led decision-making ensures effective and efficient management:

Comprehensive triggers to enable evidence-based adaptive management are in place for all phases of the program, supported by well-coordinated research.

The program designed during the workshop is expected to move through several phases:

- Founder phase
- Trial release phase
- Maintenance phase
- Release phase
- Exit phase

With two separate but concurrent strategies operating and significant knowledge gaps yet to be filled, the likely sequence and length of these phases are unknown. Participants emphasised the importance of having, from the outset, a clear sense of the conditions that need to be in place before the program can move from one phase to another (see page 10 for definition of phases), and of embedding monitoring and reporting on those conditions into any program plan.

Recommended triggers for moving from one phase to another, for exiting phases, and for exiting the program altogether, are described on pages 43-45. Triggers should be reviewed and revised periodically alongside other elements of the program.

A program of research and monitoring will be needed to establish and then monitor the recommended triggers, which currently relate to some unknown or partially known parameters such as habitat carrying capacity (and how much is available to support released birds in a given year).

Next steps: Ramp-up monitoring and research to establish and monitor program triggers as well as to provide other information valuable to establishing and running the program successfully.

Dealing with excess and retained birds

[This section combines discussions across the three main working groups]

Excess birds

Participants discussed what should be done with “excess” birds, i.e. those that will not contribute further to the breeding pool or those that do not fit release criteria. In other programs (e.g. OBPs) the number of “excess” birds is large, and it was agreed that this situation should be avoided if possible.

Two broad approaches to addressing this were recommended:

1) Avoiding the production of excess birds by:
    a. using PMx to calculate the number of breeding pairs needed each year, to generate sufficient birds to compensate for natural attrition and/or to generate enough birds for release, depending on the program phase and:
        i. either separating out into breeding aviaries (near to the main flock to maintain contact) the requisite number of breeding pairs and curtailing nesting in the main aviary through removal of nest boxes and/or replacement of all eggs produced with dummy eggs OR;
        ii. allowing birds to breed freely in the flocking aviary and replacing with dummy eggs all but the number of eggs needed to generate the required number of chicks (note: calculations for this needs to account for hatching success rates and early mortality to avoid under-production).
    b. Maximizing release suitability by managing birds in natural social groups, enriching enclosures, and maintaining the ongoing connection with wild birds and their behaviours, by cycling wild birds through the captive population.

2) Managing excess birds inadvertently produced by the program by:
    a. Mobilizing space in ZAA institutions that would not be suitable for other program birds (e.g. in mixed species and walk-through aviaries). Birds housed would be non-breeding;
    b. Engaging private aviculture in holding birds[7];
    c. Engage space in other regional programs in North America (through AZA) or in Europe (through EAZA), using the Commonwealth Government’s Ambassador Agreement system – such as that used for Tasmanian Devils.

[Note that ZAA has a Euthanasia Policy that members commit to which may be relevant here].

Retained birds

In addition, due to the variability of on-ground conditions there will be years when planned releases cannot go ahead and releasable birds have to be retained. This was identified as a challenge for participating institutions but solutions were not explicitly discussed.

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[7] Note that ZAA currently has no policies or procedures for engaging with private individuals or non-ZAA members in the context of managed programs. However, it is exploring some alternative membership options which may assist with this situation (G. Glassock, pers. comm.).

Exit strategy and program trigger points

Members: Gary Peterson (Zoos Victoria): Shannon Troy (NRE Tas), Leanne Wicker (independent), Rachel Pritchard (CPSG Facilitator).

Recommended triggers for moving from one phase to another, for exiting phases, and for exiting the program altogether, are described below. Triggers should be reviewed and revised periodically alongside other elements of the program.

Exit Phase

The Exit Phase is about winding down the program entirely and responsibly managing the remaining birds.

Recommended triggers for exiting a captive program:

1. Success:

1) Swift Parrots are downlisted to Vulnerable, or;
2) There is a stable and viable[8] population that matches the habitat's carrying capacity.

2. Failure:

3) A captive program of suitable quality cannot be established because (for example):
    a. Founders cannot be acquired;
    b. Mortality is irrevocably greater than recruitment.
4) There is long-term failure to achieve threat mitigation in the wild with little or no expectation of change. Based on experience of other programs and situations participants estimated that real threat management in the wild could take 50 years and the recommended *ex situ* program timeframe is set to accommodate that. However, check-in opportunities at 10 and 20 years are also recommended, to allow managers to assess progress with threat management in the wild, to determine whether efforts and progress there are sufficient to justify continuation of the program.

It was noted that there are multiple pathways to exiting the program. For example, where threat mitigation in the wild is successful releases may not be required and the program may exit directly from the maintenance phase. Similarly, if any phase is considered to have failed irrevocably the program may move straight to the exit phase.

What to do with the remaining birds once an exit is triggered?

Depending on circumstances, one or a combination of the following options are recommended:

Where the trigger is program success:

1. Release as many birds as possible if carrying capacity in the wild exists;
2. Rehome for display and storytelling in mixed aviaries at existing institutions;
3. Rehome in private aviculture;
4. Manage euthanasia of eggs to wind down breeding.

Where the trigger is program failure, options 2 and 4 are recommended and also:

[8] Suggested definition of viability: population viability analyses show zero extinction risk over 100 years.

5. Welfare euthanasia (in specific circumstances, e.g. where disease was the reason for the exit).

Preventing breeding completely was discussed, but largely discounted because this may make it difficult to manage the welfare of the birds.

Note that the trigger for exiting the program will not be reached suddenly. Where the trigger is program success there should be signals of this for some time, for example five years of commensurate observations are required before a species can be moved to a lower risk category, and breeding can be dialed back or releases increased over this period, while ensuring that this is done in such a way that ramping up again is still possible in case needed. Where the trigger is failure there will also be signals of this over an extended period before the exit decision is made.

Management euthanasia (i.e. where birds are otherwise healthy) is unlikely to be a palatable option for the wider community.

Founder phase

The founder phase is about capturing a representative snapshot of wild gene diversity (by capturing enough effective founders) and breeding equally and prolifically towards target population size.

Recommended triggers for exiting the captive program at the founder phase:

Sufficient wild-caught founders cannot be acquired:

1) Because birds go extinct in the wild before founders are collected.
2) Mortality related to wild capture continually exceeds recruitment into the *ex situ* population (e.g. over five years of annual collection).
3) Funding to build facilities suitable for housing wild-caught birds cannot be secured.

Recommended triggers for moving from the founder phase to the maintenance phase:

1) When target population size is reached, and the population has the desired characteristics (genetic, demographic and behavioural); and
2) Conditions do not allow for, or do not require, movement straight to the release phase.

Maintenance phase

The maintenance phase is about keeping the population demographically stable, at target size, avoiding surplus production, maximizing gene diversity retention and minimizing inbreeding accumulation.

Recommended triggers for exiting the captive program at the maintenance phase:

1) Swift Parrots are downlisted to Vulnerable or are viable at the carrying capacity of the available habitat.
2) There is not enough money to maintain the program OR the cost is failing to generate the required benefits (i.e. pre-defined captive or wild objectives).
3) After 50 years, if threat mitigation is not working in the wild.

Recommended triggers for moving from the maintenance to the release phase:

1. Trial releases have been shown to be successful.
2. Sufficient habitat carrying capacity is available for the birds to be released into.

Release phase

This phase is about releasing birds to the wild.

Triggers for starting releases (trial or large-scale):

1) Captive population is large enough and breeding well enough to support the intended harvest for release without detriment to gene diversity or demographic stability.
2) Enough suitable habitat is available to support the number of birds intended for release.

Triggers for exiting the trial release phase:

1) A three-year review finds that trial releases have failed irrevocably.
2) There are unacceptable welfare components.

The review would also determine whether to return to the maintenance or founder phases pending reconsideration of strategy, or to move to the exit phase if the problems encountered cannot be resolved.

Triggers for exiting the large-scale release phase

3) The wild population is stable or showing growth and releases are not needed.
4) At the 10-15 year mark for releases no upward trend is seen in the wild population.
5) Wild carrying capacity is reached.
6) There is insufficient evidence of threat mitigation progress (exact definition to be determined).

Depending on circumstances exiting the release phase may mean returning to the maintenance phase.

It is important to ensure the focus remains on threat management in the wild. Resources as well as ethics will prevent the *ex situ* program from producing and releasing birds indefinitely, in the presence of inadequately mitigated threats, in order to prevent extinction.

Next steps:

1) Identify and detail the elements that need to be measured/monitored, in order to be able to assess whether specific trigger points have been met.

2) Develop a method for ongoing assessment of carrying capacity.

Workshop communiqué

Leads & editors: Michelle Cooper, Rachel Pritchard

On DAY 3 of the workshop a rapid communications exercise engaged participants in providing:

- 3 ideas about the essence of the workshop and why it was needed;
- 2 things they most wanted an external audience to know; and
- 1 sentence describing the most important thing for an audience to know.

The outputs of this exercise were compiled by a small editing team to create the following workshop communiqué.

Swift action required to expedite recovery: workshop communiqué for establishing an *ex situ* population of Swift Parrots

With the Swift Parrot facing a very real risk of extinction within the next decade, a workshop was convened to develop a roadmap for an effective captive breeding and release program for this critically endangered species.

On November 6th – 8th, members of the Swift Parrot Recovery Team, along with key stakeholders from zoos, environmental NGOs, and state and federal governments, gathered to discuss the best approach for building this program.

Identified as a key action in the Swift Parrot Recovery Plan, this workshop explored methods for bolstering captive breeding and expediting the release of captive-bred birds. These actions will be critical to deliver quickly, while wild birds remain across the landscape to show captive-bred birds natural foraging and migratory behaviours.

Rapid action is needed across all fronts to secure a future for the Swift Parrot. Breeding for release is only one tool but may be critical in conjunction with managing ongoing threats in the wild across the species' range.

To act decisively for the critically endangered Swift Parrot, we need coordinated commitment, substantial investment, and strong collaboration—before it's too late.

Participants of the 2024 Swift Parrot* Ex situ *Design Workshop

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Appendix I. Workshop participants

Name	Organisation
Michelle Cooper	DEECA (Victoria)
Mark Holdsworth	Independent expert
Rob Heinsohn	Australian National University
Katherine Selwood	Zoos Victoria
Ashley Herrod	Zoos Victoria
Dan Harley	Zoos Victoria
Michael Magrath	Zoos Victoria
Tanya Paul	Zoos Victoria
Garry Peterson	Zoos Victoria
Chris Hartnett	Zoos Victoria
Kate Pearce	Zoos Victoria
Paul Eden	Wildlife Health Australia
Chad Crittle	ZAA Bird TAG co-convenor, Zoos South Australia
Monique Van Sluys	Taronga Conservation Society
Gael Glassock	Zoo and Aquarium Association Australasia
Jarrad Prangell	Symbio Wildlife Park
Shannon Troy	Department of Natural Resources and Environment Tasmania
Lainie Berry	BirdLife Australia
Beau Meney	BirdLife Australia
George Olah	Australian National University
Glen Johnson	Independent expert
Nikki Anderson	Department of Climate Change, Energy, the Environment and Water (Federal)
Leanne Wicker	Independent expert
Workshop facilitators	
Caroline Lees	IUCN SSC CPSG
Anne Wignall	IUCN SSC CPSG Oceania
Rachel Pritchard	DEECA (Victoria)
Workshop reporters (scribes)	
Gemma Cadd	Zoos Victoria
Tia Scott	Zoos Victoria
Jess Kelley	Zoos Victoria

Appendix II. Swift Parrot *ex situ* design workshop: agenda

Note that this draft agenda was used as a starting point. Adjustments were made throughout in response to the issues raised and to allow space for new ideas.

DAY 1

When	What	Who
12.45	**Welcome** and background to the workshop.	ZV
13.00	**Introduction:** to the workshop approach, methods and tools, including the IUCN *Ex situ* Guidelines and One Plan Approach.	Caroline Lees
13.15	**Participant introductions.**	ALL
13.30	**Scene setting presentations:**	
	• **The Swift Parrot Situation:** species biology, review of past and present distribution, details of recent decline, conservation action and recovery planning to date, including recovery aims. **(15mins)**	**Rob Heinsohn**
	• **The Swift Parrot Specific Needs Analysis:** process and outcomes. **(15 mins)**	**Rachel Pritchard**
	• **Captive breeding: history and potential:** experience to date of managing this species *ex situ*; review of demographic and genetic potential of the current *ex situ* population; known challenges and constraints. **(15 mins)**	**Ash Herrod**
	• **Molecular genetic analysis (wild and captive). (15 mins)**	**George Olah**
14.30	**TEA**	
14.45	**Envisioning a recovery-directed *ex situ* program** for Swift Parrots.	**Plenary**
16.15	**Challenges, opportunities, key questions or decisions:** what do we need to talk about?	**Plenary**
17.00	**Day 2 explainer** & close of Day 1.	

