how they were derived (making it impossible for others to try alternative calculations), in place of raw data.

Until theory and technique for calculating populations has addressed the problems of low detectability of animals on the midline, information from nocturnal transect surveys is best presented as contact frequencies accompanied by some contextual information:

1. Contacts are more usefully related to time than to distance because a paused observer detects new animals after several stationary minutes: no new distance is traversed, but time has elapsed. An observer cannot double the number of contacts per hour simply by covering twice as much ground, because less conspicuous animals are then overlooked. However, the balance of species recorded may change with speed: preliminary results from Borneo showed that walking faster produced more mouse-deer and fewer canopy flying squirrels (Duckworth, in press).
2. Calculations, including statistical tests, should use the number of contacts rather than the number of individuals (each group of more than one animal being a single contact) since the animals within a group are not statistically independent. Information showing the total number of animals must also be presented.
3. Visibility in the habitat should be indicated, since animals are detected at greater distances in more open habitats; results should indicate the typical sighting distance of animals.
4. Main methods of detection should be given for each species; contacts of those detected by ear are relatively unaffected by vegetation thickness.
5. Hunting pressure in the area should be indicated as this may affect both the population and its detectability.
6. Whether observations were made from roads, paths, or across the habitat at random should be stated; results should be presented separately for each category.

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# Cached fungi in non-native conifer forests and their importance for red squirrels (*Sciurus vulgaris* L.)

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**Abstract**

The caching of fungi by red squirrels *Sciurus vulgaris* was investigated in commercial conifer plantations by walking transects in Kielder Forest, Cumbria and Wauchope Forest, Scotland. In 11 transects, a total of 58 fungal fruiting bodies were observed on branches in trees, consisting of four different species (49

*Russula ochroleuca*, seven *R. metica*, one *R. vesca*, one *Colybia maculata*). Fungal stores were found to be short lived and most fruiting bodies cached were gone after 2 weeks. Based on the survey findings we estimate that within an average red squirrel home range there would be a minimum of 42 cached fruiting bodies, constituting a food store of approx. 525–714 kJ.

**Key words:** *Sciurus vulgaris*, hoarding behaviour

## INTRODUCTION

Fungi are considered to be an important food source for red squirrels in both deciduous and coniferous woodlands (Gurnell, 1987). This includes subterranean fungi, fruiting bodies from the forest floor and fungi growing under bark on trees (Moller, 1983). Fungi have been found in the stomachs of red squirrels in all months of the year, but were most prevalent in the autumn (Rajala & Lampio, 1963; Tittensor, 1970; Grönwall, 1982) and at times when tree seed crops failed (Gurnell, 1987). They are relatively rich in nitrogen and contain a number of important minerals such as calcium, magnesium and potassium (Grönwall & Pherson, 1984). Fungi are also relatively easy to digest (Grönwall & Pherson, 1984) and energy intake has been estimated to be up to five times larger per unit feeding time compared to lodgepole pine seeds (Smith, 1968). Red squirrels have been observed to store fruiting bodies on branches in trees in Finland (Sulkava & Nieholm, 1987) and it has been estimated that an individual squirrel could cover up to half its daily energetic requirement by feeding on fungi alone (Grönwall & Pherson, 1984).

Commercial conifer forests in the north of England and southern Scotland support low density red squirrel populations. This type of habitat is characterised by large single species plantations of Sitka spruce *Picea sitchensis*, Norway spruce *Picea abies* and lodgepole pine *Pinus contorta* and squirrels are subject to large temporal and spatial variations in tree seed supply (Lurz, Garson & Rushton, 1995; MacIntosh, 1995; Lurz, Garson & Wauters, 1997). There is no understorey of shrubs or ground cover present and fungi provide one of the few alternative sources of food. In this paper we investigated the occurrence and abundance of cached fungi in trees and discuss their importance as a food source for red squirrels in these resource limited conifer habitats.

## METHODS

We selected 11 study sites in plantations in the Border Forest, Scotland (Wauchope Forest) and Kielder Forest, Cumbria (Spadeadam Forest). The forests consist of plantations of Sitka spruce or mixtures of Sitka spruce with Norway spruce lodgepole pine or Japanese larch *Larix japonica* (Table 1). All sites were known to contain red squirrels based on previous surveys (Garson & Lurz, 1996) and the presence of squirrel feeding signs (stripped cones).

In each of the 11 sites a transect (≤1800 m long, Table 1) was walked twice during October–November 1997 and the branches of 2 rows of trees on either side were scanned for fungi. The number and species of fungi seen on branches were recorded. Where possible the fungi were collected and examined for tooth marks to verify that red squirrels had indeed placed them there. The wet weights of a small sample of fungi was measured.

