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**Abstract:** A large amount of young birds are caught each year, shortly after having left the nest, and brought to care centers by people. Those birds are temporarily hand-raised before release. The effectiveness of this action remains however largely unassessed. Here we monitored the fate of 119 rehabilitated Little Owls (*Athene noctua*) and found a recruitment rate similar to wild birds (11.8% of 119 rehabilitated birds vs. 10.7% of 382 wild fledglings). Whether rehabilitated birds were released in autumn, or in following spring, seems not to affect recruitment probabilities, although the latter showed a tendency for reduced breeding success and dispersal compared to wild birds, suggesting autumn releases may be favoured.

## Introduction

The period after fledging is a critical phase during which young birds leave their nest with only limited flight skills (Cox et al. 2014). During this period, they are highly vulnerable to predation, but can also be collected by unaware people and brought to bird care centres. There, they will be hand-reared and usually kept in conditions where they can improve flight skills, before being released into the wild.

This ex-situ conservation action is widespread, especially for nocturnal raptor species in which chicks leave their nest well before being able to fly. In France for instance, a total of 2333 young owls of seven species have been brought to eight bird care centres between 2009 and 2015, a collect which was unnecessary in 78% of the cases (A.-L. Dugué & Ligue pour la Protection des Oiseaux, *pers. comm.*). The effectiveness of this action has however been rarely assessed and dedicated studies often suffer from data paucity and/or the lack of a proper control group (Joys et al. 2003). Whether temporary captivity at young age affect bird probability to recruit into the wild population and successfully reproduce has not been properly investigated to date (Ellis et al. 2000, Goldsworthy et al. 2000).

Here we assessed the rehabilitation effectiveness of young Little Owls (*Athene noctua*) by monitoring the fate of birds released in an intensively-monitored study area and comparing recruitment probability, dispersal and annual breeding success to wild birds. We further tested whether releasing rehabilitated birds in the next spring, instead of in the autumn, can reduce overwinter mortality and therefore could enhance the efficacy of reinforcement/reintroduction schemes (Van Nieuwenhuyse et al. 2008, Mitchell et al. 2011).

## Methods

*Study species, study area and population monitoring*

The Little Owl is a small-sized nocturnal raptor occurring in temperate and Mediterranean regions of the Western Palearctic. There the species inhabits open farmland, including vineyards and orchards. Chicks leave their nest at 28-32 days, with limited flight skills (Van Nieuwenhuyse et al. 2008). Another 10-14 days are required to the owlets for flying properly (Schönn et al. 1991).

We monitored a wild population of Little Owls over 100 km² in the Apt valley (43°54′11″N 5°17′37″E), Luberon natural park, south-eastern France (Fig. S1). The area consists in a mix of farming areas including vineyards, orchards, cereals (74%) with wooded areas (21%). Between 97 and 115 nest-boxes have been monitored annually between 2006 and 2017, according to a standardised protocol (see online resource). The number of nest-box occupied by a breeding pair increased from 5 to 24 between 2006 and 2009, then oscillated between 25 and 34 from 2010 onwards. An unknown number of pairs bred outside nest-boxes, in natural cavities or buildings, and were therefore not monitored. A peak of vocal activities occurred in March-April and the median date of first-egg laying was April 29$^{th}$ ($N$ = 204). Nest-box monitoring included the capture and ringing of breeding adults and of all chicks when 15-20 days old (see online resource for a detailed protocol). We considered an owl as a recruit when it has been caught in a nest-box containing eggs or chicks. Dispersal distances were calculated between the birth nest-box (wild birds), or the release nest-box (rehabilitated birds), and the nest-box used for prime reproduction.

*Captive-rearing techniques and release*

Between 5 and 25 fledglings (mean = 14 ± 6 individuals), typically 4-6 weeks old, were brought annually to the bird care centre held by LPO-PACA in Buoux (43°49′55″N 5°22′42″E), 5 km from the centre of the study area. Birds were brought from the Provence-Alpes-Côte-d'Azur region (PACA), within a radius of ca. 100 km around Buoux. Owls were kept indoor for a week in a box to ascertain they were able to feed by themselves. They were

88 then transferred to small outdoor aviaries (dimensions L×W×H: 8×6×3m) for four weeks and
89 finally into a larger pre-release aviary (30×6×2.5m). Contacts with humans were limited to a
90 unique daily feeding event. Food items were a mix of dead 1-day-old chicken and mice (2
91 prey.day$^{-1}$). No live prey were given.