DAY 2

DAY 2		
8.30	**Re-cap and introduction to the day.**	Plenary
8.45	**Presentation: Small population challenges and analysis tools: implications for program design.**	Presentation
9.15	**Issue development 1:** defining and prioritising DAY 1 challenges, opportunities & questions.	Working groups
11.00	**COFFEE**	
11.15	**Issue development 2:** recommending pathways to resolving priority issues.	Plenary discussion
12.30	**LUNCH**	
13.30	**Issue development 2:** continued.	Working groups
14.30	**Brief report back session.**	Plenary
15.00am	**TEA**	
15.15	**Program sketch:** developing a sketch of each program component (i.e. *in situ*, *ex situ* and implementation framework) and associated milestones or timelines.	Working groups
16.30	**Report back .**	Plenary
17.30	**Close of DAY 2.**	

DAY 3

DAY 3		
9.00	**Re-cap and introduction to the day.**	Plenary
9.15	**Emergent issues:** opportunity to discuss unresolved topics.	All
11.00	**COFFEE**	All
11.15	**Final report back.**	All
12.30	**Next steps & concluding remarks.**	All
13.00	**Meeting ends.**	

Working groups:

1) *Ex situ* factors

2) *In situ* factors

3) Implementation framework: integrated goals, targets & governance.

Appendix III. Scene-setting presentation summaries

Status of swift parrots in the wild

Robert Heinsohn, Giselle Owens, Laura Bussolini, Dejan Stojanovic
Fenner School of Environment and Society, Australian National University
Acton, A.C.T. 2601 Australia

Background

R Heinsohn's research group at the Australian National University has been conducting research on the ecology and conservation status of swift parrots since 2006. Early research on the swift parrots' migration to the mainland was conducted by PhD student Debbie Saunders, and a research program was established in Tasmania where the birds breed in 2010. The early research in Tasmania was conducted by PhD students Matthew Webb and Dejan Stojanovic. This summary focuses on the Tasmanian research as it was pivotal in understanding the birds' greatest immediate threats.

Webb developed powerful survey methodology for nomadic species using spatially explicit occupancy models. He used this approach to map where trees were likely to be in flower and to predict if the birds would utilise the area. Repeated surveys narrowed down the possible areas until the breeding aggregations of swift parrots were located. This methodology provided an essential method for locating breeding swift parrots across a vast landscapes every year, allowing Stojanovic to climb the nest trees and monitor nest success at the breeding hollows using motion activated cameras. He discovered that most of the breeding females (83%) when nesting on the main island of Tasmania were being killed on the nest by sugar gliders, an invasive species. Swift parrots occasionally use offshore islands to breed when flowering occurs. These islands are free of sugar gliders so the population does not suffer high predation in those years.

Population viability analysis and conservation status

We combined our field data over four years in the first population viability analysis (PVA) for the species in 2015 (Heinsohn et al. 2015). The models predicted that the population was plummeting due to the impact of sugar gliders alone, with other impacts not explicitly modelled (e.g. habitat loss) compounding the situation. Our 2015 models were the basis for swift parrots being uplisted to Critically Endangered. PVAs were later updated and tested by Giselle Owens using new field data (Owens et al. 2023). Her analysis confirmed the original predictions: Model B (Figure 1) predicts a 92.3% population decline over three generations (11 years). This supported the predictions of the original conservation assessment of CR.

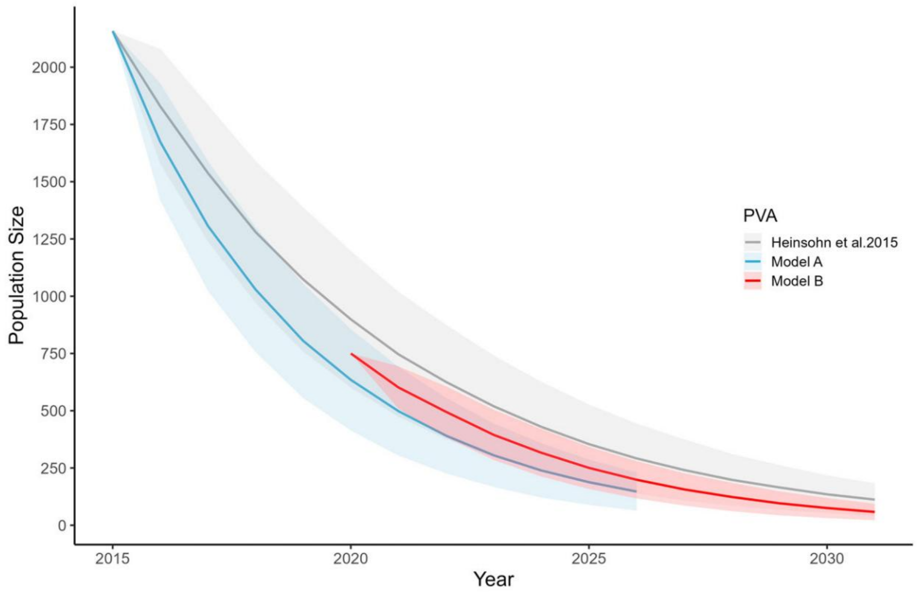

Figure 1. GREY - The original model by Heinsohn et al., 2015 – used a relatively small sample size of nests for estimating mortality. BLUE (Model A) - uses the same initial population size as in the original model but with our new parameters for mortality from 10y of monitoring, without updating the starting population size. RED (model B) - Our preferred model uses the better population estimate of 750 and our updated mortality parameters. Shaded area shows standard deviations. Models A and B are from Owens et al (2023).

Control of sugar gliders not currently feasible

Unfortunately, current options for control of sugar gliders, including protecting nesting birds and active elimination of gliders, are not feasible at scale. Nest boxes and a new device invented by our group, the 'possum-keeper-outerer', too few breeding swift parrots. One problem is that breeding females usually prefer natural hollows over nest boxes, making it challenging to protect them on the nest. Further, sugar gliders are hard to capture and control in swift parrot nesting areas.

Habitat (forest) loss is ongoing

Habitat loss is as important as the impact of sugar gliders but had not been quantified. The first quantification of land clearing and forest degradation trends in swift parrot important Breeding Areas (SPIBAs) was conducted by Giselle Owens (Owens et al. 2025). She demonstrated that >50% of the swift parrot range has experienced habitat loss historically or in the recent past. She demonstrated that forest degradation can have greater impacts than deforestation. Critically she showed that since 2014, when a major forestry policy change occurred, the rate of habitat loss has continued to increase (Figure 2). Clearly, forestry practices and land use policy need to change to conserve forests appropriately for swift parrots

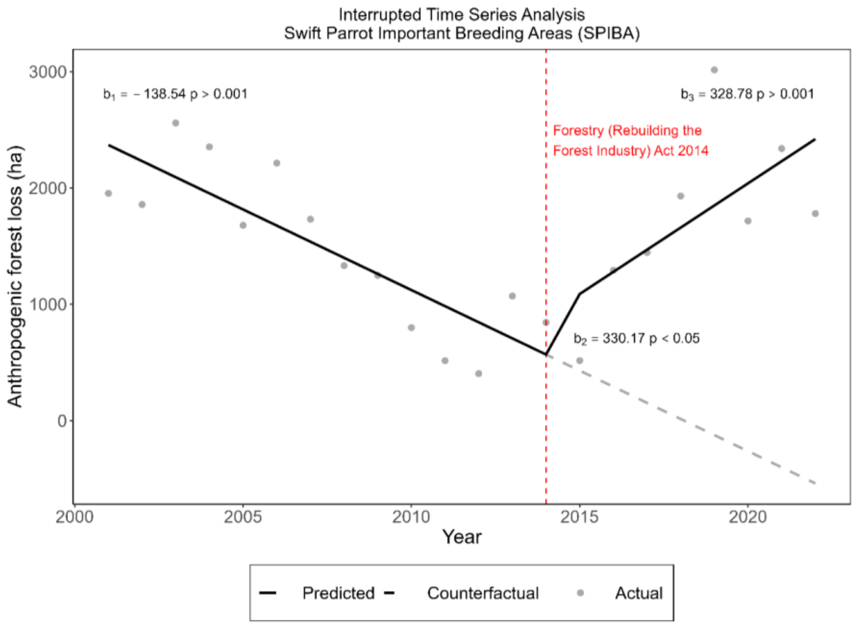

Figure 2. Rate of anthropogenic habitat loss in swift parrot important breeding areas (SPIBAs, Owens et al. 2025).

PVA of captive breeding and supplementation of wild population

Laura Bussolini has modelled scenarios of how a captive population of swift parrots might be used to supplement a wild population (Bussolini et al. preprint). She used various scenarios with a large versus small captive population to show that supplementation of the wild population 1. can only sustain low numbers in the wild (<200 in best case), and 2. does not lead to a self-sustaining population (ie population crashes again when supplementation stops), and 3. is expensive. See preprint for details.

Summary

Our research on wild swift parrots has shown that their population is declining very rapidly, to the extent that they are classified as critically endangered. Introduced sugar gliders are killing breeding females on the nest at rates too high to sustain, and loss of habitat is still increasing due to forestry operations. Solutions to both threats are elusive.

We note that captive releases alone cannot restore population growth without actions to remove the threats in the wild. They are useful for delaying extinction, avoiding extinction in very small populations (demographic & environmental stochasticity), countering Allee effects (e.g. regent honeyeaters, Heinsohn et al. 2022), and maintaining genetic variation. Fitness of captive individuals for wild release is also a major concern that must be considered very actively (e.g. regent honeyeaters, Heinsohn et al. 2022).

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The Swift Parrot Specific Needs Analysis: summary of outcomes

Rachel Pritchard, Department of Energy, Environment and Climate Action, Victoria.

This Threatened Species Framework report summarises the results of a Specific Needs Assessment (SNA) and associated Feasibility Check aimed to provide the opportunity for those involved in the recovery of the Swift Parrot and managers of its habitat, to assess the likely benefit and feasibility of different potential management scenarios, based on the current body of knowledge.

Key outcomes of the processes were:

• Participants saw the situation for the Swift Parrot is dire without more intensive management interventions.

• Participants considered that the species remains at risk of extinction, even if all the suggested management actions were to be successfully implemented.

• Participants saw the greatest risk, and the greatest opportunities to manage that risk, lying in the next 20 years.

• Participants considered that ending native timber harvesting in the species range would have an important impact on probability of persistence. The feasibility of this action was considered to be low and limited by low social and political acceptance of this action. More resources would also be required to achieve this action.

• Participants considered that effective glider control at nesting aggregations would have an important impact on probability of persistence. The feasibility of effective glider control at the scale described in the management scenarios was considered to currently be medium, with some technical and resourcing challenges still to be overcome.

• Participants considered that adding a captive-breeding and release program to the suite of management actions would provide an increase in probability of persistence, with the benefit of captive-breeding and release being greater when associated with effective threat management in a wild context. The feasibility of developing a captive breeding and release program, as described in the assessment, was considered to be medium to high, with identified feasibility challenges likely to be overcome.

• Participants considered the management of commercial beehives to have a limited impact on probability of persistence, when considered as a single action added onto the status quo. The priority and feasibility of beehive management would be informed by further research into competition for upper canopy nectar resources.

• Participants saw that the greatest opportunity for risk-reduction was likely to come from a broad management package, addressing multiple threats simultaneously, and delivered at a larger scale than current management actions. The feasibility of management actions varies, from some actions that have high to medium feasibility and can be delivered quickly when resources become available, to others requiring more enabling actions or trials before large-scale delivery.

Next steps for the recovery of the Swift Parrot include:

- Prioritising the planning, design, and initiation of an *ex-situ* conservation program;
- Identifying the enabling actions required to raise the feasibility of promising actions that have technical, resourcing, or socio-political limitations to delivery in the near term;
- Continuing to build on the effective collaboration model applied during this expert elicitation process to support timely implementation of a range of management actions;

- Consideration may also be given to adding a cost analysis to the current analysis, to provide cost-effectiveness data to inform decision making.

