Captive Red Squirrel Management:
National Recommendations & Guidance

Produced by the

National Zoological Society of Wales
Welsh Mountain Zoo – National Zoo of Wales
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Contents

The UK Squirrel Accord recognises that a co-ordinated, well-managed breeding and reintroduction programme works by mutual co-operation and trust

Background to the document

Zoological red squirrel collections provide publicly exhibited specimens which are frequently the only opportunity for communities to see this rare native species and to learn about the threats posed to remnant wild populations. Collections are also an important resource for conservation translocation.

This guidance builds upon historical recommendations for the management and husbandry of captive collections[1], evolves the co-ordination of the national studbook and integrates key IUCN guidance[2] on the selection of animals for any proposed wild release.

The maintenance of an effective studbook requires agreement and mutual co-operation. Although this document presents a current best practice, we recognise that management must be adaptive and consequently that the text is a foundation for collaboration and the sharing of future lessons learned and knowledge.

The red squirrel: A brief introduction

The red squirrel (*Sciurus vulgaris*) is a diurnal, small, native, arboreal mammal associated with mature wood habitat (Appendix 1). Its ecology and conservation are relatively well understood[3,4]. Adults typically weigh 250-350g and can be a variety of colours including various shades of red, brown and orange. Albinistic and melanistic individuals have been recorded. The belly fur is usually cream to white irrespective of the colour elsewhere on the body. Sometimes siblings within a litter may be coloured differently[5].

[1] Dickinson P (1995) The captive care, maintenance and breeding of the red squirrel (*Sciurus vulgaris*). *Ratel* 22, No 1.
[2] IUCN/SSC (2013). *Guidelines for Reintroductions and Other Conservation Translocations*. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viiii + 57 pp.
[3] Shuttleworth CM, Lurz P, Hayward MW (eds) (2015) *Red Squirrels: Ecology, Conservation and Management in Europe.* European Squirrel Initiative, Suffolk, England.
[4] Bosch S, Lurz PWW (2012) *The Eurasian Red Squirrel*. Westarp Wissenschaften,Germany.
[5] Holfert H (1983). Hinweise zur Haltung und Pflege, Zucht, Fütterung sowie Über Hygiene und Krankheiten unseres Eichhörnchen *Sciurus vulgaris*. Private published notes.

The species has declined in the United Kingdom (UK) as a result of ecological resource competition from[6], and the spread of pathogenic squirrel pox virus by[7], the introduced North American grey squirrel (*Sciurus carolinensis*). Consequently, the red squirrel is extinct across most of England and Wales.

Wild red squirrels consume a wide variety of natural foods including tree seed, flowers and buds. Mushrooms, birds eggs and a small amount of insects are also eaten. Tree seed is buried in the autumn months through scatter-hoarding behaviour[8]. Mushrooms are often cut and carried to be wedged in tree joints or hollows so they can dry and reduce the water content. Such stores provide a significant food supply in later months.

In the wild, red squirrels may live for four to five years though large numbers do not survive their first year.[9] In captivity six to nine years is not unknown[10]. Most keepers state that there does not appear to be a difference in life-span between males and females. The average breeding female would be expected to live no more than seven years[11]. The late David Stapleford[12] owned a female for 9.5 years and does not believe this to be and exceptional age. He believes that many squirrel deaths under this age are likely attributed to illness or accident rather than senility.

The red squirrel does not reach sexual maturity until it is over 12 months old. Of 14 captive-bred females, six gave birth to their first litter in the year following their own birth and eight did so in the year after. Males' readiness for breeding is determined by their testicular development which is complete by their second year. Breeding is seasonal and divided across two peaks, the first young being born in March/April/May and the second in June/July/August. Occasionally, in mild weather a litter may be produced in February. Mating is followed by a gestation period of 38 days after which one to seven young are produced. Older females tend to have larger litters, three to five young, and are more likely to produce two litters in a year. The female gives the young almost constant attention during the first ten days or so after which she is quite likely to spend a good deal of her resting period away from the young, in a nearby nest or outer nest chamber. Six captive pairs produced 30 litters over a three year period, rearing a total of 97 young. The sex ratio was 50 males and 47 females.[13]

The red squirrel is diurnal, with a period of intense activity every morning across the year. In the spring and autumn months it may be active throughout the day, whilst in the winter,

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[6] Gurnell J, Wauters L, Lurz, PWW, Tosi, G. (2004) Alien species and inter-specific competition: effects of introduced eastern grey squirrels on red squirrels population dynamics. *Journal of Animal Ecology* 73: 26-35.

[7] Sainsbury AW, Deaville, R, Lawson, B, Cooley, WA, Farelly SS, Stack MJ et al (2008) Poxviral disease in red squirrels *Sciurus vulgaris* in the UK: Spatial and temporal trends of an emerging threat. Ecohealth 5: 305-316.

[8] Bosch S, & Lurz PWW (2012) Ibid.

[9] Gurnell J (1987) Squirrels. Helm, London.

[10] Stapleford D (1995) *Pers. communication*

[11] Holfert H (1983) Ibid..

[12] Stapleford D (2003) *An Affair with Red Squirrels*. Larks Press, Dereham, England.

[13] Holfert H (1992) *Geschlechterverhältnis, Färbung und Verhalten von Eichőrnchen* (Sciurus vulgaris) im Lausitzer Bergland. Saugtierkd. Inf. 3: 461-464.

activity is typically in the morning. In hot weather activity may extend late into the evening and even into the night but animals are inactive in the middle of the day when the temperatures reach their highest.

Squirrels are renowned for their instinctive food storage activity (caching). A hand-reared squirrel was observed hiding foodstuffs in every available niche of his enclosure from as soon as he was large enough to carry a nut. All squirrels spend a portion of their day storing food. This is either buried in the ground or cached in tree joints or hollows.

History of red squirrels in captivity

Red squirrels have been kept in captivity for several hundred years[14] and there are notable publications relating to their breeding and behaviour[15,16,17]. The 1981 Wildlife & Countryside Act (as amended) affords wild red squirrels significant legal protections and consequently any zoological collection wishing to obtain wild born animals would need to possess a licence to take them.

In 1995, only a handful of British captive collections were recorded[18]. It is therefore noteworthy that the subsequent introduction of the Balai Directive (Council Directive 92/65/EEC 1996) facilitated the supply of European bred captive red squirrels to British collections for the first time and an expansion in the number of collections. Although there are no quantified figures, it is known that many animals were imported and supplied to both zoological collections and to private individuals. There are also records of the licensed removal of wild Cumbrian red squirrels from Foulshaw Moss in the early 2000s. Thus, both UK wild and captive-bred continental animals were registered within the UK red squirrel studbook. Currently the only data on genetic diversity have come from mitochondrial studies associated with reintroduction and conservation reinforcement projects in north Wales. These limited data indicate a wide genetic variation[19, 20].

It is important to stress that not all captive red squirrels are registered in the studbook (established 1995). Whilst many animals are owned by zoological collections, some are owned by individuals; in some case affiliated together in regional networks, whilst others choose to operate in relative isolation. At the time of writing, there are approximately 10 zoological collections and 15 private collections holding red squirrels.

[14] Kelway P (1940) Breeding red squirrels. *Country Life*, July 6th 1940.
[15] Stapleford D (2003) Ibid.
[16] Holm J (1989) *The Red Squirrel*. Shire Natural History, England.
[17] Shorten M (1954) *Squirrels*. Colins New Naturalist, London.
[18] Dickinson P (1995) Ibid.
[19] Ogden R, Shuttleworth C, McEwing R & Cesarini S (2005) Genetic management of the red squirrel, Sciurus vulgaris: a practical approach to regional conservation. *Conservation Genetics* 6: 511-525.
[20] Liz Halliwell *Pers. communication* relating to https://ptes.org/grants/internship-projects/using-radio-tracking-and-camera-traps-to-help-red-squirrels-in-wales/

Studbook management

Red squirrel holders may maintain mixed sex groups or trios rather than breeding pairs. This means that it is often difficult, indeed impossible, to define litter parentage accurately. The potential parentage should be qualified when juvenile animals are entered into the studbook.