92 A total of 119 Little Owls have been released between 2008 and 2015 (Table 1). Birds
93 were fitted with a metal ring (Museum Paris) and sexed using molecular techniques (see
94 online resource). Thirty-two birds have been additionally fitted with a radio-transmitter
95 weighing 2.5g glued on central tail feathers (see online resource for details). Releases
96 systematically consisted in one female and one male (one exception in 2013, see Table 1) put
97 together in a nest-box that was unoccupied during the previous breeding season. No food was
98 provided in the nest-box. Four cohorts (birds born in 2007-2010; $N = 74$) were released in
99 March of the subsequent year *t+1*, i.e. at the start of the breeding season. The rationale behind
100 this was to allow the owls to spend the winter under benign conditions, fed *ad libitum*, for
101 reducing overwinter mortality. Then, three cohorts (birds born in 2013-2015; $N = 45$) were
102 released in September of their birth year. This period precedes the autumn peak of vocal
103 activity in Little Owls, when dispersal and territory acquisition takes place (Exo 1988). No
104 owls born in 2011-2012 were released in the study area.

105 *Statistical analyses*

106 Statistical analyses were run using R 3.4.3 (R Development Core Team 2017). Recruitment
107 probabilities were modelled using generalised linear mixed models with binomial distribution
108 of error and year as random factor (function *glmmPQL*). Dispersal data were modelled using
109 linear models with log10-transformed distances (adding the minimal non-zero recorded
110 distance, δ). Breeding success was measured as the number of fledglings raised by a female
111 Little Owl (male data were too sparse for conducting similar analyses) minus the annual mean
112 number of fledgling per pair, to account for among-year variability. Relative breeding success

was then modelled using mixed linear models with female identity as random factor. Individual age was included as an explanatory covariate (log-transformed). Residuals from Gaussian models (dispersal and breeding success) were checked for normality and homoscedasticity. Regression coefficients ($\beta$) were shown ± 1 SE.

## Results & Discussion

*Recruitment probability*

Overall, owls passed through the care centre had a recruitment probability similar to wild birds from the same cohorts (14 recruits out of 119 rehabilitated birds, 11.8% vs. 41/382 wild birds, 10.7%; $\beta = 0.10 \pm 0.33$, $P = 0.76$; Table 1). Annual recruitment rates for the two groups were slightly correlated ($r = 0.74$, $N = 7$, $P = 0.057$), suggesting similar processes were governing temporal variation in recruitment. Transmitters did not seem to affect the probability of an owl to recruit (6 recruits out of 32 birds with transmitters, 3 out of 42 without transmitters; $\beta = 0.68 \pm 0.48$, $P = 0.15$). This result is not surprising given most birds had lost their transmitters before the start of the breeding season, therefore limiting the burden of carrying extra-weight (for details see Fig. S2).

*What is the best season for releasing rehabilitated owls?*

To answer this question, we compared the fate of birds released in autumn *t* vs. spring *t+1*. Although we acknowledge the optimal setting would have been to release birds from a same cohort at the two seasons, the within-cohort comparison of recruitment probabilities between rehabilitated and wild birds provides nevertheless some relevant information. Among the 79 birds kept in captivity during their first winter, 5 died overwinter (6.3%), indicating captivity strongly reduced winter mortality, apparent survival of first-year Little Owls ranges between 8 and 30% (Exo and Hennes 1980, Schaub et al. 2006, Le Gouar et al. 2011). However,

137 recruitment probabilities were not higher than for birds released during the autumn of their
138 first year of life (12.2% vs. 11.1%; Table 1). Overall, recruitment probability of wild birds did
139 not differ from rehabilitated birds released in either period ($\beta = 0.19 \pm 0.42$, $P = 0.66$; $\beta =$
140 $-0.40 \pm 0.54$, $P = 0.46$, for spring and autumn release respectively).