Reference:

Pritchard, R., and Ferraro, P. 2023. Threatened Species Framework Report: applying Specific Needs Assessment and Feasibility Check to decision making for the Swift Parrot *Lathamus discolor*, August 2023. Unpublished report to BirdLife Australia.

Captive Swift Parrot population in ZAA-accredited zoos.

Ashley Herrod, Zoos Victoria.

Background

In 2024, the Swift Parrot was assigned formal captive management by way of a Species Management Program (SMP). This was due to a combination of the species' wild conservation status (Critically Endangered), increased interest and demand for the species in zoos in Australia, and the recent completion of a captive studbook for the species. The Zoo and Aquarium Association (ZAA) leads SMPs, coordinating over 100 breeding programs at ZAA-accredited sites across Australia, New Zealand and Papua New Guinea. Managing the animals at different zoos and aquariums as one, can support genetically diverse and sustainable populations. The SMP manages animal populations for protecting threatened species, providing animals for release into the wild, conservation research and community education. Each SMP species has a Species Coordinator, who makes recommendations about the breeding and management of that species.

Captive Population

Demographics

The captive population is made up of 64 living individuals (38M and 26F) across seven institutions, represented in NSW, VIC, TAS and SA. There is a bias towards males in the population. There are a total of 421 individuals (dead and living) in the studbook.

The age distribution follows a relatively bell-shaped curve, although there is low recruitment of individuals within their first year of life due to low breeding (six offspring) in the 2023/24 breeding season. There is positive skew of individuals within their second year of life due to intake of birds from the private sector during 2024. All individuals are younger than nine years of age.

Survivorship data show a high level of mortality (50%) of birds within their first year of life. An interrogation of the studbook data shows that 75% of this mortality occurs post-fledgling and 25% mortality occurs pre-fledging when chicks are still in the nest. After age 1, there is even survivorship between the sexes until age six when there is a bias in survivorship towards males.

	Male (yrs.)	Female (yrs.)
Life expectancy	4.0	3.5
Oldest living current	8.9	7.1
Oldest living recorded	13.2	10.4

Population Trend

During the 1990s the captive Swift Parrot population remained relatively stable, followed by growth in the early 2000s and another period of stability during the remainder of that decade. From 2019 to the current time, there has been relatively rapid growth in the population due to some captive breeding but largely due to the acquisition of birds from private aviculturists (e.g., seven birds in 2019, 10 birds in 2021 and 14 birds in 2024).

Genetics

There has been a total of 31 wild founders brought into the captive population over time as injured birds requiring rehabilitation that were deemed unsuitable for release back to the wild due to health issues. It is not possible to calculate founder representation in the current captive population due to low ancestry certainty. One of the 31 wild founders is alive in the population.

Only 1.6% of ancestry certainty exists within the captive population. This is a result of:

- Unknown parentage of birds transferred into zoos from private aviculturists (59 birds);
- Unknown parentage of birds hatched at zoos due to lack of records (95 birds) and lack of uncertainty of parentage due to colony breeding with no genetic testing to determine parentage (51 birds).

Due to the low ancestry certainty, genetic software such as PMx is unable to calculate basic genetic parameters such as Genetic Diversity, Mean Kinship and Inbreeding Coefficient and hence Breeding Recommendations.

Husbandry

Swift Parrots are not a highly challenging species to breed in captivity, however they do have some aspects of their breeding ecology that require husbandry considerations. Breeding season is from August-January. Birds in their first year are sexually mature and capable of breeding however better results come from birds within their second and subsequent years even if they are prevented from breeding in their first year and do not gain experience. This suggests they are physically fitter following their first year. Vertical nest boxes are generally accepted for breeding in. If bred in a colony, individuals will select their own mate, however forced pairings in separate aviaries are also successful. Pairs will benefit however from being able to see and hear others if housed in separate aviaries.

Clutch size is between 3-5 eggs, with over 50% of nests containing four eggs. Incubation is carried out by the female and the incubation period is 19-21 days depending on the temperature inside the nest box and how frequent the female leaves the clutch unattended. Females will often double clutch if the first clutch fails or if it is successful early in the season and the weather is cool to mild.

Chicks remain in the nest for 35-40 days and are independent approximately two weeks post fledging. Fledglings are very “flighty” (easily frightened and disturbed by birds of prey or flocks of birds flying overhead) and can easily injure themselves in large aviaries where they can build up speed and collide with aviary walls. This naiveness tends to decrease with age.

Diet preferences are requirements for breeding and maintaining health and good weight are relatively established, although the species’ requirements regarding exact nutritional breakdown (particularly when it comes to nectar) are unknown. Commercial nectar mixes are available to maintain the species on in captivity.

Challenges with husbandry

During breeding, chicks can succumb to heat during hot weather when they are in the nest box; this is more relevant in the parts of Australia that experience hotter weather during December-January. Encouraging adults to breed early in the season during August-October, ensuring aviaries are well shaded, and nest boxes are well ventilated, reduces chick mortality from heat stress.

As previously mentioned, fledglings are prone to injuring themselves when housed in aviaries in which they can build up flight speed when frightened by birds of prey. Aviaries need not be oversized or have nylon netting set back from the wire mesh walls and roof to cushion the impact of collisions.

Colony breeding proves very successful for Swift Parrots which are gregarious and social, however uncertainty of parentage in colony breeding can result. Even identifying which adults have paired together may be misleading as multiple paternity within a clutch has been identified in wild Swift Parrots, and more than one male has been observed mating with a single female. Parentage can be resolved if offspring are blood-sampled, genotyped and analysed against all adults' genotypes in the colony to determine parentage. Alternatively, pairs can be housed within sight and hearing of each other to encourage breeding, but in separate aviaries so parentage is known. Aviaries can be aligned in a row or an arc formation facing north.

References

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Molecular genetic analysis of Swift Parrots (wild and captive)

George Olah
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Abstract

The swift parrot (*Lathamus discolor*) is a critically endangered species, and its wild population only breeds in Tasmania. Our previous genetic studies showed that the potential population size of the species is around 300–500 individual parrots in the wild. Our genetics studies supported earlier published results that used demographic information about swift parrots predicting that the species could be extinct by 2031. The current captive population is spread across multiple institutions. It was not established for conservation purposes, and there are significant gaps in our knowledge of the history and pedigree of that population. In addition to our existing genetic database on the wild population, here we sequenced 26 captive birds (approximately 40% of the current zoo-based captive population in Australia) and 25 museum specimens. We compared the genetics of the current and past wild populations to the captive birds to reveal important clues to aid management decisions about the potential benefits of the currently held captive populations of the species.

Introduction

Swift parrots (*Lathamus discolor*) are nomadic migrants that breed in Tasmania (including two major offshore islands) and winter on the Australian mainland. They settle in different breeding locations each year depending on the configuration of key resources across the breeding range (Webb et al., 2017). Swift parrots are critically endangered, and introduced sugar gliders (*Petaurus breviceps*) from mainland Australia are a major cause of mortality of nests and breeding female parrots (Heinsohn et al., 2015). Severe deforestation in the species' breeding range may exacerbate predation severity (Webb et al., 2018), and these factors are predicted to precipitate a 95% population decline of swift parrots within three generations (Heinsohn et al., 2015). In order to quantify the population decline in the wild, we conducted a series of genetic analyses, which – until now – did not include the captive breeding population.

Our first population genetics analysis included 109 samples of swift parrots obtained over six years from across their breeding range in Tasmania (Stojanovic et al., 2018). Importantly, we only selected one random sample from siblings of each nest site included into the study to avoid violation of Hardy–Weinberg Equilibrium (HWE) while testing for overall population genetics structure. We used seven microsatellite markers to construct genotypes. Our multifaceted analysis – which included robust tests for HWE, and multiple tests for population genetics structure, including AMOVA, G-statistics, Structure analysis, and Mantel tests – found congruent and highly consistent results. No significant deviation from HWE expectations was detected either at the species or regional levels (predator-free offshore islands vs. mainland Tasmania), consistent with a very low average inbreeding coefficient ($F'_{SR} = 0.007$). We found no evidence for any significant population genetics structure across geographically-defined regions, or among populations defined by space or time. Neither was any isolation-by-distance detected at the individual genotype level. We concluded that the entire species exists in a single, panmictic conservation unit.

In another study, we incorporated genotypes of all siblings into the analysis (371 nestlings from 85 nests), using the same microsatellite markers (Heinsohn et al., 2019). For classification of relatedness, we used ML-RELATE and COLONY 2 software. We found that 50.5% of the nests had shared paternity, although the birds remained socially monogamous. It is likely that the consistently male-biased adult sex ratio (≥73% male) further promotes this form of mating in the species. Rates of shared paternity were higher when swift parrots bred in regions with higher predation on nesting females, and hence with more (within season) male-biased adult sex ratios. We concluded that this could lead to changes in their mating system and to negative impacts on both individual fitness and long-term population viability.

Using the same microsatellite loci, we constructed genotypes for 310 swift parrot nestlings and 31 adults, collected between 2010 and 2015. We used three genetic approaches to estimate effective population size (N_e) of the species. Based on all samples, we revealed small contemporary N_e estimates across methods (range: 44–140), supporting the need to urgently address threatening processes (Olah et al., 2021). In 2010, a survey census estimated a total of 2,158 birds, including immatures, and based on this information the total population was assessed to comprise 2,000 mature birds (Garnett et al., 2011). BirdLife International estimated the population size as between 1,000–2,500 individuals in 2020.

Using existing life-history data of swift parrots, we interpolated a minimum potential contemporary population size between 60 and 338 individual swift parrots across methods (Olah et al., 2021). This was considerably lower than the previous estimates derived from expert elicitation (Garnett et al., 2011) and accorded with modelled estimates of extinction risk predicting over 80% population decline since 2015 within three generations (Heinsohn et al., 2015). We also sequenced the same samples using next generation sequencing technology and generated 3,761 SNP loci. We sequenced 457 additional samples collected between 2016 and 2019. Based on the entire cohort, estimates of N_e were comparable between markers when the same individuals were considered. The extended SNP dataset estimated the contemporary population size to be 498 (469–530 95% CI) adult individuals (Olah et al., 2024).

Swift parrots have been kept in zoos and private collections across Australia and internationally for several decades. The current zoo population was not established for conservation purposes, rather, swift parrots have been bred and housed in zoos primarily for display and occasionally for rehabilitation. The current captive population of swift parrots within zoos has a mixed origin and has not had consistent management through a studbook. Methods of breeding have varied between institutions and included flock breeding, hence their parentage is not certain. Given its purpose and history, the current zoo population has not been managed to retain genetic diversity, and the history of movement from the wild, and between zoos is not well documented. In 2024, formal management of the swift parrot zoo population commenced by way of a Zoo and Aquarium Association (ZAA) Species Management Program, so the species will now be managed by a Species Coordinator, using a studbook and genetic software to make annual breeding recommendations and maintain genetic diversity. It is not yet clear whether, or to what extent, this current captive population can contribute to a conservation breeding program.

The aims of this current genetic analysis are to:

- provide an initial assessment of the genetic diversity of the captive population of swift parrots in relation to the wild population, to assess its potential value for contributing to a conservation breeding program for the species;
- inform management of the current zoo population of swift parrots in the short term by providing relatedness or mean kinship data on individuals sampled and genotyped in the analysis;
- based on the existing wild population, estimate the number of founders required to maximise genetic diversity in a conservation breeding program.

Materials and Methods

Between 2010 and 2023, we collected and sequenced 857 genetic samples from the wild populations of swift parrots (Olah et al., 2024). In this report, we analysed an additional 66 samples, consisting of 26 captive individuals (one with duplicated samples; Table 1), 25 museum specimens, and 14 freshly collected samples from the wild population (in 2024). Blood and tissue samples from captive birds were collected between 2020 and 2023 in Adelaide Zoo (n = 16), Taronga Zoo (n = 5), Bonorong (n = 4), and Moonlit Sanctuary (n = 2), representing approximately 40% of the current zoo-based captive population in Australia that is registered on the ZIMS database (n = 64 as of November 2024). There are also a large number (>200) of birds in private collections that are not sampled here. Toepad samples from 100-year-old museum specimens were provided by the Tasmanian Museum and Art Gallery.

