Evaluation of intervention aimed at improving reproductive success in Orange-bellied Parrots *Neophema chrysogaster*: lessons, barriers and successes.

Summary

Assessing feasibility and identifying constraints that affect project implementation is a crucial step for planning long-term species recovery actions for field-based programs. We report on the outcomes of a conservation intervention on the most endangered parrot in the world, the Orange-bellied Parrot *Neophema chrysogaster.* We aimed to trial new techniques to increase reproductive success of wild nests and address key knowledge gaps. We aimed to achieve higher reproductive success using (i) intervention – where fertile eggs or nestlings would be fostered from captivity to wild nests that suffered infertility or had small brood sizes, and (ii) rescue – where wild-born nestlings would be removed from nests if they were ailing and either fostered to another nest or hand reared to improve their survival. Our project provided proof of principle that it is possible to implement intensive, individual level monitoring and intervention (via fostering of nestlings to infertile nests) to address reproductive problems for the Orange-bellied Parrot. However, we also found important factors that hindered our ability to achieve project aims (management of biosecurity), and identified unexpected factors that have important implications for future application of these techniques (nest abandonment from video camera deployment, rapid death of unhealthy nestlings hindering rescue attempts). Our project tested techniques and tools to provide new approaches for fighting extinction of the Orange-bellied Parrot, and yielded important new information about the species ecology and management options.

Key Words

Conservation intervention and management, fostering, nest monitoring, disease management, reproductive management, hand-rearing and captive management

Introduction

Conservation interventions to manage threatened species can be critical to population recovery. The most effective species recovery projects identify clear factors that are driving decline, and implement targeted conservation action to remedy these threats and alleviate pressure on populations (Scheele*, et al.* 2018). However, clear diagnosis of threats is not always possible for species lacking detailed data on ecology and demographic processes (Bland*, et al.* 2015). In such cases, by necessity managers might implement conservation actions iteratively by means of trial and error in an adaptive management framework (Gerber and Kendall 2018). Clear performance metrics that relate to the focal ecological process targeted by the intervention are crucial for effective evaluation of conservation interventions (Doherty and Ritchie 2017;Wintle*, et al.* 2010). Part of this process includes assessing feasibility and identifying constraints that affect project implementation, which is a crucial step for planning long-term species recovery actions (Walls 2018).

We report on the outcomes of a conservation intervention on the most endangered parrot in the world, the Orange-bellied Parrot *Neophema chrysogaster.* The decline of the wild population of this species to only 3 wild-born females and 13 males in 2016 triggered this project (Stojanovic*, et al.* 2018). We aimed to trial new techniques to increase reproductive success of wild nests and address key knowledge gaps. We aimed to achieve higher reproductive success using two approaches:

1. intervention – where fertile eggs or nestlings would be fostered from captivity to wild nests that suffered infertility or had small brood sizes, and
2. rescue – where wild-born nestlings would be removed from nests if they were ailing and either fostered to another nest or hand reared to improve their survival.

These approaches are not, in themselves novel because they have been successfully trialed and implemented on many other species (for a summary of techniques and case studies see Jones 2004). However, past applications of this intensive conservation management have most often been applied to sedentary, or island dwelling birds. Migratory species like the Orange-bellied Parrot pose substantial additional conservation challenges and also live in very remote, difficult to access locations. In addition, the project sought to trial video monitoring as an approach to increase the resolution of nest monitoring data and improve capacity to achieve intervention and rescue. These aims were undertaken in context of ongoing complementary work on Orange-bellied Parrots by the Tasmanian Government and their collaborators in the species recovery team (Department of Environment Land Water and Planning 2016;Troy and Hehn 2019). Here we summarize the aims, rationale, methods and results of the conservation interventions we trialed. We also explain barriers to success and limitations of our approach, in the hope that these factors can help inform other similar projects on threatened species.

