Effects of nest boxes on the most important population of red-footed falcon *Falco vespertinus* in Italy

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SUMMARY

The red-footed falcon is a near threatened species, which breeds mainly in agricultural landscapes, typically nesting in empty corvid nests on trees. In Europe, this species is declining due to habitat degradation and agriculture intensification. The aim of our study was to determine the reproductive success and the increase in the number of nesting pairs after the installation of nest boxes. This study took place in the Italian province of Parma, the southernmost part of the red-footed falcon's breeding range. Nest boxes were provided in four locations, where falcons were already breeding in corvid nests, to assess if this action could increase the falcon population and breeding success in the study area. After the deployment of 117 nest boxes from 2010 to 2018 the Parma population increased from 25 to 82 pairs, occupying up to 50% of available boxes in 2018. The breeding success remained unvaried over the study period with an average of 2.06 and 2.37 chicks fledged per pair in corvid nests and nest boxes respectively. It also did not differ between the two nest categories. These results could indicate that a lack of suitable nesting sites is a major limiting factor for the falcon population in the Parma province rather than lack of food.

BACKGROUND

The red-footed falcon *Falco vespertinus* is a raptor species, which breeds in wooded steppe, open rural environments with a predominance of extensive cultivation and pasture with stands and rows of trees (del Hoyo *et al.* 1994). It is classified as a near threatened species on the IUCN Red List (BirdLife International 2018) and as a globally threatened Species of European Conservation Concern (SPEC 1) (BirdLife International 2017). The global population has been estimated at 300,000-800,000 individuals, with 30,000-64,000 pairs in Europe (BirdLife International 2017). In central Europe, their populations declined by 30–40% between 1990 and 2000 (BirdLife International 2004). This decline is attributed to habitat degradation, pesticide spraying, loss of nesting sites, and the conversion of grasslands to agricultural fields (BirdLife International 2018). Over 90% of the Italian population breeds in the Emilia Romagna region of the Parma province (Nardelli *et al.* 2015). A serious threat to the red-footed falcon population is soil sealing: the destruction or covering of soil by layers of completely or partly impermeable artificial material such as buildings, asphalt, or concrete (Huber *et al*. 2008). This is an irreversible process and, in 2017, soil sealing increased by an average of 12% (compared to 2016) in the municipalities surrounding and including the Parma province (Rapporto ISPRA 2018).

The species does not need wooded habitats, only isolated trees for nesting and roosting. Generally, in our study area, they nested alone although, on one occasion, two pairs were found nesting in the same tree. In this region, hunting areas mainly consist of alfalfa crop. However in other areas, for example in Hungary, falcons hunt over corn or sunflower fields in early spring (when crop height is short) and over alfalfa and cereal crops later in the season (Palatitz et al. 2018). The red-footed falcon is sometimes colonial and exploits rookeries, artificial nest boxes and solitary corvid nests for breeding (Palatitz et al. 2009, Chavko & Kristin 2017). The red-footed falcon's natural nesting sites in Italy include magpie *Pica pica* and hooded crow *Corvus cornix* nests.

As with other falcon species (e.g. lesser kestrel *Falco naumanni*, see Catry *et al.* 2013; Gustin *et al.* 2017), many eastern populations of red-footed falcon use nest boxes (Fehérvári *et al.* 2015). These constitute one of the most common conservation actions for red-footed falcons in heavily transformed landscapes and are useful for research purposes, as the artificial nests can be placed in accessible locations to better enable behavioural, ecological or conservation research (Bragin *et al.* 2017). The use of nest boxes as a conservation measure has also been successful in 65% of the 22 studies (from nine countries) assessed on the Conservation Evidence website (www.conservationevidence.com/actions/489).

Our aim was to assess whether the Italian population of red-footed falcon would benefit from the provision of nest boxes. The study site, which includes six Natura 2000 sites and two nature reserves, is located in the Parma flood plain (Figure 1) and is characterised by an intensively managed agricultural landscape. Cultivated crops, such as cereals (corn, wheat, barley) and tomatoes, are alternated with forage crops, such as alfalfa and grass, - often used for cattle feed. This area represents the western periphery of the red-footed falcon's range (Grassi *et al.* 1999, Sponza *et al.* 2001, Palatics *et al.* 2018).