We provided all samples to Diversity Arrays Technology Pty. Ltd. (DArT; Canberra, Australia) for DNA extraction, molecular sexing, and SNP genotyping using DartSeq™ protocols, combining complexity reduction based on restriction fragments from enzyme pairs, with next generation sequencing technology (Jaccoud et al., 2001; Kilian et al., 2012). SNPs from all samples were called using a recently published genome assembly for the species (GenBank GCA_039999165.1). We filtered SNPs using the '*dartR'* package in R (Gruber et al., 2018; R Core Team, 2025), based on a 0.99 reproducibility threshold, minimum minor allele frequency of 5%, retaining one variant per sequence tag, and a maximum of 5% missing data for variants and 10% for individuals. We also removed a duplicated sample (#LDis067) from the same captive individual.

We used GenAlEx 6.5 (Peakall & Smouse, 2012) to estimate basic population genetics metrics. We used the 'fs.dosage' function of the 'hierfstat' package of R (Goudet & Jombart, 2022) to estimate Wright's F-statistics of the three cohorts.

We visualised the relative position of individual samples grouped by *a priori* cohorts (Table S1) in the genetic space by conducting a principal component analysis (PCA) by the 'glPca' function of the 'adegenet' package in R (Jombart & Ahmed, 2011). We also conducted a discriminant analysis of principal components (DAPC) using the 'adegenet' package in R (Jombart & Ahmed, 2011). This approach is sensitive to fine genetic differences among populations and identifies clusters where the within-group component of variation is minimized compared to between-group variation.

We followed our earlier approach (Olah et al., 2021) and used the linkage disequilibrium (LD) method (Waples, 2006, 2024; Waples & Do, 2010) implemented in the software NeEstimator v2.1 (Do et al., 2014) to estimate the effective population size (N_e) of the captive swift parrot population of the Adelaide Zoo. Given the high inbreeding expected in the Adelaide population, we also repeated the PCA and DAPC tests after excluding these birds.

We used the 'Sequoia' package in R (Huisman, 2017) with the available information on the sex and relationships of the subset of captive birds still alive at the time of the analysis (n = 23), to reconstruct pedigree by identifying all possible first-, second-, and third-order relationships based on likelihood analysis. This method focuses on well-supported and high-confidence relationships, where there is clear genetic evidence to distinguish the relationship type (e.g., parent-offspring vs. full-sibling), and it can handle multi-generational, overlapping, and inbred pedigrees. We further searched for putative relatives (e.g., full siblings and half siblings) conditional on the reconstructed pedigree.

We used the Weir and Goudet (2017) beta estimator with the 'beta.dosage' function of the 'hierfstat' package of R (Goudet & Jombart, 2022) to calculate pairwise kinships (coancestries) and individual inbreeding coefficients. We visualized kinship values with the 'heatmap' function in R (R Core Team, 2025). We also calculated pairwise genetic distance values with GenAlEx 6.5 (Peakall & Smouse, 2012).

We conducted computer simulations in R (R Core Team, 2025), to estimate the minimum number of wild individuals needed in a founder population, in order to capture a high genetic diversity. We used genetic data of 841 individuals from the wild, including siblings of the same parents, and calculated the total heterozygosity in the entire population. From these samples, we randomly selected several individuals (from 1 to 60) and calculated heterozygosity values for each of the sub-sampled cohorts. We repeated the random sampling and heterozygosity estimations 1,000 times.

Results

After the filtering process, 6,301 SNP loci and 890 samples were retained across the three cohorts ($n_{captive}$ = 25, n_{museum} = 24, n_{wild} = 841). The wild cohort was not filtered by unrelated siblings, and it exhibited the highest level of polymorphic loci (100%), while museum samples showed 98.8% and the captive population 84.6%. Observed (H_O) and expected heterozygosity (H_E) estimates were highest for the museum specimens (H_O = 0.274, H_E = 0.285), comparable to the wild population (H_O = 0.259, H_E = 0.283), while the captive cohort exhibited the lowest values (H_O = 0.2, H_E = 0.229).

As expected, both the individual inbreeding coefficient within each cohort (F_{IS}) and the fixation index among the cohorts (F_{ST}) were highest in the captive population (F_{IS} = 0.142; F_{ST} = 0.185), while they were much lower in the wild population (F_{IS} = 0.084; F_{ST} = 0.007) and lowest in the museum cohort (F_{IS} = 0.056; F_{ST} = -0.02).

The PCA showed that part of the captive cohort (16 samples from Adelaide Zoo) is separated from the rest of the samples (Fig. 1) based on the first principal component (Table 1).

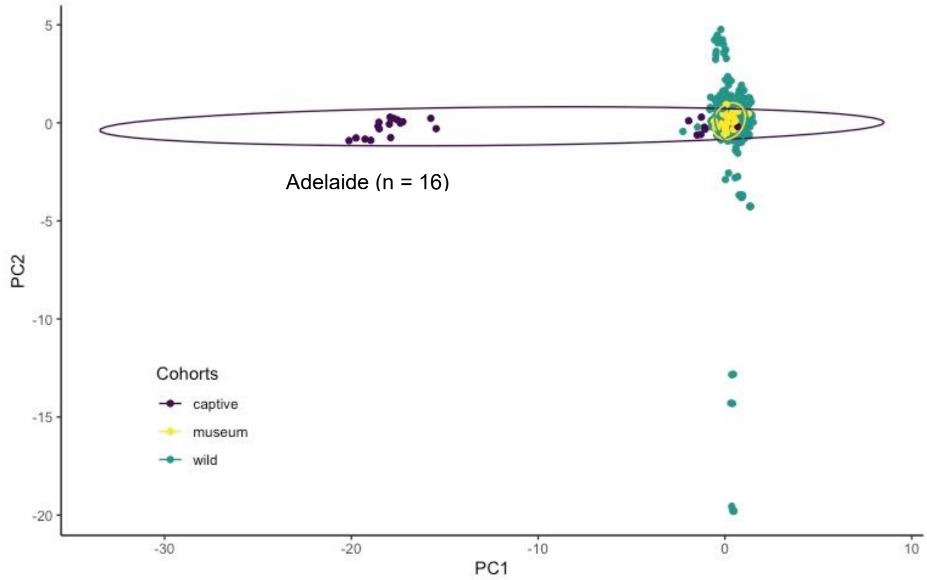


Figure 1. Principal component analysis (PCA) of 890 swift parrot genotypes.

The DAPC identified two main cohorts (k) in the genetic data (Fig. 2), showing a clear increase of Bayesian information criterion (BIC) until k = 2 clusters, after which BIC increased.

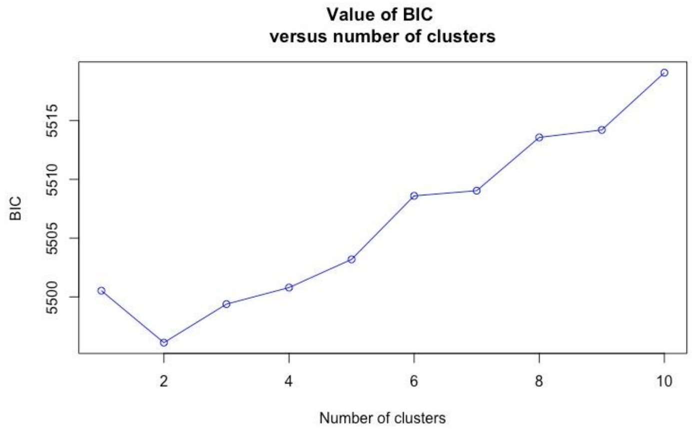


Figure 2. Bayesian information criterion (BIC) values for number of clusters (k_{max} = 10) in a discriminant analysis of principal components (DAPC).

Using the first discriminant function in DAPC, the wild and museum samples clearly form a single cluster, and the Adelaide Zoo samples from the captive cohort separate out to a second cluster (Fig. 3).

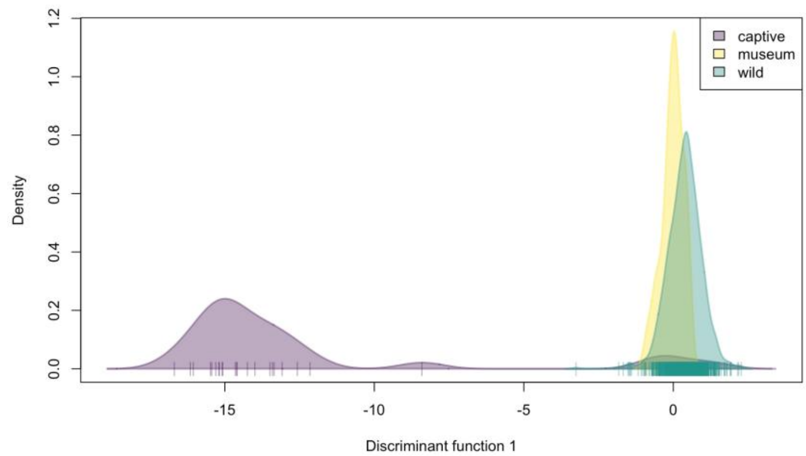


Figure 3. Grouping of 890 swift parrot samples on discriminant analysis of principal components (DAPC) using the first discriminant function based on 6,301 SNPs. Colours show *a priori* cohorts of sample origin (captive, museum, wild).

The closed Adelaide Zoo population only retained 79% of the polymorphic loci of the wild population, and their estimated N_e was 3.5 (1.8–3.1 95% CI), compared to N_e = 314 (296–334 95% CI) of the wild population.

Once we excluded the Adelaide population, the same filtering retained 6,274 SNP loci and 874 samples. Here, the wild cohort exhibited the highest level of polymorphic loci (100%), while museum samples showed 97.4% and the captive population 82.7%. Observed (H_O) and expected heterozygosity (H_E) estimates were highest for the museum specimens (H_O = 0.269, H_E = 0.274), comparable to the wild population (H_O = 0.261, H_E = 0.285), while the captive cohort exhibited the lowest values (H_O = 0.259, H_E = 0.259).

The updated PCA showed that the captive and museum cohorts clustered well with the wild samples (Fig. 4) based on the first principal component.

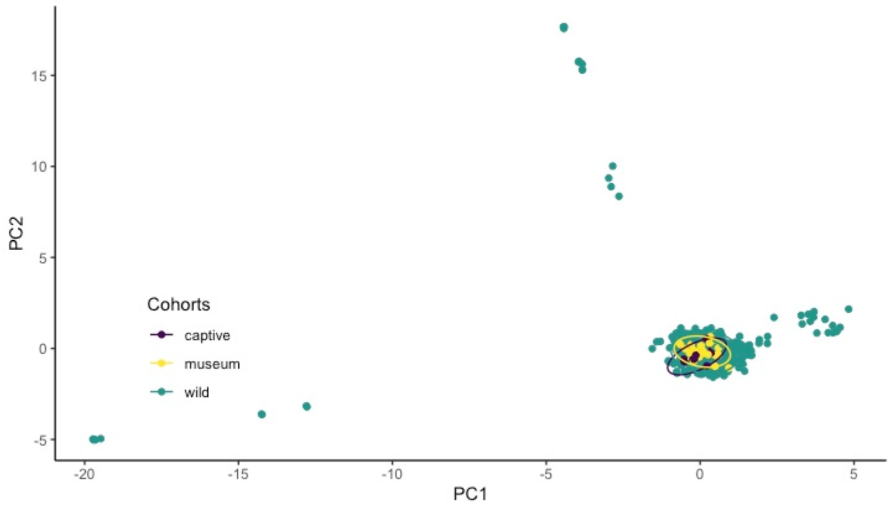


Figure 4. Principal component analysis (PCA) of 874 swift parrot genotypes (excluding the Adelaide population).

The updated DAPC could not identify more than one cohort, but the separation of some of the captive birds from the rest of the samples were clearly visible on the first discriminant function of the DAPC (Fig. 5). These birds are from Taronga Zoo (LDis044, LDis043, LDis063, LDis042) and Moonlit Sanctuary (LDis027 and LDis038). The birds from Bonorong (LDis028, LDis040, LDis039) cluster within the wild samples (Table 1).