It is proposed that:

- All captive animals are identifiable, where possible using unique numbered PiT tags.
- Animals are moved between breeders following discussion with the studbook keeper and that all movements are recorded. This will maximise the maintenance of genetic diversity and reduce the likelihood of inbreeding.
- Necessary pre-movement health checks should include screening for asymptomatic infection including adenovirus, as advised by the program veterinary advisor.
- Deaths of all animals are reported. This should include any juvenile animals that had not yet been recorded in the studbook.
- Where possible, tail hair samples (20-30 hairs with root bulbs) are opportunistically collected from each individual during routine health checks or when being marked or handled.
- Hair samples, stored in an envelope at -20C, can then be used to undertake genetic studies and viral screening, where techniques are currently being researched by APHA.
- Stock are provided for release into the wild only if a project follows the IUCN guidelines and if a written assessment of the proposals has been produced following the associated guidance Annexes[21].

[21] IUCN/SSC (2013). *Guidelines for Reintroductions and Other Conservation Translocations*. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viiii + 57 pp.

Biosecurity

Adenovirus: An emerging threat to captive red squirrels

There is now significant evidence that adenovirus infection has been spread between captive red squirrel collections[22]. This virus can produce pathogenic intestinal disease in red squirrels[23] and was associated with significant mortality within captive red squirrels during a reintroduction programme[24].

Pathogenic infections are characterised by the presence of viral particles in faecal material using electron microscopy analyses. Recent pioneering research by the Animal and Plant Health Agency has shown that it is possible to detect amplified adenovirus DNA from hair samples. This additional test option means that it may now be possible to identify red squirrels carrying the infection in the absence of clinical signs of disease.

It is therefore recommended that captive collections integrate faecal and, potentially, hair analyses as an additional surveillance option into their health screening protocols.

Health screening

There are a number of important infections and red squirrel holders should familiarise themselves with the published literature[25, 26].

Enteric bacterial pathogens include *Salmonella* spp., *Campylobacter* spp., *Yersinia* spp. and *Brucella* spp.[27]. Pathogens have been associated with respiratory disease, facial abscesses and wound infections. Other infections of possible significance are rodent viruses, *Chlamydiosis*, *Erysipelothrix*, *Listeriosis*, Tyzzer's disease, leptospirosis and Q fever[28]. EMCV and *Francisella tularensis* are potential causes of infection but are not considered enzootic in the UK.

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[22] Everest DJ, Shuttleworth CM, Grierson SS, Dastjerdi A, Stidworthy MF, Duff JP, Higgins RJ, Mill A & Chantrey C (2018) The implications of significant adenovirus infection in UK captive red squirrel (*Sciurus vulgaris*) collections: How histological screening can aid applied conservation management. *Mammalian Biology* 88:123-129

[23] Everest DJ, Shuttleworth CM, Stidworthy MF, Grierson SS, Duff PJ, Kenward RE (2014) Adenovirus: An emerging factor in red squirrel *Sciurus vulgaris* conservation. *Mammal Review* 44: 225-233

[24] Everest D J, Shuttleworth CM, Grierson SS, Duff JP, Jackson N, Litherland P, Kenward RE (2012) Systematic assessment of the impact of adenovirus infection on a captive re-introduction project for red squirrels (*Sciurus vulgaris*). *Veterinary Record* 171, 176 10.1136/vr.100617

[25] Keymer IF (1983) Diseases of squirrels in Britain. Mammal Review, 13:155-158.

[26] Meredith AL, Romeo C (2014) Disease and causes of mortality in red squirrel population. pp115-128 In Shuttleworth C, Lurz PWW & Hayward MW (eds.) *Red Squirrels: Ecology, Conservation & Management in Europe.* European Squirrel Initiative, Suffolk, England.

[27] Sainsbury AW (2008) Medical aspects of red squirrel translocation pp236-242. In Fowler ME, Miller RE (eds.) *Zoo and wild animal medicine:6 Saunders Philadelphia.*

[28] Greenwood A (1995) *Pers. communication*

A fatal exudative dermatitis has a widespread occurrence in wild populations and is consistently found with a specific clone of *Staphylococcus aureus*[29, 30]. Mycobacterium (leprosy) infections have been found in wild populations[31, 32, 33] and rotavirus has been detected in a small number of wild populations[34, 35] in Britain and in a single captive collection with a combined reovirus infection.

Although squirrelpox virus (SQPV) remains the single most important factor in the red squirrel's decline, in terms of captive husbandry, it does not currently make a significant disease contribution. Only a small number of infections have been detected in captive collections so far. In one case, infection ultimately resulted in only a small proportion of deaths from within the affected enclosure.

Non-infectious diseases include metabolic bone disease and hypoglycaemia, which may be linked to UV levels and diet.

Finally, animals routinely have both endo- and ecto-parasites including fleas (*Monopsyllus sciurorum, Orchopaeas howardi, Tarsopsylla octodecimdentata*), ticks (*Ixodes ricinus, Ixodes trianguliceps*), helminths (*Enterobius sciuri, Trichostrongylus retentaeformis, Oxyuris acutissima, Oxyuris ungula*) and protozoons - hepatozoon, coccidia (*Eimeria scuirorum, Eimeria andrewsi, Eimeria silvana*). An outbreak of toxoplasmosis has been described in red squirrels.[36]

For more information on heath screening, please contact your veterinary advisor, or the program coordinator.

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[29] Simpson, V, Davison, N, Kearns, A, Pichon B, Hudson, L, Koylass, M, et al. (2013). Association of a lukM-positive clone of Staphylococcus aureus with fatal exudative dermatitis in red squirrels (Sciurus vulgaris). *Veterinary microbiology*, 162: 987-991.

[30] Simpson VR, Hargreaves J, Butler HM, Davison NJ, Everest DJ (2013a) Causes of mortality and pathological lesions observed post-mortem in red squirrels in Great Britain. Veterinary Research 9: 229.

[31] Meredith, A., Del Pozo, J., Smith, S., Milne, E., Stevenson, K., & McLuckie, J. (2014). Leprosy in red squirrels in Scotland. Veterinary Record, 175: 285-286.

[32] Simpson, V., Hargreaves, J., Butler, H., Blackett, T., Stevenson, K., & McLuckie, J. (2015). Leprosy in red squirrels on the Isle of Wight and Brownsea Island. *Veterinary Record*, 177: 206-207.

[33] Schilling, A, Del-Pozo J, Lurz, PW, Stevenson K, Avanzi C, Shuttleworth CM, et al ... & Meredith, A. L. (2019). Leprosy in red squirrels in the UK. *Veterinary Record*, 184: 416-416.

[34] Everest DJ, Dastjerdi A, Gurrala R, Banks M, Meredith AL, Milne EM Sainsbury AW, (2009) Rotavirus detected in red squirrels from Scotland. Veterinary Record 165: 450

[35] Everest DJ, Duff JP, Higgins RJ, (2011) Rotavirus in a wild English red squirrel (Sciurus vulgaris) identified by electron microscopy. *Veterinary Record* 169: 160

[36] Jokelainen P, Nylund M. (2012). Acute fatal toxoplasmosis in three Eurasian red squirrels (Sciurus vulgaris) caused by genotype II of *Toxoplasma gondii*. Journal of Wildlife Diseases, 48: 454-457

Management in Captivity

Enclosure dimensions

Enclosure size is probably best determined by:

(a) the number of animals it is expected to house;
(b) how long the animals are to be kept;
(c) whether it is intended to breed them;
(d) the funds available to build the unit.

The Welsh Mountain Zoo holds pairs or trios within enclosures measuring 6 m x 9 m with a height varying from 2.7 m to 4.5 m[37] (3). In contrast, the late David Stapleford successfully bred red squirrels in breeding enclosures measuring as small as 2.7m x 2.7m with a height of 2.2 m. In Holland, a variety of enclosure dimensions have been historically used for successful breeding e.g. 1.5m x1.5m x 2m high; 1m x 2m x 2.5m high; 4m x1.25m x 2m high; 2m x 2m x 2m high. This suggests that providing both basic biological requirements and husbandry rules are satisfied, the 'quality of space' is probably of greater significance than dimensions of the enclosure provided.