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ACTION

From 2009 to 2012 the authors were all involved in the LIFE Project "Interventions for bird life of Community interest in the Natura 2000 sites of the lower Parma plain" (Fior & Gustin 2012) that funded the installation of the first nest boxes and partially funded the subsequent 3 years of monitoring. Afterwards, all monitoring was carried out on a voluntary basis. Monitoring covered approximately 580 km^2 and was carried out during the breeding season from May to August (40 days per year during the breeding season). Every road within the study area was travelled by car or on foot (if inaccessible by car) and once one individual falcon was spotted (hunting or resting), it was followed in order to locate the nest (if present). Stops were made at previously known nesting sites in order to assess the number of active nests. Agricultural areas with rows of trees, isolated trees, or groves were considered suitable for the species and these were also checked for signs of nesting activity. Red-footed falcon nests were mapped at the beginning of the breeding season (May-June) in order to identify the most popular breeding sites within the study area and these were monitored at least once a week to assess breeding success. After the LIFE Project ended in 2012, LIPU-BirdLife carried out routine monitoring until 2018, using the same methods. In addition, we compared reproductive parameters and breeding success (number of chicks fledged) in nest boxes and natural nests using monitoring data collected in 2009-2018 in the lower Parma plain. We then interpreted these results in the context of management programmes in Italy.

From 2010 to 2018 we placed a total of 117 nest boxes in four sites where the red-footed falcon had previously nested in high densities using natural nesting sites (corvid nests, Figure 1). Table 1 provides details of the number of nest boxes installed at each of the four sites. The sites were: i) Viarolo (44°53.958'N-10°16.583 E), consisting of a 980 m row of black poplar *Populus nigra* and oak *Quercus* sp.; ii) Frescarolo (44° 58.506' N- 10° 07.056'E), consisting of a 200 m long row of black poplar; iii) Baganzola (44° 53.676'N- 10° 17.763'E) consisting of a 700 m line of black poplar and oak; iv) Crociletto (44° 58.715'N- 10° 10.670'E) consisting of a 200 m row of black poplar. In order to simulate colonies, nest boxes were placed near existing corvid nests in clusters 10 – 20 m high on rows of trees spaced 3 - 20 m apart. Boxes were fastened to the main tree trunk in locations accessible to the falcons and often close to a branch that could be used as a perch. One single tree could hold up to three nest boxes at different heights and aspects.

The nest box design was selected using the recommendations of Kotymán *et al.* 2015 (Figure 2). Both nest boxes and natural nesting sites were monitored throughout the breeding season with at least four visits to each occupied nest (from the discovery of the nest) in order to assess the breeding success (number of fledged chicks per pair).

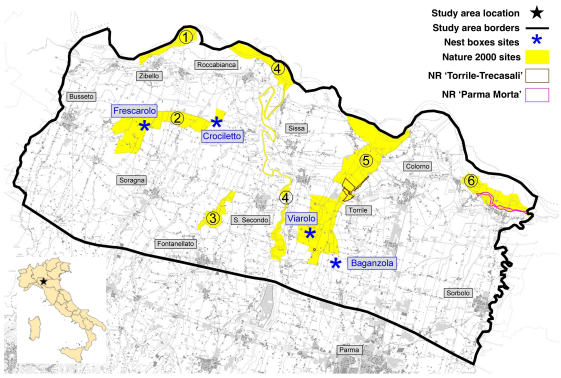

Figure 1. Study area in the Parma province including the four main red-footed falcon nesting sites where the nest boxes were placed and the two nature reserves (NR). Special Protection Areas (SPA) and Special Areas for Conservation (SAC) within the study area are also indicated. 1) SPA IT4020019 Golena del Po presso Zibello; 2) SPA IT4020018 Prati e ripristini ambientali di Frescarolo e San Boseto; 3) SAC IT4020024 San Genesio; 4) SAC-SPA IT4020022 Basso Taro; 5) SAC-SPA IT4020017 Aree delle risorgive di Viarolo, Bacini di Torrile, Fascia Golenale del Po; 6) SAC-SPA IT4020025 Parma Morta.

Table 1. Number of nest boxes present in each monitoring site from 2010 to 2018. In 2009 there were no nest boxes. Vi = Viarolo, Fr = Frescarolo, Ba = Baganzola, Cr = Crociletto.