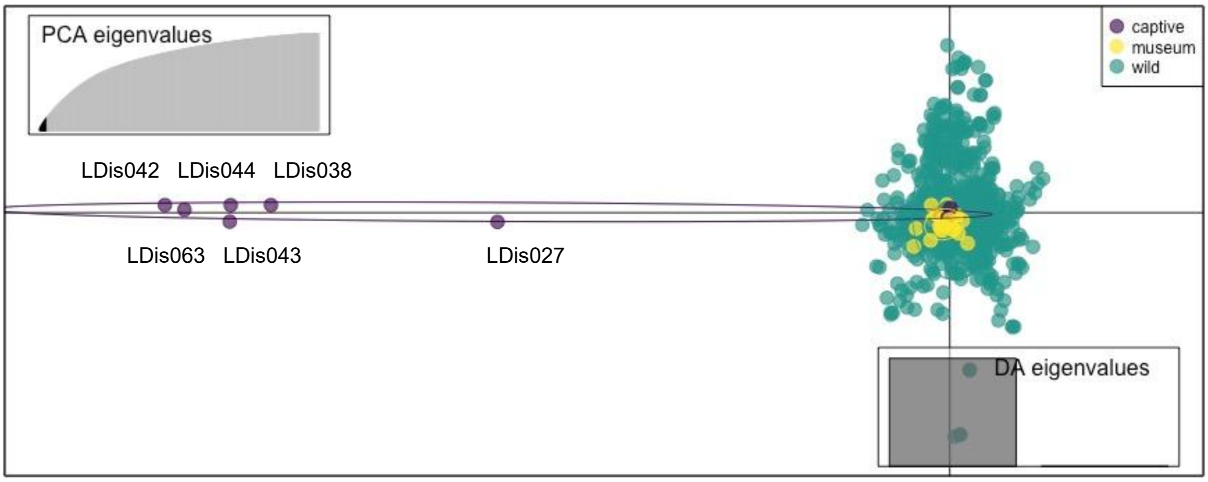
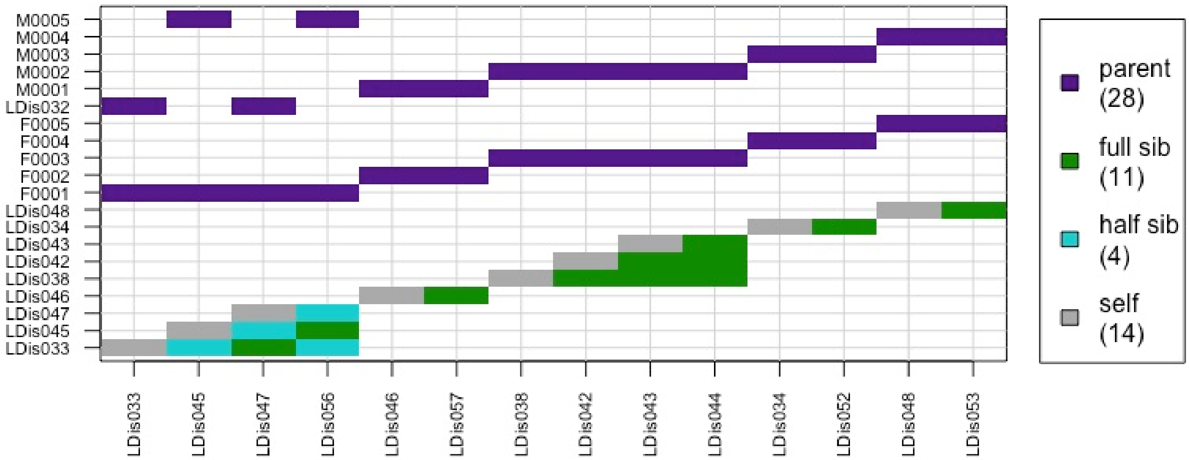


Figure 5. Grouping of 874 swift parrot samples on discriminant analysis of principal components (DAPC) using the first discriminant function based on 6,274 SNPs. Colours show *a priori* cohorts of sample origin (captive, museum, wild).

After excluding dead birds from the captive cohort, the filtering retained 3,816 SNP loci and 23 samples. The reconstructed pedigree identified many putative relatives, including parent-offspring relationships, full- and half siblings, full avuncular, and 2nd degree relationships (Fig. 6).

(A)



(B)

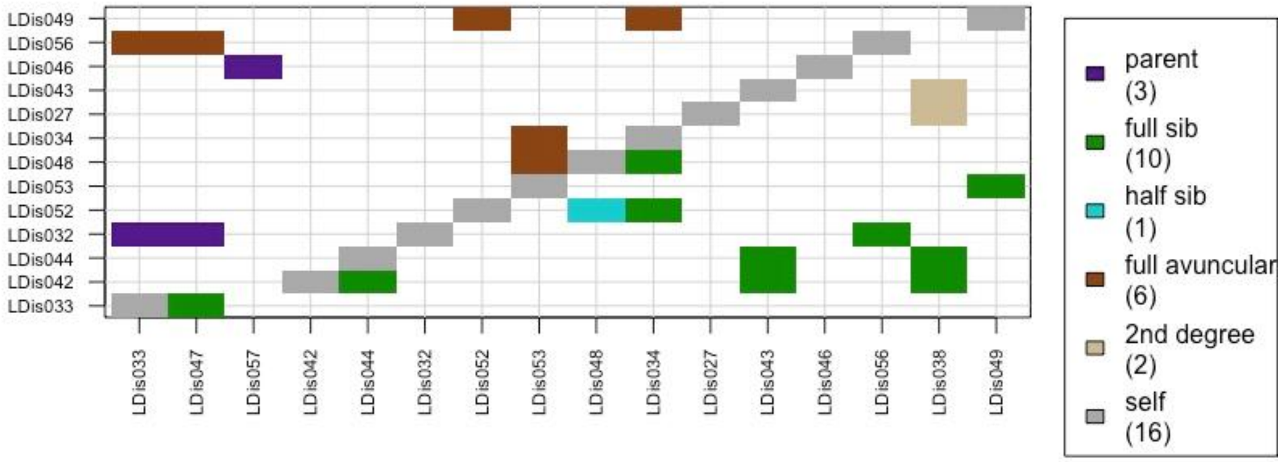


Figure 6. Reconstructed pedigree based on genetic data with assigned putative relatives (A) and non-assigned likely pairs of relatives (B) among the live swift parrots of the captive cohort, excluding unrelated contrasts.

The individual inbreeding coefficients are presented in Table 1 and the pairwise kinship values in Table 2, with a heatmap representation in Fig. 7.

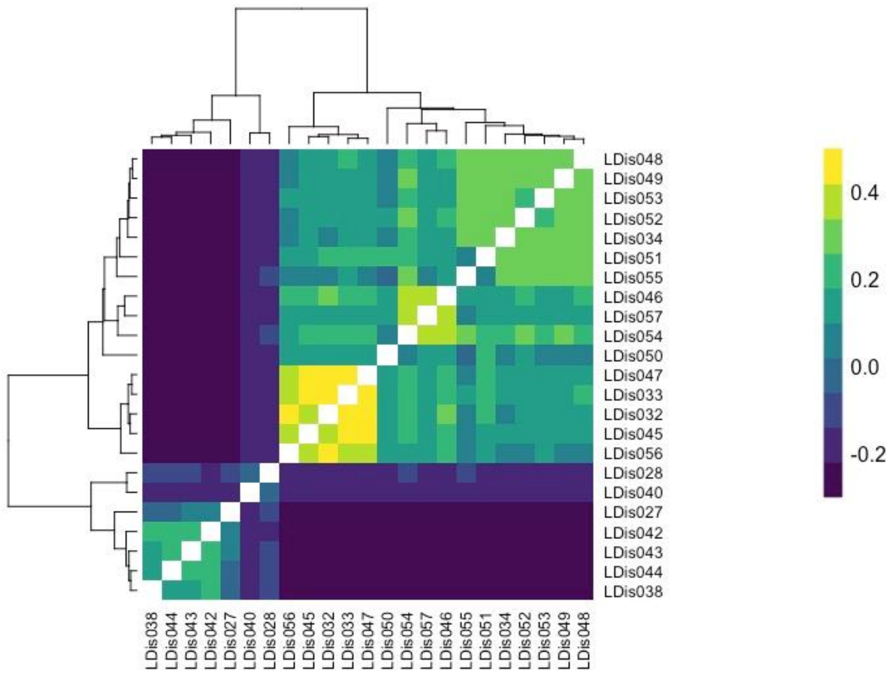


Figure 7. Pairwise kinship estimates plotted using hierarchical clustering of individuals.

We have found that a minimum of 11 individual swift parrots from the wild population would retain 95% of their total heterozygosity (Fig. 8A), while 28 individuals would represent 98% of their genetic diversity (Fig. 8B).

(A) (B)

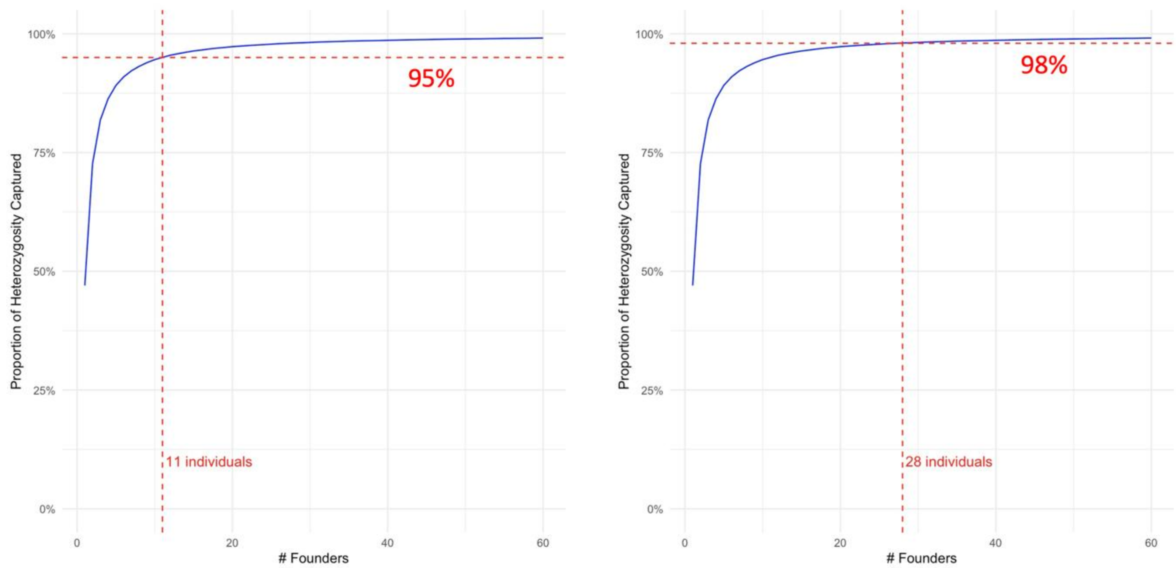


Figure 8. Proportion of total heterozygosity captured of the wild swift parrot population, based on 1,000 simulations on empirical data.

Discussion

Based on the initial assessment of the genetic diversity of the captive swift parrot individuals tested here, they represent an already reduced diversity when compared to the past museum samples or the current wild population. However, this reduction of genetic diversity is not equal in the tested captive populations. The highest loss of genetic diversity is presented in the Adelaide Zoo population (Figs. 1–3, Table 1). It is important to note that the birds at Adelaide Zoo represent 67% of the sample, however they have been bred as a closed flock since 2009. When the previous studbook was ended in 2009, Adelaide Zoo retained the remaining breeding flock in the region. The decision was made to continue breeding with a closed flock to maintain husbandry skills and improve *ex situ* knowledge, and to keep animals for potential research. The estimated effective population size of this population showed that the loss of genetic diversity equals to 14.3% in a single generation, compared to the 0.2% / generation rate in the wild. This highlights the need of a close management when establishing a new founder population for conservation breeding or rewilding programs. The Adelaide Zoo population of swift parrots should not be considered to such a program.

When the Adelaide Zoo population was excluded from the analysis, the remaining captive cohort better clustered with the wild birds in a PCA (Fig. 4) but still exhibited the lowest values of genetic diversity. Upon closer examination in a DAPC, a few of these captive birds from Bonorong clustered the closest with the wild and museum cohorts (Fig. 5). Based on available provenance information of these birds, some of them (LDis028, LDis039, LDis040) seem the be rescued wild individuals (Table 1), and hence considered when establishing a new founder population for conservation breeding.

