The Eurasian Red Squirrel

Sciurus vulgaris

First edition

Stefan Bosch

Peter W. W. Lurz

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With 81 illustrations and 14 tables

Cover photo: Red squirrel eating on a tree stub in the montane forest of Davos (Switzerland). Foto: Bosch

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Foreword

A Sunday walk to enjoy the beautiful colours of autumn in a woodland near town. A slight rustle among fallen leaves; pausing, we see a red squirrel making little jumps, apparently undecided which direction it should take. It stops, sitting on its hind legs to look around, the ears, adorned with long elegant eartufts, seem like antennae to capture the lightest of sounds that could mean 'danger'. The squirrel is carrying a hazelnut in its mouth. Suddenly it jumps again and then pushes its muzzle against the earth, shaking the head; it looks up, the hazelnut has disappeared. The squirrel makes fast tapping movements with its front paws, looks up again, sees us, and with a chattering sound hurries up the nearest oak tree, hiding on the opposite side of the stem from where we are standing.

This is certainly one of the most likely 'close encounters' an attentive hiker can have with a mammal in forests and woodlands all over Europe. In fact, being day-active, the red squirrel is one of the most attractive and easily spotted animals in our forests. Unfortunately, in some places, like on the British Isles and parts of North Italy, this is no longer the case and I will come back to this later.

For any man or woman interested in nature and its amazing creatures such an observation would make them wonder: what is it doing and why? Answers to this question and many others can be found in this book.

I have been a squirrel biologist for several decades. I made my first steps in squirrel research in 1983, for my bachelor thesis, and have never subsequently abandoned them. Although I always keep myself updated with the scientific literature on red and other squirrel species, I remain amazed at the amount of information given in this book: it contains nearly everything ever written about the red squirrel.

There have been several other volumes dedicated to our favourite tree acrobat but never one so extensive. Whether the one who opens this book is a squirrel specialist, a professional biologist, an amateur naturalist or a casual reader, she or he will not only discover many new facts about its evolutionary origins, how a squirrel is 'built' and how it spends the day, but also understand how nuanced the interactions between this animal and its environment are. How, for example, stone pines depend on red squirrels for seed dispersal and germination. Squirrels bury many of their seeds to

have energy-rich food stores the next spring, but do not recover all of them. How squirrels, on their turn, depend on how many seeds the trees have produced that year to find enough food to meet the high energy demands for a female to produce young. The quite astonishing fact that red squirrels seem to be able to anticipate a mast-crop, starting to breed in large numbers *before* the enormous amount of energy-rich seed become available. All this is the result of a long story of natural selection to a hard and changing environment that has led to a co-evolution of squirrels and (some of) their food plants and that has made the red squirrel what it is today.

Reading the chapter on the Evolutionary History of sciurid rodents and the distribution of the Eurasian red squirrel, one learns that the species evolved in a world void of other tree squirrels and thus was not subject to selective pressures that made it a 'tuff guy' ready to face competitors with similar tree-dwelling and seed-eating habits. Very different from the situation faced by its cousins in North-America, where often up to three tree-squirrel species are sympatric in parts of the continent.

Hence, the red squirrel was the only arboreal squirrel species in Europe until man decided to 'fool' around with the precarious interdependencies that had evolved between squirrels and trees by introducing other squirrel species from far away continents. The release of 'alien' Eastern gray squirrels, whose home is central and east USA and south-east Canada, into the British Isles and Italy has reduced our red squirrel from an overall presence in all suitable forests, woodlands and even parks, to a threatened species in most of the British Isles and in a large part of northern Italy. Moreover, the Italian populations of invasive gray squirrels are bound to spread into neighbouring countries in the next 20–40 years (or sooner, should people continue to irresponsibly release bought pet squirrels), if no steps are taken to stop them from advancing towards France and Switzerland. This is not a natural process but caused by human intervention and we are responsible for the extinction of our red squirrels in areas colonised by the introduced congener. We thus have the responsibility to do all we can to save this wonderful animal, so well-adapted to our forest ecosystems but not to the presence of a heavier, faster-growing and introduced competitor, from wide-scale extinction in Europe.

Let's hope that this book will reach readers throughout Europe and convince them of the uniqueness and beauty of our red squirrel and of our duty to do all we can to save it, so that also the future generations, while having their Sunday walk, can remain surprised and spellbound by a red squirrel jumping around and hiding its precious hazelnut.

Dr Luc Wauters

Varese, Italy

Introduction

Every book has its history and the history of our book began in 1956. In that year the 'Neue Brehm-Bücherei' published a monograph on the red squirrel. It encompassed 56 pages, 51 images and 28 literature sources and was written by Dr Wolfgang Gewalt (1928–2007), a well known zoologist and director of the Duisburg Zoo. This was followed by two landmark publications on squirrels in 1987 by Dr John Gurnell and Dr Jessica Holm respectively. Since then there has been a huge and world-wide interest in squirrels, with research into their ecology, behaviour, conservation and competition, providing a wealth of new information on these fascinating forest animals. In particular, research on red squirrels in Belgium, the UK and Italy applying new methodologies such as radio-tracking, genetics, computer modelling and geographic information systems have revolutionised our understanding of this species and its role in forest ecosystems. April 2011 therefore saw the publication of a revised red squirrel monograph in Germany (Westarp Verlag), which thanks to the interest of the publishers in an English language edition will now be accessible to English-speaking readers. This seemed an obvious way to go, given that one of the authors has spent the last 20 years living and 'chasing' squirrels in the British Isles.

The book tries to give a comprehensive overview of our current knowledge and published scientific research on red squirrels and includes, for example, details and images of red squirrel anatomy and behaviour that have never been published before. Advances over the last 25 years in our understanding of red squirrels were especially made with respect to their space use, activity patterns, population dynamics, dispersal behaviour and the complex ecological interactions and interdependencies between squirrels and the plant and animal species community that comprise forest ecosystems.

