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Vertical segregation by breeding ring-necked parakeets *Psittacula krameri* in northern Italy

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Abstract

Cavities represent a limiting resource for breeding birds, thus triggering potential competition, mostly in urban ecosystems. The ring-necked parakeet *Psittacula krameri* is one of the main alien invasive bird species of the world. Introduced populations are reported for over 35 countries, Italy included. This parakeet mainly depends on trunk cavities for reproduction but, occasionally, it may nest within building holes. A growing population of this species is present in the urban area of Pavia (northern Italy). Differently, from what has been observed in other colonies of the global introduced range, most of this urban population nests within the putlog holes of the Visconti castle and surrounding towers, together with four native species. In this work, we counted the breeding pairs of ring-necked parakeets nesting within putlog holes of castle and tower walls and estimated the breeding population size. Observations were carried out once a week, 30 min before sunset, for an hour, from the start of April to the end of August 2016 and 2017. We assessed whether a vertical segregation occurred between parakeets and native species (i.e. the rock pigeon, the jackdaw, the Italian sparrow and the common swift) through a dissimilarity index. Inter-specific interactions have never been observed, despite two pigeon ticks being detected on rescued parakeets. A strong vertical segregation was observed between ring-necked parakeets and pigeons, and between ring-necked parakeets and common swifts. Ring-necked parakeets and jackdaws were mostly observed in the highest putlog holes. No breeding parakeet pair was observed within plain trunk cavities in the surroundings of the castle walls, which were instead occupied by jackdaws and tawny owls. Most parakeet nests were located on the eastern wall, where they receive the first light at dawn.

Keywords Invasive alien species · Dissimilarity index · Bird communities · Nest site orientation · Nest heights · Putlog holes

Introduction

Nest site selection is one of the main components of habitat selection in bird communities (Stiles 1980; Stauffer and Best 1982). Adaptations to reduce nest predation and to facilitate access to nests has been evolved by naturally coexisting birds (Stiles 1980; Nilsson 1994). Cavities may suffer a lower predation risk with respect to other nesting sites (Nice 1957), and are therefore being widely used by many bird species (Cody 1985; Newton 1994). By contrast, they often represent a limiting resource (Wesolowski 2007; Cornelius et al. 2008), thus enhancing inter-specific competition. This is mostly evident in urban areas, especially when alien species are involved (Ingold 1989; Orchan et al. 2012). Alien species are not coevolved within the native community and may perturb the ecological balance amongst indigenous communities (Cody 1985; Orchan et al. 2012). A complete understanding of the interactions occurring between native and alien species is necessary to prioritize and improve management actions and control efforts (Mack et al. 2000).

The ring-necked parakeet *Psittacula krameri* (hereafter, RNPs) is among the most successful bird invaders of the world (Menchetti and Mori 2014; Le Le Gros et al. 2016), with established alien populations in over 35 countries

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(Menchetti et al. 2016). This parrot, whose original range includes sub-Saharian Africa and Indian subcontinent (Menchetti et al. 2016), is currently expanding its range, where introduced, becoming the most widespread species in many areas where it occurs (Strubbe and Matthysen 2009; Di Di Febbraro and Mori 2015; Menchetti et al. 2016). A wide range of impact typologies may be exerted by invasive RNPs, ranging from crop damage to behavioural interference and to parasite-mediated competition with native species (Mori et al. 2015; Le Le Louarn et al. 2016; Menchetti et al. 2016).