When considering to establish a new founder population from the wild panmictic population of swift parrots, the main goal must be to retain the species as a dynamic evolutionary entity for subsequent release (Frankham et al., 2010). Since the founding process strongly affects the conservation value of the captive population, a well-designed plan needs to be put in place before any actions. A population size bottleneck is inevitable at the foundation, which can lead to loss of genetic diversity and inbreeding. The current population of captive swift parrots has not been managed to maximise genetic diversity, rather it has been maintained as a population of birds for display in zoos, so it is unsurprising that loss of genetic diversity and evidence of inbreeding has been observed in this sample. In establishing an *ex situ* population for conservation purposes, the founder population needs to represent a high allelic diversity of the wild population.

For all captive swift parrots currently alive, we calculated individual inbreeding coefficients (F) that quantify the probability that an individual's alleles at a locus are identical-by-descent (IBD) due to shared ancestry. F measures the degree of homozygosity caused by inbreeding and indicates how much genetic diversity an individual has lost due to mating between relatives. This measure facilitates decisions to minimize future inbreeding by pairing individuals with low F values (Table 1). This will also help to exclude birds (e.g. the Adelaide Zoo population) from the new breeding cohort. We also calculated pairwise kinship values for the same cohort of birds (Table 2, Fig. 7), which is a more precise tool for managing genetic diversity, as it helps identify individuals likely to contribute unique alleles to the population. Selecting breeders by minimizing mean kinship ensures that individuals with rare alleles are prioritized, reducing the loss of genetic diversity over generations.

Based on our simulations, 11–28 randomly selected wild individuals of swift parrots (with 1:1 sex ratio of M:F) would possibly retain 95–98% of the current genetic diversity in the wild (Fig. 8). These estimates needed to be taken with caution, as only a proportion of wild-caught individuals will breed successfully in captivity and transmit their alleles to the next generation. In this regard, these numbers rather reflect the effective population size of a founder population.

IUCN guidelines require captive populations to maintain 90% of genetic diversity for 100 years in captivity (Frankham et al., 2010). Genetic analysis of the founder population and their offsprings can help to design mating schedules to minimize inbreeding and loss of genetic diversity, for instance by breeding individuals with the lowest kinship values (Table 2). Maximising N_e should also be an important aim by equalising sex ratio (maintaining equal number of males and females in the breeding population), family size (where breeders contribute equal number of offsprings to the next generation), and generations in captivity (maintaining the same lifespan among individuals). Furthermore, partially fragmented population structure, where breeders are managed in subpopulations and offsprings rotated to a new subpopulation regularly, can reduce genetic adaptation to captivity (Frankham et al., 2010).

If captive birds with lower genetic diversity were included into the founder population, they would reduce the retention of total genetic diversity, and more birds should be considered in the founder cohort to reach the same results. Further simulations including captive birds could help to quantify these measures. A limitation of the current genetic dataset is that only about 40% of the captive birds were sampled for this analysis. Most of these were from the closed and inbred population of the Adelaide Zoo. To best consider the genetic contribution of all available swift parrots in captivity to a new breeding population before birds are taken from the wild, all available swift parrots should be sampled from zoos and the avicultural industry.

Table 1. Swift parrots (*Lathamus discolor*) samples from the captive population used in this study. Presented are the individual inbreeding coefficients (F) based on 3,816 SNPs, the coordinates of the first principal component (PC1) from the principal component analysis based on 6,301 SNPs, and the coordinates of the first discriminant function (DAPC1) from the discriminant analysis of principal components based on 6,274 SNPs.

GEN Code	Source	Date collected	Sample type	Bird_ID_local	Bird_ID_GANS	Sex	Alive/Dead	Note	Birth year	F	PC1	DAPC1
LDis032	Adelaide Zoo	20/04/2022	Blood on FTA	C00294	DTD20-20495	M	Alive		2020	0.201	-19.5	NA
LDis033	Adelaide Zoo	20/04/2022	Blood on FTA	C10441	DTD21-21504	F	Alive		2021	0.334	-20.4	NA
LDis034	Adelaide Zoo	20/04/2022	Blood on FTA	C10454	DTD21-21514	M	Alive		2021	0.067	-17.2	NA
LDis045	Adelaide Zoo	20/04/2022	Blood on FTA	B70416	DTD17-17396	F	Alive		2017	0.093	-19.0	NA
LDis046	Adelaide Zoo	20/04/2022	Blood on FTA	B70417	DTD17-17404	M	Alive		2017	0.174	-18.7	NA
LDis047	Adelaide Zoo	20/04/2022	Blood on FTA	C10442	DTD21-21505	F	Alive		2021	0.367	-19.7	NA
LDis048	Adelaide Zoo	20/04/2022	Blood on FTA	C10456	DTD21-21517	M	Alive		2021	0.136	-18.1	NA
LDis049	Adelaide Zoo	20/04/2022	Blood on FTA	C00397	DTD20-20681	F	Alive		2020	0.112	-17.9	NA
LDis050	Adelaide Zoo	22/02/2022	Blood on FTA	B50629	DTD15-15690	M	Alive		2015	0.036	-15.3	NA
LDis051	Adelaide Zoo	22/02/2022	Blood on FTA	B60518	DTD16-16658	M	Alive		2016	0.125	-18.7	NA
LDis052	Adelaide Zoo	20/04/2022	Blood on FTA	C10455	DTD21-21516	M	Alive		2021	0.149	-18.0	NA
LDis053	Adelaide Zoo	20/04/2022	Blood on FTA	C00398	DTD20-20688	M	Alive		2020	0.147	-17.7	NA
LDis054	Adelaide Zoo	20/04/2022	Blood on FTA	B20547	DTD12-01201	M	Alive		2012	0.225	-18.6	NA
LDis055	Adelaide Zoo	20/04/2022	Blood on FTA	B50540	DTD15-15619	F	Alive		2015	-0.073	-15.9	NA

LDis056	Adelaide Zoo	20/04/2022	Blood on FTA	C00285	DTD20-20479	F	Alive		2020	0.261	-17.8	NA
LDis057	Adelaide Zoo	20/04/2022	Blood on FTA	B80366	DTD18-18372	F	Alive		2018	0.093	-17.0	NA
LDis067	Bonorong	10/09/2022	Toepad (from whole toe)	BON4499 - Pickle	NA	F	Dead		unknown	NA	NA	NA
LDis028	Bonorong	24/02/2021	Blood on FTA	Taylor Swift Parrot	SYZ21-02447	unknown	Alive	wild origin	unknown	0.100	-0.1	0.0
LDis040	Bonorong	28/10/2022	Blood on FTA	BON4663	NA	unknown	Alive	wild origin	unknown	0.016	0.8	0.0
LDis039	Bonorong	10/09/2022	Blood on FTA	BON4499 - Pickle	NA	F	Dead	wild origin	unknown	NA	-0.1	-0.2
LDis027	Moonlit Sanctuary	23/08/2022	Blood on FTA	B90068	NA	F	Alive		unknown	0.050	-1.1	-10.3
LDis038	Moonlit Sanctuary	23/08/2023	Blood on FTA	B90070	NA	M	Alive		unknown	-0.023	-0.8	-15.4
LDis064	Taronga Zoo	27/05/2020	Blood in EtOH	20B160	WYR20-16043-IA	unknown	Alive		unknown	NA	NA	NA
LDis044	Taronga Zoo	17/01/2022	Blood on FTA	B90613	WYR19-15636	F	Alive		2019	0.026	-0.7	-16.3
LDis043	Taronga Zoo	21/03/2021	Blood on FTA	B90611 T20502	WYR19-15634	M	Alive		2019	0.110	-1.5	-16.4
LDis063	Taronga Zoo		Toepad (from whole toe)	B90304	WYR19-15186	M	Dead		2018	NA	-0.6	-17.4
LDis042	Taronga Zoo	23/03/2022	Blood on FTA	B90612	WYR19-15635	F	Alive		2019	0.128	-1.3	-17.8

Table 2. Pairwise values of kinship (above diagonal) and genetic distance (below diagonal) among the live swift parrots in captivity tested in this study. Find the identification of samples in Table 1.

	LDis051	LDis045	LDis042	LDis057	LDis032	LDis044	LDis055	LDis047	LDis052	LDis043	LDis033	LDis040	LDis050	LDis056	LDis028	LDis027	LDis053	LDis054	LDis048	LDis046	LDis038	LDis049	LDis034
LDis051	-	0.175	-0.252	0.132	0.199	-0.263	0.072	0.179	0.308	-0.229	0.202	-0.190	0.185	0.128	-0.155	-0.220	0.295	0.183	0.315	0.175	-0.231	0.299	0.309
LDis045	2020	-	-0.256	0.168	0.361	-0.251	0.098	0.440	0.147	-0.233	0.433	-0.162	0.153	0.339	-0.140	-0.221	0.146	0.210	0.143	0.218	-0.253	0.131	0.106
LDis042	4291	4341	-	-0.216	-0.236	0.229	-0.243	-0.244	-0.245	0.230	-0.258	-0.172	-0.251	-0.216	-0.136	0.048	-0.236	-0.229	-0.237	-0.242	0.187	-0.244	-0.253
LDis057	2207	2065	4050	-	0.171	-0.237	0.097	0.165	0.142	-0.204	0.172	-0.187	0.151	0.168	-0.138	-0.197	0.107	0.338	0.126	0.371	-0.244	0.133	0.125
LDis032	2056	1140	4379	2149	-	-0.236	0.072	0.466	0.144	-0.215	0.469	-0.169	0.144	0.411	-0.132	-0.222	0.161	0.211	0.152	0.248	-0.245	0.143	0.098
LDis044	4294	4234	1617	4107	4318	-	-0.222	-0.243	-0.238	0.188	-0.255	-0.147	-0.237	-0.225	-0.117	0.002	-0.233	-0.241	-0.245	-0.241	0.120	-0.245	-0.247
LDis055	2267	2151	3908	2178	2417	3799	-	0.097	0.280	-0.223	0.106	-0.148	-0.019	0.042	-0.116	-0.208	0.274	0.259	0.268	0.158	-0.239	0.260	0.255
LDis047	2399	945	4656	2454	975	4589	2540	-	0.170	-0.226	0.441	-0.172	0.159	0.368	-0.136	-0.237	0.139	0.216	0.163	0.227	-0.251	0.152	0.108
LDis052	1388	2266	4235	2285	2400	4164	1271	2535	-	-0.221	0.154	-0.161	0.134	0.077	-0.132	-0.209	0.216	0.260	0.294	0.183	-0.229	0.269	0.314
LDis043	4159	4157	1710	4010	4223	1815	3828	4506	4129	-	-0.246	-0.166	-0.219	-0.204	-0.115	0.053	-0.219	-0.204	-0.214	-0.226	0.105	-0.222	-0.242
LDis033	2196	936	4693	2359	910	4620	2475	1303	2588	4547	-	-0.181	0.135	0.339	-0.134	-0.234	0.160	0.229	0.186	0.238	-0.268	0.156	0.132
LDis040	3781	3665	3724	3692	3835	3555	3260	4066	3695	3630	4109	-	-0.188	-0.174	-0.041	-0.140	-0.164	-0.168	-0.162	-0.178	-0.149	-0.161	-0.168
LDis050	1917	2061	4180	2088	2305	4075	2672	2442	2237	4018	2501	3694	-	0.120	-0.160	-0.224	0.058	0.059	0.075	0.125	-0.244	0.094	0.086
LDis056	2541	1387	4360	2266	1157	4335	2682	1590	2891	4266	1719	3894	2530	-	-0.137	-0.203	0.113	0.140	0.091	0.219	-0.223	0.089	0.076
LDis028	3683	3595	3600	3586	3709	3417	3248	3936	3637	3476	3971	2996	3632	3790	-	-0.112	-0.137	-0.121	-0.144	-0.136	-0.125	-0.129	-0.138
LDis027	4039	4025	2614	3854	4177	2771	3688	4478	4027	2520	4411	3432	3930	4164	3342	-	-0.202	-0.215	-0.201	-0.218	0.012	-0.227	-0.217
LDis053	1439	2253	4320	2494	2351	4243	1314	2696	1967	4204	2539	3738	2632	2726	3724	4066	-	0.189	0.304	0.160	-0.234	0.291	0.266
LDis054	2092	1968	4299	1321	2072	4318	1503	2321	1782	4167	2206	3783	2755	2569	3657	4143	2213	-	0.218	0.365	-0.228	0.246	0.204
LDis048	1337	2239	4244	2386	2349	4273	1332	2552	1563	4124	2333	3686	2568	2760	3718	3976	1486	1999	-	0.185	-0.235	0.249	0.272
LDis046	2155	1897	4346	1108	1865	4283	1948	2234	2197	4258	2095	3832	2376	2108	3682	4104	2320	1289	2194	-	-0.231	0.173	0.155
LDis038	4078	4122	1769	4057	4242	2030	3789	4473	4040	2177	4546	3407	3967	4229	3323	2673	4203	4160	4145	4147	-	-0.236	-0.243
LDis049	1381	2205	4258	2242	2295	4211	1316	2500	1611	4124	2427	3650	2378	2692	3610	4076	1516	1767	1724	2150	4101	-	0.255
LDis034	1261	2375	4236	2252	2569	4157	1324	2776	1413	4186	2601	3658	2422	2796	3554	3982	1544	2003	1554	2226	4061	1610	-

Acknowledgements

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Appendix IV. *Ex situ* genetic management strategies

Caroline Lees (IUCN SSC CPSG)

The following two genetic management strategies were discussed as options at the meeting. More detailed information is provided here to reduce duplication in the body of the document.