Year	Site				Total Nest Boxes
	Vi	Fr	Ba	Cr	
2010	27	36	0	0	63
2011	27	36	11	0	74
2012	25	36	11	0	72
2013	24	36	11	0	71
2014	48	36	10	5	99
2015	57	33	8	5	103
2016	59	37	6	5	107
2017	55	36	2	18	111
2018	62	35	2	18	117

Nest boxes were cleaned once a year (October - February) before the arrival of red-footed falcons. Broken boxes were removed, replaced or repaired.

In order to assess whether the red-footed falcon population increased following the introduction of nest boxes we first assessed the overall population trend (measured as the number of breeding pairs). The response variable was set as the number of breeding pairs per year while the explanatory variable was represented by the year. In this way we established the relationship between population and years.

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Figure 2. Left: nest box design. Right: machinery used to install the nest boxes.

We tested whether the proportion of pairs occupying nest-boxes (Nests in NB/total nests, Table 2) increased significantly during the study period by fitting a binomial generalised linear model using the proportion of pairs breeding in nest boxes as the response variable and the year as the explanatory variable. We used paired t-tests to compare seasonal average breeding success (average number of chicks fledged per pair) between pairs breeding in nest boxes and in natural nesting sites (corvid nests).

The relationship between the total number of breeding pairs and the number of available nest boxes was assessed using linear regression with the number of breeding pairs as the response variable and the number of nest boxes as the explanatory variable.

All statistical tests were carried out using the open source program R (R Core Team 2019).

CONSEQUENCES

The red-footed falcon population in the Parma plain increased during the study period. The number of breeding pairs rose from 25 (in 2009) to 82 (in 2018). This rate of increase in the breeding population was significantly different from zero (R^2 = 0.87, d.f. = 8, $p < 0.001$, Table 2 and Figure 3). The nest box occupancy rate increased from 11.1% during the first year (2010) to 50.8% during the final year of the study (2018) and doubled from the second to third year and from the third to fourth year (Table 2). In 2018, 73.2% of breeding attempts occurred in nest boxes and the proportion of pairs occupying nest boxes increased significantly during the study period (% deviance explained = 0.65, d.f. = 8, $p < 0.01$). The number of red-footed falcon breeding pairs was positively correlated with the number of available nest boxes (R^2 = 0.74, d.f. = 8, $p < 0.01$, Table 2 and Figure 4).

There was no significant difference in breeding success between pairs using nest boxes and natural nest sites (paired t-test: t = 1.36, d.f. = 8, p = 0.21) (Table 2).

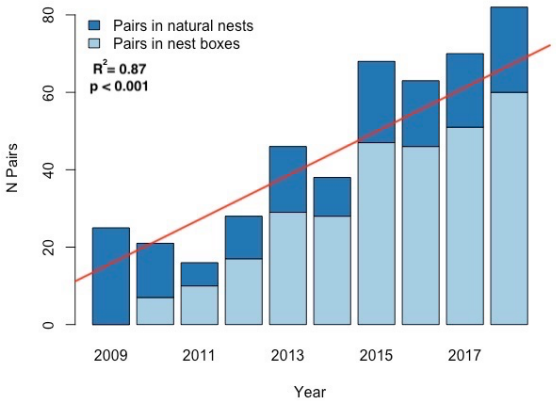

Figure 3. Number of breeding attempts in nest boxes and natural nests. In red the regression trend of the total breeding attempts across the years (with corresponding R^2 and p value), showing a significant positive upward trend.

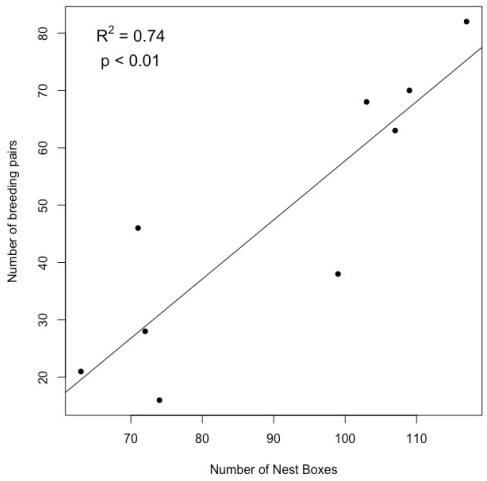

Figure 4. Relationship between the number of available nest boxes and the number of breeding pairs with the linear trend.

