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The post-release fate of hand-reared orphaned bats: survival and habitat selection

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Abstract

Although bats are frequently admitted to rescue centres — mainly as orphans — very little information is available on their survival after release. Our study answered the following questions: i) do hand-reared bats survive over a short time; ii) which activities and habitat selection do they exhibit; iii) are bats loyal to the release area; and iv) are they able to join local colonies? We radio-tracked 21 hand-reared Pipistrellus kuhlii *over a two-year period released on a site that differed from that where they were rescued. At the study site they were provided with the same bat boxes used in the rehabilitation room. Nineteen bats were confirmed to survive, stay in the area and actively forage over 4–14 days. Fourteen day roosts in buildings (nine of which hosted a local colony) were used by 12 subjects. Bats travelled less than 5 km in total each night; their most frequent activity was night roosting, followed by foraging and commuting. We recorded typical foraging behaviour, including hunting around street lamps at sites exploited by many conspecifics. A comparison of habitats available within individual home ranges with those within the study area showed that urban areas, riparian vegetation and farmland were equally important and preferred to woodland. When the foraging time spent in each habitat was compared with habitat composition within individual home ranges or within the study area, urban sites were preferred for foraging over all other habitats, followed by farmland and woodland and finally riparian vegetation. Overall, we showed that hand-raised orphaned* P. kuhlii *may readily adapt to environments they are not familiar with, exhibit a high short-term survival and select key resources in the release area, provided appropriate rehabilitation and training techniques are adopted.*

Keywords: *animal welfare, Kuhl's pipistrelle, post-release survival, rehabilitation, roost, sociality*

Introduction

Every year, thousands of wild animals are admitted to rescue centres worldwide. A main reason for wildlife rehabilitation is that it provides a solution to an animal welfare problem. Injured, ill, diseased and orphaned wild animals have the potential to suffer and rehabilitation improves their welfare. Moreover, rehabilitation plays a major role in educating people towards the importance of wildlife preservation. It also provides valuable scientific information, such as timing of births — defined on the basis of the arrival of orphans at the centres (Biasoli *et al* 2004) — or the assessment of human-related factors in mortality impacting selected species (Reeve & Huilser 1999; Lesiński 2008).

Individuals that are unable to be released can still be employed in captive breeding or educational programmes (Lollar & Smith-French 2002), and also provide the opportunity to test new management techniques (eg hand-rearing, housing, environmental enrichment). By examining the occurrence of pathogens or other health problems, rescue centres also offer an important opportunity for passive surveillance, with significant implications for both animal and human health (Ghatak *et al* 2000; Blanton *et al* 2008; Sleeman 2008).

However, assisting animals that are in difficulty to allow their return to the wild to reinforce populations can be criticised especially because data on the actual rehabilitation success, measurable as the chance that rehabilitated subjects will survive after release and adapt to the environmental conditions faced, are for most target species almost non-existent (Tribe & Brown 2000; Kelly *et al* 2010; Reid & Harrison 2010). In fact, although at present the veterinarian protocols for wild animals are relatively standardised (eg Wilson 1988; Hutchins *et al* 1991; Aguirre *et al* 2000; Miller 2000; Woodford 2000; Lollar & Smith-French 2002; Lewbart *et al* 2005; Barnard 2009a), if we consider the wide distribution of rescue centres, very few tests of post-release survival in rehabilitated subjects have been carried out, and those done either used small samples (Clumpner & Wasserman 1991; Westgate *et al* 1998; Lander & Gulland 2003) or focused on charismatic species (Morgan *et al* 1993). Only in the last few years has the fate of rescued and hand-reared wild animals received more attention, thanks in part to the recent advances in tagging technology permitting the radio-tracking of many species, including small ones (Kelly *et al* 2008, 2010; Leighton *et al* 2008; Reid & Harrison 2010).

A major concern with the usefulness of rehabilitation regards the location selected for the release of rehabilitated subjects. Because the latter often come from sites that are either unknown or so far (tens of kilometres or more) from the rehabilitation centre to make release on-site unfeasible due to limiting funds, staff, or both, *ex situ* release (ie the release on a site that differs from where the subjects were rescued) is a commonly adopted solution. Especially for adults, there is concern that releasing them into unfamiliar environments may affect their ability to survive more than naïve juveniles.

Finally, a large number of rehabilitated individuals are represented by infants not independent from their parents or naïve juveniles, which will inevitably miss the early social experiences needed to best perform in nature and interact with conspecifics (Fujita & Tuttle 1991; Robertson & Harris 1995; Cleveland *et al* 2006).