With regard to reproduction, RNPs mainly rely on existing trunk holes (Cramp 1985). Where these cavities are limiting, RNPs outcompete native species, advantaged by being early breeders and by their aggressive behaviour (Jones 1980; Strubbe et al. 2009), which is used to displace those already settled (Hernandez-Brito et al. 2014; Menchetti et al. 2014; Yosef et al. 2016; Mori et al. 2017). Very few breeding pairs are known to build their nests in wall holes or crevices in buildings (i.e. ~15% of pairs in northern India, ~5% in Seville, Spain and 0.001% in Rome, Italy: Grandi et al. 2016). A very peculiar case is represented by the city of Pavia in northern Italy, where a growing population of RNP has been present since at least 1999–2000 (Parau et al. 2016). The entire population is known to breed within the scaffold holes of the Visconti castle and surrounding towers (Grandi et al. 2016). During the breeding period, in urban areas, nests are also used as roosts by RNPs (Cramp 1985). Aims of our work where therefore *(i)* to assess the population abundance of the RNPs; *(ii)* to determine whether a vertical segregation with native species nesting within the same holes occurs and *(iii)* if nests faced a particular direction or were randomly located throughout the castle and the tower sides. We predicted that *(i)* the population of RNPs in Pavia is still increasing and that *(ii)* breeding pairs occupied the highest holes (as representing the best position to reduce predation risk and as being strong competitors: cf. Orchan et al. 2012) forcing native lower competitors to build their nests at lower elevation above the ground.

Materials and methods

The work was conducted within the city of Pavia, in southern Lombardy (62 km^2, 45.19°N-9.16°E) on the lowest part of the Ticino river near its confluence with the Po river. The study area is located in the continental-temperate zone at 65–70 m above sea level, with a mild climate. Mean monthly temperature (± SD) between April and August (i.e. the reproductive period of the studied species) is about 17.5 ± 7.0 °C, while mean precipitation (± SD) is about 75.3 ± 4.1 mm (https://it.climate-data.org/location/1101, accessed on 20th March 2018). The urban area is surrounded by farmlands (wine, rice, cereals, and dairy products) and factories (Colombo and Galeotti 1993).

The RNP population is located within the city center, with the breeding area occurring within the scaffold holes of the Visconti castle and four Medieval towers. The main feeding areas are located in the University garden and the main winter roost is along the Ticino river (Fig. 1). Scaffold holes (called “putlog holes”) are small holes commonly found in the walls of Italian castles and towers, to receive the ends of poles which support scaffoldings. In Pavia, a total of 3204 putlog holes are available in the Visconti Castle and Medieval towers (Table 1).

Population data of RNP in Pavia were collected within the European Cooperation in Science and Technology COST Action ES1304 (“ParrotNet”) to analyse the population trend. Counts of breeding pairs was carried out following Luna et al. (2016). Parrots were surveyed at nesting sites once a week between the start of April to the end of August 2016 and 2017. Censuses were conducted from the middle of the square, where a clear and complete overview of the area occurred. Counts started 30 min before sunset and continued for five minutes after no more birds came to roost. Four other species use the scaffold holes of Pavia castle and towers for nesting: the rock pigeon *Columba livia domestica*, the jackdaw *Corvus monedula*, the common swift *Apus apus* and the Italian sparrow *Passer italiae.* Number of breeding pairs of each species was counted at each week survey, together with nest elevation above ground (measured through a precision rangefinder ©Bushnell Tour V4) and exposure (measured as the orientation of nest hole and assigned to one of the four main cardinal directions). The vertical position of the nest was assigned to one of the following elevation categories: 1) 0–10 m; 2) 10–20 m; 3) 20–30 m; 4) over 30 m. Tree cavities of the surroundings plane trees *Platanus* spp. (at a radius of 550–1000 m around the castle) were also surveyed. The Dissimilarity Index (DI) was used to test if a vertical segregation occurs between the RNP and each native bird species (White 1986), both in 2016 and in 2017. DI was computed through the following formula:

$$\mathrm{DI} = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{n(ix)}{N(X)}-\frac{n(iy)}{N(Y)}\right|$$

where *n(ix)* is the number of records of the alien species, i.e. the RNP at the *i*-elevation level, *N(X)* the total number of records of RNPs, *n(iy)* is the number of records of each of the native species (i.e., the jackdaw, the rock pigeon, the common swift and the Italian sparrow) at the *i*-elevation level and *N(Y)* the total number of records of each of these species. We considered that a strong vertical segregation occurs at DI > 0.4 (White 1986). Differences in nest exposure were evaluated through a χ^2 test.