We would suggest a 3 m x 3 m x 3 m high enclosure as being highly suitable to house a mixed sex pair (noting that some breeders have considered it desirable to separate off the male once the female shows signs of pregnancy in small enclosures). Groups (3-4 individuals) of young, non-breeding animals, have been housed in the short term in enclosures of 3 m x 1.5 m x 2.5 m high without any problems[38].

The most important dimension to consider is that of height; generally speaking, the higher the better. Height appears to offer the squirrels a greater sense of security and they appear much calmer[39] when people enter or are near the enclosure. It has been observed that individuals that showed extreme nervousness in low enclosures became much quieter and bolder within 24 hours of being moved to a taller cage.

Enclosure construction

The weldmesh (or similar) used to wall an enclosure should be suitable to prevent escape by juvenile red squirrels and entry by various rodents. A 16 gauge 25 mm x 25 mm mesh is recommended, to deter small rodents. Where one or more sides to the enclosure are solid brick or timber panels it is advised that this surface be covered with wire or bark so that the animals can run up and down it. It is noted that they are capable of using rendered surfaces with some agility.

Irrespective of enclosure dimensions, it is important that the mesh walls are buried to 30 cm depth into the ground to prevent potential predators digging under and gaining access

[37] Dickinson P (1995) Ibid.
[38] Dickinson P (1995) *Pers. observation*, *Pers. notes*.
[39] Witalfsky H (1995) *Pers. communication*

to the interior, although some holders recommend full underwiring with 25 mm x 25 mm mesh, to fully exclude rodents. A solid or double weld mesh wall/division between adjoining enclosures can reduce the risk of aggressive interactions between animals. It has been observed that a single wire division encouraged neighbourly play behaviour rather than aggression, some animals choosing to sit close to each other on opposite sides of the wire.

Where grey squirrels *Sciurus caroliniensis* are present in the vicinity of a red squirrel enclosure and an individual climbs onto the mesh, red squirrels have been observed to show an aggressive response[40]. In published studies inter-specific aggression has not been observed[41].

Preventing escapes

It is essential that escapes are minimised, especially if grey squirrels are resident within the area surrounding the enclosure. Left to their own devices, squirrels will sometimes return to their enclosure after exploring the surrounding area and may be caught in baited live-capture traps. They may however venture quite a distance and be away several days before they return[42] or they may remain in the vicinity of the enclosure but prove hard to catch. If an animal is recaptured, it should be transferred to a quarantine enclosure and not placed directly back in with con-specifics. Quarantine disease screening protocols should be prepared for this scenario.

Enclosure substrate

A natural substrate provides the opportunity for animals to dig, forage and collect additional nesting material. Foods such as whole hazel nuts can be hidden within course ground covering material to enrich behaviour and reduce stereotypical behaviour. Wood chippings have been used to good effect either placed over the natural earth or covering a concrete base. Small pebbles, sand and leaf litter have similarly been used. It is important that the material is cleaned with the regularity necessary to prevent a build-up of 'contamination'.

[40] Dickinson P (1995) Ibid.
[41] Shuttleworth CM, Everest JD, McInnes CJ, Greenwood A, Jackson NL, Rushton S, Kenward RE (2014) Inter-specific viral infections: Can the management of captive red squirrel collections help inform scientific research? *Hystrix, Italian Journal of Mammalogy* 25: 3-8
[42] Witalfsky H (1995) *Pers. communication*

In the relative security of captivity, the squirrel tends to be active for longer periods of time than in the wild and yet does not have to spend long hours in search of food. Perhaps some further experimentation on making obtaining food a little more difficult, and therefore, the squirrels busier for a greater period of time, will be of value.

Enclosure cleaning

Hygiene is extremely important in the management of captive squirrels. Cage cleansing (removal and replacement of branches and ground surface substrate) is largely dependent on situation and type. Large natural enclosures may be cleaned once or twice a year, whereas smaller units may need cleaning much more frequently.

HALAMID™ and DETTOL™ have been used in small units (8) with good effect, as has iodine based disinfectant[43]. TRIGENE™, SAFE4™, and TEGO™ have all proved to be extremely useful in larger units, when utilised at correct dilutions, as specified by the manufacturer and following a thorough clean.

Provision of climbing materials

Natural timber uprights should rise as high into the enclosure as possible, allowing the fixing of many horizontal branches. It is essential that horizontal branches and or 6 cm diameter ropes are provided and that these are placed carefully with respect to maximizing use of three dimensional space within an enclosure. Rope works well and is particularly easy to fix and adjust to a span.

Branching should, where possible, be changed annually or bi-annually. New branching is clean, it gives the animals something novel to explore and offers behavioral enrichment of the enclosure. Therefore, providing a variety of branches from different tree species is best as these provide different textures, tastes and scents. The bark of western red cedar and lime are frequently stripped and used as nest material. Additionally, branches can offer locations for squirrels to build dreys.

Providing older and partially decaying timber can also be beneficial as squirrels have been observed to 'tear up' such material.

Care should be taken when sourcing branches to avoid areas of high grey squirrel population density. Using material exposed to the natural disinfection of sunlight and rain is also good practice[44].

It is common practice to additionally furnish an enclosure with high platforms for squirrels to use when feeding or grooming. Hanging baskets are sometimes provided and, like platforms, provide good places on which to construct dreys[45]. In addition to the above,

[43] Marsden J (1995) *Pers. communication*
[44] Stidworthy M (2019) *Pers.communication*
[45] Stapleford D (2003) Ibid.

commercial wooden fruit crates have been provided. One European breeder[46] has covered these with brushwood, sacks and old clothing items and suspended them from the roof of the cage. The squirrels use these as hiding places and may sleep there when the weather is hot.

Drey construction

Dreys are built by both sexes. These will be constructed out of leaves, twigs, hay etc and may be situated on platforms or amongst branches within the enclosures. Pregnant females may construct their own dreys during the breeding season.

Additional behavioural enrichment

Squirrel 'gyms' are easy to construct and provide exercise and problem solving tasks. Using a combination of short chains and short natural branches, a 'mobile' can be made for suspension from the enclosure roof. At various points around the mobile there should be fixing points for food treats. Squirrels really have to work to get at the food items.

Branches attached at either end by rope gives swinging movement to improve balance and dexterity and the mental capacity of captive born squirrels, as can provision of branches of varying diameter. Lengths of natural rope hung from the roof, with the fibers can be parted, and food items inserted within the rope fibers prolong the time and dexterity to take the food items.

When a wheel, larger but otherwise similar to those used by hamsters, is provided, squirrels will regularly use it. A diameter of 45cms and a wheel track with a width of approximately

[46] Witalfsky H (1995) *Pers. communication*

10cms is recommended. Care with measurements should be taken to ensure there is no strain to the back of the squirrel when running.

Finally, the regular provision of piles of 15-30 cm long twigs, leaves and moss will offer construction material for dreys or for use when nesting in nest boxes.

Stereotypic behaviour

The red squirrel is especially prone to show stereotypic behaviour in a captive situation. This may manifest as repetitive running back and forward along an area of enclosure wall or, less frequently, jumping on or off a wall or log at the same point. It does not appear to adversely affect animals; they will breed and otherwise behave normally.

It does not appear to be related to cage size as animals are just as likely to exhibit such behaviour in a large enclosure as in a relatively small one. It was noted that in a litter of three captive bred red squirrels, although one started stereotypic traits within three weeks of leaving the nest box for the first time, the siblings were not seen to exhibit this behaviour even two months later.

Enclosure enrichment and providing foods that require lengthy handling time (e.g. pine cones) can help to reduce this behavior, but it is impossible to prevent it entirely.

Nest boxes

Wild red squirrels will occupy a range of nest box designs if these are of a suitable size and with a large enough entrance hole (55-65 mm diameter)[47] [48]. Captive collections are typically provisioned with nest boxes and animals will readily nest within these. At least one box is provided per animal and some institutions supply one extra box, especially if they anticipate breeding and a female subsequently suckling young. Outside the breeding season, it is not uncommon for one box to be shared by as many as five individuals.