Management by Mean Kinship

Management by Mean Kinship (Lacy et al. 1995) is the genetic management strategy most commonly practiced in the international zoo community. Its application relies on the analysis of pedigree data maintained in a studbook. As a minimum it requires the following information (or informed estimate) for each bird: an individual identifier, parental ID, sex, birth and death dates, and current location. Management by Mean Kinship using PMx (Lacy et al. 2012) combines demographic and genetic analysis to identify both the required number of pairings a population requires to meet population targets, and a ranked list of the most valuable genetic pairings. Using the tools within PMx managers are able to:

1) Ensure the number of animals to be bred is calculated to:

- Maintain stable age-structure;
- Prevent excess production;
- Achieve population size targets as quickly as possible or where required, to generate animals for release.

2) Determine pairings to maximise gene diversity retention and minimise the rate of accumulation of inbreeding by:

- Prioritising pairings between animals with low and similar mean kinship values relative to the population average;
- Minimising pairings between close relatives.

3) Select genetically and demographically suitable cohorts for release aimed at preserving the genetic and demographic potential of the managed source population until it is no longer needed as well as ensuring a genetically diverse release population by:

- Initially releasing birds from genetic lines that are sufficiently well represented in the captive population (i.e. with higher mean kinship values);
- Retaining in the captive population enough breeders, with an age structure that will allow for smooth succession of those breeders;
- Releasing over time a population of birds carrying >90% wild source gene diversity.

Management by Mean Kinship works best where there is 100% known pedigree and managers have a high degree of control over pairings. It is therefore particularly suited to pair-wise breeders. For social species that breed most successfully in groups, where it can be difficult or counter-productive to control pairings and where accurate parentage can be difficult to track, additional or alternative strategies can be applied.

MateRx

Within the PMx tool suite, MateRx is a tool that ranks potential pairing combinations in the population on a scale of 1-7 where 1 are high value pairings and this can be used successfully with flock or colony breeders where promoting natural behaviour means there may be only limited opportunities to promote high value pairings but at least a reasonable chance of disrupting damaging ones. MateRx also relies on accurate pedigree information.

Maximal Avoidance of Inbreeding

Maximal Avoidance of Inbreeding (MAI) schemes (e.g. Princee 1995) are another option for supporting group-living species to breed in natural social groups, while still working towards good gene diversity retention and low inbreeding accumulation. MAI works by separating the founder generation into a number of discrete groups and then managing a systematic rotation of one sex, each generation, to minimise within-group inbreeding accumulation. Provided that animals within groups contribute evenly to the breeding pool this can also retain gene diversity effectively. Figure 1 describes a scheme beginning with eight separate groups in which the starting male and female lines are each denoted by a letter. As the scheme progresses the groups become increasingly inter-related. While inbreeding accumulation is inevitable in a small, closed population, this approach minimises the rate at which it accumulates.

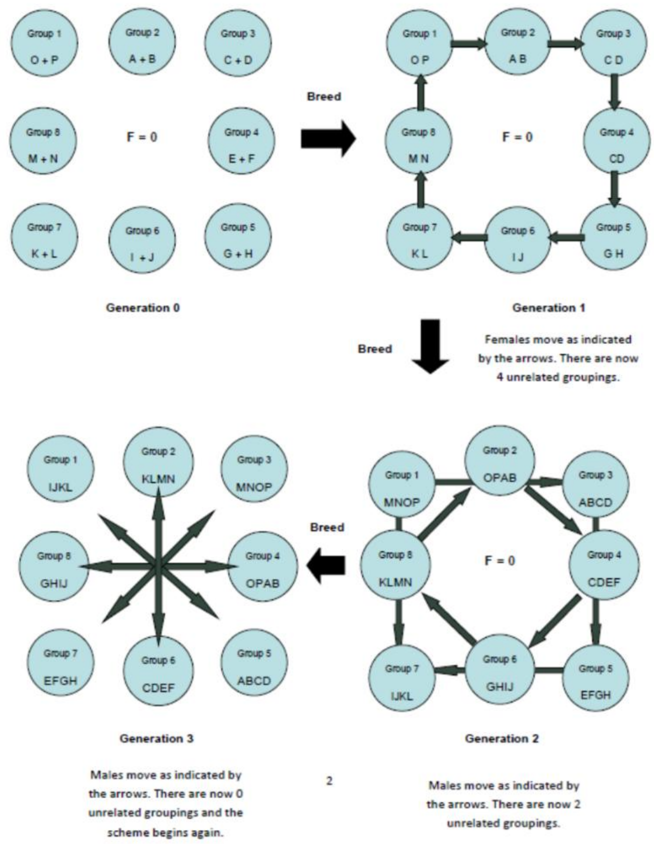

Figure 1. Example of a Maximal Avoidance of Inbreeding scheme beginning with eight groups of unrelated founders. Three generations without inbreeding is achieved.

MAI can be difficult to apply in practice for several reasons: it works best where generations are discrete, whilst in most managed populations they are overlapping; social species will not always tolerate easily the removal and then replacement of one sex; tracking which individuals belong to which MAI group can be challenging as this is not well supported by standard population management software such as ZIMS and PMx. Nevertheless, applied in combination with a mean kinship approach, MAI-style within-population structuring can assist genetic management where gaps in pedigree are likely to occur from time to time and the systematic isolation of lines can have added benefits for disease management.

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Appendix V. Workshop PMx and Vortex models

Caroline Lees (IUCN SSC CPSG), Ashley Herrod (Zoos Victoria)

Vortex (Lacy and Pollack 1995) and PMx (Lacy et al. 2012) captive population models were built in advance of the workshop, to support discussions. PMx models were built directly from the current ZAA studbook for the species provided by Ashley Herrod (Zoos Victoria). Vortex models were built using a combination of parameters taken from previously published wild Swift Parrot Population Viability Analyses (Heinsohn et al. 2015; Owens et al. 2023) and parameters calculated from studbook data (see below).

Information from previous Vortex PVA studies (Heinsohn et al. 2015; Owens et al. 2023; Bussolini et al. in press) were presented at the start of the workshop and data from these were used to inform discussions wherever applicable. The PMx and Vortex models described here were built for practical application during the workshop to answer questions not covered in these published studies. PMx scenarios were run prior to the workshop to establish the scale of program likely to be needed to achieve common insurance targets (retention of 95% gene diversity for 50 years). Additional PMx models, and Vortex models, were run during the workshop at the request of individual working groups to test specific scenarios. All are presented below.

To limit the length of the report, detailed explanations of how the models work are not included here but are available in the references provided. Further information on the tools can be found here: https://scti.tools

PMx

The PMx goal-setting function was used before and during the workshop to estimate the target population size and/or rate of supplementation with wild-origin birds required to retain 95% gene diversity over 50 years.

The following parameters were used:

Fixed:

1. Generation time (T) =3.4 years (from studbook data)
2. Ne/N ratio = 0.3 (typical genetic efficiency in captive vertebrates)
3. Starting N = number of founders=30 (assumed possible)
4. Starting GD: = 98.3%, based on 30 effective founders

Varied:

5. Number of founders added after the founder phase=0, 2 and 4 per generation (each contributing 0.5 Founder Genome Equivalents)

6. Estimated sustainable maximum growth rate: 1.20 – 1.7 [range based on SP growth rates calculated by PMx[9] for the managed population (see graph below) and the maximum growth rate estimated for OBPs (λ=1.7 – S. Troy pers. comm.)]

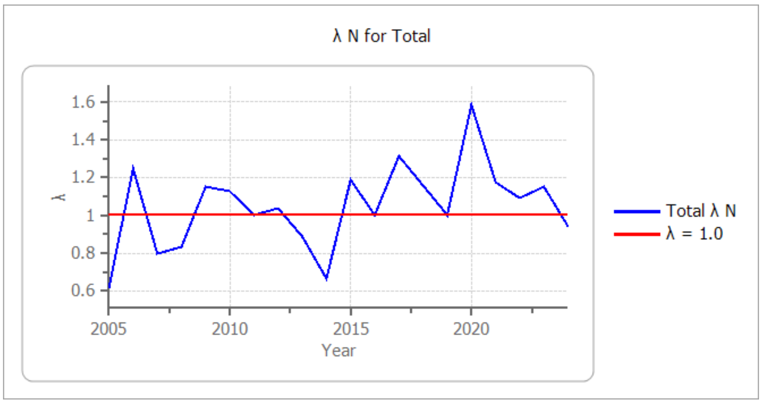


Figure 1. Lambda values for the ZAA population since 2005. Note that this reflects i) total change in N, including movement of birds in and out of ZAA facilities, as well as captive births and deaths and ii) the influence of breeding management.

PMx was also used during the workshop to estimate how long it would take to wind down the current captive population by preventing breeding, allowing spaces to be filled with birds from the new program. This was modelled by setting age-specific risk of breeding (M(x)) to zero for all female age-classes.

Results and conclusions

1. Population size and founder supplementation rates

Red values fall short of the 50-year, 95% gene diversity retention target.

Table 1. 30 founders year 1, no supplementation, varied growth rate, varied carrying capacity. Gene diversity retention over 50 years with varied *ex situ* carrying capacity (K=150-300 at increments of 50) and varied growth rate (λ=1.2, 1.5, 1.7), for a scenario in which 30 effective founders are provided in year 1, with no further supplementation.

		Gene Diversity Retained at 50 yrs		
	Max. Annual Growth Rate (λ)	**1.2**	**1.5**	**1.7**
Carrying capacity (K)	**150**	79.3	81.2	81.6
	200	81.9	84.3	84.7
	250	83.5	86.2	86.7
	300	84.6	87.4	88.0

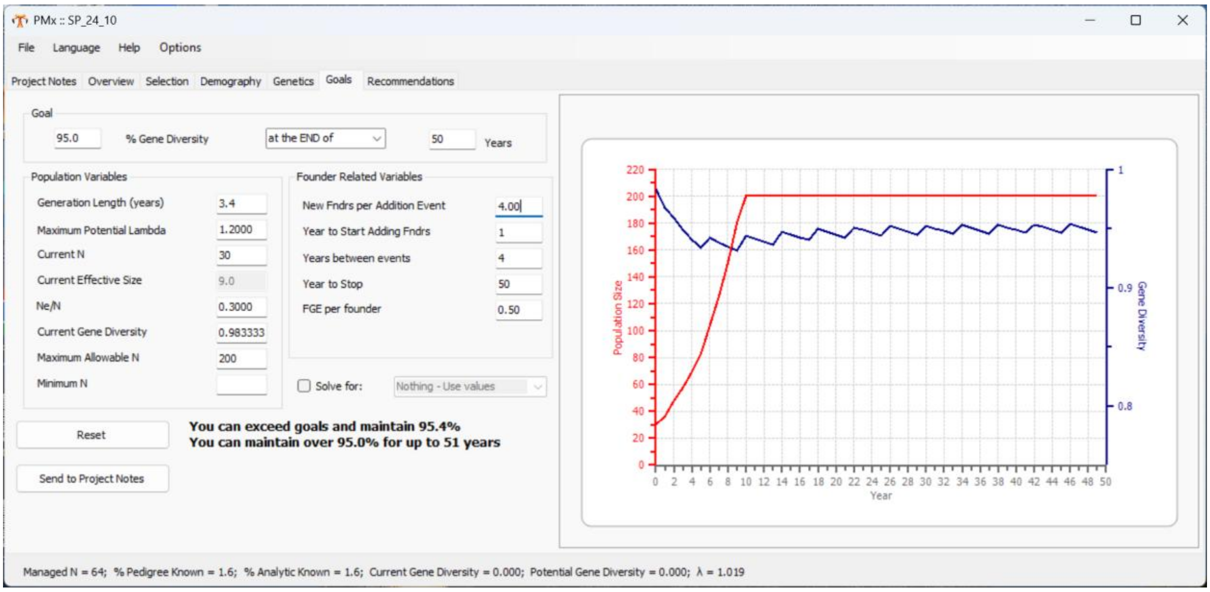
With N=300 captive spaces available and a growth rate of λ=1.7, the population retains 88% gene diversity over 50 years which falls short of the 95% target. Losses are from genetic drift which is particularly rapid during the growth phase.