Number of adult and subadult individuals of common swifts fallen on the ground were counted once a week during

Fig. 1 **a** location of the study area (city of Pavia, northwestern Italy); **b**: Visconti castle (photo Prelvini: Wikimedia Commons); **c**: Medieval towers (photo Welleschik: Wikimedia Commons); **d**: pair of *P. krameri* in front of a scaffold hole (photo G. Grandi, A. Brambilla); E: a human-selected turquoise-cobalt morph of *P. krameri* in front of a scaffold hole (photo G. Grandi, A. Brambilla)

their reproductive period by local ornithologist. We used this information to assess whether take-off failures by this species was correlated to an increase in the RNPs population, and thus to vertical segregation.

Results

Before the RNP invasion (i.e., 1990–2000), local ornithologists and birdwatchers reported that highest holes (i.e.

Table 1 Vertical segregation between RNPs and native birds nesting in the same area

	Rock pigeon	Jackdaw	Common swift	Italian sparrow
RNP (2016)	0.43*	0.15	0.53*	0.14
RNP (2017)	0.48*	0.14	0.64*	0.13

*, strong vertical segregation

category 3 and 4) were mainly used by jackdaws (>60%), pigeons (~25%) and common swifts (~15%: G. Boffi, personal communication). The population of RNPs in Pavia is currently showing exponential growth and counts are currently near 100 individuals (Fig. 2). About 5–6% of this population shows the human-selected turquoise-cobalt morph.

Nests of all surveyed bird species were located between 2 and 36.6 m in the Visconti Castle, with some nests of RNP up to 48.5 m in the Medieval towers. This altitude range included 1674 (i.e. 52.31%) out of 3204 holes of the castle and towers. A total of 96 holes in 2016 and 95 in 2017 were used by birds (5.7 and 5.8%, respectively): 7 holes were used by two species in the same year (2017), i.e. the rock pigeon before March and the RNP after March. No interspecific interaction was observed, with the exception of harassment by RNPs on jackdaws in the surroundings of nests. Holes in plane trees ($N = 17$ total holes on trees) were occupied by jackdaws (70.6%) and tawny owls *Strix aluco* (5.8%).

The DI showed a high vertical segregation between RNPs and common swifts and, to a lesser extent, between RNPs and rock pigeons, in both years. Vertical segregation between RNPs and common swifts markedly increased between 2016 and 2017, with increasing RNPs population (Tab. 1; Fig. 3): the increase in fallen swifts (Fig. 4) was correlated to the increase in RNP population size ($r = 0.87$; $p = 0.04$).

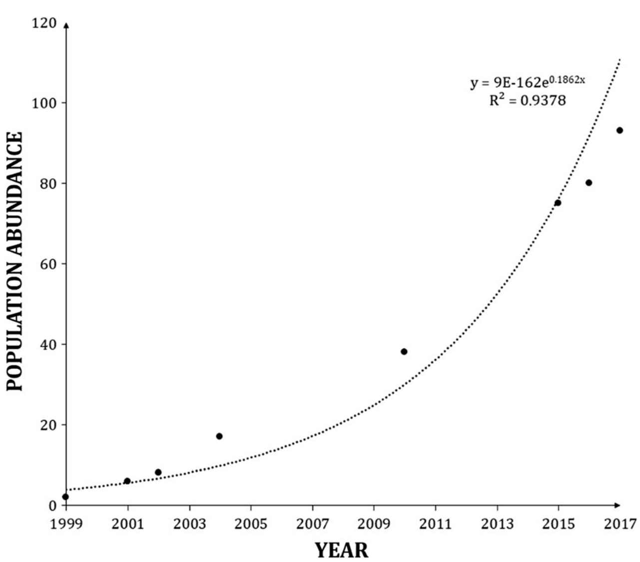

Fig. 2 Increase of RNP population size (number of birds) between 1999 and 2017

In 2016 and 2017, categories 3 and 4 were mainly occupied by RNPs (~52% occupied cavities at the same elevation category) and jackdaws (~40%). With respect to previously published data (Colombo and Galeotti 1993), the mean altitude used by breeding swifts decreased (Shapiro-Wilk $W = 0.91$, $p = 0.02$; Mann-Whitney $U = 422.5$, $p = 0.03$).