Methods

The project ran between September 2016 – June 2019, spanning three field seasons overlapping the Orange-bellied Parrot breeding season (Sep – Mar). We present our aims, monitoring approaches and evaluation criteria based on the Australian Government Monitoring Evaluation Reporting and Improvement Tool (MERIT: https://fieldcapture.ala.org.au/;jsessionid=FE76A594F6E3D265018D76D295501F88) because this approach is widely utilized for evaluating on-ground environmental projects in Australia. Project outcomes and monitoring indicators are presented in Table 1. Nest boxes were checked either manually by climbing trees or by reviewing recordings from video cameras (model HK101182w www.handycam.com) mounted inside nest boxes or on the outside of boxes (Reconyx Hyperfire HC600). We checked egg fertility by candling eggs using a small flashlight. We monitored nestling condition (for the rescue component of the work) using the approach described by Stojanovic et al. (2020b) for estimating body condition. We tested all captive animals selected for use as donors of eggs or nestlings for Psittacine beak and feather disease virus (BFDV) from blood samples (Troy and Kuechler 2018).

Results

Below we summarize our evaluation of success against the project outcomes and monitoring indicators. We also identify key barriers, lessons, costs and benefits for each method used in the project. In total we monitored 53 nests, deployed video recorders inside 15 nest boxes, attempted intervention to correct egg infertility on 4 nests, and rescued 5 nestlings either by fostering or hand-rearing. Unfortunately most nestlings fostered in the intervention component of the project died (only one of five nestlings survived to migrate), but these results were skewed by a disease outbreak (Stojanovic*, et al.* 2018). Disease risk management was a major challenge during implementation of the project, and outbreaks of disease directly hindered our project objectives in two of three years. We developed an index of nestling body condition that was used to identify candidates for rescue (Stojanovic*, et al.* 2020a), and evaluated the efficacy of nest competitor control (Stojanovic*, et al.* 2019).

On average per year, the project cost approximately $20,000 AUD for travel to and from the field site, $50,000 for personnel, $5,600 for disease screening of captive birds for BFDV (comprising ~$280 in tests per bird), plus capital expenditure ($15,000 for video cameras, $3,000 for purchase of additional nest boxes).

Desired outcome	years implemented	Monitoring approach	Evaluation	Barriers	Key Lessons	Benefits of the approach	Costs of the approach
Nest boxes cleaned and video cameras installed	2016 - 2018	1) record the ID of boxes cleaned and fitted with cameras	All nest boxes were cleaned annually; video cameras installed on active nests (2017 n = 5, 2018 n = 10)	Video camera deployment could not be ruled out as a cause of two nest abandonments (one each in 2017, and 2018)	Dummy cameras (matchboxes wrapped in black tape) were installed in all boxes in 2018 to enable acclimatisation to cameras	Improved resolution of nest monitoring at reduced effort; new information about breeding behaviour	Risk of nest abandonment (1/15 nests); high per unit cost of video cameras
Early identification of nest productivity and	2016 - 2018	1) Determine parent provenance (captive- or wild-born) to	All nests monitored (2016 n = 17, 2017 n = 14, 2018 n = 22);	Personnel costs are high for the frequent monitoring required to	Parent provenance difficult to ascertain with cameras, easier with direct observations.	High quality, detailed data on nest timing, early identification of infertility provides	High workload for frequent nest checking, requiring extensive climbing effort (minimum

identification of foster candidates		ensure only captive origin nests used in fostering 2) Timing of important nest phases determined 3) Identify infertile eggs within 14 days of egg laying 4) develop and index of body condition for	egg fertility monitored; nestling survival and body condition monitored	determine nest timing and fertility, but costs alleviated by video cameras because the interval between manual checking is longer without loss of information due to video recordings. Personnel costs high to identify fathers.	Identification of mothers inside the nest box is disruptive. Body condition index is costly to develop but removes ambiguity of subjective health assessments.	opportunity to improve productivity in poor nests. Identification of mothers very accurate. Reduced uncertainty for identifying when nestlings are unwell and need to be fostered or rescued.	four climbs per nest to clean box, confirm nest initiation, check egg fertility and ring nestlings). Development of body condition index is labour intensive and requires very frequent handling of animals for model development

