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Review Article

Preparing captive-bred birds for reintroduction: the case of the Vietnam Pheasant *Lophura edwardsi*

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Summary

The Vietnam Pheasant *Lophura edwardsi* (including *L. hatinhensis*) is only known from a small area of central Vietnam, where it occurred in wet forest below 300 m. It is probably extinct in the wild, but some 1,500 birds, derived from 28 individuals caught in 1924–1930, survive in captivity. Guidelines for reintroducing galliforms date from 2009. Subsequent literature was reviewed for new research findings to help maximise the chances of success in reintroducing birds. Studies confirmed that non-parent-reared captive-bred galliforms survive poorly, primarily owing to inadequate anti-predator responses. These reflect both genetic and ontogenetic unsuitability to wild conditions, with progressive maladaptation of stock being related to the number of generations spent in captivity (at least 35 in the case of Vietnam Pheasant). To compensate as far as possible for this deficiency, a reintroduction programme should use: environmental enrichment (including the provision of perches in aviaries), dietary enrichment (especially involving practice with live food), parent-rearing over several generations (although how many are needed for a species almost a century in captivity is unknown), soft releases (allowing full familiarisation with the future environment over at least 50 days), rigorous anti-predator training (against both air and ground attacks), anti-predation release stratagems (relocating and deterring predators, releasing birds at several stations, offering post-release support), determining appropriate numbers (per batch, with at least 300 in total per site) and time-frame for release (around five years) and the selection of fully suitable releasees in (as far as possible) naturally formed social groups, including parent-guided offspring aged around four months. Six sites need survey for extant populations or use for reintroduction, and the choice of reintroduction site will depend primarily on habitat extent and condition. The costs of these measures will be high and the overall project schedule will need to extend beyond the overall five years currently planned.

Keywords: Reintroduction, captive breeding, galliforms, maladaptation.

Introduction

In the past 25 years the reintroduction of species into areas they once occupied has become a standard conservation technique. The scientific literature on the theory and practice of animal reintroductions has accordingly proliferated, disseminating important new insights based on experience and experiment. Conferences on reintroductions are now routine, and efforts have been made to assemble key strands of what has been called 'reintroduction biology' in order to provide potential practitioners with a greater understanding of the issues (e.g. Ewen *et al*. 2012, IUCN/SSC 2013, McGowan *et al*. 2017). Even so, new information is constantly improving the resource base on which conservationists can draw as they deal with individual reintroduction challenges.

Few such challenges can be as problematic as that posed by the Vietnam (formerly Edwards's) Pheasant *Lophura edwardsi*, a mid-sized galliform bird with a tiny and perhaps now non-existent range in the forests of central Vietnam (BirdLife International 2019). The case is rendered still more difficult by the fact that what was thought to be a close relative, Vietnamese Pheasant *L. hatinhensis*, is now considered conspecific with *L. edwardsi*, after being judged to be a white-tailed aberrant of that species and hence an invalid taxon (Hennache *et al*. 2012). What was 'Edwards's Pheasant' is or was restricted to wet low-elevation forest in three provinces in central Vietnam on the eastern approaches to the Annamite mountains, having been recorded at a total of 14 sites, eight not since 1950; these 'historical' sites are now believed to be deforested, and the six more recent sites are also subject to significant degradation and clearance (Collar *et al*. 2001, Pham and Le 2015, Eames and Mahood 2017). What was 'Vietnamese Pheasant' is or was known from lowland forest at six sites clustered just to the north of the northernmost record of *edwardsi*, in and around Ke Go Nature Reserve, Ha Tinh province, and the adjacent Khe Net watershed, Quang Binh province, plus a seventh site 225 km to the south, deep within the range of *edwardsi*; all sites are known to be under significant pressure from timber extraction and use (Collar *et al*. 2001, Pham and Le 2015, Eames and Mahood 2017). Moreover, indiscriminate snaring—the sheer scale of which in South-East Asia's forests has recently been highlighted (Gray *et al*. 2017)—represents a major ongoing threat (Eames and Mahood 2017): four of the six recent sites for 'Edwards's Pheasant' and two of the seven sites for 'Vietnamese Pheasant' were only identified owing to hunters showing trapped birds to researchers (Collar *et al*. 2001, Pham and Le 2015).