It is not possible to write a book about the Eurasian red squirrel without mentioning the Eastern gray squirrel, which has been released in the UK, Ireland and Italy, and its devastating impact on native red squirrel populations. 125 years after its first release in the UK, mainland England and Wales are almost completely 'grey'. Red-gray squirrel interactions and how Eastern gray squirrels compete with and replace red squirrels have

therefore been the focus of research in the UK and Ireland, highlighting the initially undetected but critical role of wildlife diseases in competition and decline. The book attempts to explain the range of factors that contribute to red squirrel populations going extinct and stresses the dangers posed by expanding gray squirrel populations in northern Italy to red squirrel populations in neighbouring Switzerland, France, and Central and Southern Europe beyond. The problem is made worse by continuing and irresponsible releases of bought North American or Asian squirrels in parks or woodlands which in many cases lead to the establishment of new populations and range increases of these alien squirrels. Both the Eastern gray squirrel or the Pallas squirrel, which have been introduced to a number of European countries, are linked to extensive tree damage as well as damage to agricultural crops and impacts on native wildlife. They illustrate the complex issues posed by non-native species introductions and the need for management decisions that are based on conservation and economic, legal, and ethical considerations.

The book contains a large number of references to the Eastern gray squirrel, as it is imperative to understand the ecological requirements of both gray and red squirrels in order to develop an effective conservation strategy. Where it helped to illustrate tree squirrel specific behaviours, we have made reference to squirrels in general or to particular squirrel species. Readers should not be surprised to see a number of red squirrel colour morphs that may be unfamiliar to them. Coat colour variation of the red squirrel varies tremendously across its Eurasian range and this is well illustrated by the images taken at different altitudes in montane forest near Davos (Switzerland), showing red, grey and dark-coated individuals.

Red squirrels are amazing and incredible animals and we would like to encourage readers to see and use this book as a window into the life of this unique rodent species and see the world from its perspective. To echo the sentiment of Thorington & Ferrell (2006): 'think like a squirrel'.

Stefan Bosch

Peter W. W. Lurz

Sternenfels and Edinburgh, April 2012

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1.2 Squirrels (Sciuridae)

The classification of related kinds or forms of animals into families, subfamilies, genus and species is made on the basis of observed characteristics of examined specimens (e.g. morphological traits). This process is ultimately a subjective judgement made by the individual taxonomist that is by no means absolute (Corbet 1978) and classifications are subject to change, as novel analytical techniques, for example DNA analysis, allow new interpretations. A comprehensive and detailed history of rodent classification is given by Carleton & Musser (2005).

Within the order *Rodentia*, and the suborder Sciurognathi (Tullberg 1899), squirrels are grouped in the family Sciuridae (see Table 1). Related families within the suborder are: mountain beavers (Aplontidae), beavers (Castoridae), mice and rats (Muridae), pocket gophers (Geomyidae), kangaroo rats (Heteromyidae) and jerboas (Dipodidae). An alternative classification includes a different suborder of Sciuromorpha (squirrel-like-rodents, Brandt 1855) with three families, 61 genera and 307 species (see Carleton & Musser 2005). In both classifications the family Sciuridae contains two subfamilies (Nowak 1999): Petauristinae (Flying squirrels) and Sciurinae (Tree and ground squirrels). However, new molecular research supports a revised classification of squirrels and recognition of five rather than two distinct subfamilies: Sciurinae (Eurasian, North and South American tree squirrels and all flying squirrels), Callosciurinae (southern Asian tree squirrels), Ratufinae (giant tree squirrels), Sciurillinae (South American pygmy squirrels) and Xerinae (African bush and tree squirrels and Eurasian, North American and African ground squirrels) with a total of 51 genera and 278 species (Thorington & Hoffmann 2005). The calibration of a molecular clock also suggests that the divergence of the five groups took place in the late Eocene and early Oligocene periods at a time of marked climatic change (Mercer & Roth 2003, Steppan et al. 2004, Thorington & Ferrell 2006).

Table 1: Eurasian red squirrel classification (Lurz et al. 2005).

Class:	Mammalia (mammals)
Order:	Rodentia (rodents)
Sub-order:	Sciurognathi
Family:	Sciuridae (squirrels)
Sub-family:	Sciurinae (tree and ground squirrels)
Tribe:	Sciurini (tree squirrels)
Genus:	*Sciurus*
Species:	Eurasian red squirrel (*Sciurus vulgaris* Linnaeus 1758)

Fig. 1: Eurasian red squirrel (*Sciurus vulgaris*). Photo: Bosch.

Fig. 2: The Eastern gray squirrel (*S. carolinensis*) was originally introduced from North America and it competes with and replaces the native Eurasian red squirrel. The left image shows a gray squirrel in its native North American range (New York) and the right a gray squirrel in London's Hyde Park. Photos: Haas (left), Bosch (right).

Fig. 3: The North American pine squirrel (*T. hudsonicus*) is also referred to as the North American 'red squirrel' but is in fact a different species. Similarly to the Eurasian red squirrel, coat colour is variable. Left: a pine squirrel. Right: a pine squirrel with Ponderosa pine cone (*Pinus ponderosa)*. Photos: Howie (left), Larsen (right).

2 Distribution

2.1 The red squirrel, Eurasia's tree squirrel

The Eurasian red squirrel has the largest distribution of all tree squirrels. Its range stretches from the Atlantic coast of Ireland across the whole of Eurasia to China, Korea and northern Japan (e.g. Sidorowicz 1971, Lurz et al. 2005; Fig. 4). It is found wherever there is suitable woodland habitat.

