Birds introduced in new areas show rest disorders

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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 (\textit{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.
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 conspecics), 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 `lmer` function of the `lme4` package (v. 0.999999-2) for R [13].

A bird was considered to be at roost when it did not change location until dark. In eight cases out of 32 roost locations, the hour of roosting was known with an average uncertainty of 6 min (range: 1–9 min). In that case, we used the mean value between the earlier and the latest possible hours in analyses. Results remain unchanged if we used the first or the last time of roosting (results not shown). The roosting times were 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 status of the individuals (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 probability of roosting in the normal habitat (tree) was analysed with a GLMM for binomial data. Repeated measures were accounted for by random individual effects. Electronic supplementary material, table S1 reports the sample sizes for each analysis.

3. Results

On the day of arrival in unknown, conspecific-free areas, introduced sparrows had difficulties finding suitable roosting places. They started to search relatively late for a place to sleep, trying several sites before settling somewhere. They went to roost 23.6 ± 6.8 min later than control individuals (*F*1,10 = 18.459, *p* = 0.002; after accounting for the individual propensity to roost relatively early or late, *X*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*1,9 = 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 (*X*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
2. Blackburn TM, Cassey P, Lockwood JL. 2009

3. Armstrong DP, Seddon PJ. 2008 Directions in

References

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, unpub-
lished data; [14]). This intense activity should be 

compensated for by an increased duration of rest-based recov-

ery [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, intro-
duced 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 dis-

orders, 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 indi-
ciduals [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 disorganization 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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References

1. Sol D, Duncan RP, Blackburn TM, Cassey P, Lefebvre 

L. 2005 Big brains, enhanced cognition, and 

response of birds to novel environments. Proc. Natl 


0408145102)

2. Blackburn TM, Cassey P, Lockwood JL 2009 
The role of species traits in the establishment 

success of exotic birds. Glob. Change Biol. 15, 


01841.x)

3. Armstrong DP, Seddon PJ. 2008 Directions in 

reintroduction biology. Trends Ecol. Evol. 23, 


behavioral and personality traits influence the 

success of unintentional species introductions? 


2011.09.010)

5. Cassey P, Blackburn TM, Duncan RP, Lockwood JL. 

2008 Lessons from introductions of exotic species as 

a possible information source for managing 


(doi:10.1071/wr07109)

6. Cassey P, Blackburn TM, Duncan RP, Lockwood JL. 

2005 Lessons from the establishment of exotic 

species: a meta-analytical case study using birds. 

J. Anim. Ecol. 74, 250 – 258. (doi:10.1111/j.1365-

2656.2004.00918.x)

7. Teixeira CP, De Azevedo CS, Mendil M, Cipreste CF, 

Young RJ. 2007 Revisiting translocation and 

reintroduction programmes: the importance of 


1016/j.anbehav.2006.06.002)

8. Dickens MJ, Delehanty DJ, Romero LM. 2010 Stress: 

an inevitable component of animal translocation. 


j.biocon.2010.02.032)

9. Wright TF, Eberhard JR, Hobson EA, Avery ML, 

Russello MA. 2010 Behavioral flexibility and species 

invasions: the adaptive flexibility hypothesis. Ethol. 


2010.505580)

10. Rattenborg NC, Martinez-Gonzalez D, Roth TC, 

Pravosudov VV. 2011 Hippocampal memory 

consolidation during sleep: a comparison of

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.