All records of 'Edwards's Pheasant' have been stated to stem from 'exceedingly damp forests… at low and moderate altitudes' (see Collar *et al*. 2001), although in fact there is no good evidence that any involved a locality above 300 m (Eames and Mahood 2017). *Lophura* species tend not to co-occur but to replace each other with changes in habitat (Davison 1981, Thewlis *et al*. 1998, Eames and Mahood 2017) and, given that records of Vietnam Pheasant coincide with a region of high year-round humidity, it is plausible that the species occupies or occupied a specialised niche in a circumscribed area of ever-wet low-elevation forest (Eames and Mahood 2017). Anecdotal evidence supports this: the species has been said to be the only pheasant to 'like rain' (Hennache 2001), and in one zoo it was the only pheasant species which, given the freedom of a small wood, invariably occupied the lowest accessible area and confined itself to ground adjacent to standing water (J. Gregson pers. comm. 2018).

Most forest below 300 m within the Vietnam Pheasant's range has now been cleared, and whatever remains may have become drier and therefore unsuitable owing to the effects of fragmentation (Eames and Mahood 2017). In the twenty-first century there have been very few records of the species, one in 2000 and two in 2009 (one of them possibly another *Lophura* species and both discounted by Pham and Le 2015), leading to speculation, backed by substantial evidence, that it may be extinct in the wild, perhaps since 2004, although the nature reserves at Khe Net, Khe Go, Dakrong, Phong Dien and Bac Huong Hua, and Bach Ma National Park, have all been recommended for re-survey (Eames and Mahood 2017, Grainger *et al*. 2017). By contrast, even at the start of the present century the captive population comprised around 1,500 individuals (Hennache and Ottaviani 2005, Pinceel 2015), and this pool of birds has long been judged vital to the long-term preservation of the species (Collar *et al*. 2001, Eames and Mahood 2017). However, all captive birds are derived from 28 individuals, of which only 6–8 were females, collected between 1924 and 1930; they are therefore genetically homogeneous and have been calculated to have passed through at least 35 generations (Hennache *et al*. 1999, 2012). Moreover, language barriers, legal constraints and the 'self-imposed isolation' of some breeders mean that only a relatively small proportion of the global captive population is available for restocking programmes

(Collar *et al*. 2001). On present evidence the number of such birds is unclear, but in December 2018 there were 155 birds in the EAZA European Endangered Species Programme (EEP), 470 under management by the World Pheasant Association (WPA), 51 in the (American) Association of Zoos and Aquariums Species Survival Plan (SSP) and 35 under the control of the Japanese Association of Zoos and Aquariums, thus 711 apparently pure-bred individuals distributed between a total of 204 institutions, plus an unreported but far smaller number of phenotypically '*hatinhensis*' birds (Kapic *et al*. in prep.).

Clearly, when there is so strong a probability that the species is now represented on earth only by captive stock—making it of incalculable biological importance—the reintroduction of a proportion of this stock must be undertaken to the highest standards and guided by the best information that conservation biology can provide. Extensive experience with other species of animal and plant have been synthesised into cornerstone guidelines by IUCN's Reintroduction Specialist Group (IUCN 1998, IUCN/SSC 2013). Between these two documents, however, IUCN also worked with WPA and the four WPA/IUCN Galliformes specialist groups to produce guidelines for galliforms themselves (WPA 2009). All three documents are, inevitably, longer on process and generalisation than on detail and practicalities, but it is WPA (2009) which supplies the most relevant and valuable evidence and argument, and can therefore most appropriately serve as the key point of reference from which to consider the specific case of the Vietnam Pheasant.

According to WPA (2009), to stand a strong chance of success while having no negative effects, a reintroduction project involving captive-bred birds must have: a genuine need; clear aims, objectives and success indicators set within a realistic time-frame; well-researched evidence from previous projects; an appropriate release site; suitable release stock; certainty that donor stock and the ecology of the release site will not be negatively affected; legal, political and local support boosted by awareness programmes and preferably with socio-economic benefits; a comprehensive budget with sufficient resources; and the oversight of a multidisciplinary team. Furthermore, the project must: decide on rearing techniques in relation to preparing birds for release; consider behavioural issues relevant to the survival of releasees; ensure the optimal health and genetic fitness of releasees; develop a strategy for maximising the survival of releasees; manage habitat as needed, before and after releases; mark releasees and agree on methods of monitoring their survival and wellbeing; be fully prepared to intervene in case of problems; and document the endeavour in order to provide transparency to all interested parties and the opportunity for feedback from them.

Some of these recommendations are obvious and sensible, but there are aspects that remain uncertain for any species; and this uncertainty is greatly amplified when it is compounded by the lack of basic biological information on such poorly known birds as the Vietnam Pheasant (Grainger *et al*. 2017). Assuming that the administrative, veterinary, legal and logistical aspects of the reintroduction plans are understood and accounted for, what remains are questions relating to release site and its management; release stock and its management; rearing techniques; and release techniques and protocols, including post-release monitoring.