141 Dispersal distances between natal or release and breeding nest-boxes ranged from 0 to
142 14010 m (median = 1960, $N = 86$). Females dispersed slightly further than males (log10-
143 transformed values + $\delta = 190$; $\beta = 0.20 \pm 0.08$, $P = 0.02$). Rehabilitated birds released in
144 spring showed shorter dispersal distance compared to wild birds ($\beta = -0.56 \pm 0.14$, $P <$
145 0.001), while there was no such difference when release took place in autumn ($\beta = -0.01 \pm$
146 0.17, $P = 0.95$; Fig. 1).

147 Breeding success of female Little Owls increased with age (log-transformed age; $\beta = 0.61$
148 $\pm$ 0.26, $P = 0.02$, $N = 114$ breeding events from 60 known-age females, including rehabilitated
149 birds). Rehabilitated females released in spring *t+1* tended to have lower breeding success
150 than wild females ($\beta = -1.21 \pm 0.70$, $P = 0.09$, $N = 5$ females for 6 breeding events vs. 50/99),
151 while those released in autumn *t* did not suffer from such a reduction ($\beta = -0.30 \pm 0.62$, $P =$
152 0.63, $N = 4/9$).

153 *Towards efficient owl release techniques*

154 Here we took advantage of the intensive monitoring of a wild population to accurately record
155 the recruitment of rehabilitated young Little Owls and released into the wild. The fate of
156 rehabilitated birds is rarely assessed and usually focus on survival, ignoring recruitment (i.e.
157 survival till effective reproduction), although this measurement is crucial to evaluate the
158 effectiveness of bird care centre (Van Nieuwenhuyse et al. 2008). Despite a hard-release
159 protocol (Haase 1993, Mitchell et al. 2011), our results showed that temporarily captive-raised
160 Little Owls had recruitment probabilities similar to wild birds and reproduced successfully.

However, we cannot rule out the possibility that wild birds have actually higher recruitment rate than rehabilitated ones, associated to a higher propensity to successfully disperse outside the study area (Amar et al. 2000). Our dispersal results, however, did not provide evidence for this hypothesis. Contrary to our expectations, birds kept in captivity and thus provided with food throughout winter, did not show higher recruitment rates than birds released in autumn. This result suggest that mortality of juveniles may occur to a large extent shortly after fledging, rather than throughout the winter season (Exo and Hennes 1980, Coles and Petty 1997, Cox et al. 2014, Perrig et al. 2017). Rehabilitated birds, whatever their timing of release, escaped this critical period. Furthermore, evidences for reduced breeding success and dispersal for birds released in spring suggest it may be preferable to release rehabilitated Little Owls in autumn, during the dispersal phase, rather than in next year's spring. Under such conditions, breeding success of rehabilitated birds did not significantly differ from wild birds. Spring release might however be of interest in a reintroduction program for setting birds locally.

In conclusion, while people education should be implemented to reduce the unnecessary collect of young birds, our results demonstrate that simple hand-rearing and release techniques are appropriate for rehabilitating young Little Owls.

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**Table 1**: Numbers of young Little Owls released annually after being brought to bird care centre and later recaptured as breeder, to be compared with wild birds monitored in the same study area (Luberon natural park). Rehabilitated birds were released either in autumn of their first year of life (autumn *t*) or in next spring (spring *t+1*), after a winter kept in captivity.

| Cohort | Release period | Number of birds released | Number of rehabilitated birds recruited | % | Number of ringed wild birds | Number of wild birds recruited | % |
|---|---|---|---|---|---|---|---|
| 2007 | Spring *t+1* | 20 | 1 | 5% | 16 | 1 | 6.3% |
| 2008 | Spring *t+1* | 14 | 3 | 21.4% | 37 | 7 | 18.9% |
| 2009 | Spring *t+1* | 18 | 3 | 16.7% | 63 | 8 | 12.7% |
| 2010 | Spring *t+1* | 22 | 2 | 9.1% | 59 | 9 | 15.3% |
| Total in spring *t+1* | | 74 | 9 | 12.2% | 175 | 25 | 14.3% |
| 2013 | Autumn *t* | 13 | 2 | 15.4% | 65 | 7 | 10.8% |
| 2014 | Autumn *t* | 12 | 1 | 8.3% | 71 | 5 | 7% |
| 2015 | Autumn *t* | 20 | 2 | 10% | 71 | 4 | 5.6% |
| Total in autumn *t* | | 45 | 5 | 11.1% | 207 | 16 | 7.7% |
| Grand total | | 119 | 14 | 11.8% | 382 | 41 | 10.7% |

228 Figure 1: Dispersal distances (± 1 SD) between natal or release nest-boxes and nest-boxes
229 where first breeding was recorded for Little Owls according to sex and bird type (rehabilitated
230 birds released in autumn [*N* = 5 females, 1 male] or in spring [*N* = 5, 4], and wild birds [*N* =
231 32, 39]).