Nests of parakeets were unevenly exposed to the four cardinal points ($\chi^2 = 73.46$; df = 3; $P < 0.001$), being mostly located (42.08%) on the eastern walls of the castle and towers.

Discussion

In most of its range (both native and introduced), RNPs nest within tree cavities with very few breeding pairs using buildings (Grandi et al. 2016). Human settlements are occasionally used by breeding RNPs where tree holes are scattered (for instance, in Agrigento and Palermo, Southern Italy: EM, personal observation), or where a large number of competitors is present (e.g. in Sevilla, Spain: Grandi et al. 2016). In South Africa, scarcity of tree cavities is mainly supplemented by artificial nest-boxes, although some pairs also use building holes (Roche and Bedford-Shaw 2008; Symes 2014).

The population of RNPs settled and spreading in Pavia is growing exponentially (cf. Parau et al. 2016). This parakeet population is unique among introduced ones, as all the individuals breed in wall cavities rather than in trunk holes (Cramp 1985). This peculiarity may depend on the presence of many ancient buildings with putlog holes in Pavia, as well as on the limited availability of trunk cavities not yet occupied by native breeding birds (Colombo and Galeotti 1993). Gory (1987) reported that holes are the safest nest type, as they protect nestlings from predator attacks, but RNPs use mostly tree-cavities for nesting purposes in the introduced range (Grandi et al. 2016). One cannot rule out that the use of putlog/scaffold holes by breeding RNPs represents the result of a "cultural behavioural adaptation" (Alcock 2009). First pairs may have started to breed within putlog holes because of their local high availability (Colombo and Galeotti 1993); then, given the colonial roosting habits of this species (Menchetti et al. 2016), succeeding RNP generations followed the same behaviour. Predators of the RNP in the invaded range are mainly represented by raptor birds, such as the peregrine falcon *Falco peregrinus* (Menchetti and Mori 2014; Menchetti et al. 2016). Together with the peregrine falcon, some pairs of tawny owls, whose diet includes diurnal birds (Galeotti et al. 1991), are present and breeding in the surroundings of the Visconti castle (Galeotti 1990; Bernini et al. 1998). In Pavia, tawny owls breed in tree holes (Galeotti 1990), possibly forcing RNPs to avoid their usual breeding sites to reduce predation risk. Most nests of the common swift were located on warm, south-exposed walls (Colombo and Galeotti 1993), whereas those of RNPs were mostly east-