Methods

The guidelines developed by WPA (2009) were informed by a substantial body of scientific evidence, the most recent publication date for which was 2008, although inevitably some potentially relevant research publications prior to that date were not cited and possibly not consulted. Allowing for this, I conducted searches on Google Scholar and Web of Science using 1990 as the earliest date for publications relating to reintroductions, and filtered on the word 'reintroduction' coupled with 'galliform', 'pheasant', 'junglefowl', 'grouse', 'partridge', 'quail', 'turkey', 'curassow', 'guan', 'megapode' and various others. I assembled a list of 224 contributions, almost all of them peer-reviewed papers, that were not already considered in WPA (2009), the majority of them dating from 2009 or later. I searched this material for cases which would inform the aspects identified above (release site, stock and techniques for rearing and release) and result in improvements to current understanding and practice.

Recently the word ‘translocation’, which has traditionally denoted the capture of wild animals at one site and release at another (‘trap and transfer’: Dowell 1992), has been adopted to serve as the generic word for all forms of human-mediated releases of wild animals, and thus has replaced the word ‘reintroduction’. The IUCN Reintroduction Specialist Group has accordingly changed its name to the IUCN Conservation Translocation Specialist Group. However, for the purposes of this review the term ‘reintroduction’ is retained. Translocations, in the traditional definition above, are not possible in the case of the Vietnam Pheasant, and the literature relating to such translocations involving galliforms (often coded—entirely appropriately—under the heading ‘reintroduction’) was largely set aside.

Results

Confirmation: captive-bred galliforms are maladapted

One of the more surprising findings of this review is that supplementations continue to be made and experiments conducted using unparented captive-bred galliforms, despite the overwhelming evidence that such animals are seriously maladapted for life in the wild, surviving very poorly and, if they live long enough, also breeding very poorly (e.g. Hill and Robertson 1988, Dowell 1992, Parish and Sotherton 2007). If further evidence is needed, several recent papers, dealing with both reintroductions and introductions (after establishing that the habitats and conditions were sufficiently similar to justify the attempt), provide it.

- It took the release of 17,000 Common Pheasants *Phasianus colchicus* over 12 years (1968–1980) to establish a population in Texas, USA (Sokos *et al*. 2008).
- A supplementation of Common Pheasants in Idaho, USA, compared the performance of translocated wild birds and released pen-reared birds, and found ‘wild female pheasants were seven times more likely to survive to 1 October, 10 times more likely to survive to the nesting season, eight times more productive, and one-third as expensive per egg hatched than [*sic*] pen-reared females’ (Musil and Connelly 2009).
- In a study of translocated wild and commercially reared Grey Partridges *Perdix perdix* released into a new area in the Czech Republic ‘none of the commercially reared birds survived in the wild until the end of the nesting period, and none produced a fledged brood’, demonstrating ‘the uselessness of releasing adult commercially reared partridges in an effort to establish viable populations’ (Rymešová *et al*. 2013).
- Fostering propensity in Red-legged Partridges *Alectoris rufa* is much higher in wild than captive-bred birds (suggesting ‘fostering is strongly related to parental care behaviour’), and an experiment to study adoption in wild and captive-bred pairs already with their own broods had to be discontinued because captive-bred pairs simply failed to breed (Sánchez-García *et al*. 2011).
- The state of Virginia, USA, spent 30 years (1930–1960) working on releases of and release techniques for Wild Turkey *Meleagris gallopavo* from game farms before abandoning the programme as a total failure; Pennsylvania persisted for another 20 years, releasing over 200,000 birds ‘with little to no evidence that any had established populations’ (which was achieved instead by translocations) (Hughes and Lee 2015).
- Between 1961 and 1971 some 10,000 Red Junglefowl *Gallus gallus*, derived from 117 pure individuals imported from India, were introduced into the south-eastern USA, but no descendants survive today (Condon *et al*. 2019).

Causes and consequences of maladaptation

Filial imprinting in chickens takes place from hatching for about three days; the primary object of imprinting is the mother, but to a lesser degree it also involves co-hatched siblings such that, in the

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absence of a mother, chicks will imprint on each other (Nicol 2015). Early social experience promotes normal reproductive behaviour (Wood-Gush 1958). It follows that galliform chicks deprived of the opportunity to bond naturally with their mother must be significantly disadvantaged in later life. Videos in cages at Paignton Zoo, UK, revealed that Vietnam Pheasant chicks stay within 1 m of their mother for 80% of their first month of life and for almost 50% of their second (J. Gregson *in litt.* 2019).