Bats are an important component of global vertebrate diversity, with over 1,100 species (Simmons 2005), and a key functional component in ecosystems (Whittaker & Jones 1994). Their sensitivity to anthropogenic alteration has put them at risk, and many populations are threatened or locally extinct (Lloyd & McQueen 2000; Lane *et al* 2006). Bats are protected in all European countries. In Italy, the national law protecting homothermous fauna and regulating game hunting (L 157/92) establishes that all bats are protected. Moreover, Italy has ratified international directives and conventions protecting both bats and their habitats (Bern Convention 1979; Bonn Convention 1979; EEC/92/43 Habitats Directive).

Although *in situ* conservation, based on the protection of existing roosting and foraging habitats, represents the main way to preserve this mammal group (Fenton 1997), rehabilitation has the potential to constitute a locally important ancillary approach to bat conservation. In theory, even house-dwelling species that are still frequent in urban areas are conservation-dependent because they are exposed to major threats such as roost destruction and direct mortality caused by conflict with people. From this point of view, effective procedures succeeding in rehabilitating significant numbers of bats found in difficulty could help counter population decline and, overall, contribute to preserving urban biodiversity.

To-date, there is little information on the survival of rehabilitated bats after release. Kelly *et al* (2008) related the post-release survival capabilities to the different rehabilitation protocols in common (*Pipistrellus pipistrellus*) and soprano (*Pipistrellus pygmaeus*) pipistrelles. In that study, hand-reared infants were subjected to different rehabilitation protocols and radio-tracked after release. Of 12 study subjects, seven released after limited flight training during rehabilitation had to be rescued or appeared to have died. In contrast, the five bats allowed prolonged flight training in a large flight cage survived after release, at least for the short term. Apart from this interesting study, which did not deal with the issue of habitat selection by released individuals, a few others (Adkins & Wasserman 1993; Dicke 1994) only provided anecdotal information on post-release survival. There is also very little information concerning translocation of bats for conservation reasons (see Ruffell *et al* 2009) and information from rehabilitated bats could prove useful to conservationists considering translocation.

Overall, the question of whether rehabilitated bats survive in the wild after release in a short-term basis and how habitat selection patterns develop still deserves attention: accordingly, we focused on such issues and selected for our study a house-dwelling species of bat, the Kuhl's pipistrelle (*Pipistrellus kuhlii*), common in urban areas or other human-altered habitats of southern Europe (Schober & Grimmberger 1997). The species roosts mostly in fissures and crevices in buildings, although it originally roosted in natural cavities such as rock crevices or tree holes (Sachanowicz *et al* 2006). The close proximity of this species to people makes it one of the bats most frequently admitted to rehabilitation centres, as adults or especially infants. Most *P. kuhlii* enter Italian centres for wildlife rehabilitation in June–July, when pregnant females give birth and infants or non-flying juveniles are present at roosts (Agnelli *et al* 2006). For instance, most (77%) of the 202 bats admitted in 2009 to the bat rehabilitation centre in Rome were juveniles. This sample was dominated by *P. kuhlii* (69%), followed by Savi's pipistrelles (*Hypsugo savii*; 30%) and common pipistrelles (*P. pipistrellus*; 1%) (MT Serangeli, personal observation 2009). For our radio-tracking experiment we therefore chose *P. kuhlii* as a representative model species for bats admitted to rehabilitation centres.

Radio-tracking bats provides an extremely valuable picture of their spatial use, foraging behaviour and habitat selection, but the amount of data collected is still constrained by the short duration of miniaturised batteries. Thus, although one of the aims of our study was to test whether hand-raised bats survive after release, our test was inevitably limited to the short (generally < 2 weeks) time corresponding to battery life.

We also aimed to answer the following questions: i) which activities and habitat selection do hand-released bats exhibit; ii) are they loyal to the release area; and iii) can they join local colonies?

Therefore, we assessed bat activity and habitat preferences, determined whether they remained within the release area and whether they were accepted by local conspecifics, ie they joined their colonies.

This knowledge can clearly be important for optimising rehabilitation and release protocols.

Besides having implications for the management of rehabilitated bats, our study offered a chance to explore the onset of behavioural patterns of foraging and roosting by fully naïve bats with little or no previous social experience and complete lack of knowledge about the landscape they faced following release. Because this condition is potentially similar to that

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faced in reintroduction or restocking programmes, we discuss our findings in the light of the experience gained with bats and other taxa and consider potential implications for bat translocation. Our study is the first to employ rigorous habitat selection testing to look at these issues.