		nestlings to empirically evaluate nestling quality and identify fostering candidates					(Stojanovic*, et al.* 2020a).
Reproductive success improved by implementing intervention and rescue actions	2016 - 2018	1) implement intervention (fostering of nestlings to correct egg infertility or nestling mortality); 2)	Intervention had mixed results (2016 – one of five nestlings successfully fostered, 2017 - no fostering	Intervention was dependent on the availability of donor nests in captivity to supplement wild nests. Donor nest availability limited	(1) Biosecurity is important but the impacts of disease on demographic parameters must be weighed against the impact of biosecurity	Intervention showed (limited) proof of concept that fostering is a potential tool for increasing reproductive output. Rescues	The feasibility of intervention is subject to several unrelated limiting factors (need, timing, biosecurity, funding) and in

		implement rescue (ailing nestlings identified by body condition and either removed for hand-rearing or fostered to other wild nests)	necessary due to high fertility in the wild, 2018 - fostering abandoned due to BFDV in captive donor parents. Rescue was attempted in 2016 (one nestling) and 2018 (four nestlings) but in all years most candidates for	by: (1) biosecurity, e.g. disease outbreaks in 2016 and 2018 stopped transfer of birds from captivity to wild, affecting project implementation and outcomes; (2) timing, e.g. captive and wild nests must be initiated in close synchrony with one another to be potential	protocols reducing scope for on-ground intervention. (2) high personnel costs may be unavoidable if rescue is to improve survival of nestlings, with at least twice daily nest checks (via video or manually) necessary to improve odds of detecting	showed that nestlings benefit from being removed from nests where they are underperforming if detected before they die.	two of three years these factors prevented implementation of interventions. Rescue had limited success when the interval between checks was long, but smaller intervals between checks will equate to a substantial increase in personnel costs

			rescue died before they were found (2016 - six dead nestlings, 2017 - three dead, 2018 - sixteen dead). One successful nestling rescued in 2018 showed a 12.1 g improvement in mass over 14 days after	candidates for fostering based on the timing of hatching and fledging dates. Rescue was highly dependent on the frequency of monitoring, with most ailing nestlings dying in the four-day nest check intervals. Cameras improved monitoring detail but still required	underperforming nestlings before they die. (3) Fostering eggs worth considering as an alternative approach to nestlings, which had mixed success.		and potentially nest disturbance.

			fostering to a new nest. Another fostered nestling temporarily gained weight but was later feather plucked by the host mother and so was taken for hand-rearing. Three nestlings were hand reared, over the	personnel to manually review video and detect problems. Logistic issues with site access made regular manual checking challenging.			

			project (2016 – 1, 2018 – 2) but two were later euthanized.				

Discussion

Our project provided proof of principal that it is possible to implement intensive, individual level monitoring and intervention to address reproductive problems for the Orange-bellied Parrot. Other projects have applied similar efforts to other species (Jones 2004), but this is the first time these approaches have been attempted for Orange-bellied Parrots. Our results are important because lessons around ways to improve management of threatened species typically go unpublished, and we hope to make 'reinventing the wheel' unnecessary for other projects seeking to deploy similar actions in remote field sites for migratory birds like the Orange-bellied Parrot. We found and report important factors that hindered our ability to achieve project aims, and identified unexpected factors (e.g. potential sensitivity of parrots to deployment of video cameras after nesting has begun) that have important implications for future application of these techniques. Based on the severity of the barriers, benefits and costs of each method, we discuss which elements of the project may be worth incorporating or excluding from future management efforts.

Useful components (including caveats): We provide proof of principle that nestling fostering to control brood sizes and correct infertility are methods that could improve reproductive success of the Orange-bellied Parrot. However, intervention by fostering is dependent on having donor captive nests that meet disease screening requirements (i.e. no evidence of BFDV) and logistic and timing constraints in the availability of donors of eggs/nestlings. The presence of disease in the captive population may have compromised the results of fostering in 2016 (*Pseudomonas*) (Stojanovic*, et al.* 2018), and prevented it altogether in 2018 (BFDV detected in donor parents) (Troy and Kuechler 2018). In both of those years, there were opportunities for fostering in the wild due to infertility of eggs, but this was not corrected due to biosecurity precautions.