McPhee and McPhee (2012) observed that 'captive environments can relax selective pressures on various traits, resulting in significantly more trait variance in captive-bred versus wild populations'. These traits include 'fecundity, immune-genetics, digestive morphology, temperament and intrinsic and learnt behaviours including anti-predator responses' (Dolman *et al.* 2018). From the evidence furnished by the many studies of galliform introductions, reintroductions and supplementations to date, it is anti-predator responses that are the most decisive in determining the fate of releasees. Study after study has testified to the poor survival rates of captive-bred birds (all references in the preceding section plus, e.g., Leopold 1944, Robertson 1988, Dowell 1992, Priddel and Wheeler 1994, Putaala and Hissa 1998, Buner *et al.* 2011, Gaudioso *et al.* 2011b, Gruychev 2014, Mihaylov *et al.* 2014, Sanchez-Donoso *et al.* 2014, Carter 2015, Merta *et al.* 2015 and multiple citations in each). However, the degree to which anti-predator responses and other traits are inherited (genetic) or developmental (ontogenetic) is not clear, and the apparent naïvety of birds towards predators may reflect such things as reduced feeding ability and/or resistance to disease, attributable to the lack of parental superintendence. One study showed that captive-bred Grey Partridges *Perdix perdix* occupy field margins, which are rich in both food and predators and hence represent an ecological trap that wild birds avoid, apparently through cultural transmission (Rantanen *et al.* 2010). Lack of the opportunity for mother–offspring cultural transmission is equally believed to explain the failure of captive-bred Wild Turkeys to survive in the USA (Hughes and Lee 2015). Research has increasingly focused on finding techniques to compensate for this behavioural deficit in pen-reared birds, but recent work on inherited tameness in junglefowl finds a correlation with reduced brain size (Agnvall *et al.* 2017), a condition that may be relatively difficult to reverse.

Recent research has also highlighted the role of stress in curtailing survival rates in released captive-bred animals (Dickens *et al.* 2010). While the 'unfearfulness' (lack of vigilance and awareness) resulting in predation might be considered the consequence of lack of stress, any kind of new environment, making unprepared-for demands on an animal's stamina and resourcefulness, will itself elevate levels of stress: having to find food and shelter in unfamiliar contexts potentially represents a shock to an individual, one effect of which may be reduced cognitive ability, including predator identification (Teixeira *et al.* 2007). One cause of the Red Junglefowl's failure to become established in the south-eastern USA (see above) was rapid long-distance dispersal, but birds were also reported to move, where possible, into denser vegetation (Condon *et al.* 2019); rapid dispersal was probably therefore a highly stressed response to the absence of appropriate cover. Captive-bred Grey Partridges were more stressed by unpredictable food supply—which is far more likely a circumstance in the wild than in captivity—than wild ones, and survived less (Homberger *et al.* 2013, 2014). However, evidence is mounting that even in the confinement of a cage an animal can be unduly stressed by multiple factors including, simply, the lack of behavioural stimuli (see next section).

Meanwhile, it is predictable that changes in the traits listed by Dolman *et al.* (2018) (above) will become more pronounced with number of generations, as a result of (unintended) artificial selection and cultural transmission. Since cases are rare where this is an issue, it is not a mainline topic in reintroduction biology (it is not mentioned in WPA 2009 or IUCN/SSC 2013). However, recent research has begun to indicate that a serious effect exists. In a rodent species McPhee (2003) found that 'the more generations a population has been in captivity, the less likely an individual is to take cover after seeing a predator', while a review of 90 papers simply concluded that 'the best approach to minimize genetic adaptation is to reduce the number of generations that a species spends in captivity' (Williams and Hoffman 2009).

Such testimony is of alarming relevance to the case of the Vietnam Pheasant, and is supported by evidence documented nearly 40 years ago and cited by Ridley (1986): 'Pielowski (1981) found that pheasants were substantially changed merely by being kept in captivity for 20 generations. Their chances of surviving in the wild were reduced to about half of those of identically reared chicks from the eggs of wild birds'.

Given that the Vietnam Pheasant has passed through at least 35 generations (Hennache *et al.* 2012), any project to return the species to the wild must accept the obligation to research this problem and provide the fullest set of management procedures and practices to offset and neutralise it.

Managing maladaptation, 1: environmental enrichment

A review of the evidence relating to the release of captive animals found that 'a lack of complexity in the developmental environment of an individual negatively impacts its neural development, with wide-ranging implications for adult behavior and survival' (Reading *et al.* 2013). Consequently, it was recommended that when animals are being bred and kept for release into the wild the conditions in their cages should mimic the release site habitat as closely as possible, since the benefits include reducing the chance of dispersal, increasing physical fitness, and promoting locomotory, anti-predator, foraging and social skills.