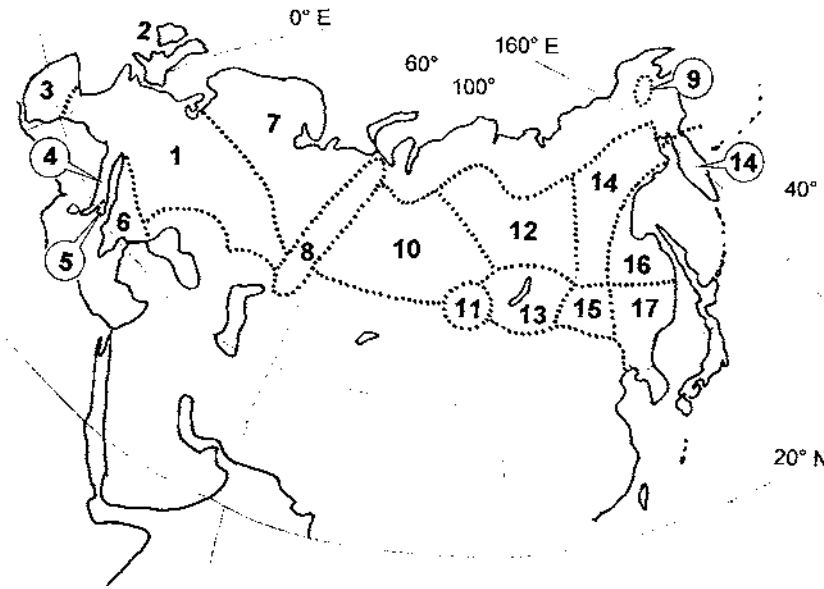

Fig. 4: Geographic distribution of described red squirrel subspecies in Eurasia (based on Sidorowicz 1971). Individual subspecies are numbered and their approximate range indicated by dotted lines: (1) *S. v. fuscoater*, (2) *S. v. leucourus*, (3) *S. v. infuscatus*, (4) *S. v. italicus*, (5) *S. v. meridionalis*, (6) *S. v. balcanicus*, (7) *S .v. vulgaris*, (8) *S. v. baschkiricus*, (9) *S. v. anadyrensis*, (10) *S. v. argenteus*, (11) *S. v. exalbidus*, (12) *S. v. jenissejensis*, (13) *S. v. altaicus*, (14) *S. v. jacutensis*, (15) *S. v. fusconigricans*, (16) *S. v. rupestris*, (17) *S.v. mantchuricus*. Map: Bosch.

Fig. 5: Examples of different woodland habitat types in Europe:

a) boreal conifer forest in Sweden, **b)** Scots pine forest in Scotland, **c)** production spruce forest in northern England, **d)** coniferous forest on the northern edge of the Schwäbische Alb, Southern Germany, **e)** forested island Amrum, North Sea, Germany, **f)** forest landscape in northern Italy. Photos: a–c, f) Lurz, d–e) Bosch.

Table 2: Red squirrel subspecies (based on Sidorowicz 1971, Lurz et al. 2005).

European Subspecies	
Sciurus vulgaris	Geographic region
balcanicus Heinrich 1936	Balkans, eastern Balkan mountains, Bulgaria Synonyms: *ameliae* Cabrera, *croaticus* Wettstein, *istrandjae* Heinrich, *lilaeus* Miller und *rhodopensis* Heinrich
fuscoater Altum 1876	Central and Eastern Europe; Pyrenees to Urals and Denmark to Switzerland and northern Italy. Synonyms: *alpinus* Desmarest, var. *brunnea* Altum, *carpathicus* Pietruski, *cinerea* Hermann, *fedjushini* Ognev, var. *fuscoatra* Altum, var. *gothardi* Fatio, *kessleri* Migulin, *ognevi* Migulin, *rufus* Barrett-Hamilton, *rufus* Trouessart, *russus* Miller, *rutilans* Miller, *subalpinus* Burg, *vilnensis* Udziela, and *ukrainicus* Migulin
italicus Bonaparte 1838	Italy, except northern Italy and Calabria
infuscatus Cabrera 1905	Iberian Peninsula; Spain (Provinces of Madrid, Soria, Avil). Synonyms: *baeticus* Cabrera, *numantius* Miller and *segurae* Miller
leucourus Kerr 1792	British Isles and Ireland
meridionalis Lucifero 1907	Southern Italy, Calabria, Sila. Synonyms: *alpinus* Costa and *silanus* Hecht
vulgaris Linnaeus 1758	Northern Europe; Norway, Sweden Finland and northwest Russia. Type locality Uppsala, Sweden Synonyms: *albus* Billberg, *albonatus* Billberg, *europaeus* Gray, *formosovi* Ognev, *niger* Billberg, *rufus* Kerr, *typicus* Barrett-Hamilton and *varius* Gmelin

Asian subspecies	
Sciurus vulgaris	Geographic region
altaicus Serebrennikov 1928	Altai mountains, Kok-Su river, estuary of Yamanuch
anadyrensis Ognev 1929	Anadyr region, from 50-60 km north of Markovo in forests along Anadyr river for approx. 170 km, Maina river
argenteus Kerr 1792	Ural mountains to left bank of Yenisey river Synonyms: *albus* Dvigubsky, *martensi* Matschie and *nadymensis* Serebrennikov
bashkiricus Ognev 1935	Buzuluk-forest, and forests of Bashkiria, to middle reaches of Belaya river
exalbidus Pallas 1778	along Irtysch river and right bank of Ob, pine forests in the Kulundin Steppe Synonyms: *goltzmaieri* Smirnov and *kalbinensis* Selevin
fusconigricans Dvigubsky 1804	Transbaikal, along Barguzin, Upper Angara, Vitim, Olekma and Shilka rivers
jacutensis Ognev 1929	Upper reaches of Lena river, and along Olenek, Aldan, Khanym, Indigirka, Yama, Kolyma and Omolon rivers Synonyms: *arcticus* Trouessart, *borealis* Brass, *calotus* Gray and *fuscorubens* Dvigubsky

3 Body form and function

3.1 Appearance, body size and weight

The striking ear tufts combined with a distinctive, long and slender body and a bushy tail make the red squirrel easily recognisable. Body shape, size and weight are of critical importance for an animal that is adapted to live high up in the tree crowns and which may need to forage on slender branches.

Body measurements vary distinctly between regions and are influenced by a number of different factors such as marked population fluctuations, local age structure, season and the type of subspecies present (Table 4). Head and body length in red squirrels ranges from 180–332 mm, tail length from 130–222 mm and hind foot length from 49–66 mm. The ear is between 20 and 35 mm long.

Bergman's rule would predict an increase of body size with increasing latitude as the ratio of body mass to volume is an important factor in thermo-regulation. However, Gurnell (1987) notes that strict adherence to Bergman's rule has only been demonstrated in a few species and Barnett (1977) showed that observed changes in size in four Eastern gray squirrel populations consistent with Bergman's rule in North America did not include skull features related to feeding. He suggested that features linked to foraging may be subject to selection pressures which may override selection linked to thermo-regulation (Barnett 1977).

Body weight changes seasonally and is influenced by seed food availability. Reported adult body weights vary between 202 and 484 g (Table 4). However, weights for different age classes may differ with respect to subspecies type and what is classed as subadult or adult in different studies. Research in Belgium, England and Germany found no significant differences in body mass between the sexes, with the exception of pregnant females (Wauters & Dhondt 1989a, Lurz 1995, Münch 1998).

Body mass tends to be highest in autumn and early winter and lowest in early summer. An increase of 10 % of body mass was observed in mixed

Table 4: Red squirrel body mass and size from different populations across Eurasia (all size measurements are given in millimetres (mm) and weights in gram (g); N/A indicates no available data).