Materials and methods

Housing and rehabilitation

The study subjects were orphaned newborn and infant *P. kuhlii* coming from different areas of the Lazio region, central Italy (their age ranged from one day to three weeks) which in summer 2008–2009 were admitted to Rome's Rescue Centre of the Italian League for the Protection of Birds, in the same region. We aged them according to our experience and published information (Lollar & Smith-French 2002). Bats were initially housed in 25 × 30 × 18 cm (length × width × height) cardboard boxes and sorted according to their age into small groups of five or six subjects. The box walls were perforated to allow sufficient air flow. The boxes were also fitted with strings and fabric strips upon which bats could hang. A section of the box was warmed by placing it on a Zoo Med heat cable (15 Watt voltage, supplied by Zoo Med Europa, Ekeren Antwerpen, Belgium) for reptile terrariums. Bats were first fed on First Age-Royal Canine powdered milk (First Age by Royal Canine, Italy) replacement for puppies until they were three to four weeks old (Kelly *et al* 2008) using a syringe with a plastic cannula (Catheter Radiopaque Jelco®, Smiths Medical, USA). After this period, bats were weaned with mealworms (Barnard 2009b). By the end of the weaning period, juveniles had learned to feed independently. Water was available *ad libitum* in small, steel bowls. While still in the boxes, bats were presented with food in the same bird feeders later provided in the rehabilitation room they were moved to. Once they learned to self-feed, 18 bats in 2008 and 19 in 2009 were moved from the cardboard boxes to an 8 × 5 × 3 m (length × width × height) room and allowed to fly freely. The room was fitted with four bat boxes (artificial shelters for bats) and several bird feeders. Three windows allowed sufficient light and exposed bats to the natural photoperiod. An open window, protected by a thin mesh, also allowed temperature to vary naturally during the day. Once moved to the room, bats were visited twice a day to provide food and water, test their progress and body condition. Body condition was assessed by visually examining bats and palpating their abdomen. Those showing signs of debilitation (ie a deep space between shoulder blades, sunken abdomen or dehydrated wing membranes) were hand-fed.

Radio-tracking experiment

After 12 nights in the rehabilitation room, bats were tested for their flight performance: to be considered ready for release they had to fly continuously for ≥ 10 min on one night (Lollar & Schmidt-French 2002). Selected bats were veterinary-screened to ensure they carried no diseases and transferred to the release site using transport boxes supplied with water and mealworms. On day one of the experiment, forearm length and bodyweight of all bats were measured, then bats were fitted with Holohil Systems LB-2N (Holohil Systems Ltd, Canada) radio-tags (weight = 0.35 g) attached between the shoulder blades with Skinbond® adhesive (Smith & Nephew, USA) after partly clipping the fur. The weight of the transmitters was ≤ 6.2% of body mass (mean 5.3%), ie well within the range for other studies (eg Kurta & Murray 2002; Russo *et al* 2002; Kelly *et al* 2008). Due to the small amount of glue used, its influence on the total weight was considered negligible.

Two of the bat boxes used in the rehabilitation room — the same used by the study subjects — were hung at the release site to trees near a riverbank: this provided bats with a familiar roosting site. To minimise stress, we released the experimental subjects in the bat boxes immediately after tagging, about 1 h prior to sunset.

To avoid outbreeding between populations of different geographical origin, hand-reared bats were released in the same region (Lazio) they came from. The release site was situated in Villa Latina council, on the boundary of the buffer zone of the Abruzzo, Lazio And Molise National Park (Lat 41.62°N, Long 13.84°E): this rural area offered plenty of suitable roosting (buildings) and foraging sites, including street lamps at which many *P. kuhlii* are commonly seen foraging (D Russo, personal observation 2008), woodland and riparian vegetation.

The study area boundaries were determined *a posteriori* by generating a Minimum Convex Polygon (MCP) encompassing all bat fixes (Figure 1). A land-use map was generated by photo interpretation of orthophotos distributed by The Italian Ministry for the Environment, Land and Sea and using the gvSIG open-source GIS software (Iver, Generalitat Valencia, Universidad Jaume I and Prodevelop, Spain). Land use was categorised as follows: 'farmland' (63.9% of total study area), including both annual crops (grain, forage, vegetables) and multi-year woody plantations (vineyards, olive groves, orchards); 'urban areas' (14.0%), including all built-up sites and small rural towns; 'woodland' (20.5%), including both mountain forests stands and riparian woodland; and 'riparian vegetation' (1.6%).

To track bats, we used a Sika VHF receiver (Biotrack Ltd, UK) connected to a three-element Yagi antenna (Ziboni Tecnofauna, Italy). Each night we scanned the study area for the presence of bats and radio-tracked at least one of them (focal subject) continuously, recording the time spent commuting (ie moving from the roost to foraging areas, between foraging areas or returning to the roost after foraging), foraging or roosting. Rapid, directional and longer movements between sites were assumed to be commuting, whereas persistence at a given site, characterised by small-scale movements and abrupt changes in direction was categorised as foraging. Bat activity could be recognised by radio-tracking and often confirmed by direct observation or detection of feeding buzzes revealed with a D1000X bat detector (Pettersson Elektronik AB, Sweden) switched to the heterodyne mode. To determine MCP home ranges (Figure 1), the location of bats tracked (hereafter termed fix) was recorded every 15 min — a time interval judged sufficient to reduce autocorrelation (Parsons & Jones 2003); when contact with one or more subjects was