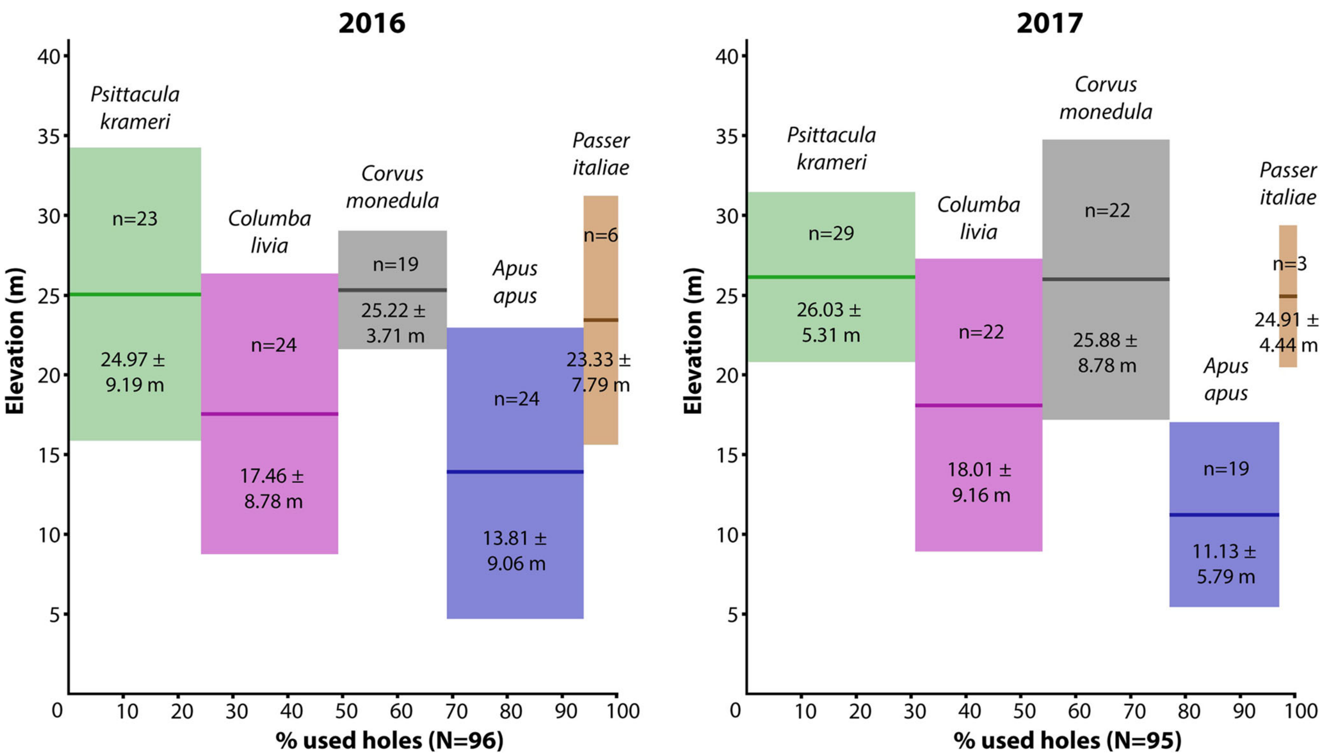

Fig. 3 Breeding pairs of all bird species detected in scaffold holes in Pavia during the surveyed years. Lines within boxes show the mean elevation (m), box heights show the SE and box widths show the percentage of the used holes by each species

exposed. East-exposed nests are the first to see light at dawn. During the breeding season, parakeets are active from dawn (about 06:00–7:00 a.m.) to dusk (07:30–08:00 p.m.: cf. Luna et al. 2016; Luna et al. 2017). Waking up early allows parakeets to reach feeding areas, shared with species having similar feeding habits (e.g. starlings, crows and jackdaws: Czajka et al. 2011; Strubbe and Matthysen 2011; Le Le Louarn et al. 2016), before them.

Together with RNPs, four native species currently use scaffold holes of the Visconti castle to breed. Native species are coevolved in the same environment and, even if they show similar nesting preferences, they are supposed to be adapted to share the breeding areas with other coexisting species (cf. Orchan et al. 2012). The low overlap in breeding seasons and the early breeding behaviour of the RNP with respect to native species (cf. Luna et al. 2017; Mori et al. 2017) may have prevented nest displacement events by the alien species. Despite this, the five species showed partially unparalleled breeding seasons (e.g. Brichetti et al. 1992; Sacchi et al. 2002; Salvati 2002; Sicurella et al. 2015; Luna et al. 2017). All species also used their nesting holes as roosts throughout the study period, allowing us to test for vertical segregation by the alien RNP. Co-occurrence of alien and native species did not result in any direct interaction, with the exception of some alarm calls of RNPs against jackdaws nesting in their immediate surroundings. RNPs used holes at the top of the castle and the towers together with the jackdaws, which were the most aggressive indigenous species and the only ones able to cope with alien parrots (cf. Mori et al. 2017).