Geografic Region	Source	Head–body length	Tail length	Hindfoot length	Ear length	Body weight
Europa	Corbet & Ovenden 1982	180–250	140–200	51–63	N/A.	290–400
No specific location (Eurasia)	Grimmberger et al. 2009	180–280	130–205	49–65	21–36	202–480
Germany (West)	Wiltafsky 1978	210–250	150–200	51–63	27–36	
Germany (Baden-Württemberg)	Münch 2005	210–332	175–198	62.7 with claws	26–32	267–410
Germany (Rheinland)	Münch 2005	208–245	150–199	55–63	27–32	211–359
Germany (Westfalen)	Münch 2005	204–236	155–220	52–64	28–33	237–415
Switzerland	Fraevel 1995	240–274	160–185	54–60	N/A	N/A
Switzerland (Graubünden)	Bosch 2010, unpubl. data Bündner Naturmuseum Chur (males n=9 subadults and adults)	206–238	158–177	53–61	28–35	232–320
Switzerland (Graubünden)	Female n=1 subadult	214	181	60	31	288
Great Britain	Gurnell et al. 2008a	240–285	140–195	54–61	N/A	270–360
Ireland	Poole 2007	N/A	N/A	N/A	N/A	240–310
Belgium	Wauters & Dhondt 1989 a,b	214–217	N/A	59–60	N/A	270–380
Ireland	Poole 2007	N/A	N/A	N/A	N/A	240–310
Italy	Wauters et al. 2007	N/A	N/A	55–59	N/A	240–400
Russia (*S. altaicus*)	Ognev 1940 n=15	200–240	140–170	50–65	20–30	N/A
Russia (*S. exalbidus*)	Ognev 1940 n=23	214–293	153–222	56–66	33–38	379–484
Russia (*S. jenisseyensis*)	Ognev 1940 n=8	207–240	140–191	56–62	25–33	N/A

deciduous forests in England (Gurnell et al. 2008a). However, this gain in weight is habitat and food dependent and has not been recorded in spruce dominated forests (Lurz & Lloyd 2000). Autumn fat accumulation appears less pronounced in coniferous forests where manoeuvrability to forage in the canopy is important and winter food supplies (cones visible in the crowns) are more predictable (Lurz & Lloyd 2000).

Over the course of the winter red squirrels in Bavaria lost 35 g or almost 10 % of their pre-winter body weight (Münch 1998). Squirrel body weights also change in relation to the seasonal availability of different types of food and the onset of sexual activity (Wauters & Dhondt 1989a, Lurz 1995). Loss of condition and body weight is common in late spring and early sum-

Fig. 8: Squirrel skull (Bündner Naturmuseum Chur): **a)** right side of head, **b)** right side of skull with top of the spine and ribcage, **c)** head from the front, **d)** skull with incisors from the front, **e)** base of skull from below. Photos: Bosch.

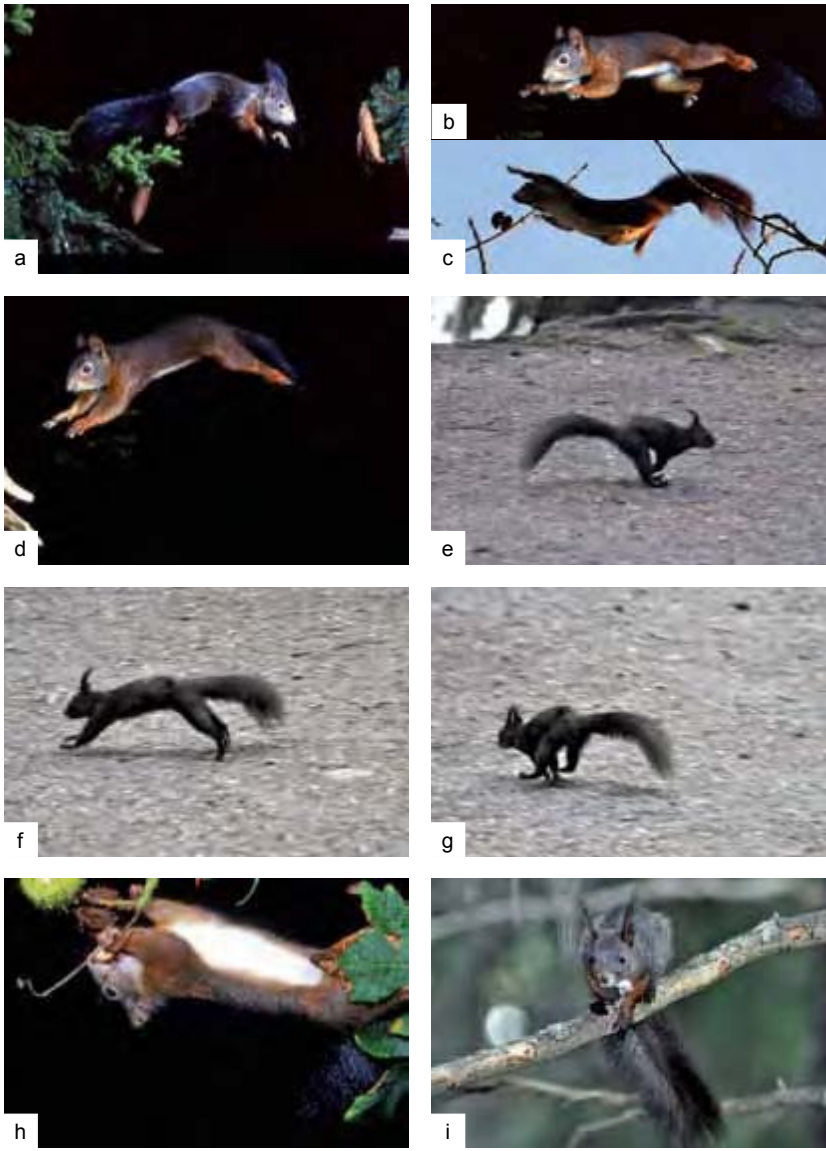

Fig. 13: Types of locomotion in squirrels: Jump from branch to branch: **a)** Start phase, **b–c)** during the jump, **d)** just before the landing; **e–g)** on the ground squirrels can move quickly with large jumps; **h)** during foraging they can stretch to reach food at the tip of branches; **i)** they can walk or sit on small branches. Photos: **a, b, d, h)** Haas, **c, e–g, i)** Bosch.

4 Reproduction and development

4.1 Conditions for successful reproduction

Successful reproduction in females is dependent on two important elements: a good body condition and a high quality home range with sufficient resources in terms of nesting opportunities and available seed food. Home ranges are defined as the area an animal moves through during the course of its daily activity (Gurnell 1987). Studies tend to distinguish between the area as a whole and a core area where the animal spends most of its time (see also Chapter 6).