A suitable nest box template can be downloaded[49] and here we provide some examples of design used in European captive breeding (Table 1). It is advisable to have several 10 mm holes drilled in the bottom of each box to facilitate drainage and to allow some air flow in an area that can often otherwise become damp. All box designs have a removable lid for access, this may be hinged or otherwise secured in place. It is not uncommon for boxes to also have a hinged side access panel which assists with easy inspection when the box is

[47] Shuttleworth CM (1999) The use of nest boxes by the red squirrel *Sciurus vulgaris* in a coniferous habitat. *Mammal Review* 29: 61-66.
[48] Shuttleworth CM, Selonen V & Kopowski (2016) Grey squirrel nesting ecology and the use of nest sites in European population management. pp349-368 In Shuttleworth CM, Lurz PWW & Gurnell J (eds.) *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*. European Squirrel Initiative, Suffolk, England.
[49] Shuttleworth CM, Halliwell (2018) Red squirrels in my garden: Guidance and tips to help encourage and conserve local populations. European Squirrel Initiative. http://www.redsquirrels.info/wp-content/uploads/2018/04/Red-Squirrels-In-My-Garden-WEB.pdf

positioned at height. Boxes are typically treated with proprietary non-toxic waterproof stain on only the exterior surfaces.

Table 1. Examples of nest box designs used by captive breeders

	Base Area	Max depth	Entrance hole size	Materials & notable design features
Welsh Mountain Zoo[a]	30.5 x 30.5 cm	61 cm	7 cm	14 mm marine ply-board. The roof slopes and overhangs the box sides. Only box exterior treated with non-toxic wood-stain.
Stichting Eekhoornopvang	40 x 40 cm	30 cm		Access hole in the top left hand corner.
Herbert Witalfsky	60 x 36 cm	42 cm	9 cm	Boxes had double 2 cm wooden walls with sytopor insulation between the two. [b]
Private breeder	51 x 40 cm	40 cm		14 mm ply. There are two entrances, one at the front left and a second smaller one at the back right of the box
David Stapleford	35 x 35 cm	30 cm	8 cm	Constructed from timber although one fibreglass box was used.
Private breeder	27 cm x 27 cm	42 cm	10 cm	Timber box with aluminum strips to prevent chewing of sides.
Wildwood Trust	34 cm x 34 cm	55 cm	8 cm	12 mm plywood, entrance hole with sliding door to close squirrel in

[a] Noted boxes frequented by the bee moth *Aphomia sociella* and domestic bees occupying a box, which has also been observed in the wild[50]

[b] Boxes were 'parceled up' in commercial plastic fertilizer sacks with fist sized access holes cut into the side. However, mice sometimes chewed the plastic sacks thus allowing the rainwater to enter. Condensation was also sometimes a problem when more than one animal was within the box.

Boxes should be stocked with suitable nesting material. A variety of materials can be used including woodwool, coconut fibre, straw, leaves and hay. It is noted that hay and straw can quickly compact and, if insufficient material is initially provided, it may therefore not provide adequate cover for the squirrels[51]. Hay can also quickly become mouldy under damp conditions and many breeders avoid using it as a result. Some breeders avoid using woodwool alone as this may not have sufficient thermal properties in cold weather.

It is recommended that nest boxes are cleaned and contents replaced with a regularity reflecting the likely rate of soiling and projected weather conditions. JACUTIN™ flea powder or other proprietary insecticide (suitable for use with rabbits) may be applied.

[50] Shuttleworth CM (2001) Interactions between the red squirrel (*Sciurus vulgaris*), great tit (*Parus major*) and jackdaw (*Corvus monedula*) whilst using nest boxes. *Journal of Zoology London* 255: 269-272.
[51] Witalfsky H (1995) *Pers. communication*

Cleaning boxes during the breeding season (Feb to August) should generally be avoided. This will ensure no disturbance of a box containing dependent young.

Nest box management - lessons from breeders

- Given a choice of identical boxes, squirrels show a preference for the highest. The disadvantage for the keeper is that the higher the box the more difficult it is to carry out a routine check[52].
- Virtually all breeders have stressed the importance of providing more boxes than there are animals, in particular during the breeding situation when young may be moved by the mother several times between different nests.
- In spite of ample boxes being available, squirrels may still build dreys given the material availability to do so. They may use the bedding from within the nest boxes.
- In captivity it is essential that breeding boxes are deep enough to prevent dependent young from accidentally falling out and that young are not disturbed when they make their first exploratory ventures out of the box as they may move away from the box when startled[53]. Although easily captured (if accessible) at this time, if returned to the box they may jump out once again and, in some cases, the mother squirrel does not return the young to the box if they have left in this manner. This risks the young dying from exposure.

[52] Witalfsky H (1995) *Pers. communication*
[53] Dickinson P (1995) *Pers. observation*

Diet and food provision

Animals should be provided a rich and varied diet. A few basic items typically form the main seed food constituents (Appendix 2): sunflower seeds, pumpkin seed, peanuts, hazelnuts, walnuts and pine nuts. A variety of fruit, vegetables and fungi can also be provided with apples, pears, soft fruit and sliced carrot as mainstays.

It is recommended to provide captive squirrels with natural foods including pine cones, beech mast, elm seed, hawthorn seed, rowan seed and acorns where these can be sourced.

If 'wild' food is used, care should be taken to avoid sourcing from areas of high grey squirrel population density. If this is unavoidable advice should be taken from the vet on a suitable, safe method of disinfection.

Though daily feeding is advisable, making food available at irregular times is of benefit as this leads to longer periods of activity. Food containers can be placed in two or more locations, preferably within a shelter or open fronted box to protect the items from the weather. Some feed (e.g. unshelled nuts) may be spread over the floor of the enclosure or hung from branches or foliage to encourage foraging. Hunting out and collecting these items provides valuable occupation.

Determining daily food consumption is extremely difficult due to the instinctive food storage behavior of squirrels. Some days food dishes will be scarcely touched and yet the squirrels may be seen or heard feeding within the enclosure. Squirrels may urinate whilst feeding in food dishes and it is therefore advisable to replace uneaten feed after three days. Care should be taken not to give too much feed lest it foul, particularly in warm weather.

Special dietary requirements

Experience within the captive breeding community has provided invaluable guidance regarding supplemental foods and highlights items where careful thought is required before offering these foods to captive animals:

- Avoid sweet refined carbohydrates foods as these may lead to osteodystrophy, dental cavities and obesity[54].
- Brazil nuts are difficult for squirrels to open and if cached they can become rotten and consumption has been associated with death.[55]
- Provide antler, sterile animal bone and or cuttle fish shell as a source of calcium for lactating females and newly weaned young which require the mineral for growth.
- Consider offering chopped boiled egg and dried mealworms during the breeding season to increase protein sources.

[54] Bonar S (1995) *Pers. communication*
[55] Stapleford D (1995) *Pers. communication*

- Peanuts are high in phosphorous and low in calcium. Large and regular peanut consumption where animals have no access to calcium rich foods (carrots, tree buds) can lead to metabolic bone disease.
- Salt licks and mineral (e.g. calcium) tablets added to water are appropriate if the manufacturer's instructions are followed.
- It is advised that consideration is given to the calcium and vitamin D content of any diet[56]

Water

Care should be taken to ensure squirrels have access to fresh clean drinking water at all times. An individual Welsh Mountain Zoo squirrel was monitored over several days during the summer of 1995 and drank between 45 to 82 ml each day. Water is best presented either in easily cleaned shallow stainless steel or ceramic pots or via pet drinking bottles. Drinking water may be a medium for presentation of oral medication where advised by a veterinarian. As an example, the Welsh Mountain Zoo has found that a soluble multivitamin suitable for guinea pigs and rabbits to be both palatable to squirrels and easy to administer. During freezing weather it is wise to present fresh clean drinking water twice daily.

Group or pair selection

Pairs, trios or large groups?

The best way to keep squirrels is in mixed sex pairs and, failing that, in trios. It is possible to keep several pairs together in a suitable sized enclosure, although in the early stages there will be some aggression until a social hierarchy is established. Having multiple adults of both sexes in one enclosure will make it often difficult or impossible to establish the parentage of young, especially if there is more than one male and/or more than a single female breeds and litters wean simultaneously. Such an arrangement is discouraged.