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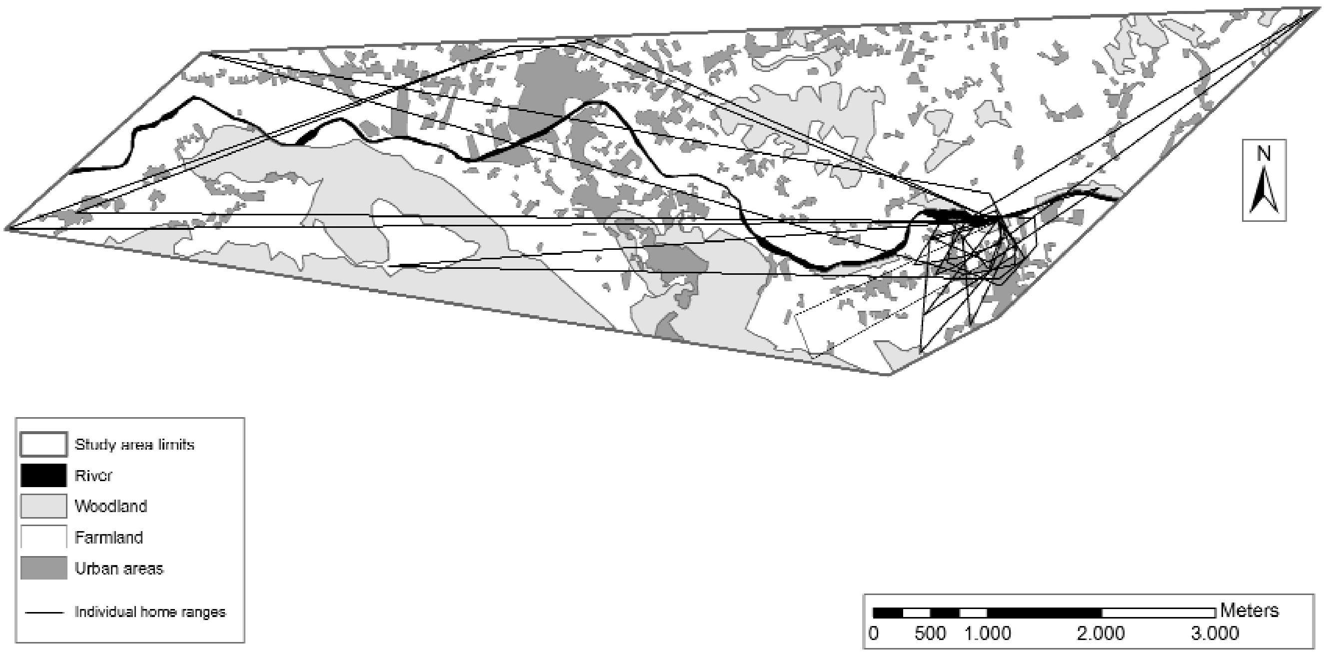
Figure 1



Study area limits, land use types and individual home ranges (Minimum Convex Polygons) of the 13 radio-tracked, orphaned *Pipistrellus kuhlii* for which habitat selection was assessed.

lost for ≥ 15 min, other tagged bats that could be detected were tracked. Whenever possible, the bats' position was ascertained by homing-in, ie by getting as close as possible to the tracked subjects. Signals so strong to be non-directional, even when the receiver gain was lowered to the minimum, were attributed to close proximity of the bat tracked (eg Russo *et al* 2002). Rarely, when access to the position occupied by the bat was not possible (such as in private property areas), it was located by triangulation. Fixes were recorded with an E-Trex Legend GPS receiver (Garmin, USA) and the corresponding activity performed by the bat noted (foraging, commuting or roosting).

During the day, we surveyed the study area to detail foraging areas and features of day-roosts used by bats. We recorded roost position and characteristics and checked for the presence of colonies by looking at droppings on the ground, or (in two cases) by visually counting bats emerging at dusk.

Data analysis

To analyse habitat preferences, we used foraging time recorded for each bat and considered only subjects for which at least 3 h of foraging time were recorded.

Habitat selection was assessed by Compositional Analysis (Aebischer *et al* 1993). To assess selection at different scales, three analyses comparing habitat availability with habitat use were performed: i) percent habitat composition of individual MCPs (use) was compared with that of the study area (available); ii) foraging time recorded in each habitat was expressed as a percentage of total time sample, entered as the 'used' proportion and compared with habitat composition of the study area (available); and (iii) percent foraging time recorded in each habitat (use) was compared with percent habitat composition occurring within individual home-ranges (available).

Significance of multivariate selection models was determined by both parametric statistics and randomisation tests. Where proportions of used habitat were zero, these were substituted with a small value, ie 0.000001 (Aebischer *et al* 1993). Analyses were performed with the software Compositional Analysis Excel tool 3.1 written by Peter Smith (University of Aberdeen, UK). All statistics, matrices and rank orders were generated with this software. Habitats were ranked according to their relative importance.