DISCUSSION

The red-footed falcon population in the Parma plain has increased significantly since the installation of nest boxes in areas already frequented by the species. This trend was positively correlated with nest box availability and this, together with our analysis of the occupancy rate, suggests that the addition of nest boxes is an important factor promoting this population increase. This was also observed in the Hungarian population where two thirds of red-footed falcons breed in nest boxes (Palatitz *et al.* 2015). In our study the occupancy rate increased after two years from the initial deployment. This population increase, after new nest sites were available, may indicate that the main limiting factor for this species is a lack of suitable nesting sites, such as corvid nests on high trees (Cramp & Simmons 1980).

In addition, over the past 20 years, agricultural operations in the Parma plain have intensified and many trees and hedges have been removed. Urbanisation and agricultural soil sealing in this area increased over the same period. For example, in 2016/2017 in the municipalities of Sissa-Trecasali

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and Fontevivo (both included in the study area), soil sealing increased by 7% on average; Sissa-Trecasali is the municipality with the highest soil sealing in the province (Rapporto ISPRA 2018). These processes may have reduced the availability of nesting sites (mainly because of tree felling), forcing the falcon population to increasingly rely on artificial nests (Bragin *et al.* 2017). The Hungarian population also suffered a large decline until 2000 due to the lack of nesting sites as most of this population nested in rook's (*Corvus frugilegus*) nests, a species that also suffered a population decline (Palatitz *et al.* 2015). At present, breeding success of the Italian population is high compared to the Hungarian and Slovakian populations, (Chavko & Kristin 2017, Palatitz *et al.* 2015) in both artificial and natural nests.

One nest box costs approximately €60 and, including the cost to rent an appropriate machine for installation and maintenance of nest boxes, the total cost of this operation over 9 years was approximately €10,000, (€1,120 per year). The greatest expenses were incurred during the first two years of the project (2010 and 2011) for the purchase of the first 60 nest boxes (Fior & Gustin 2012).

In conclusion, providing nest boxes proved to be an important action (although it was the only one we tested) for the red-footed falcon population in the Parma plain and, as such, is a conservation effort that should be maintained. However, concentrating the breeding pairs in only few areas may expose them to localised threats, such as increased urbanisation close to the colony or the removal of the rows of trees holding the nest boxes (either by natural or anthropogenic causes). Natural nesting sites are decreasing with the removal of rows of trees as a result of agriculture intensification and soil sealing. Therefore, it is important to influence agricultural policy in the area by promoting less industrialised agriculture by reducing soil over-sealing throughout the plain to provide more breeding sites and manage and increase the number of nest boxes. Nest sites should also be included in protected areas although this could be limited by the high financial cost and effort required from conservationists and stakeholders to install and maintain nest boxes.

Table 2. Number (N) of red-footed falcon breeding pairs and breeding parameters. Where NN = natural nesting sites (corvid nests), NB = nest box.

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
N pairs	25	21	16	28	46	38	68	63	70	82
N Nest Boxes*	-	63	75	73	71	99	104	107	111	117
N pairs in NN	25	14	6	11	17	10	21	17	19	22
N pairs in NB	-	7	10•	17•	29	28	47•	46	51	60•
N chicks fledged	48	18	36	72	128	111	132	152	160	195
N chicks fledged in NB	-	7	25	42	95	89	81	114	112	148
Nests in NB/total nests (%)	-	33.3	62.5	60.7	63.0	73.7	69.1	73.0	72.9	73.2
% occupied NB	-	11.1	12.0	21.9	40.8	28.3	44.2	43.0	45.9	50.8
N breeding success[#] in NN	1.9	0.8	1.8	2.7	1.9	2.2	2.4	2.2	2.5	2.2
N breeding success[#] in NB	-	1.0	2.5	2.5	3.3	3.2	1.7	2.5	2.2	2.5
Total[+] breeding success[#]	1.9	0.9	2.3	2.6	2.8	2.9	1.9	2.4	2.3	2.4

*nest boxes available at the beginning of the breeding season

•In 2011, 2012, 2015 and 2018 a pair of red-footed falcon occupied a kestrel nest box, deployed for another study. The number of pairs in those years includes this pair. Therefore, N Nest Boxes available is increased by one compared with Table 1.

[#] average number of chicks fledged per pair

[+] nest boxes and natural nests

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