Changing group structure

In the breeding season males are very hierarchical and aggressive towards other males because red squirrels are promiscuous and do not form male/female pair bonds. If two or more males are kept together, then care should be taken to separate them early in the year and before the breeding season. Great care should be taken when introducing a new male into an enclosure which already contains a male. The introduction of females should be much less of a problem. Any newly introduced animal should be placed in the enclosure early in the day and definitely within its own familiar nestbox. Juvenile animals are much easier to integrate. A `howdy` cage within the enclosure proper will be of greater use with older animals.

[56] Sainsbury AW et al. (1995) *Studies on the Health and Welfare of Red Squirrels in the UK*. In Hughes DG, Tew, T. (eds). 2nd NPI Red Alert UK Forum for Red Squirrel Conservation, Forum Proceedings.

Breeding

Mating

Oestrus and, therefore, conception can occur between January and July. The majority of prenuptial activity takes place in the mornings from dawn to midday. The female may be chased by several males (if more than one present) during this courting ritual, but may actually mate with only one male. The likelihood that mating is going to occur may be determined by the females acceptance of the male in close proximity[57]. The male may stand sideways in front of the female swishing his tail from side to side and trying to look larger. Mating in captivity has been described as being preceded by vocalization and a slow chase accompanied by clicking of the teeth by the male and low tones from the female. She eventually adopts a static position with the tail raised. The male then approaches and copulation of 20 seconds is typical although this may take longer. Both animals will then retire to other parts of the cage and groom themselves. Detailed reference to mating can be found.[58]

There are opinions that the red squirrel is not an indiscriminate breeder and that pair bonding based on choice occurs[59]. This assumption is based upon the fact that certain pairs will just not breed, and that a female, even if offered a choice of several partners, will only mate if she finds one she 'likes`. One breeder pairs his animals up for the breeding season by observing those squirrels which sit closest to each other whilst feeding and he has noted that breeding pairs will also usually sleep in the same nest box.

Pregnancy

Pregnancy may sometimes be determined by the belly swelling, the hair thinning around the four pairs of nipples and the selection and protection of a single nesting site. Young females, pregnant for the first time are less likely to show the pronounced swelling.

Dietary changes include a strong preference for animal protein and a liking for egg shells and deer antler[60] [61]. Pregnancy lasts 38 days[62] [63] though there is a suggestion that it may be as long as 42 days in the subspecies *Sciurus vulgaris exalbidus*. Pregnant females become both aggressive and dominant towards the male. Aggression is also shown towards other females in the enclosure though this is less pronounced. A few days before parturition she will retire to her nest box, only venturing out to feed. The box containing newborn young is defended against the male for some days after the birth[64].

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[57] Eibl -Eibesfeldt I (1951) *Beobachtungen Zur Fortpflanzungsbiologie und Jugendentwicklung des Eichhornchen.* Zeitschrift fur Tierpsychologie 8: 370-400.
[58] Stapleford D (2003) Ibid.
[59] Witalfsky H (1995) *Pers. communication*
[60] Kimura T, Kitada Y, Nose N (1995) Keeping Japanese Squirrels. Animals and Zoos, 471: 408.
[61] Dickinson P (1995) Ibid.
[62] Eibl -Eibesfeldt I (1951) Ibid.
[63] Holfert H (1983) Ibid
[64] Dickinson P (1995) *Pers. observation*

Two litters in one breeding season are not unusual, there being two definite breeding peaks. In the British Isles these are in March/April and July/August. Throughout the red squirrel's extensive range in the wild these peaks will be determined by the weather, temperature and food availability. A captive population in Germany which had reproduced over several generations has started to produce three litters a year now with some regularity[65]. Of six captive females held during 1988-1990 there were six occasions when three litters were produced.

A peaceful undisturbed environment is essential for pregnant females to reduce the probability of young being abandoned. The keeper should develop a thorough knowledge of the behavior patterns of individual animals and only investigate if they have not been seen for three days[66]. In a minority of collections, success with breeding has been attributed to the removal of the male as soon as the female is seen to be pregnant, although the majority of collections have encountered no problems by allowing a single male to remain with the female.

Birth

Birthing problems are not that unusual, these include young being presented in a breech position or becoming stuck[67]. First litters produced by yearling females are sometimes deserted and the reabsorption of the foetus is not uncommon in squirrels, suggesting unfavourable conditions[68] [69]. The male is not usually tolerated near the nest for the first few days after the birth of the young[70].

Development and care of young

The development of young squirrels is dependent on the time of the year, weather conditions, number of young in the litter and the expertise of the nursing mother. Young have been seen to leave the box for the first time at 36-45 days and from 40-46 days[71]. They have been seen to feed for the first time at 6 to 7 weeks and wean at 8-10 weeks[72]. A rough guide to development is presented in Table 2.

Young squirrels will first leave their nest in the morning or around midday. Although it is possible to keep squirrels together as a family group for 12 months, it is recommended that young are separated from the parents at 12 weeks. This guidance will vary with enclosure size and number of adult animals held.

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[65] Holfert H (1992) Ibid
[66] Witalfsky H (1995) *Pers. communication*
[67] Stapleford D (1995) *Pers. communication*
[68] Witalfsky H (1978) *Sciurus vulgaris* Linnaeus, 1758 - Eichhornchen. In Nethammer J & Krapp F (eds.) *Handbuch der Säugtiere Europas*, Bd.1: Rodentia 1. Aula-Verlag, Wiesbaden.
[69] Shuttleworth CM *Pers. observation* in gross post mortem examinations.
[70] Liebermann E (1930) Beobachtungen bei der Auftzucht Junger Eichhornchen. Bericht Senckenbergische Naturforsch. Ges 60: 130-133.
[71] Stapleford D (1995) *Pers. communication*
[72] Stapleford D (2003) Ibid.

Hand-rearing

Where circumstances necessitate hand-rearing may be undertaken. Squirrel milk is composed of 39.6% solids, 67% fat, 20% protein, 10% carbohydrates and is 2.85 Kcl/ml.

A variety of different formulas have been used to hand-rear red squirrels. Some of the successful ones are described in Appendix 3.

Efforts should be made to try and avoid imprinting as, once done, it is a difficult trait to reverse. Imprinted squirrels are less likely to be good breeders and are poor subjects for release. It is advisable that hand-reared squirrels are never given consideration for release projects as they are at a positive disadvantage. It has been noted by some holders that hand reared squirrels may not be appropriate for walkthrough exhibits, due to the manner in which some have been observed to interact with visitors.

Time from birth	Notes on development
New-born	Blind and deaf, their skin is pink and devoid of hair except for short whiskers. They weigh approximately 8-15 g[73] [74] [75]
1- 5 days	Young uncoordinated, movements consist largely of treading and clutching[76]
1 week	Still pink with very small whiskers which are about 1 mm in length[77]
5 to 10 days	Capable of emitting alarm calls[78]
2 weeks	A light fuzz of hair along the back though belly and limbs are still bare[79]
15 to 20 days	Quiet `cooing` sounds are made prior to feeding
25 days	Weight approximately 56 g, hair on tail 3mm, on back 2 mm, on ear tip 2 mm. From tip of nose to base of tail measure about 105mm, the tail exclusive of hairs is 70 mm, hind leg with nails 65 mm, front leg 46 mm. Longest whisker 15 mm[80]
3-5 weeks	Eyes and ears open, muzzle head and tail quite well furred. Approximate weight is 50 g[81]
4 weeks	Able to climb out of the nest, claws well developed[82]
5-6 weeks	Whole body is covered in hair. Lower incisors are prominent and lower incisors start to show
7-9 weeks	Begins to leave nest. Weight approximately 110-130 g. Weaning begins[83]
10-11 weeks	Weaned (150 g). Note adult weight typically 250-350 g

[73] Bonar S (1995) *Pers. communication*
[74] Stakhrovskii VGK (1932) Izucheniiu Biologii Belki Pri Soderzhanii v Vol`Ere-Parke. Zool. Jou. USSR 11: 82-104
[75] Holfert H (1983) Ibid.
[76] Eibl -Eibesfeldt I (1951) Ibid.
[77] Kelway P (1940) Breeding Red Squirrels. Country Life July 6th 1940.
[78] Eibl -Eibesfeldt I (1951) Ibid.
[79] Liebermann E (1930) Ibid.
[80] Kelway P (1940) Breeding Red Squirrels. *Country Life* July 6th 1940.
[81] Holfert H (Ibid.)
[82] Bonar S (1995) *Pers. communication*
[83] Kelway P (1940) Ibid.