We also compared time spent roosting, commuting or foraging by bats with an ANOVA (activity represented the 'treatment'). The analysis was made with MINITAB rel 13. Significance was set at $P = 0.05$.

Results

In all, 28 bats (11 out of 18 hand-reared in 2008, and 17 out of 19 in 2009) passed the flight test and were selected for release. Of those, 11 bats in 2008 (6 males, 5 females) and 10 in 2009 (2 males, 8 females) were tagged before release, making a total of 21 tagged bats (8 males, 13 females) (Table 1). With the exception of one female, only bats that had selected bat boxes in the flight room passed the test.

Table 1 Sex, year of release, forearm length (FAL), body mass, % tag mass/body mass, first active contact (AC), last active contact (dates expressed as dd/mm/yy) and tracking details (days tracked provide the minimum ascertained post-release survival) for 21 hand-reared, orphaned *Pipistrellus kuhlii* radio-tracked after release.

Bat code	Sex	Year	FAL (mm)	Body mass (g)	% tag mass/body mass	First AC	Last AC	Days tracked	Time tracked (min)	Foraging time (min)	Max distance (m)	Reason for interruption of data collection
0197	M	2008	32.5	7.0	5.0	270808	070908	12	1,245	225	940	Battery exhausted
7186	F	2008	33.6	6.0	5.8	270808	090908	14	1,305	540	637	Battery exhausted
1304	F	2008	31.9	6.2	5.6	270808	310808	5	585	60	390	Tag lost
1586	F	2008	32.2	6.0	5.8	270808	070908	12	1,260	285	3,380	Battery exhausted
1907	F	2008	32.4	6.0	5.8	270808	280808	2	135	30	106	Contact lost
2513	M	2008	32.2	6.0	5.8	270808	300808	4	495	90	164	Tag lost
2989	M	2008	33.4	5.6	6.2	270808	080908	13	795	300	4,000	Battery exhausted
3386	M	2008	32.3	5.8	6.0	270808	090908	14	1,245	180	834	Battery exhausted
6000	M	2008	31.2	5.6	6.2	270808	300808	4	570	30	506	Tag lost
1005	M	2008	31.7	5.9	5.9	270808	080908	13	525	255	4,485	Battery exhausted
7901	F	2008	32.5	6.4	5.5	270808	800908	13	1,200	255	768	Battery exhausted
1369	M	2009	31.5	6.1	5.7	250809	050909	12	1,515	345	944	Battery exhausted
2198	F	2009	30.4	7.9	4.4	250809	050909	12	1,320	240	2,031	Battery exhausted
3200	F	2009	32.2	7.2	4.9	250809	050909	12	1,230	180	676	Battery exhausted
2906	M	2009	31.0	6.5	5.4	250809	270809	3	270	105	585	Tag lost?
2583	F	2009	33.0	7.1	4.9	250809	010909	8	735	330	5,358	Tag lost
0805	F	2009	31.8	7.1	4.9	250809	280809	4	360	45	319	Contact lost
4400	F	2009	31.5	7.5	4.7	250809	020909	9	570	45	513	Contact lost
0723	F	2009	32.5	7.4	4.7	250809	050909	12	1,590	390	1,043	Battery exhausted
0589	F	2009	34.5	8.1	4.3	250809	280809	4	360	60	359	Tag lost
0362	F	2009	33.6	7.3	4.8	250809	300809	6	510	315	962	Tag lost
Mean (± SD)			32.3 (± 0.97)	6.6 (± 0.8)	5.3 (± 0.6)	–	–	8.95 (± 4.26)	848.57 (± 451.84)	205 (± 140.50)	1,380.95 (± 1,541.81)	

Short-term survival

One bat (subject 1907) was tracked for only two days, after this the transmitter was unable to be detected despite large-scale searches. Another, (2906), was tracked over three consecutive nights; it roosted in a private, unused building from which we detected a fixed signal on the fourth day. Since we could not access the site it was not possible to check whether the tag had detached or the bat had died.

Another 19 were tracked for ≥ 4 nights, during which they were clearly active and foraging. For three out of four bats tracked for four nights (two of which joined a nursery colony in the area), radio-tracking was interrupted due to tag detachment. A female, followed over five nights, also joined a nursery colony on the second night and lost the tag at a foraging site while we were tracking it. The remaining bats were all tracked over 6–14 days, and for them radio-tracking ceased when the battery was exhausted or had a technical failure or bats moved to an area outside the detection range. The average tracking time was 849 min (Table 1).

Roost use

Bats released in 2008 all returned to the same bat box used for release at the end of their first night of activity. This was also observed for eight out of ten bats released in 2009, whereas the remaining two moved to a new roost from their first night. Several other bats left the bat box for a new roost in the course of the study, as follows. A new roost was used by 12 out of 21 bats, and two of them (2989 and 2906) switched between two new roosts. In all, 14 roosts other than the bat box were used. All were in buildings and nine were occupied by a local conspecific colony. Two such colonies, containing 50 and 27 bats, were permanently joined by four and two study subjects, respectively.