Support for this position came in a study in which the introduction of perches to the cages of captive-bred Common Pheasants had the dramatic effect of allowing birds to reduce aggression, improve body development and spatial memory, roost more securely and, overall, survive better (Whiteside *et al.* 2016). In the light of this it is perhaps salutary to recall that, when liberated into wild habitat, artificially reared Cheer Pheasants *Catreus wallichii* roosted on the ground at night and were heavily predated (Garson *et al.* 1992).

Managing maladaptation, 2: soft releases

The value of 'soft' releases (where animals are conditioned to the release environment by being caged within it for varying periods of time) is well recognised by WPA (2009) and IUCN/SSC (2013). Evidence relating to galliforms was furnished by Lockwood *et al.* (2005), but more recent research has further demonstrated the value of habituating birds to the habitat into which they are to be released.

The duration of acclimatisation within the soft-release enclosure positively influenced post-release survival of Red-billed Curassows, and a period of at least 47 days was consequently recommended (Bernardo *et al.* 2011). Nine Cabot's Tragopans *Tragopan caboti* kept for over 50 days in a soft-release enclosure in the species's montane habitat survived far better than 11 birds held there for only three days (86% *vs* 20% after 50 days), and they selected habitats more typical of wild birds (Liu *et al.* 2016). In Grey Partridges 'longer acclimatisation time at the release site was related to lower levels of corticosterone [associated with passive and therefore sociable behaviour] and partly enhanced survival after release' (Homberger 2014).

The failure of the huge project to introduce Red Junglefowl to the south-eastern USA (see above) has largely been attributed to the use of 'hard' (i.e. instant) releases (Condon *et al.* 2019). The fact that some birds were found in or seen heading toward dense vegetation (as mentioned above), when matched with the finding in Liu *et al.* (2016) that soft-released birds selected more appropriate habitat, strongly implies that establishing the release site amidst dense cover is likely to help releasees in terms of stress minimisation and survival capacity. Armstrong and Wittmer (2011) emphasised that 'the quality of the release site is a particularly important factor affecting the benefits gained from large releases.'

Soft releases may include the provision of food and shelter for released birds. This can help anchor birds to the release site and prevent rapid, perhaps panic-driven dispersal. In the case of the White-winged Guan *Penelope albipennis*, productivity has bluntly been attributed to food supplementation: 'since 2001 there have been 50 wild White-winged Guan chicks born from reintroduced birds at CPCA… due to food availability' (Angulo 2008).

Managing maladaptation, 3: parent-rearing

Buner and Schaub (2008) found that the survival of captive-bred but parent-reared Grey Partridges was lower than in translocated wild individuals and captive-bred birds fostered to wild parents, attributing the difference to wild birds being more familiar with predators. Nevertheless, several recent studies have demonstrated that there is some value in parent-rearing galliforms intended for release.

Breeding stock (25 males, 25 females) of Red-legged Partridges was obtained from a game farm, introduced in autumn into a 4,000 m^2 pen enclosing grass and shrubs, and allowed to mate freely (a strategy already shown to benefit females); a year later the 42 offspring were caught at night, released into a 7.5 km^2 protected area alongside a cohort of 36 artificially reared birds, and after six months achieved a re-sighting rate of 22.6% against 0 for the 'artificial' stock (Santilli *et al.* 2012). Similarly, parent-reared Red-legged Partridges greatly outperformed intensively reared birds in terms of survival and behaviour, and came moderately close to figures achieved by wild birds (Pérez *et al.* 2012). Western Capercaillies *Tetrao urogallus* reared in semi-liberty by their captive mother and released next to her cage survived far better (males 549 *vs* 253 days, females 293 *vs* 56 days) than chicks reared in captivity and released in the absence of their mother, suggesting that 'mother-assisted rearing and release reduces the mortality of capercaillie chicks because they are assisted by anti-predator behaviour of their mother and explore the new environment in a similar way as chicks hatched in the wild' (Merta *et al.* 2015).

Managing maladaptation, 4: dietary enrichment

High-protein low-fibre diets commonly fed to commercially reared galliforms do not prepare them for the high-fibre dietary conditions that tend to apply in the wild (Parish and Sotherton 2007). Exposing Northern Bobwhite *Colinus virginianus* chicks to insects, in part to allow them to broaden their foraging skills and in part to add a nutritional component considered vital to feather growth (and hence to thermoregulation and flight), has been presumed but not (yet) proved to enhance post-release survival rates (Gall *et al.* 2000).