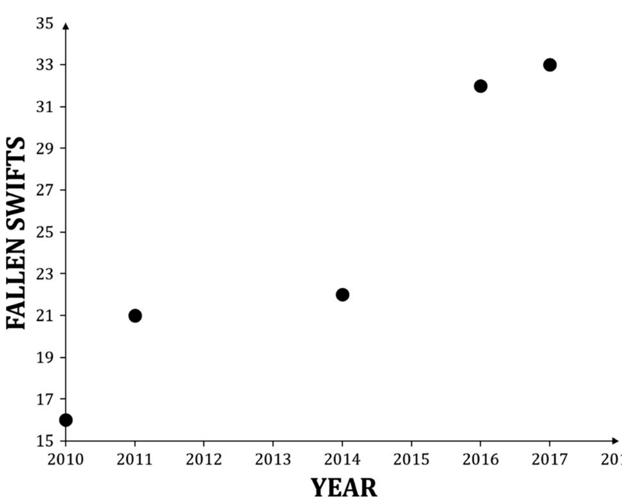

Fig. 4 Trend of fallen swifts on the ground per year in Pavia

Despite differences in body size (cf. Johnston and Selander 1973; Menchetti et al. 2016), RNPs and sparrows use similar holes to nest in (Orchan et al. 2012). Where they coexist at high population densities, RNPs are reported to display aggressive behaviour against sparrows (Orchan et al. 2012). In our study, we did not observe any interspecific interaction between these species, possibly because of the low density of the Italian sparrow nesting in the walls of the Visconti castle (cf. Orchan et al. 2012; Shwartz et al. 2008). Our data do not prevent us to exclude that the decline in Italian sparrow density in the study area might be due to competition with RNPs. Given the endemic status of the Italian sparrow, potential competition with introduced parakeets might affect its conservation status (cf. Bernini et al. 1998; Brichetti et al. 2008).

Vertical segregation in nest height occurred mainly with rock pigeons, which used nests located <10 m above the ground, and with the common swift. Year by year, RNPs occupy holes previously occupied by pigeons and become increasingly infestated by nest-living pigeon parasites (i.e. the pigeon tick *Argas reflexus*: Mori et al. 2015). On the other hand, the common swift facilitates its take-off success by building nests in holes located high in human settlements (e.g. towers: Lack 1956; Colombo and Galeotti 1993). Before RNP invasion, the common swift mainly used high holes (up to 23 m) for nesting (Colombo and Galeotti 1993). Currently, the species is nesting lower and lower each year, with most nests currently occurring lower than 8 m. Furthermore, the abundance of swifts breeding within the holes in Pavia towers and castle is currently declining with respect to the 1990s (Colombo and Galeotti 1993).

Before parakeet invasion, swifts bred at lower elevations than RNPs currently do and their nests were mainly south exposed. Together with the fact that over 90% of available holes are not used by breeding birds, one may have predicted that no competition would have occurred between RNPs and common swifts after the RNP invasion. Conversely, the number of swift take-off failures, measured as the number of adult and subadult swifts found on the ground at the bases of the castle and the towers increased with increasing RNP population size. Therefore, interspecific competition may be suggested, probably because RNPs occupy high cavities before the arrival of swifts from wintering quarters, forcing them to use lower ones.

Management of invasive alien species within urban areas is very challenging, as many actions are often boycotted by animal-right groups (Howald et al. 2010; Bertolino and Genovesi 2003; Perry and Perry 2008), thus failing. These ill-advised actions are particularly evident when alien species of charismatic and pleasing appearance, such as parakeets, squirrels and minks, are involved (Macdonald and Harrington 2003; Genovesi 2005; Bremner and Park 2007). Boycotts have led to the expansion of invasive alien species even far from their introduction sites, increasing their impacts on native biodiversity (e.g. Bonesi and Palazon 2007; Bertolino et al. 2014). Although there is no strict need to control RNP populations in Europe (Menchetti and Mori 2014), an increase in their population size may be detrimental for native species and human activities and infrastructures (Menchetti et al. 2016). The RNP spread outside of urban strongholds where most established populations currently live is likely to occur, thus increasing the concern of future conservation scenarios (Strubbe et al. 2015). Therefore, the sooner each control measure is taken, the more likely they will succeed and the cheaper they will be (Genovesi and Shine 2004; Genovesi 2005; Vall-Llosera et al. 2016). RNPs in Pavia may represent one of the easier removal scenarios in Europe, as the population size is relatively low (Fig. 2) and all the individuals roost and nest in putlog holes. Therefore, they could be relatively easy to be captured during the breeding season. Direct killing may be avoided by carrying out sterilization programs, economically acceptable with small populations, and by keeping captured individuals in captive conditions. Egg-removal would be another measure to take to avoid the RNP spread towards the countryside.

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