In one case, we observed the first access of a tracked bat to a site containing a colony. After roosting for 2 h at night in the bat box, bat 0723 (female) flew away from the artificial roost to fly in the surroundings of the new one. This female entered the new roost, stayed inside it for approximately 10 min, then returned to the bat box. On the following night the bat night-roosted for 41 min in the bat box after foraging,

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Table 2 Percentage habitat composition of Minimum Convex Polygons (MCP) of 13 hand-reared *Pipistrellus kuhlii* radio-tracked after release.

Bar code	MCP area (ha)	Urban %	Woodland %	Farmland %	Riparian vegetation %
0197	27.11	22.99	8.39	61.89	6.73
1005	651.31	21.51	17.16	58.49	2.84
1586	66.63	11.42	7.64	76.15	4.80
2989	749.88	20.60	17.91	58.96	2.53
3386	18.90	14.04	11.27	69.27	5.42
7186	35.75	34.50	7.53	51.24	6.73
7901	275.45	20.51	3.86	71.53	4.10
0362	41.86	24.36	3.39	72.09	0.17
0723	17.34	36.17	4.65	58.93	0.24
1369	21.63	24.60	6.40	64.63	4.37
2198	67.80	23.13	1.94	74.93	0.00
2583	146.00	20.84	21.77	51.90	5.52
3200	12.20	9.33	18.16	48.94	23.56
Mean (± SD)	163.99 (± 249.7)	21.85 (± 7.71)	10.01 (± 6.6)	63.0 (± 9.25)	5.15 (± 6.01)

Table 3 Ranking matrix obtained by Compositional analysis (n = 13 bats) based on comparing (top) percentage habitat composition of the study area with percentage habitat composition of individual home ranges; (middle) percentage habitat composition of the study area with percentage foraging time spent by bats in each habitat; and (bottom) percentage habitat composition occurring within individual home ranges with percentage foraging time spent by bats in each habitat.

	Urban %	Woodland %	Farmland %	Riparian vegetation %	Rank
Urban %		+++	+++	+	3
Woodland %	–––		–––	–	0
Farmland %	–––	+++		–	1
Riparian vegetation %	–	+	+		2
Urban %		+	+++	+++	3
Woodland %	–		–	+++	1
Farmland %	–––	+		+++	2
Riparian vegetation %	–––	–––	–––		0
Urban %		+	+++	+++	3
Woodland %	–		–	+++	1
Farmland %	–––	+		+++	2
Riparian vegetation %	–––	–––	–––		0

The signs show whether the habitat placed in the corresponding row was more or less (+ or –) important than that in the corresponding column. A triple sign (+++, –––) indicates occurrence of significant differences, one sign shows non-significant trends. Habitats were ranked according to preference (rank '0', least important habitat).

then moved again to the site used by the colony. The bat alternated short (few seconds) roost inspections to flights in the immediate surroundings. In such circumstances other bats from the colony also flew in the surroundings and broadcast numerous social calls. After about 20 min the bat entered the roost again where it spent the rest of the night.

Activity

In general, rehabilitated bats did not move long distances per night, never exceeding 5 km (Table 1, Figure 1).

Bats spent a longer time night-roosting (600.7 [± 361.9] min); this activity was followed by foraging (205 [± 140.5] min and commuting (40 [± 25.7] min). Such differences were all significant according to an ANOVA ($F_{2, 62} = 34.56$; $P < 0.05$) followed by a Tukey's *post hoc* test.

Foraging took place in the first part of the night, about 3 h after sunset, then in most cases bats returned to the roost where they stayed until the following evening.

Tracked bats often showed street-lamp foraging at sites frequented by many conspecifics where numerous feeding buzzes and social calls were heard on a bat detector.

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Habitat selection

Thirteen bats (eight females and five males) provided sufficient data for habitat selection analysis (Figure 1, Table 2).

When the percent habitat composition of individual home ranges was compared with that of the study area, selection was not random ($\lambda = 0.187$; $\chi^2 = 21.79$; df = 3, $P < 0.0001$). In this case, urban areas, riparian vegetation and farmland were selected equally and were preferred over woodland (Table 3).

Likewise, a non-random selection pattern resulted from comparing the percent foraging time spent by bats in each habitat with percent habitat composition within individual home ranges ($\lambda = 0.1001$; $\chi^2 = 29.92$; df = 3, $P < 0.0001$). A different preference ranking was obtained in this case: urban was significantly preferred over all other habitats, farmland and woodland both ranked second in importance, whereas the least preferred habitat was riparian vegetation (Table 3). The same ranking was obtained when percent foraging time spent in each habitat was compared with percent habitat composition ($\lambda = 0.133$; $\chi^2 = 26.24$; df = 3, $P < 0.0001$).