Improved post-release survival was, however, achieved in Common Pheasants through their prior exposure to more naturalistic diets, which meant that they kept better watch because they took less time to forage, handled live prey faster, relied less on supplementary feed and developed different gut morphologies; and therefore reduced the risk of predation by their vigilance, fed themselves better, and coped better with natural forage once supplementary feeding ceased (Whiteside *et al.* 2015). In Western Capercaillies, the lower diversity of bacterial microbiota in the caeca produced by a captive diet 'may be responsible for the high mortality of captive birds released into nature' (Wienemann *et al.* 2011), and captive ducks developed relatively short, light intestines that were judged to compromise digestive efficiency and hence survival prospects in releasees, a condition considered remediable by high fibre and greater diversity in the diet (Moore and Battley 2006).

Managing maladaptation, 5: anti-predator training

Anti-predator training prior to the release into the wild of captive-bred animals has become a widespread practice in reintroduction biology (review in Griffin *et al.* 2000), where it is also labelled 'environmental enrichment' (Roberts *et al.* 2011). It has been used occasionally in some galliform programmes: as early as 1975 a Northern Bobwhite release project included the harassment of potential releasees by humans, dogs and hawks, but found that too few birds could be trained in that way (Carpenter *et al.* 1991). More recently captive-bred adult Red-legged Partridges trained by caged birds calling and reacting to model aerial predators survived six times longer than untrained birds (105.2 *vs* 17.8 days), although when the training shifted to terrestrial (non-avian) predators the panic caused fatalities and work was suspended (Gaudioso *et al.* 2011a). Visits by predators to release cages at night (see next section) are assumed to stress releasees (Keiter and Ruzicka 2017), but presumably may still benefit the birds by familiarising them with the shape, smell and sound of hostile animals (and are perhaps less stressful than—albeit not necessarily a substitute for—training sessions). This dilemma requires further evaluation, along with the need to train birds to fear humans.

Training (calling) animals should preferably be of the same species as the trainees, but this is not always necessary; and training should coincide with the period of maximum learning receptiveness—evidently before six months (see below)—in young birds.

Managing maladaptation, 6: anti-predation stratagems

Unnaturally high concentrations of predators attracted to the vicinity of release pens (containing potential prey for up to 50 days) obviously prejudice the survival of releasees (Robertson 1988, Dowell 1992, Parish and Sotherton 2007). One stratagem to overcome this problem is to deploy multiple smaller release stations within the release site. Gortázar *et al.* (2000) released one cohort of Red-legged Partridges at a single central site and a second the following year at multiple sites around the centre: although both groups suffered 25–34% mortality in the first 72 hours after release, 37% of birds at dispersed sites survived the first month as against 6% at the central site. Eitniear (2010), seeking to reintroduce Montezuma Quail *Cyrtonyx montezumae* to an area of Texas, set up night-cameras around release pens to record what mammalian predators came to the area; live-trapped and translocated as many of these predators as possible; and placed seven male quails in a small cage within the larger release enclosure to lure the releasees back for food and roosting each night.

Straightforward predator control was practised by Angulo (2006, 2011) with White-winged Guans. A technique apparently untried with galliform reintroductions is the deployment of top predator odours such as tiger faecal extract to deter potential meso-predators from entering the area (Murray *et al.* 2006, Garvey *et al.* 2016).

Managing maladaptation, 7: numbers to release

Success rates in reintroductions correlate positively with number of animals involved; projects releasing over 100 individuals—not necessarily or desirably all at once—have been most successful, since populations below this number (and even above it, if the sexes are not in balance) are disproportionately susceptible to the influence of demographic events and the disruption of social and sexual interactions, including through Allee effects (sources in Faria *et al.* 2010, Armstrong and Wittmer 2011, Tracy *et al.* 2011). Moreover, compensation for persistent 'behavioral variation' (maladaptive behaviour resulting from generations in captivity, notably loss of fearfulness) requires an increase in the number of releasees, in one case calculated at 30–50% (McPhee and Silverman 2004).

For European grouse a review found that 'annual releases of at least 30 birds are needed for a period of more than 6 years, to reach a 50% probability for survival and reproduction of released birds' (Seiler *et al.* 2000), i.e. at least 180 birds altogether. However, a 50% probability of success is an unacceptable threshold for a Critically Endangered species that might already have died out in the wild; a far higher number of releasees (below I arbitrarily assume double) would be necessary to achieve 95% or 99% probability.

Guidance exists (Canessa *et al.* 2014) on how to balance numbers released with numbers retained in captivity to preserve full genetic diversity. Guidance does not exist, however, on how birds should be released (for which many options exist, e.g. 180 birds over six years could involve 30 in each year, as mentioned above, or 80 in year 1 and 20 each in years 2–6; and the 80 in the first year could involve one, two or three batches, at various several-month intervals, etc.). Without full explanation, Lockwood *et al.* (2005) concluded that future releases of Prairie Chickens *Tympanuchus cupido* should be multiple, 'with the initial release containing the fewest number of birds' but including 'excess males' as a priority.

