Birds introduced in new areas show rest disorders

Pierre-Yves Henry1,2, Catalina Landeta Salgado3, Fanny Paucar Muñoz1 and Martin C. Wikelski1,4,5

1Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ, USA
2UMR 7179, CNRS—Muséum National d’Histoire Naturelle, Brnoy, France
3Laboratorio de Biología, Pontificia Universidad Católica del Ecuador, Quito, Ecuador
4Department for Migration and Immuno-Ecology, Max Planck Institute for Ornithology, Radolfzell, Germany
5Department of Biology, University of Konstanz, Konstanz, Germany

All colonizing individuals have to settle in a novel, conspecific-free environment. The introduction process should be poorly compatible with a good rest. We compared the resting behaviour of radio-tagged house sparrows (Passer domesticus) experimentally translocated into new, conspecific-free areas (introduced individuals, n = 10), with that of translocated sparrows that settled in naturally established populations (controls, n = 5). Resting habits of introduced sparrows markedly differed from those of control birds: they did not vocalize before going to roost, they changed their roosting habitat and they roosted 24 ± 7 min later and departed 13 ± 4 min earlier from the roost, resulting in a 5% rest debt. Because colonizing a new environment is expected to require heightened cognitive and physical activities, which in turn are constrained by the quality and duration of rest, we hypothesize that rest disorders and resulting cognitive impairments of newly released individuals could functionally contribute to the low post-release survival observed in (re)introduction attempts.

1. Introduction

Arrival and establishment of individuals in a novel, conspecific-free environment is an obligate step in the life of introduced, reintroduced and naturally expanding species. Biologists search for the traits that determine the establishment success [1–6]. Behavioural challenges that introduced individuals have to overcome during the initial stages after release are the rapid acclimation to new food sources, the interactions with native competitors, the avoidance of new predators and the ability to keep in contact with other introduced conspecifics (e.g. for reproduction) [4,6–9]. The rapid and effective adjustment of these behaviours to the new, local conditions is likely to be an important proximate determinant of the fate of introduced individuals [1]. On average, half of all translocated individuals die within days or months after release [3,5].

Learning and remembering the identification and location of new resources (food and shelters) and predators probably require heightened cognitive activities [1,9]. To maintain high, efficient cognitive performances, an organism has to rest and sleep [10]. The duration and the quality of the rest constrain the quality of cognitive operations [10,11], including predator avoidance [12]. But the introduction process seems poorly compatible with a good rest and sleep: individuals arrive in a new environment, devoid of informed conspecifics that otherwise could help to find a safe resting place. Hence, we hypothesize that the introduction process induces rest disorders, which could contribute to the low post-release survival of introduced individuals.

We predicted that resting habits (timing, habitat choice and social interactions) should be disturbed in animals introduced into a new, conspecific-free
environment. We tested these predictions with 17 house sparrows (*Passer domesticus*) from invasive populations that we translocated beyond an invasion front. Five of them unexpectedly joined established natural populations close to the invasion front and serve as control individuals characterizing the normal resting habits of sparrows in the study area.

2. Material and methods

We translocated adult house sparrows 5–10 km beyond an invasion front in the Central Andean valley of Ecuador (0° 55′–1° 56′ S, 78° 28′–46′ W; 2300–3600 m). Eight males were released with one female (single pairs), and nine males were released with four males and five females (groups of five pairs). Because the cohesion among individuals was very low (eight individuals ended up alone within a day, and four with one to three conspecifics), hereafter, we do not account for group size. Birds were released at a distance of 73 ± 15 (s.d.) km from their capture site. Experiments took place at the end of the breeding season (April–July). All birds were captured at roosts in urban parks, colour-ringed and were kept in an aviary for 3–7 days. On the day before release, one male per replicate received a 1.2 g radio-transmitter (Sparrow Systems, Fisher, IL, USA) attached on its back by a leg harness. Release sites were agricultural terrains at 0.21 ± 0.16 km from rural human settlements. Birds were caged at 06.27 ± 19 min and released 41 ± 7 min later. During this recovery time, they were provided ad libitum with food (barley and apple) and water. After release, radio-tagged individuals were followed for the entire period of diurnal activity (06.00–18.30) on days 1, 2, 3 and 7. When they were located precisely (± 20 m; 62% of the time), the GPS location of the bird was noted every minute. To document whether the pre-roosting vocal activity (dusk chorus) was affected by the introduction process, we systematically counted calls per minute (n = 19 322 counts, 64 578 calls). From these call counts, we computed a relative calling rate per hour (see the electronic supplementary material) that was compared between introduced and control individuals with a generalized linear mixed effect model (GLMM) for Poisson data, adjusted for overdispersion, using the ‘lme4’ function of the ‘nlme’ package (v. 3.1–109) for R. Explanatory variables were the status of the bird (introduced versus control) and the number of nights after arrival at a site (see the electronic supplementary material). Only two roost habitat types were observed: Eucalyptus trees and manmade buildings. The propensity to roost in the normal habitat (tree) was analysed with a linear mixed effect model, using the ‘lme’ function of the ‘nlme’ package (v. 3.1–109) for R. Explanatory variables were the number of nights after arrival at a site (see the electronic supplementary material). Only two roost habitat types were observed: Eucalyptus trees and manmade buildings. The propensity to roost relatively early or late, \( \chi^2 = 10.481, p = 0.001 \). The roosting time took several days to return to normality (figure 1a). Being alone or in a group of introduced birds did not influence the hour of roosting of introduced individuals (\( F_{1,11} = 0.033, p = 0.860 \)). In the morning, introduced house sparrows departed 13.0 ± 3.7 min earlier from the roost than control individuals (\( F_{1,10} = 12.246, p = 0.007; \) figure 1b). Overall, introduced sparrows roosted for 11.9 ± 0.3 h (n = 9), whereas control individuals roosted for 12.5 ± 0.2 h (n = 4). The average daily resting debt was 37 min, corresponding to a 5% reduction of the total rest duration, and a 27% reduction of the daytime spent at the roost (1.7 versus 2.3 h, respectively, for introduced and control sparrows).