Discussion

Our study showed that hand-reared *P. kuhlii* can survive after release, select suitable feeding sites and even be accepted into existing colonies. We highlight that post-rehabilitation release can be successful, at least in the short term, when done at sites other than those where bats were rescued, provided bats show sufficient flight performances after rehabilitation.

It is likely that such promising results are at least in part linked with the ecological plasticity typical of this species — *P. kuhlii* uses many roost types and forages in a range of different habitats (eg Russo & Jones 2003) — which would explain the quick adaptation of our study subjects to a new environment and the ready selection of foraging and roosting sites. However, in agreement with Kelly *et al* (2008), we found that appropriate rehabilitation is crucial even for opportunistic house-dwelling bats such as pipistrelles.

We also recorded active foraging and social behaviour (ie colony acceptance) — which might be regarded as promising for long survival expectancy. However, we know nothing about the long-term life expectancy of bats we released *ex situ*, and no reliable prediction could be made. Only one case of long-term (eight months) monitoring following translocation of bats is known for a New Zealand species, the lesser short-tailed bat (*Mystacina tuberculata*). In a first unsuccessful attempt, 50 adult bats were moved 40 km to Ulva Island (Ruffell *et al* 2009). As in our study, several bats were fitted with radio-tags, but in that instance signal was lost within hours and no bat passes were heard on acoustic surveys. A second attempt involved 20 juveniles reared by their mothers in captivity (juveniles were selected to reduce the risk of imprinting on their source area) and moved to Kapiti Island, again 40 km from the source site (Ruffell & Parsons 2009). In the second experiment, although 45% of bats were still found on the island eight months later, all those checked had developed ear infections and two were balding. Certainly, one limitation to assessing the long-term success of translocation actions regarding bats is the short life of radiotag batteries and the difficulty of monitoring them over a long period of time. It is likely that future generations of tags, lasting longer, will make this kind of study possible.

At present, no other reference study exists on the fate of rehabilitated bats after hand-release except Kelly *et al* (2008)'s work. Studies on a variety of species (eg Csermely 2000; Beringer *et al* 2004; Leighton *et al* 2008; Kelly *et al* 2010) suggest the minimum time necessary to ascertain rehabilitation outcomes is species-dependent, but the monitoring techniques adopted may also affect it significantly.

The release of orphaned hand-reared wild animals has many similarities to that of captive-born animals used in captive-breeding projects since both activities imply releasing naïve individuals into an area they are unfamiliar with. The main biological and ecological factors contributing to the outcomes of such projects (Jule *et al* 2008) are habitat suitability, long-term food availability, the season of release, type of release (soft or hard) and finally the source of released animals (captive-born or wild-caught).

P. kuhlii favours urban areas not only for foraging but also for roosting and breeding. It forages usually around street lamps (Barak & Yom-Tov 1989; Russo & Jones 1999) but also in farmland, at woodland edges, in gardens or riparian vegetation (Schober & Grimmberger 1997; Russo & Jones 2003). From this perspective, the release area we selected, characterised by a heterogeneous habitat mosaic including farmland, woodland, riparian vegetation and urban sites, offered plenty of foraging opportunities. The habitat selection analyses adopting percent foraging time as an indication of habitat use showed that hand-reared bats exhibited selection patterns matching well the typical foraging behaviour described for *P. kuhlii*, with a strong preference for built sites (where we observed bats foraging at street lamps), followed by farmland and woodland and finally by riparian vegetation (eg Russo & Jones 2003; Korine & Pinshow 2004).

Interestingly, when habitat composition of individual home ranges was compared with the available habitat composition of the study area, riparian vegetation was the most preferred habitat. This can be explained by the role of this landscape feature in commuting activity. In our study, although riparian vegetation did not represent the most important habitat for foraging, the river was often used as a landmark for commuting both from and to feeding areas and also as a reference landscape element for searching for new roosts — so much so that some new roosts were in fact located along the river. For this reason, riparian vegetation was overrepresented in individual home ranges relative to the entire study area. It is known that in many bat species linear landscape elements are important for migration (Serra-Cobo *et al* 1998, 2000; Ahlén *et al* 2009; Furmankiewicz & Kucharska 2009) and commuting (eg Entwistle *et al* 1996; Russo *et al* 2002).

Insect availability is directly related to temperature (eg Taylor 1963) and therefore the season of release may be important for survival (Fleming & Eby 2003; Zahn *et al* 2007; Wang *et al* 2010). The earlier the release happens during summer the more time the bats will have to improve foraging capabilities and store fat.