Managing maladaptation, 8: choice and treatment of birds

Pre-release Red-billed Curassows suffered mortalities caused by aggressive individuals in release pens, leading to the suggestion that cameras should be used to identify dangerously dominant behaviour early and allow the problematic individuals to be isolated (Bernardo *et al.* 2011). This recommendation did not imply that these individuals should not be released. However, 'boldness' and 'risk-taking' in captive-bred animals has been found to be a threat to the individuals themselves (Bremner-Harrison *et al.* 2004, Roberts *et al.* 2011), and in Grey Partridges survival increased with diminishing levels of both temerity and timidity (Homberger 2014). Clearly such individuals need to be either treated for their behaviour or removed from the reintroduction programme. Importantly for the many galliform birds which seasonally form social groups, which includes most *Lophura* pheasants (Hennache and Ottaviani 2005), 'coveys' or social groups appear to serve to regulate corticosterone in individuals, such that 'the substantial covey effects… suggest that strategic manipulation of the social group prior to release could prove useful to enhance re-introduction success' (Homberger 2014). Releasing in coveys has proved relatively efficacious in Grey Partridge restocking (Buner *et al.* 2011).

Little information appears to exist on the selection of individuals for release. In a White-winged Guan reintroduction, only first- or second-generation and parent-raised birds were selected, requiring (a) maximum distance in blood relationship between selected individuals, (b) 1:1 sex ratio, (c) optimal health status and (d) sexual maturity (Angulo 2006, 2011). These criteria are clearly sound, but there is a strong case for varying the ages of birds by releasing immature individuals with their parents, since the former have a higher capacity to learn and adapt up to the age of six months, so that release at 4–5 months (allowing for 50 days in the release aviaries) might be expected to balance high levels of security with the opportunity to adjust to wild conditions (C. J. Nicol *in litt.* 2019). Learning by the releasers (i.e. the staff in charge) as well as the releasees allows adaptive management of the process, with the proportion of adults and juveniles determined by circumstance (Runge 2013).

Discussion

Given the apparent difficulties of galliform reintroductions using captive-bred stock, the value of finding an extant wild population of Vietnam Pheasant cannot be underestimated. At least six sites have been identified for survey (see Introduction). The use of camera-traps and food bait in a variety of microhabitats within 'ever-wet forest' below 300 m, consulting and, since the urgency is so great, perhaps even working with hunters using snares (Eames and Mahood 2017), should certainly be attempted. Nevertheless, two considerations render the chances of success relatively remote: first, if the species naturally lives at low density, the inevitably small size of any remaining habitat may itself constrain the viability of the population; second, such habitat may in any case have become drier and less suitable (see Introduction). Both these possibilities need evaluation in the course of surveying the six sites, with the accumulated evidence (primarily on habitat extent and condition but also snaring levels, local receptivity, abundance of potential competitor galliforms) determining whether and how to proceed with a reintroduction at any one of them. If wetness of forest proves not to be an issue, areas fenced against non-arboreal, non-avian terrestrial predators, perhaps also with the removal of competitor galliforms, might provide sanctuaries within which descendants of releasees could develop behaviours that would ultimately allow survival in the wild (J. W. Duckworth *in litt.* 2019).

Unfortunately, but understandably, guidelines for reintroductions (WPA 2009, IUCN/SSC 2013) do little to cater for extreme cases where wild populations are extinct, perhaps especially those on continental landmasses where factors may be more complex and difficult to manage. In birds seemingly the only instances comparable to the plight of Vietnam Pheasant are Alagoas Curassow *Mitu mitu* and Spix's Macaw *Cyanopsitta spixii* (BirdLife International 2019). Clearly every reintroduction must be elaborately bespoke, with more attention to detail than any guidelines can offer; but, particularly in cases where the value of the captive stock is incalculable, the assiduous compilation of information to optimise the chances of success is imperative. The release of birds incapable of surviving in the wild has been characterised as 'an immoral act' (McLean *et al*. 1999); how much more would this be so when the birds are among the last representatives of a species which nature itself cannot replace?