In the long term, further research to understanding the demographic impact of disease should be a high priority in the Orange-bellied Parrot so that disease mitigation is managed to reduce impacts on other aspects of management. We suggest that nestling fostering may be a useful way to maximize reproductive success of the wild population if disease risk and biosecurity protocols are modified to: (i) address the likelihood of exposure through both vertical and horizontal transmission to eggs and nestlings, (ii) identify methods to mitigate risk while maximizing available management options. Fostering of nestlings was achieved, but further evaluation of whether fostering eggs could improve outcomes is worthwhile (this was not tested in this project). Fostering fertile eggs from captive to wild nests mid incubation may be a more effective method of increasing nest productivity than using nestlings. However further evaluation of biosecurity risks of moving eggs between nests must be evaluated.

During this project we developed a body condition index as a way to evaluate nestling condition of Orange-bellied Parrots (Stojanovic*, et al.* 2020a). This was a useful, empirical way of assessing which nestlings might benefit from intervention and rescue. It also provided a useful means of evaluating the impacts of this intervention. The method is fast and relatively repeatable among observers, and reduced uncertainty about how to identify when a nestling is underperforming. We suggest that nestlings that fall below one standard deviation for first or middle-hatched nestlings (Stojanovic*, et al.* 2020b) could be considered for intervention/rescue. If such nestlings are identified before they die, and exhibit no symptoms of infectious disease, rescue could be implemented via fostering to other wild nests with small broods (if available). In cases where suitable host nests are not available, rescuing nestlings by hand-rearing them has major limitations (see below).

Video monitoring of nests has the potential to yield large volumes of high-resolution data on the performance of nests and individual animals. However, we suggest that to derive the maximum benefit from this method, personnel should review camera footage daily (preferably twice daily) so that rescue may be undertaken before nestlings die. Because of the 3-5 day intervals between manual checks of videos in our project, recordings mostly served to confirm when and (sometimes) how mortalities occurred. Had more regular checks occurred, some of these mortalities may have been prevented. Video deployment midway through incubation may have caused failure of two nests due to female abandonment. In 2018 (in response to the first abandonment) we deployed dummy cameras in all boxes to habituate parrots to the hardware, but one of the 10 mothers abandoned her nest despite this modified approach. We note though that three other nests (without cameras) were abandoned in that same week, so we are uncertain of the true cause of nest failure. Nevertheless, if the potential risk of nest abandonment from deploying live cameras during incubation is unacceptable, real cameras could be deployed in all boxes before breeding begins. Those boxes eventually occupied by parrots could have the necessary additional hardware for functionality (solar panels and battery) assembled from the ground once nest box occupancy is confirmed, with no disturbance to incubating parrots. This approach is more expensive (because of the need to purchase a real camera for every box), but will greatly reduce the risk of abandonment (because dummy cameras were ignored by all parrots).

Components that could be discontinued

Unless more frequent manual checking can be achieved without nest disturbance, the rescue component of our project could be discontinued, or implemented opportunistically (e.g. when underperforming nestlings are discovered early and can be fostered to other nests). The logistic, financial and personnel constraints that currently prevent permanent availability of staff at the field site are unlikely to be overcome without substantial new funding. After rescue is completed, hand-rearing nestlings is labour intensive if suitable foster nests are not available. In one case during 2018, a nestling that was successfully rescued and fostered to an available wild nest had to be removed along with its foster nest mate because their (captive-born) mother plucked their feathers. This example shows that irrespective of whether suitable host nests are available, careful monitoring of rescued nestlings is crucial to ensure success of the initial intervention. Unless suitably skilled personnel are deployed permanently in the field during the breeding season, even checking intervals of 3 days can be too long to intervene if something goes wrong in a nest. However, if skilled staff are always present, video monitoring and more regular checking may make rescue worth trialing again.

Consideration should be given to evaluating the cost versus benefit of rescuing a given nestling relative to its importance to the population. If the nestling is from a genetically valuable lineage, then more intensive interventions (e.g. hand-rearing) may be justifiable, compared to another nestling whose lineage may be over represented in the population.

Conclusion

Our project tested techniques and tools to provide new approaches for fighting extinction of the Orange-bellied Parrot. Our study has yielded important new information about the species ecology (Stojanovic*, et al.* 2018;Stojanovic*, et al.* 2020b;Stojanovic*, et al.* 2019) and provided managers with new options for data collection and intervention to address reproductive problems facing the species. We hope our study provides a useful template for practitioners to trial these techniques and evaluate their efficacy on other species.

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