As typical with pipistrelles (Grodzinski *et al* 2009), our bats always foraged in an aerial hawking style, in restricted areas and during the first 3 or 4 h of the night (Barak & Yom-Tov 1989). Noticeably, although the bats had initially showed difficulties in finding mealworms in the flight room, already on the first night of release they were street-lamp hunting at sites where many other conspecifics were foraging (D Russo, personal observation 2008). It is most likely that bats detected suitable foraging sites by eavesdropping on conspecifics (Barclay 1982; Balcombe & Fenton 1988; Fenton 2003).

Release protocols are often classified as either hard or soft (eg Lewis 2006). In the former, animals are immediately released upon delivery to a release site whereas in the latter an acclimatation period at the release site is adopted to encourage animals to stay in the surroundings after being released (Lewis 2006). Although our subjects were released without an acclimatation period at the release site, we adopted a soft-release protocol, since we released the hand-reared bats using the same bat boxes that had been used in the flight room. This proved useful, since only two bats moved to a new roost on the night of release, some selected a new site gradually, and seven roosted at the bat box until the end of the monitoring programme. Although we have no direct evidence, rehabilitated bats released directly into the wild might show a lesser survival rate than those with established patterns of returning to a safe roost (the bat boxes) because finding suitable roosting opportunities at the release site may not be easy. Juvenile lesser short-tailed bats released on Kapiti Island were kept in captivity for two months at the release site and provided with supplementary roosts and food after release to help them cope with the new environment (Ruffell *et al* 2009). Besides, the aviary where bats were kept before release was left accessible after study subjects were released: the structure was used frequently over the eight months of post-release monitoring, and almost half of released subjects were re-observed within that time (Ruffell & Parsons 2009).

In our short-term monitoring, 19 of our rehabilitated bats remained on the release site and did not disperse after release. Released subjects are more likely to remain in the release area when adequate food supply and roosting opportunities are present. Of course, the fact that we used juveniles with no imprinting over source areas helped greatly to avoid homing behaviour, as seen in bat translocation (see Ruffell *et al* 2009). Overall, this type of soft protocol appears important for the release of rehabilitated bats and translocation operations.

Jule *et al* (2008) supported previous reports that reintroduction projects using wild-caught subjects are more successful than those using captive-born animals. In particular, regardless of the success or failure of a reintroduction project, while the causes of death were the same for both wild and captive animals, the incidence of mortality from the various causes was higher for captive-bred animals. Jule *et al* (2008) did not consider the influence of the rehabilitation protocol in the success of re-introductions; however, we believe this is important. Rehabilitated barn owls (*Tyto alba*) trained using live prey had better survival rates than the untrained owls fed only with meat (Fajardo *et al* 2000). For aerial-hawking bats, such as pipistrelles, flight training is important (Kelly *et al* 2008; this study), but we suggest that no specific training to pursue live prey is needed at least for aerial hawkers. Our bats all fed on static, non-flying prey in captivity, but appeared to feed on flying prey once released. However, this might not hold true for bats showing different prey strategies such as substrate gleaners, eg greater mouse-eared (*Myotis myotis*), Natterer's (*Myotis nattereri*) and brown long-eared (*Plecotus auritus*) bats which might require appropriate training, so caution is needed to apply our findings to training naïve bats of species with different foraging strategies.

At least some bat species reproduce easily in captivity (Barnard 2009a). We ourselves have recorded several instances of successful mating, parturition and natural raising in stocks of rehabilitating Kuhl's pipistrelle (MT Serangeli, personal observation 2009). Studies such as ours may help explore the possibility of using captive-bred echolocating bats for reinforcing declining populations or reintroducing locally extinct ones, provided appropriate management and training of captive stocks are carried out.

Animal welfare implications and conclusion

Although rehabilitation aims to improve the welfare of individual animals, if treatments and/or rehabilitation protocols are poor or inappropriate they may in fact compromise it. Likewise, subjects unable to show normal behaviour once released (foraging, territoriality, roost selection, reproductive behaviour, etc) may suffer and eventually die. Therefore, evaluating post-release survival is fundamental to measure the 'success' of rehabilitation and rehabilitators should be more proactive in assessing the fate of released subjects. Although popular among rehabilitators, the equation release = rehabilitation success is incorrect: we should assume that all rehabilitated subjects die unless we can provide evidence to the contrary, at least for a significant sample of animals belonging to the released taxon. By showing that *P. kuhlii* survive at least for the time corresponding to the transmitter's battery life, our study provided evidence that neither rehabilitation nor release compromise the welfare of bats. Moreover, we demonstrated that besides surviving, bats also foraged and roosted in sites typically used by wild *P. kuhlii* and were even accepted in local conspecific colonies, again suggesting that their welfare was not compromised.

Given the great importance of post-release monitoring (Ruffell *et al* 2009), it is hoped that our study will be followed by others on different bat species to obtain a broader picture of bat survival and behaviour in these situations, and that appropriate techniques will be implemented to assess survival on a long-term basis, an achievement so far limited by the short battery duration of the small radio-transmitters employed for monitoring.

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