This review highlights eight areas of practice where improvements to standard reintroduction procedures for captive-bred galliforms, assuming the birds in question are maladapted by captive conditions, can and should be made. This means:

1. constructing release aviaries within the release area and therefore containing vegetation that fully matches that environment, including areas of the densest cover, and with roof netting high enough for birds to perch freely in sheltered spots;
2. committing releasees to at least 50 days in the release aviaries in order to ensure total familiarisation with the release environment;
3. maintaining the breeding stock in well-vegetated pens tall enough for perches to be provided and large enough for birds to select their partners and rear their own young, which may then form (at least a major part of) the released population;
4. providing food that mimics what the birds will encounter in the wild in due course (*Lophura* pheasants take vegetable matter and invertebrates in seemingly equal measure: Hennache and Ottaviani 2005), for the multiple benefits this provides;
5. training releasees to recognise and respond to aerial and terrestrial predators, using methods that balance effectiveness with safety;
6. establishing several release aviaries (preferably capable of being moved to new sites) to disperse predator concentrations, neutralising predation risk through the capture and relocation of predators that visit the sites, deploying olfactory animal repellent, and possibly providing food and shelter for releasees (via one-way 'pop-holes' that allow birds to move back into the aviaries) for a period of time;
7. preparing to release at least 300 individuals over a period of 5–6 years, i.e. around twice the number but in the same time-frame as in the grouse review by Seiler *et al*. (2000), while ensuring the donor stock is not genetically or otherwise compromised;
8. releasing natural groups of birds formed in captivity, following any protocols which optimise group development before or after release, and allowing an age structure in released groups that maximises learning opportunities for younger birds.

This is best regarded as a minimum list, as other insights and ideas will predictably emerge in the course of contemplating the particular circumstances of the species in question. Moreover, it is predicated on the assumption that hunting, one of the two main causes of the loss of the species from the wild (this applies to both Vietnam Pheasant and Alagoas Curassow), has been eliminated.

The implications of this body of measures are, however, considerable. The costs of certain components, notably creating large aviaries for natural breeding, may be expected to be high. The logistics involved in achieving release and donor populations that equally retain what little genetic diversity there is in the species are potentially daunting. The time-frame in which these measures can be implemented as a package will be far greater than the five years projected in Pham and Le (2015). Clearly these and other factors need to be compiled into a document to serve as a baseline reference, as detailed and thorough as (e.g.) the 160-page recovery plan for Washington state's Sharp-tailed Grouse (Stinson and Schroeder 2012); at present they are only being itemised in outline form for Vietnam Pheasant (Kapic *et al*. in prep.).

Population viability analysis (among galliforms examples include Marshall and Edwards-Jones 1998, Grimm and Storch 2000, Zhang and Zheng 2007, Bernardo *et al*. 2014 and Milligan *et al*. 2018) may also help clarify the type and number of activities and targets that could give shape and force to a recovery plan. However, demographic data on Vietnam Pheasant are very sparse and, on wild birds, non-existent. Other *Lophura* pheasants can furnish missing parameter values, but among galliform genera receiving research attention in the past 30 years *Lophura* has had the least (Tian *et al*. 2018), and in any case the few results can be highly variable—e.g. Siamese Fireback *L. diardi* occurring at a density of 5.6 birds per km^2 in Thailand (Suwanrat *et al*. 2014) but Kalij Pheasant *L. leucomelanos* averaging 321 birds per km^2 in Hawai'i (Zeng 2014).

WPA (2009) judged it 'probably inappropriate' to reintroduce species when (1) the security of the birds is at risk from (e.g.) poaching, (2) habitat requirements or life-history traits are inadequately known, (3) a disease outbreak might occur, (4) the causes of the original extirpation are not well mitigated, and (5) there is inadequate logistic, financial, institutional or public support. Of these, only the danger of disease outbreak can relatively easily be addressed (by providing a health plan programme for the birds at every stage, especially at times of stress such as capture and movement between areas: E. Simpson *in litt*. 2019). The threat of poaching (points 1 and 4) remains: forest blocks are now so small that trappers access all parts, employ largely non-selective techniques, and continue to snare more hunting-tolerant species (Eames and Mahood 2017); moreover, many trappers are rattan-collectors, and rattan harvesting is known to have 'adverse effects on understorey vegetation density' (Widayati and Carlisle 2012), which may severely affect the cover which Vietnam Pheasants require. Knowledge (point 2) of the habitat requirements and life history of Vietnam Pheasant is, as just noted, negligible. Financial support for the project is currently minimal, and in any case cannot properly be gauged or sought until a budget is agreed that covers all aspects of the project, some of which are outlined for the first time in this paper.

If, therefore, an attempt is to be made to re-establish a population of Vietnam Pheasant in the wild, it clearly needs to justify itself against these potentially fatal objections. Perhaps the most compelling response would deploy the argument that, with no birds likely to be extant in the wild and a diaspora of generations-old individuals held in captivity, it is of the highest urgency to take radical remedial action to save the species from extinction. Even so, any such action needs to demonstrate that it is grounded in best practice, guided by best practitioners and driven by the best information. This paper is mainly an attempt to support the last of these considerations.

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