Female red squirrels are polyoestrous and in the sexual cycle, oestrous is the critical phase. Females are only in heat for one day per cycle (Gurnell et al. 2008a) and only if their body condition is good. Studies in Belgium showed that only females that weighed 300 g or more came into oestrous (Wauters & Dhondt 1989a). In northern England where local red squirrels are smaller in size, this minimum weight was 280 g (Lurz 1995). Reproductively active males appear to be able to detect females in heat or their olfactory clues from relatively large distances. At Spadeadam Forest, Northern England, males from home ranges over a kilometre away, were trapped below the drey of a female in oestrous (Lurz 1995).

4.2 Mating system

The mating system of red squirrels is described as polygynous-promiscuous (Gurnell et al. 2008a). Both males and females may mate with more than one individual and there are no permanent or lasting pair-bonds between the two sexes.

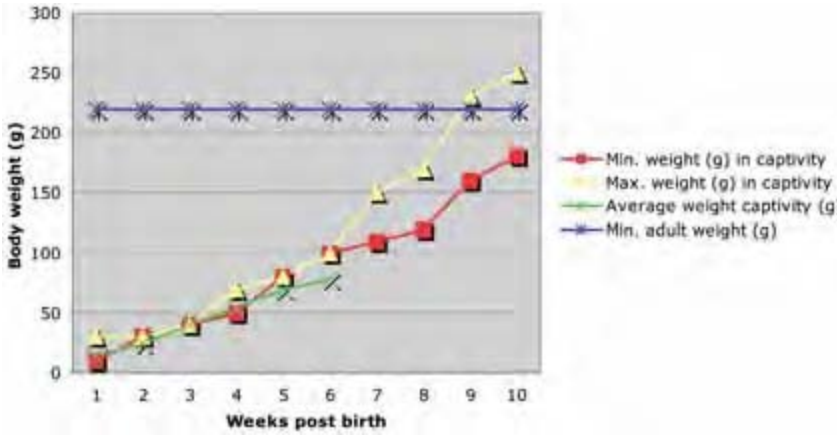

Fig. 32: Body weight increase in juvenile red squirrels during the first 10 weeks of life (based on Eibl-Eibesfeldt 1951 [green] and Rothenheber & Kaus 2010 [yellow and red]). Graph: Bosch.

During week ten, they take food out of the hand of the keeper and collect and bundle together nesting material to take inside. Everything is chewed intensively and random objects are taken into the nest. Animals engage in sexual play with each other and produce chucking calls. From day 60–70 the young play near the nest including chasing, mock attacks (play fighting) and taking flight. The tenth week marks the end of development, after which the young are weaned. At this point, young red squirrels (in Central Europe) weigh approximately 180 g (Figures 4.2 and 4.3).

Eibl-Eibesfeldt separates mother and young in week 11. The young now drink milk from a bowl. On day 75, moans and chirping sounds are heard for the first time. By week 12 the young eat a varied diet of solid foods. By week 17, small testes become visible and in week 19 the first copulation at-

Fig. 33: Young red squirrels completely covered in fur (left) and inquisitive young squirrel emerging from a nest box (right). Photos: Haas.

5 Behaviour

5.1 Food, dreys and behaviour

Red squirrels in the wild appear busy and always full of activity. However, there are more sides to red squirrels than meet the eye and resting animals are seldom spotted. Their apparent ceaseless activity has an endearing quality for many people and adjectives such as alert, eager and industrious are synonymous with them. But when by chance our paths cross with red squirrels in the local park or woodland, we only witness a brief moment in their daily life and glimpse just a fraction of their behavioural repertoire.

Finding food is one of the key drivers for red squirrels. Summer or winter, they have to find food and feed each day. Red squirrels forage where they live: in the tree crowns, on branches and twiggs and on the forest floor. The time spent in these different vertical layers varies with the type of forest habitat, season and food availability. For example, when beech mast or mushrooms are available in autumn, they spend a lot of time on the forest floor but most of the time they are arboreal.

5.1.2 Dietary range and food preferences

Fig. 34: Eastern gray squirrel approaching a visitor to Edinburgh Botanical Gardens, UK, for a share of her lunch. Photo: Lurz.

The diet of red squirrels is highly varied and linked to the spatial and temporal availability of seeds, fruits and other food types. In urban areas potential food from litter and garbage bins is also utilised, and visitors to Parks in London or Edinburgh can most likely attest to the Eastern gray squirrel's