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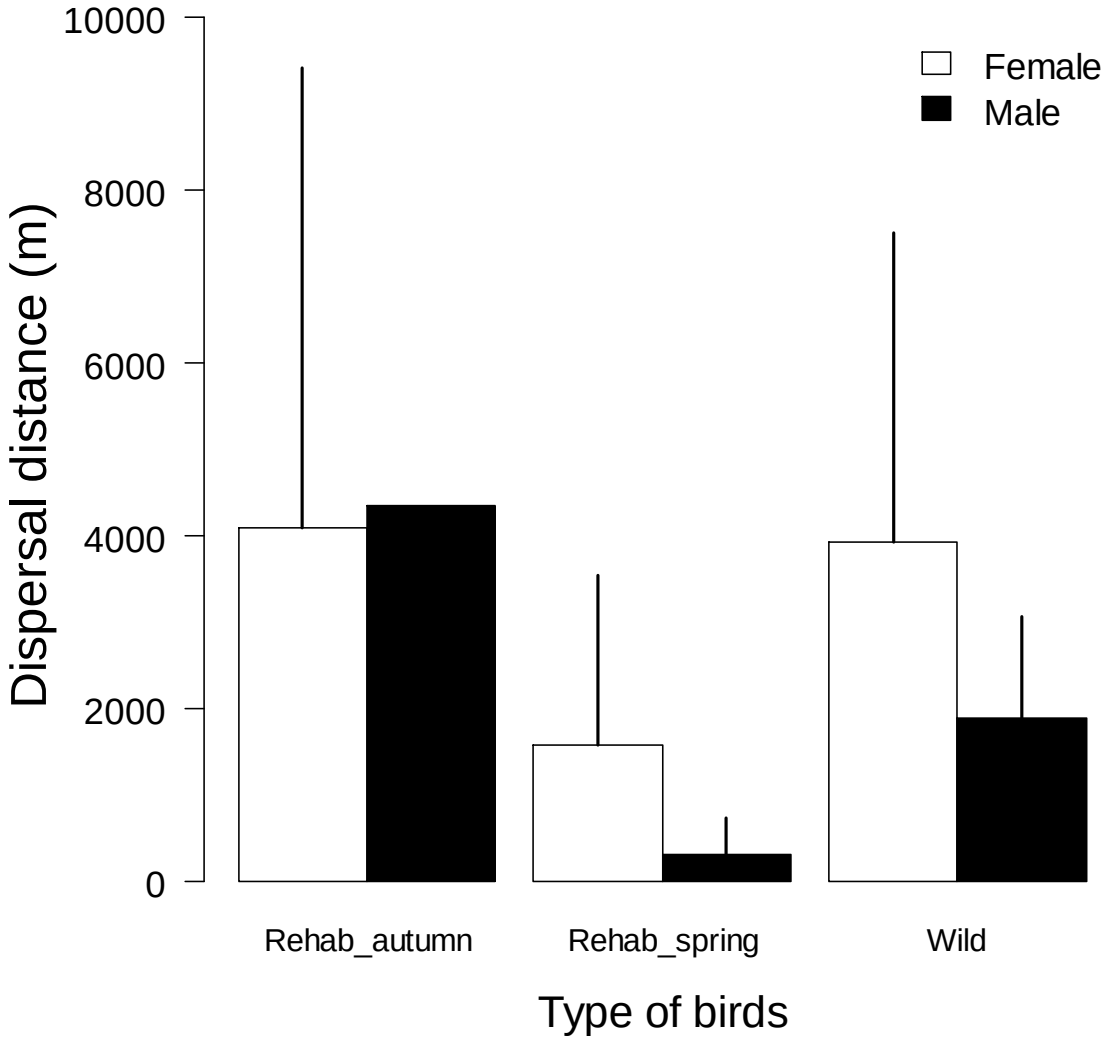


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