Individual identification, sexing and collection of hair samples

There is often a degree of difference in coat colour, markings and behaviour in squirrels. If only few animals are maintained, then they will quickly become readily identifiable to their keeper. Staff may change however and mistakes may be made, so a more permanent form of identification is essential.

We would *strongly advise* that all captive squirrels are routinely implanted with TROVAN PiT microchips, ideally situated between the shoulder blades. It is absolutely essential that animals can be correctly identified to ensure the successful management of the breeding programme. The failure rate with the chips is extremely low and stress to the animals is minimal when the implant is carried out in professional hands. If microchips are properly placed they will rarely be lost, though they do sometimes migrate.

The use of stamp tattoo, ear tags and toe-clipping to identify individuals would require a Home Office license and, given the ease and minor discomfort of PiT tags, are wholly unnecessary methods.

The sexing of young animals is best done at the same time as the microchipping. This avoids an extra need to catch. Males and females are readily distinguishable from one another: in males there is at least 1 cm gap between the anus and the penis in the smallest juveniles, whilst in females the vulva is only a few millimetres from the anus. We would advise those unfamiliar with squirrel genitalia to spend some time sexing young domestic rats, which are virtually identical to squirrels.

Finally, if hair samples (20-30 hairs) can be collected from the tail and stored (in a sealed envelope marked with the animal's PiT number) in a freezer, the material can be used for genetic studies. This technique is currently under development by APHA, with publications expected in the near future.

A note on general handling

Handling should be kept to an essential minimum, with some holders refraining from handling young until they are 6 months old, to avoid stress. Handling should ideally be carried out by someone who is confident and familiar with the routine. Red squirrels scratch and are capable of inflicting an extremely painful bite. There are several zoonotic infections potentially carried by squirrels that are of some concern[84].

All bites should be thoroughly cleaned and a check made that the handler's tetanus injection is up to date. Some people may prefer to use gloves, although, because handler sensitivity is lost when thick gloves are worn, this may be detrimental to the animals well-being.

When handling a red squirrel, grip firmly but loosely around the neck with the thumb and forefingers of one hand while the other hand is used to restrain and support the body. If

[84] Greenwood A, Sanchez S (2002) Serological evidence of murine pathogens in wild grey squirrels (Sciurus carolinensis) in North Wales. Vet. Rec. 150: 543–536.

gripped confidently, the animal quickly becomes calm and may be examined or moved at will. Squirrels unfamiliar with handling have been known to die of shock[85]. One tried and tested method of handling squirrels is the 'zip cone' bag. Constructed of strong cotton, it allows the animal to be weighed and examined with practical ease. Perhaps the biggest advantage is that it allows the handler to constantly feel the animal's heartbeat and so monitor stress. Use of a mesh handling cone similarly allows sexing and routine examination. The 'zip cone' design and use is described[86, 87].

Handlers should be aware that squirrels can and do play 'possum' and should the grip be relaxed they will quickly escape, possibly biting a finger along the way.

Capture and restraint

In a small confined enclosure or quarantine yard, squirrels may be quickly and easily caught in a cloth bird net. In large enclosure, they are best captured by confining them in their nest boxes, by plugging holes with a form of substrate such as woodwool or hay, or using a live-capture trap, such as a vole trap (see available online resource[88]), as it is important to keep stress to a minimum. Captive squirrels show great curiosity in anything new and are quite quick to enter traps. A darkened trap is less stressful to the animals and so best practice is to cover it.

Catching one animal at a time means there is less likelihood of animal injury. It is noteworthy that a previously caught and released individual may return to the trap several times a day and be caught again.

Useful notes relating to health checks

Anaesthesia: Effective anaesthesia has been induced by using 4% isoflurane along with oxygen maintained at 2 to 2.5%. Post anaesthesia delivery of 5 ml of 5% dextrose saline is advised to aid recovery[89]. BSAVA manual of wildlife casualties should be consulted for further details.

Blood collection: Blood is best taken from the femoral vein using a 0.4 x 12 mm needle. From 0.8 to 1.0 ml can be taken safely[90].

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[85] Muench S, Zscheile K (1995) Fang, Markierung und Telemetrie von Europäischen Eichhőrnchen *Sciurus vulgaris* L., 1758. Pp 455-465 in Methoden Feldőkologischer Säugetierforschung. (Stubb M, Heidecke D, Stubbe A. eds)

[86] Muench S, Zscheile K (1995) Ibid

[87] Margaret Mantor, Sara Krause and Lynette A. Hart (2014) Trapping and Handling Squirrels: Trap Modification and Handling Restraint to Minimize Injuries and Stress. Wildlife Society Bulletin Vol. 38, No. 1 pp. 152-159

[88] https://www.forestry.gov.uk/PDF/fcpn004.pdf/$FILE/fcpn004.pdf

[89] Sainsbury AW, Gurnell J (1995) An investigation into the health and welfare of red squirrels, *Sciurus vulgaris*, involved in reintroduction studies. Veterinary Record 137:367-70.

[90] Sainsbury AW, Gurnell J (1995) Ibid

X-Ray: 2 views should be taken, at right angles (eg a lateral and ventrodorsal or dorsoventral view). Ideally, the whole animal should be radiographed, including the long bones, for signs of developmental bone pathology.

Blood biochemistry: Published findings from a small number of squirrels are described elsewhere[91].

Coccidiosis treatment: It is advised that a preventative treatment be carried out twice a year to preclude problems with coccidiosis. A course of toltrazuril has proved to be effective. This is administered in the water supply for five days, rested for 10 and then repeated again for another five. Please take advice from your vet re treatment dose and length of treatment.

Tooth overgrowth: This is sometimes known as 'Elephant Tooth' and can be a problem in some animals. Once this problem occurs, regular teeth burring appears to be the only effective solution.

Adenovirus: This infection can cause pathogenic intestinal disease and is a difficult infection to identify in squirrels showing no obvious signs (diarrhoea). Routine screening of faecal samples (via electron microscopy) will confirm likely disease, whilst genetic screening of hair samples will reveal current or historical subclinical infection.

Squirrel pox: The red squirrel population of the UK has declined greatly in the last decade, largely due to squirrel pox. Grey squirrels are carriers of the virus, but have developed immunity to it. More information can be found following the link: https://bmcvetres.biomedcentral.com/track/pdf/10.1186/1746-6148-9-229

Variegated squirrel bornavirus: This zoonotic virus caused fatal encephalitis in three breeders of variegated squirrels (*Sciurus variegatoides*) between 2011 and 2013. More information can be found following the link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5382762/

The Red Squirrel Hospital, 'Stichting Eekhoornopvang': This establishment has been using a variety of different medications for squirrel treatment. These are shown on the chart in Appendix 3. It is crucial to avoid products using Lindane or allied pesticides as these are fatal to squirrels. (see biosecurity section above).

[91] Robinson I (1995) Red squirrels - diseases and injuries. In Collins LM, Hughes DG, Ward L (eds.) *Rehabilitation of Red Squirrels: A Workshop.* NPI Red Alert North West.

Mortality, post mortem and histological studies

It is strongly recommended that all deceased red squirrels be sent for a comprehensive post-mortem examination by a veterinary pathologist with relevant experience. Even if bodies are not fresh, samples can be used for viral research. Examination should include direct microscopy during the post-mortem examination itself. Samples collected during the examination should include a complete set of formalin-fixed tissues for histology and appropriate fresh samples for parasitology and microbiology. Routine retention of a set of frozen (ideally ultra-frozen) tissues (liver, spleen, lung, kidney, brain and gut content) is desirable. Faecal screening for adenovirus by transmission electron microscopy and PCR testing is recommended in all suspicious acute deaths. Diagnosis is not straightforward from gross post-mortem examination alone, particularly if the carcass is autolysed. In these circumstances, the additional option of hair selection as an analytical matrix for PCR analysis may be of particular benefit, as internal organs may not be available for analysis. The findings should be shared with the studbook keeper so that managers can record the findings and, where necessary, inform the studbook members.