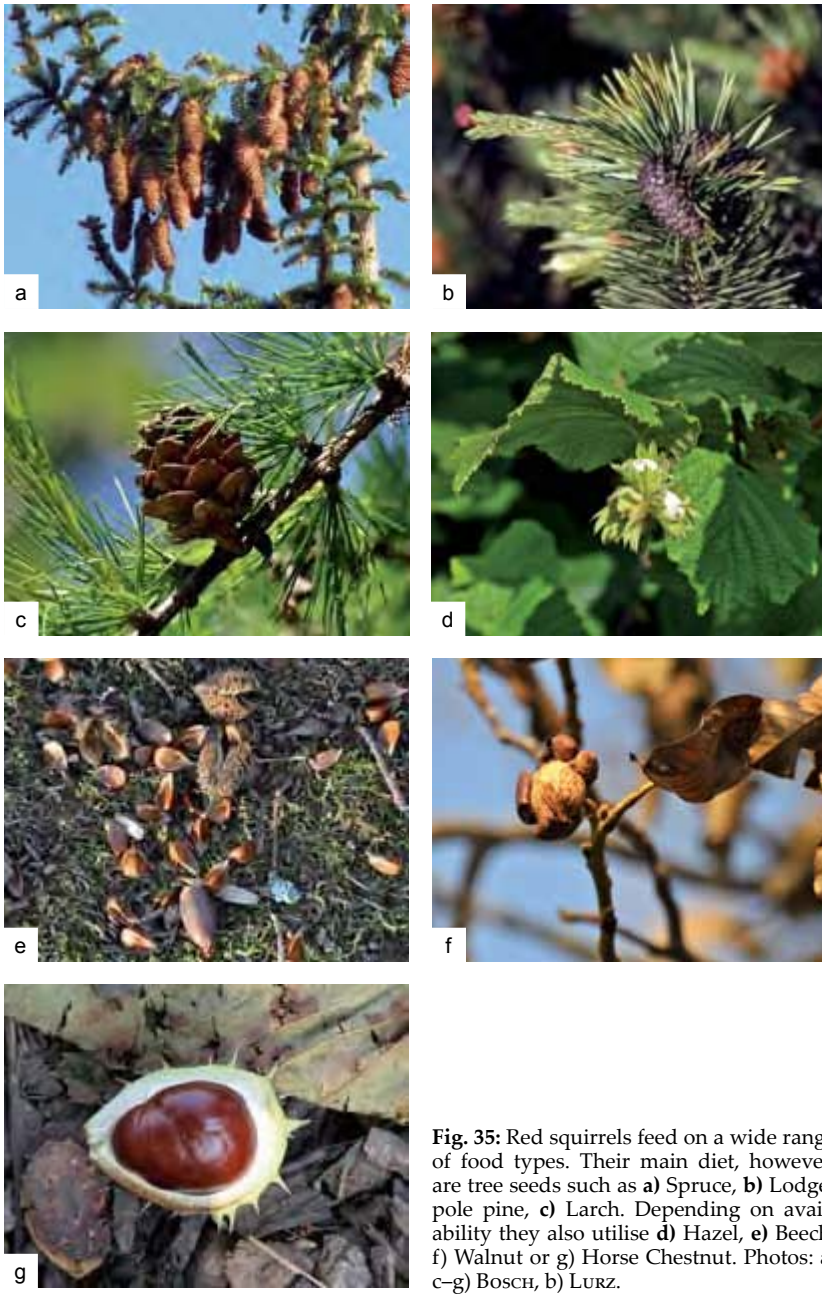

Fig. 35: Red squirrels feed on a wide range of food types. Their main diet, however, are tree seeds such as **a)** Spruce, **b)** Lodgepole pine, **c)** Larch. Depending on availability they also utilise **d)** Hazel, **e)** Beech, f) Walnut or g) Horse Chestnut. Photos: a, c–g) Bosch, b) Lurz.

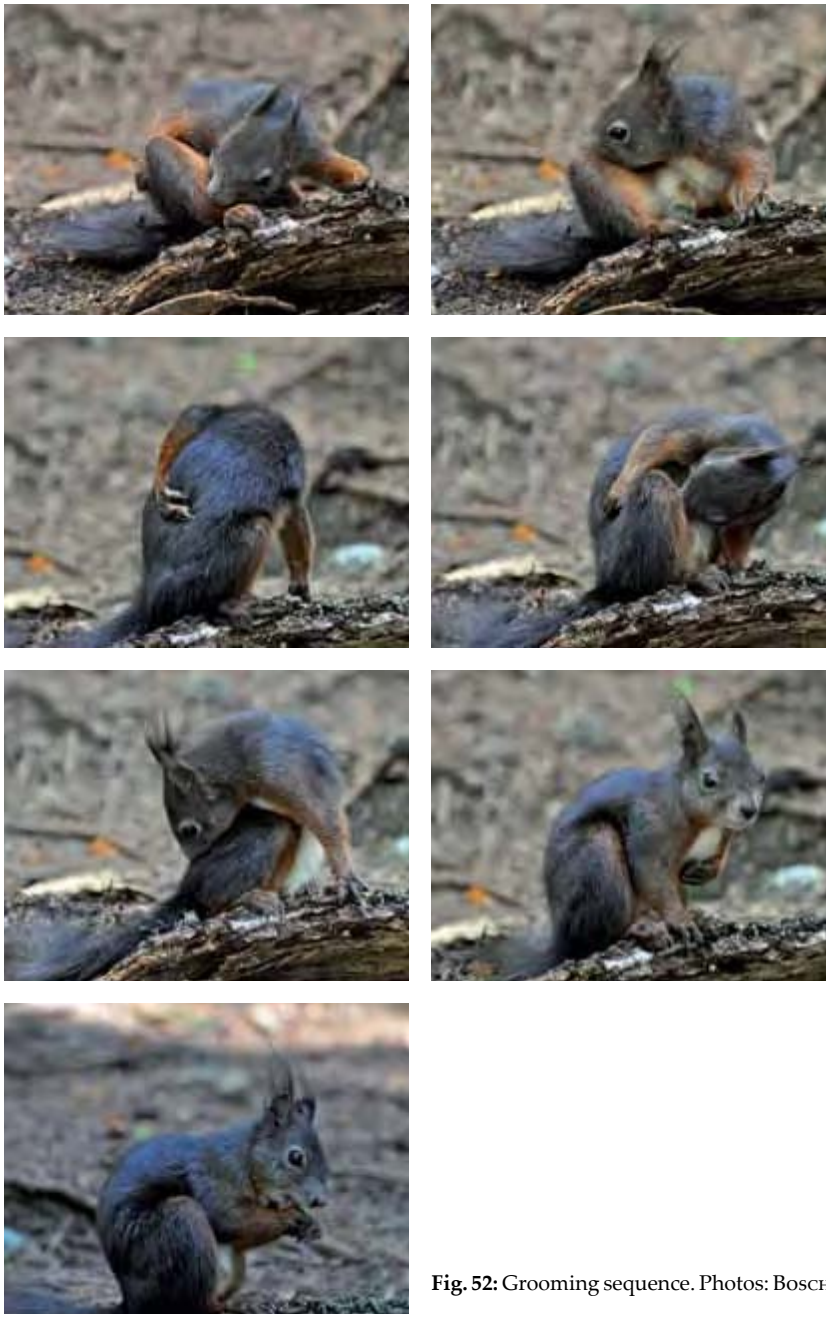

Fig. 52: Grooming sequence. Photos: Bosch.

6 Ecology

6.1 Red squirrels are forest dwellers

'What makes a wood good for squirrels? In short, plenty of food, shelter and other squirrels.' Jessica Holm 1987

Red squirrels are an arboreal forest species whose survival and success is dependent on two critical factors: the availability of suitable woodland habitat and food (primarily high energy tree seeds). Other factors include nesting opportunities, cover and the presence of other squirrels of the opposite sex (Holm 1987, Münch 1998). Red squirrels are highly flexible in their use of woodland habitat and are essentially opportunists. They prefer woodlands of mature seed bearing trees with a closed canopy that allows movement through the tree tops and provides sufficient cover (Gurnell et al. 2002, Samaras & Youlatos 2010).