[9] Note that this estimate is not a reliable indicator of SP population potential. Firstly, it will be influenced by active management of production. Secondly, though PMx shows that relatively few wild-origin birds have contributed to population growth since 2005, several captive origin birds have been added from the large population held outside ZAA institutions (see previous report from Ashley Herrod).

Table 2. 30 founders year 1, regular supplementation, varied carrying capacity, fixed growth rate. Gene diversity retention over 50 years with growth rate fixed at λ=1.2 and varied *ex situ* carrying capacity (K=150-300 at increments of 50), for a scenario in which 30 effective founders are provided in year 1 and either 2 or 4 additional founders are added every 4 years.,

		Gene Diversity Retained at 50 yrs	
	Founders added every 4 years (each =0.5 FGEs)	**2**	**4**
Carrying capacity (K)	**150**	92.5	94.7
	200	93.4	95.4
	250	94.0	95.8
	300	94.4	96.1

The smallest carrying capacity at which targets can be met is K=200, requiring supplementation with 4 individuals every 4 years.



For the successful scenario requiring the smallest carrying capacity, as shown in the PMx screen capture above and as for the previous trials, gene diversity loss is rapid initially because population size is small and genetic drift, which is inversely proportional to effective population size, is therefore rapid. Periodic supplementation with new founders is essential to maintaining gene diversity at or above target levels. Drift slows as the population size increases. This reduces but does not remove the reliance on supplementation.

Note that the lambda value of 1.2 (20% annual growth) set in these supplementation trials is a rate that is conservatively estimated to be achievable based on past performance of the studbook population. However, it is not known whether this can be sustained over time in a captive population, or whether it can be achieved in a captive population comprising large numbers of wild-origin birds. The current ZAA population shows growth of only 1.9% per year, however, this is assumed to be the result of management to prevent excess production. A potential population growth rate of λ=1.7 was estimated for Orange-bellied Parrots during the workshop (by S. Troy). If higher growth rates can be achieved for Swift Parrots it may be possible to achieve gene diversity targets with fewer birds (i.e. lower K) (though noting that gene diversity retention is only one of the factors determining required carrying capacity for a program).

2. Time to replacement of current population (if needed)

The graph below shows the impact of setting age-specific risk of breeding (M(x)) to zero for all age-classes. The purpose is to emulate the rate of natural attrition of the current *ex situ* population should a decision be made to replace it with birds from a newly-founded population.

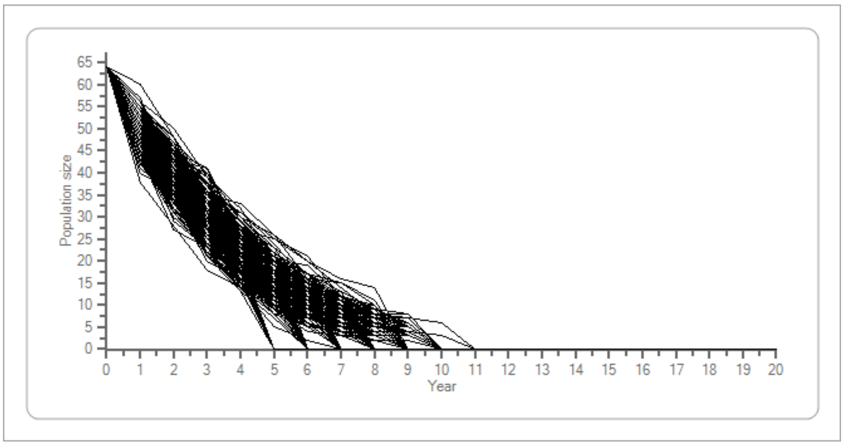


Figure 2. Impact of preventing further breeding on the current ZAA Swift Parrot population (500 iterations).

The population declines to zero in 5-11 years with around 50% of birds gone in 3-4 years (500 iterations).

This scenario was modelled on request to inform discussions but no decisions were made about whether it would be a likely course of action. Freeing-up existing facilities (if required) by transferring birds to non-ZAA institutions was also discussed. Further, it was agreed that a new population would require purpose-built facilities and these may be designed to provide sufficient holding capacity.

Vortex

PMx is a tool for managing living populations. It accommodates individual-based breeding and management decisions towards population-level targets. While there is some flexibility to accommodate different population scenarios, PMx models are closely anchored to a specific studbook population, its past performance and current characteristics. Vortex models are not, allowing much more freedom for scenario-testing and planning both for individual populations and for the interactions between populations (e.g. wild and captive). Before the workshop, baseline models were built for Wild, Captive and Optimised Captive populations as follows:

Wild: based on parameters reported in Heinsohn et al.2015.

Captive Model: based on studbook parameters for the current captive population adjusted to provide a model in which breeding is not constrained by management (by adopting wild breeding rates from Heinsohn et al. 2015)

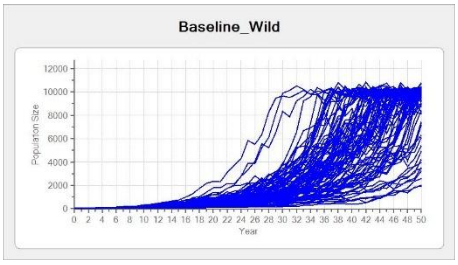
Optimised Captive Model: the Captive Model with the currently high first year mortality reduced by half.

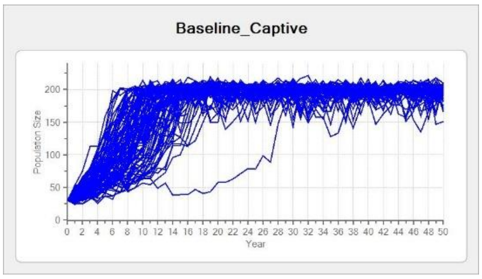
To allow direct comparison, all models began with 30 individuals. *Ex situ* carrying capacity was set at 200 individuals, *in situ* capacity at K=10,000 (as per Heinsohn et al. 2015).

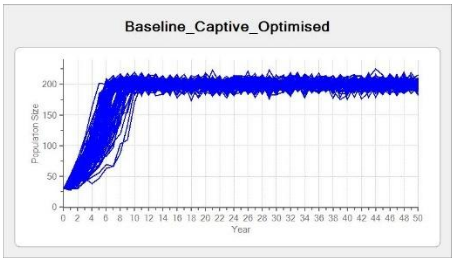
During the workshop a further trial was run, using captive OBP age-specific mortality values, which are considerably lower than those for Swift Parrots.

Results and conclusions

Fifty-year trajectories for the three models are shown below (100 iterations).







Statistics for the three Baseline Models are shown in the table below:

Scenario	stoch-r	SD(r)	PE	N-all	SD(N-all)	GeneDiv	SD(GD)
Baseline_Captive	0.1581	0.1424	0.0000	197.65	9.52	0.8993	0.0242
Baseline_Captive_Optimised	0.2729	0.1014	0.0000	199.13	6.35	0.9054	0.0219
Baseline_Wild	0.1292	0.1339	0.0000	9035.08	2038.14	0.0000	0.0000

Stoc-r= instantaneous growth rate; PE=probability extinct by year 50; N-all=mean population size across all iterations at year 50; GeneDiv=proportion gene diversity retained at year 50.

As illustrated, none of the models show a risk of extinction over the 50-year period and all grow strongly. The Wild Model shows the slowest growth (stoch-r=0.1292). Reducing first year mortality by half in the Captive Model increases growth from stoch-r=0.1581 to r=0.2729. For a population size of 200 birds, this could increase the number of animals available for release from around 30 to more than 50 birds per year, though noting in all cases that applying program-specific criteria for release suitability will ultimately determine the number of animals available for release.

The trial using the lower OBP captive mortality rates elevated stochastic growth to r=0.4552 (SD=0.0426).

Adaptation to captivity is one route through which mortality in captivity can decrease. This is usually avoided as far as possible in populations destined for release.

In-line with the PMx models, neither of the captive models meet gene diversity targets (as they are not supplemented after year 1).

The growth rate of the Vortex Baseline Captive Model (not optimised) is lower than that used as standard in the PMx model. The latter (λ=1.2) was selected from a varied range of rates observed in the ZAA population over the past 20 years. However, these rates reflect all population growth, including that resulting from birds translocated into or out of the population, as well as those generated by births and deaths within the population. They will also reflect management choices rather than biological potential. The Vortex rates are generated from the parameter values set, which are also drawn from studbook records subject to the same biases as described, but include additional stochastic elements. As a result neither are likely to be be good indicators of what is likely to be achievable in a new population, or even in the current population under different management.

These results should therefore be considered preliminary. Further work and testing should be carried out on the models if results are to be used to make operational decisions. In particular:

1. **Further analysis of growth rates achieved in the captive population to date** using studbook data, ideally excluding growth due to translocations in and out, and focusing on periods of the program's history, or on a subset of institutions, where there were no constraints on reproduction. If sufficient data for this are not available, eliciting information and estimates of values from a small group of experienced breeders would be valuable.
2. **Further analysis of early mortality in captive Swift Parrots** to determine the causes and the likely options for mitigation, will allow refinement of estimates for this parameter value, and therefore for overall population growth potential estimates, which is currently crucial to estimates of target population size and likely numbers available for release.
3. **Comparisons of OBP and Swift Parrot vital rates and circumstances**, to determine how much guidance on parameters and targets can be drawn from OBPs.

Example values (for Captive Model)

VORTEX 10.5.5.0 -- simulation of population dynamics

Project: SwiftParrot2024
Scenario: Baseline_Captive
02/01/2025
1 population simulated for 50 years for 100 iterations
Scenario Settings Notes: uses values derived from the ZAA studbook for Swift Parrots and, where needed, from wild PVA models developed by Heinsohn et al.
Sequence of events in each time cycle:
EV
Breed
Mortality
Age
Disperse
Harvest
Supplement
rCalc
Ktruncation
GSUpdate
PSUpdate

ISUpdate
Census

Extinction defined as no males or no females.

Inbreeding depression with a genetic load consisting of
3.14 total lethal equivalents per individual, of which
50% are due to recessive lethals,
and the remainder are lethal equivalents not subjected to removal by selection.

Populations:
Population1
Reproductive System:
Monogamy, with new selection of mates each year
Females breed from age 2 to age 10
Males breed from age 2 to age 12
Maximum age of survival: 12
Sex ratio (percent males) at birth: 50

Correlation of EV between reproduction and survival = 0.5

EV sampled from binomial distributions.
Population specific rates for Population1

Percent of adult females breeding each year: 90
with EV(SD): 5
Percent of adult males in the pool of breeders: 100
Normal distribution of brood size with mean: 3.14 with SD: 1.7

Female annual mortality rates (as percents):
Age 0 to 1: 48 with EV(SD): 9.6
Age 1 to 2: 20 with EV(SD): 4
After age 2: 24 with EV(SD): 8.6

Male annual mortality rates (as percents):
Age 0 to 1: 46 with EV(SD): 9.2
Age 1 to 2: 25 with EV(SD): 5
After age 2: 27 with EV(SD): 8

Initial population size:

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Females	0	6	3	3	1	1	0	1	0	0	0	0	0	15
Males	0	6	4	2	1	1	0	0	1	0	0	0	0	15

Carrying capacity: 200 with EV(SD): 0

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