Transportation

Ideally, animals should be transported singly to avoid fighting. Transportation of less than 4 hours is recommended, although journeys of 10+ hours have taken place without adverse effect on animals.

It is good practice to provide slices of apple and carrot as sources of water along with some mixed nuts and sunflower seed.

If transporting animals over a short distance i.e. from one cage to another, it is important that they are moved in their own nest box. The access hole should be blocked during movement and once the box has been positioned in the new enclosure, this can be removed

and carefully replaced with woodwool. The squirrel will usually remove the blockage itself a few hours later, but can be given assistance if this is not done.

Legislation

Wild red squirrels are given protection under Schedule 5 of the Wildlife and Countryside Act (1981). This makes it an offence to intentionally take, kill or injure an animal. It is also an offence to disturb an animal within a nest (place of shelter), to prevent access to nests, or to destroy them.

Red squirrels also receive a degree of protection under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) where, under Appendix III their exploitation is subject to regulation.

Captive red squirrels are property and are protected under Animal Welfare legislation. An escaped captive-bred red squirrel can be trapped by the owner without a licence. However, when captive animals are deliberately released it is likely that, given the intent of the owner, they will be covered by the 1981 Act. This is an important consideration in translocation projects. We recommend that owners contact national nature conservation authorities should animals escape or where a translocation/release of reds is being considered.

Squirrel release proposals

Increasingly, breeders of captive red squirrels are approached as a potential source of stock for conservation translocations (Figure 1). We recommend that caution and careful consideration are given to proposals, particularly island introductions (where red squirrels were never present) and reintroductions (where red squirrels have become extinct).

The IUCN guidelines relating to conservation translocations are extensive and require early and meaningful discussion of proposals with national nature conservation authorities. They also require detailed planning with respect to:

- Identification and removal of the cause of historical red squirrel extinction.
- Prevention of infection and pathogen spread via the release of animals.
- Demonstration that habitat is suitable to support a population in the long-term. This means having sufficient numbers to remove the risk of inbreeding and genetic loss, buffering against significant declines during periods of low food availability and with resources in place to carry out long-term population study/monitoring, in line with animal welfare legislation.
- Genetic screening, selection and management must be defined.
- Contingency and risk assessments must be in place.

Given the increasing emphasis within guidance for genetic study and minimizing the risk of inadvertently spreading infection, we recommend that members of the studbook routinely collect hair samples from animals and ensure that post mortem examinations of

dead red squirrels are carried out. Published studies of previous translocations using captive red squirrels are available[92] [93] [94] [95] [96] [97].

For further details on relocation and release guidance and policy, please see the IUCN Guidelines for Reintroduction and Other Conservation Translocations[98], and the BIAZA Translocation Policy, available from BIAZA.

[92] Shuttleworth CM, Kenward RE, Jackson N (2008) *Re-introduction of the red squirrel into Newborough forest on the island of Anglesey, UK*. pp 163–166. In: Soorae P (ed) Global Re-Introduction Perspectives: Re-Introduction Case-Studies from Around the Globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE..

[93] Shuttleworth CM, Everest JD, McInnes CJ, Greenwood A, Jackson NL, Rushton S, Kenward RE (2014) Inter-specific viral infections: Can the management of captive red squirrel collections help inform scientific research? *Hystrix, Italian Journal of Mammalogy* 25:3-8

[94] Everest DJ, Shuttleworth CM, Grierson SS, Dastjerdi A, Stidworthy MF, Duff JP, Higgins RJ, Mill A, Chantrey J (2018) The implications of significant adenovirus infection in UK captive red squirrel (*Sciurus vulgaris*) collections: How histological screening can aid applied conservation management. *Mammalian Biology* 88 123-129

[95] Shuttleworth, CM, Signorile, AL, Everest DJ, Lurz PWW (2015) Assessing causes and significance of red squirrel (*Sciurus vulgaris*) mortality during regional population restoration: An applied conservation perspective. *Hystrix, The Italian Journal of Mammalogy* 26:69-75.

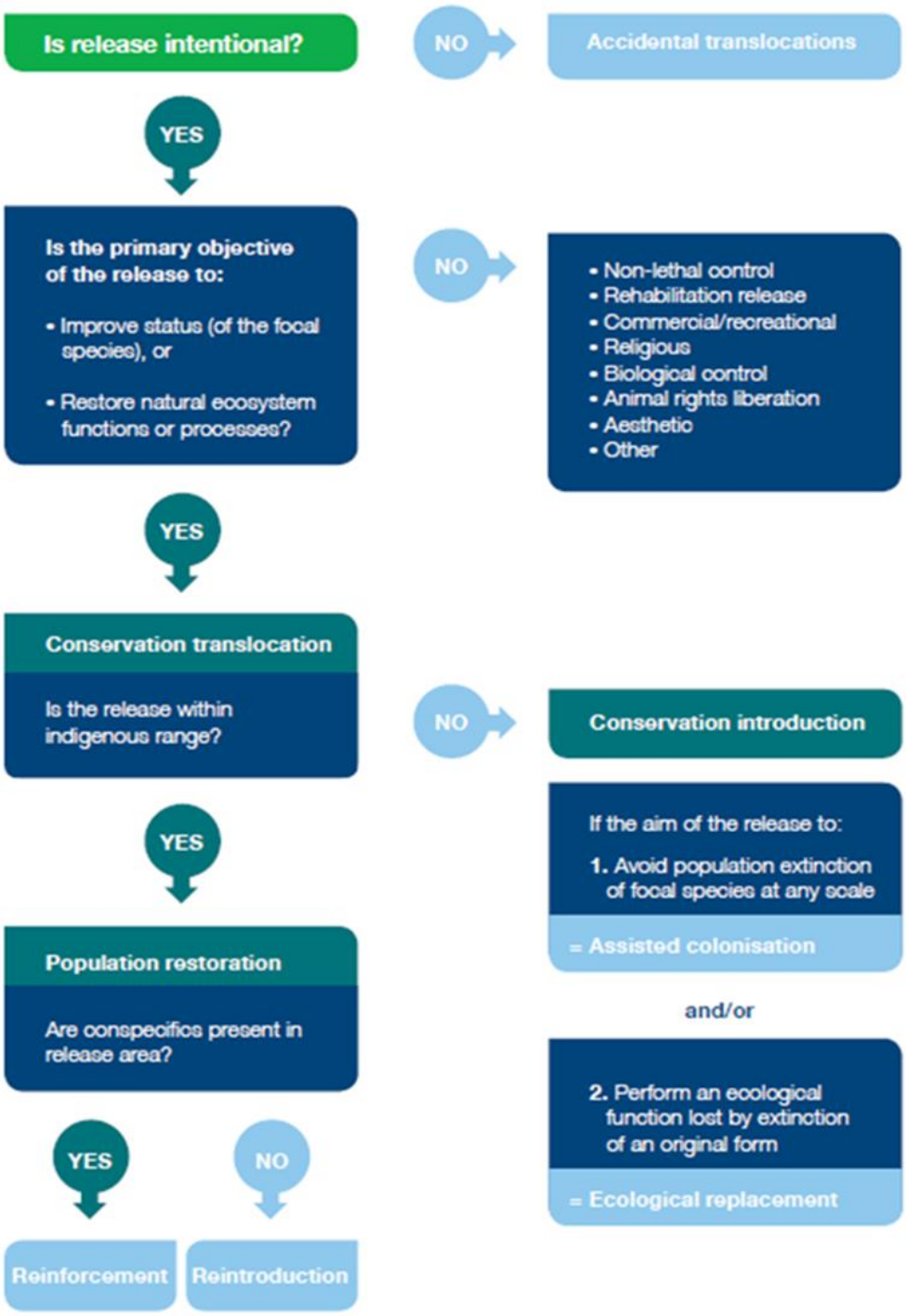
[96] Shuttleworth CM, Kenward RE, Jackson NL (2016) Developing red squirrel re-introduction techniques for use during regional grey squirrel eradication programmes in Europe. In Soorae P (ed) *Global Reintroduction Perspectives: 2016 Case Studies from Around the Globe*. IUCN/SSC Reintroduction Specialist Group and Abu Dhabi, UAE Environment Agency, Abu Dhabi.