Red squirrel evolution was strongly shaped by their Holarctic distribution and the northern forest ecosystems. The ecology of these woodland environments has influenced red squirrel life history strategies, behaviours and social organisation (e.g. Gurnell & Anderson 1996; Fig. 5). Typical tree species representative of Holarctic forest systems are spruce (*Pinaceae*), pine (*Pinaceae*), birch (*Betulaceae*), beech (*Fagaceae*) and willow (*Salicaceae*). Both the Mediterranean Sea and the Alps acted as barriers to post glacial dispersal and recolonisation events by species, and the Eurasian part of the Holarctic as a result tends to contain fewer tree (and squirrel) species than the North American region. Despite very strong human influences on woodland composition, size and levels of fragmentation, few holarctic tree squirrel species are considered endangered. Most species at risk as a result of human impacts, alien species introductions, habitat loss and habitat degradation are in the tropical regions with flying squirrel species being particularly vulnerable (Gurnell 1987, Koprowski & Nandini 2008).

Fig. 58: Woodland birds such as the **a)** Jay or **b)** the Nutcracker observe red squirrels while they cache seeds and then dig up them up afterwards, **c)** for example caches placed next to a tree stump. Photos: Bosch.

Birds also benefit from squirrel feeding: Seeds discarded or dropped while processing conifer cones are taken by coal tits, crested tits (*Parus cristatus*) or chaffinches. Squirrels thus provide access to a food resource that would still be inaccessible to these species prior to seed shed. Yet squirrels also benefit from the birds around them and their vigilance. The birds respond to danger or the seemingly careful and quiet approach of researchers and can act as an 'early warning system' to the squirrels (P. Lurz pers. obs.).

e. Defensive behaviour

Some bird species react with warning displays and mock attacks towards red squirrels similar to defensive behaviour to ward off a predator. Species include: boreal owl, pygmy owl (*Glaucidium passerinum*), grey-headed woodpecker (*Picus canus*), black woodpecker (*Dryocopus martius*), robin, nightingale, redstart (*Phoenicurus phoenicurus*), fieldfare, goldcrest, spotted flycatcher, red-brested flycatcher, pied flycatcher (*Ficedula hypoleuca*), blue tit, nuthatch (*Sitta europaea*), golden oriole (*Oriolus oriolus*), magpie (*Pica pica*), rook (*Corvus frugilegus*) and house sparrow (*Passer domesticus*).

7 Threats and conservation

7.1 Risk status

Continental populations of the red squirrel are currently not considered to be endangered and the International Union for the Conservation of Nature (IUCN) lists the red squirrel as 'least concern'. The red list account does note a decreasing population trend and potential hunting impacts in Mongolia (Shar et al. 2008). However, the situation is much more serious on the western fringe of the red squirrel's range in the British Isles. Populations in Ireland and Great Britain have declined dramatically and are considered to be at risk of extinction in England and Wales as a result of competition by the introduced North American Eastern gray squirrel (see Chapter 6).

Introduced Eastern gray squirrels are also causing a relentless regional decline in red squirrel populations in northern Italy in the provinces of Liguria, Piedmont and Lombardy. Attempts to eradicate the population in Piedmont in 1997 were delayed by legal action from an animal rights group. The lengthy judicial enquiry led to a 3-year suspension of control during which gray squirrels greatly expanded their range. With gray squirrels having reached pre-alpine areas, eradication was no longer considered feasible due to a lack of political will as well as for economic and logistic reasons (Bertolino & Genovesi 2003). Eastern gray squirrels in northern Italy will expand into neighbouring countries in the short to medium term and colonise large parts of Eurasia in the long term. This represents a major threat to the endemic Eurasian red squirrel and has the potential for significant and costly damage to forestry and agriculture in the region (e.g. Signorile & Evans 2007, Gurnell et al. 2008b).

Computer models simulating likely rates of expansion of Eastern gray squirrel populations in northern Italy in the absence of control suggested that Switzerland could be reached within 30 to 40 years and France within 70 to 75 years. A worst case scenario predicted arrival in 2026–2031 in France and 2031–2041 for Switzerland (Lurz et al. 2001, Bertolino et al.

7.2.2 Red squirrel conservation in Great Britain

Red squirrel conservation encompasses several key components: designation of red squirrel reserves in large conifer dominated forests (termed 'strongholds'; e.g. Forestry Commission 2012) that reduce or negate the competitive advantages Eastern gray squirrels have in deciduous woodlands (see Chapter 6); the monitoring of red squirrel population trends and gray squirrel range expansion, public information and education initiatives on the threat the introduced gray squirrel poses to the native squirrel; research into squirrel pox virus disease epidemiology, transmission and vaccine development; and targeted local Eastern gray squirrel control to prevent or reduce squirrelpox virus disease outbreaks and gray squirrel incursion into stronghold areas.

Forestry Commission, Kielder Forest District, took a lead and designated the first English red squirrel reserve at Spadeadam Forest, Cumbria, in 1995 (McIntosh 1995, Lurz 1995). This was followed by the launch of the Kielder, Kidland and Usway Forest in 2003. Following a successful bid by the Wildlife Trusts to the Heritage Lottery Fund, these four areas were expanded to a network of initially 16 (later 17) English squirrel reserves (now termed 'strongholds') with agreed management plans (Lurz et al. 1998, 2003a, b, Parrott et al. 2009). Similarly, there are plans for the designation of 18 red squirrel strongholds in large conifer dominated forests across Scotland (Parrott et al. 2009, Scottish Natural Heritage 2006, 2009, Forestry Commission 2012).

Habitat management plans for red squirrels focus on:

1. The maintenance of a suitable age structure and conifer species composition to ensure a dependable seed food supply (see Tables 11 and 12);
2. Ensuring that ongoing forest operations minimise detrimental impacts on red squirrels;
3. Monitoring to obtain data on population trends, red and Eastern gray squirrel distribution and to assess changes in response to forest management;
4. If necessary, carry out targeted control of gray squirrels in and around strongholds to reduce or prevent squirrelpox disease outbreaks and reduce competition (Lurz et al. 1998, Pepper & Patterson 1998). Single species management is difficult and may often clash with other biodiversity or conservation objectives (as well as economic or amenity objectives). It is therefore critical that sites for red squirrels are selected carefully in order to avoid or minimise conflicts.

Table 11: Overview of tree species with respect to red-gray squirrel competition. Species are classed based on the utility for the two squirrel species respectively (based on Gurnell & Pepper 1988, 1993; Pepper & Patterson 1998; Lurz et al. 1998).