Introduced birds also differed from controls in their habitat choice for roosting (\( \chi^2 = 5.381, p = 0.020 \)). In 48% of cases, they roosted in manmade constructions (houses or barns), whereas birds in established populations roosted in Eucalyptus trees in 94% of cases. In their populations of origin, all translocated birds roosted in the trees of urban parks. The vocal activity of introduced sparrows was also strongly disturbed. They lacked the dusk chorus that normally takes

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\[ 13.0 ± 3.7 \text{ min} \]

\[ 11.9 ± 0.3 \text{ h (n = 9)} \]

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\[ 37 \text{ min} \]

\[ 5\% \text{ reduction} \]

\[ 27\% \text{ reduction} \]

\[ 48\% \text{ of cases} \]

\[ 94\% \text{ of cases} \]
Figure 2. Vocal activity of introduced sparrows (white bars) and control sparrows (black bars). The relative calling rate (± 1 s.d.) is defined in the electronic supplementary material. A value higher than one indicates a calling activity x times higher than the daily average per status. p-values correspond to quasi-likelihood ratio tests of differences in dusk chorus per hour.

place at pre-roost sites and when sparrows join the roost (figure 2).

4. Discussion

Experimentally introduced sparrows exhibited several rest disorders: they did not vocalize before going to roost, they changed their roosting habitat and they roosted later and departed earlier from the roost, resulting in a 5% resting debt. But the behavioural challenges associated with the introduction process should require an extended and improved—rather than a reduced and disturbed—amount of rest and sleep. On the first few days after release, the physical activity of introduced birds is increased, with restlessness linked to exploratory movements (P.-Y. Henry 2004, unpublished data; [14]). This intense activity should be compensated for by an increased duration of rest-based recovery [15–17]. Unfamiliarity with the new environment probably induces some food shortage [8], in turn increasing the need of sleep-based energy saving [16]. In addition, introduced animals are likely to acquire an important amount of new vital information which they need to process, analyse and memorize, such as the location of food, predators and sleeping sites. The associated extra load of cognitive operations suggests that a long and good sleep might be needed [10,16]. The contradiction between these expectations and our observations allows us to hypothesize that rest disorders, and subsequent impairments, may contribute to the transitory low chances of survival of introduced animals in the days after release. Because the timing of rest and the birds’ ability to tolerate sleep deprivation differ between individuals [11,17], there should be room for selective filtering on the resilience of cognitive performances according to rest disorders.

Chronic stress may have enhanced the desynchronization of the resting behaviour in introduced sparrows. The translocation process stresses the animals to a level that can even result in the lack of responsiveness against predators [8]. Chronic stress also hampers cognitive performance, including memory, learning and decision making [7]. This may explain the decreased ability of introduced individuals to choose suitable roosting places. Indeed, an experimental increase in circulating corticosterone alters the structure of sleep in captive sparrows [18].

Social disorganization may also have contributed to the desynchronization of the resting rhythm in introduced sparrows. House sparrows are gregarious. In group-living species, the pre-roosting social gathering and the dusk chorus probably play a positive role in the synchronization of roost timing between individuals. But our introduced house sparrows were alone or in small groups (see also [2,4]) and lacked the dusk chorus. The lack of pre-roost, social stimuli phase may have contributed to the temporal and spatial disorganization of their resting behaviour.

We have formulated a number of hypotheses about the potential links between rest disorders, cognitive impairments and post-release mortality in (re)introduced species. These hypotheses are new and remain to be substantiated by observational and experimental evidences.

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