[97] Jackson N.L. (1999) *The Reds Return – Two trial releases of captive-bred red squirrels (Sciurus vulgaris) to a woodland site in Colwyn Bay, North Wales.* pp 67-78 In: Collins LM & Cooper MD (Eds) 3rd NPI Red Alert Forum for Red Squirrel Conservation: Forum Proceedings, Scottish Natural Heritage, Perth.

[98] https://portals.iucn.org/library/efiles/documents/2013-009.pdf

Figure 1. The translocation spectrum

This diagram explains the different terminology used in translocations.



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These guidelines are a living document, comments on the content are always welcome and will be included in the next revision. Please see contacts list for details.

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Appendix 1 Classification and sub-species

The red squirrel *S. vulgaris* is a rodent in the family Sciuridae. It has a wide Palearctic distribution and is one of four species of tree squirrel in that biogeographical region. The others are *S. anomalus* (Persian squirrel), *S. lis* (Japanese Squirrel) and *S. meridionalis* (Calabrian black squirrel).

Sciurus vulgaris has around twenty or so defined subspecies[99, 100]. Historically, a possible British subspecies, *Sciurus vulgaris leucourus*, was proposed but as this was based on coat colouration alone it is no longer listed. Animals have been imported into the UK from Scandinavia *Sciurus vulgaris vulgaris* and possibly *Sciurus v. varius*, Germany and Austria *Sciurus v. fuscoate*r and probably France *Sciurus v. russus*.

Appendix 2 Dietary examples

Basic Diet 1: 5 parts parrot seed, 4 parts sunflower seed, 2 parts cedar nuts, 1 part carob cake, 1 part dried mountain ash berries, 1 part fir seeds, 1 part peanuts in shell. Occasionally a mix of dried baby cereal, glucose, calcium, multi-vitamins and raisins is given. Each animal is offered 2 hazelnuts by hand.

Basic Diet 2: 70% sunflower seeds, 15% cedar nuts, 5% maize and the remainder made up with items such as pumpkin seeds, peanuts, carob cake, chestnuts, walnuts and hazelnuts. In a separate dish a 50/50 mix of MILUPA and ground monkey pellets is offered. Marrow bone and cuttlefish bone are always available, though are used mainly by the female during the breeding season. Seasonally, fresh willow branches, green pine cones, oak flowers, young oak leaves, buds from elm and maple, dandelion leaves and roots are offered, as well as carrots and apple.

Basic Diet 3: 37% Sunflower seed, 26% Barley (whole and flaked), 19% Whole wheat, 11.8% Grass pellet, 6.2% Maize (Whole and flaked) available 24 hours. 34gms of cedar nut are offered daily in rota with 68gms hazelnut in shell and occasional monkey nuts. Also, when available, pine cones, beech masts, maple keys and hornbeam seeds are given. They only take green acorns and scrape off the outer green skin of the seed. Vegetables favoured are fresh sweetcorn, butternut squash with seeds in, sugar snap peas, cucumber, celery. Offered one fruit item a day either pear, apple, grape or blackberry. (Wildwood Trust)

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[99] Lowe VPW & Gardiner AS (1983) Is the British squirrel (*Sciurus vulgaris*) British? *Mammal Review*: 13, 57-67.

[100] Shorten M (1954) *Squirrels*. Collins New Naturalist, London.

Appendix 3 Hand-rearing examples

Stichting Eeekhoornopvang

Though there are many ways to hand-rear a squirrel the most successful method would appear to be that used by Stichting Eekhoornopvang in the Netherlands. As of 1995 they had reared 130 squirrels using their own milk formula (Eekhomel.493) which is made up of water, sunflower oil, lactose-free baby powder, calcium and multivitamins.

Their feeding schedule is as follows:

0-2 weeks 0.5 ml every 2 hours
2-4 weeks 0.5 – 1 ml every 2-3 hours
4-6 weeks 1-2 ml every 3-4 hours
6-8 weeks 2-3 ml every 4 hours
8-10 weeks 4-5 ml every 5 hours

Milk is given at body heat and presented in a syringe. In the past they have used specialist animal feeding bottles but found these led to choking (inhalation pneumonia) or suffocation problems. Currently for young of up to four weeks of age they use a 0.3 ml syringe, progressing upwards to a 1 ml syringe.

They draw special attention to the importance of using lactose free milk. At weaning the milk is mixed with liquidised fruit baby food. Young are kept at a temperature of 30-33 C.

National Zoological Society of Wales

A pair of young squirrels arrived: the male weighing 90 g and the female 86 g. They were both fully-furred and estimated to be just under a month old. They were fed every 2-3 hours from 06.00 to 23.00 on Cimicat. No problems were encountered using this formula. Initially keepers tried presentation using both CATAC and HAGEN bottles but abandoned these for a more controllable 1 ml syringe tipped with a MIKKI TEAT. At the first feed of the day they would take as much as 2.5 ml before settling off to an average of about 0.5 – 0.75 ml per feed. There was a slight increase in feed taken each day until shortly before weaning, 5 – 7 ml per feed was not unusual.

They were not given any artificial heat and were kept in a small cage with an internal nest box . The box had nesting material made up of woodwool, hay and paper tissues. For the first couple of weeks the squirrels did not leave the nest box except for milk feed and occasionally to toilet. The nest was cleaned every 2-3 days. A small dish of feed was made available at all times and, although regularly inspected by the squirrels, was not seen to be of interest. About two weeks after arrival, when they were approximately 45 days old, they started to nibble at foods. Apple was a great favourite as was Shaws egg biscuit which, due to being very light, was usually dragged back to the nest box and eaten. The young squirrels, once on solid food, would feed at any time of the day or night, leaving the nest box to collect items from their dish in the darkness. Once solid food was being taken water was presented in a pet drinking bottle. This was being used within 20 minutes of it first being introduced. Milk feeds were still presented daily but often ignored. At about 55 days of age milk feeds were constantly refused so were stopped altogether.

Scottish SPCA

They have used a variety of different formulas dependent on the situation at the time. By choice they have used LACTOL at one part to three parts of water with one drop of ABIDEC added to the first feed. Young are fed three hourly from 06.00 to midnight. Soft solid foods are first introduced at about four weeks and the number of milk feeds reduced at about the same time. They say that warmth is critical at rearing. A little brown sugar is sometimes added to the formulas to alleviate constipation.

Wirral Wildlife Rehabilitation Unit

A youngster weighing 105 g was fed five times daily with CIMICAT, it took from 1.5-6 ml per feed. Another infant arrived weighing 90 g and was syringe fed with ESBILAC three times a day. It took from 3-11 mls per feed. In four days its weight had increased to 110 g. It was put into the outside enclosure nine days after arrival.

Appendix 4 Drugs and endo-/ecto-parasites

Please consult your veterinary surgeon regarding appropriate dose rates and treatment regimes.

Reported endo and ecto parasiticides used in red squirrels include:

- Johnsons anti mite powder/spray
- Ivomectin (small animal spot on products for ectoparasite treatment)
- Toltrazuril (for coccidiosis treatment)
- Fenbendazole (for gastrointestinal nematode treatment)

- Marbocyl fd 1% (Antibiotic)

Appendix 5 Recommended reading

Bosch S, Lurz PWW (2012) *The Eurasian Red Squirrel.*Westarp Wissenschaften, Germany.
Dickinson P (1995) The captive care, maintenance and breeding of the red squirrel (*Sciurus vulgaris*). Ratel 22, No 1.
Gurnell J (1987) *The Natural History of Squirrels*. Christopher Helm, London.
Holm J (1987) *Squirrels*, Whittet Books Ltd. London
Laidler K (1980) *Squirrels in Britain.* David and Charles, London.
Shorten M (1954) *Squirrels*. Collins New Naturalist, London.
Stapleford D (2003) *An Affair with Red Squirrels*. Larks Press, Dereham, England.