Favourable for red squirrels	Neutral	Large-seeded tree species that give grey squirrels a competitive advantage
Sitka spruce	Willow	Oak*
Norway spruce	Alder	Beech
Serbian spruce (*Picea omorika*)	Ash	Chestnut
Douglas fir (*Pseudotsuga menziesii*)	Birch	Sycamore
Larch (all species and hybrids)	Poplar (*Populus* sp.)	Hazel
Yew (*Taxus baccata*)	Elms (*Ulmus* **sp**.)	
Scots pine	*Firs* (*Abies* sp.)	
Lodgepole pine	Western hemlock (*Tsuga heterophylla*)	
	Riesen-Lebensbaum (*Sequoia sempervirens*)	
	Cypress species	

* Note that oak in particular will give Eastern gray squirrels a competitive edge and its presence has been linked with red squirrel replacement in oak dominated woodlands (see also Chapters 6 and 7).

Table 12: Data on seed crop cycles and seed energy values for selected tree species in relation to red squirrel conservation and the provision of a dependable seed food supply (data are based on Grodzinski & Sawicka-Kapusta 1970, Gurnell 1987, Matthews 1989, Lurz et al. 2003b).

Tree species	Interval betwee seed mast crops (years)	Age 1st seed crop (years)	Age 1st mast crop (years)	Average energy content (kJ/seed)
Scots pine	2–3 (3–4)	5–10	15–20	0.05–0.18
Lodgepole pine	2–3	5–10	15–20	0.098
Corsican pine	3–5	-	25–30	0.29
Norway spruce	3–5 (3–10)	20–25	30–35	0.07–0.13
Sitka spruce	3–5	20–25	30–35	0.04
Larch	3–5	10–15	15–20	0.09
Douglas fir	5–7	30–35	30–35	0.26

Note that seed crops and energy values will vary with respect to factors such as local climate, latitude and tree species provenance.

Tree species composition: the right mix is important

The overall aim of forest management actions for red squirrels should be to provide a dependable food supply. How this is realised in specific sites is likely to vary depending on local factors such as forest objectives, silvicultural systems, climate and soil or fencing needs (and costs) to protect vulnerable saplings from browsing damage by deer. Table 11 gives an over-

8 Methods and research

8.1 Survey and monitoring methods

Monitoring and survey techniques have been extensively researched in Italy and the UK as a result of the dramatic spread of introduced Eastern gray squirrels and their threat to native red squirrel populations. Census, survey and monitoring have slightly different meanings that relate to the specific objectives of a study. A census is the process of obtaining information about every member of a population – in other words, it is a complete count. Surveys, in contrast, sample from only a subset of a population, whereas monitoring is the repeated sampling of a population in order to detect trends in numbers and distribution over time (Gurnell et al. 2009).

Mammals are monitored for a variety of reasons: determining absolute or relative numbers of a population, determining population trends, determining distribution and habitat preference of species, guiding conservation efforts, managing introduced or problem species, setting hunting targets for game species, assessing impacts of pollution or road traffic on local populations or the effects of land use change or fragmentation (Gurnell et al. 2007). In the UK, the purpose of monitoring squirrel populations predominantly focuses on obtaining information on squirrel distributions as well as assessing the impact of grey squirrels and the effects of conservation management on local red squirrel populations. Gurnell et al. (2001, 2009) provide a comprehensive overview and distinguish between direct (involving the physical handling of squirrels) and indirect monitoring methods.

8.1.1 Direct Methods

Any activity that involves handling red squirrels or disturbing them in a place of shelter (e.g. trapping or checking a nest box with red squirrels) requires a licence in most countries. Advice and permissions should be sought from respective country agencies.

(to check for hyperventilation). Should the animal become stressed, it can simply and carefully be laid on the ground and covered with a dark cloth. This allows it to calm down before it is released (Lurz 1995, Münch 1998). Handling bags are an alternative to cones. This is a much more elegant approach, but it requires skill and practice. Handling bags are cone shaped cloth bags with a head-sized opening at the narrow point that can be widened or closed with the use of Velcro or a zip (see Koprowski 2002 for a description of the design).

Fig. 68: Methods used in red squirrel research: **a)** live-trapping, **b)** handling cone to reduce stress during handling, **c)** radio-tracking of radio-collared squirrels using handheld antennae and a receiver, **d)** baited hairtubes to collect squirrel hair for identification and **e)** blocks covered in sticky tape containing squirrel hair from hairtubes. Photos: a,b,d,e) Lurz, c) Moorman.

9 Squirrels and people

9.1 Origin and meaning of the word 'squirrel'

The word squirrel has its origin in ancient Greek from 'skia' meaning shadow or shade and 'oura' meaning tail (see also Chapter 9.7). It arrived in the English language via the Latin word '*sciurus*' (now the scientific name for the genus the red squirrel is assigned to in mammal taxonomy, see Chapter 1) and the Anglo-Norman '*esquirel*'. The latter was derived from '*sciuriolus*', a diminutive form of '*sciurus*' in Vulgar Latin. Etymologically the word therefore means 'little shadow tail' (Lurz et al. 2005, Ayto 1990). In continental languages such as German the word for the red squirrel: 'Eichhörnchen' stems from the middle-high German words for 'Eih' meaning oak and 'hurno' meaning horn. The suffix '-chen' again is a diminutive to

Table 14: The names for the red squirrel in different languages across its western range (based on Corbet & Ovenden 1982 and additions).

Language	**Name**
Danish	eker, egernet
German	Eichhörnchen
Finnish	orava
French	ecureuil d'Europe
Greek	Επίσης
Italian	scoiattolo rosso
Norwegian	eekhoorn
Polish	wiewiórka
Portuguese	esquilo
Swedish	ekorrar
Spanish	ardilla común
Czech	veverky
Hungarian	vírushordozó
Rhaeto-romanic	Stgilat
Scientific	*Sciurus vulgaris*

Fig. 71: Squirrels are a symbol in heraldry such as in the coat of arms of the city Titisee-Neustadt, Black Forest, Southern Germany. Photo: Bosch.

Fig. 72: Leaflet of the Save our Squirrels project in Northern England with contact details and information on red squirrel conservation and how to get involved. Image: Bosch.

Fig. 73: Symbolic forest species: **a)** wooden squirrel sculptures at the Triberger waterfall advertising the nature park 'Südschwarzwald', **b)** sign giving directions to the nature trail at Brackenheim-Neipperg, **c)** road sign asking drivers to drive with caution. Photos: Bosch.