## RESULTS

Fungi were found to be placed on branches next to the trunk at heights ranging from 0.6 m to approx. 8 m. We observed single mushrooms or groups of three to six placed individually at different heights on different branches of the same and adjacent trees. Four different species were found cached: common yellow russula *Russula ochroleuca*, sickener *Russula emetica*, bare-toothed russula *Russula vesca* and spotted tough-shank *Colybia maculata*. On the 11 transects we found a total of 58 fruiting bodies that showed squirrel teeth marks and had been placed on branches near the trunk of trees (49 *R. ochroleuca*, seven *R. metica*, one *R. vesca*, one *C. maculata*). This is a minimum estimate as more fruiting bodies may have been cached higher up in the crown of the trees out of view. The common yellow russula and the sickener were the most abundant fungi in the plantations and commonly associated with stands of Sitka spruce and lodgepole pine (*R. emetica* in particular), although we also observed a variety of other species (Table 2) none of which were found cached. A sample of 10 fruiting bodies indicated a mean ($\pm 1$ SD) wet weight of $8.15 \pm 3.85$ g.

A comparison between the number of fruiting bodies found and the location of trees in relation to forest edge (including forest rides) and the inside of plantations suggests that more fruiting bodies are cached in trees next to rides and on the forest edge (Table 1; chi-square test $\chi^2 = 25.12$, $P < 0.001$, d.f. = 1). Based on the survey results (Table 1) we calculated a minimum estimate of the number of fruiting bodies stored by a squirrel within an average sized home range:

$$\text{Estimated number of cached fungi} = (\text{number found/transect area}) * \text{mean home range area}$$

Within a mean home range of 9.13 ha, typical for this type of habitat (minimum convex polygon; Kenward, 1987; Lurz, 1995), one would expect to find an estimated 42.23 cached fruiting bodies.

**Table 1**. Transect length (nearest 100 m), composition (Sitka spruce SS, Norway spruce NS, Lodgepole pine LP, Larch L) and the number of fungi stored on branches in the 11 surveyed sites. Sites 1–8 were located at Wauchope Forest and sites 9–11 at Spadeadam Forest

| Site | Transect (m) Length | Inside | Edge | Tree species | Total | Fungi Inside | Edge |
|---|---|---|---|---|---|---|---|
| 1 | 1800 | 1700 | 100 | SS/LP | 0 | – | – |
| 2 | 1700 | 1700 | – | SS/LP | 1 | 1 | – |
| 3 | 1400 | 1400 | – | SS | 8 | 8 | – |
| 4 | 1800 | 1800 | – | SS | 5 | 5 | – |
| 5 | 1800 | 1100 | 700 | SS/L | 0 | – | – |
| 6 | 900 | 500 | 400 | SS/LP | 6 | 1 | 5 |
| 7 | 500 | 900 | 400 | SS/LP | 8 | 3 | 5 |
| 8 | 1600 | – | 1600 | SS/LP | 11 | 3 | 8 |
| 9 | 1700 | 1200 | 500 | SS | 17 | 2 | 14 |
| 10 | 1500 | 1100 | 400 | SS/NS/LP | 2 | 2 | – |
| 11 | 1700 | 1300 | 400 | SS/NS/LP | 1 | 1 | – |

**Table 2**. Other species of fungi found in different conifer plantations (Sitka spruce SS, Norway spruce NS, Lodgepole pine LP)

| Species of fungi | Plantation type |
|---|---|
| *Clitocybe nebularis* | NS |
| *Cystoderma aminthinum* | NS, SS, LP |
| *Hygrocybe pustulatus* | NS |
| *Lactarius deterrimus* | NS, SS |
| *Lactarius rufus* | NS, SS, LP |
| *Lycoperdon perlatum* | NS |
| *Marasmius androsaceus* | NS |
| *Russula atropurpurea* | NS |
| *Russula quelti* | NS |
| *Tricholomopsis rutilans* | NS |

## DISCUSSION

Red squirrels in Sitka spruce dominated conifer plantations typical of Kielder and the Border Forest Park live in a system shaped by marked seasonal and annual changes in tree seed availability. Their flexible home range behaviour, patterns of habitat use, low levels of site fidelity and the occurrence of breeding dispersal (Greenwood, 1980; Lurz, 1995; Lurz, Garson & Wauters, 1997) all appear to be a response to the variability of food resources in space and time.

The caching of food items is thought to be a strategy to increase food availability during periods of scarcity (Anderson & Krebs, 1978). Hoarding behaviour is observed in a number of mammal and bird species (Smith & Reichman, 1984) and is well documented in tree squirrels (Thompson & Thompson, 1980; Gurnell, 1987; Rice-Oxley, 1993). In red squirrels it has been suggested that caching is an adaptive strategy to preserve temporarily abundant food resources and individuals that hoarded were found to be more likely to survive and reproduce (Wauters, Suhonen & Dhondt, 1995).

The large number of *Russula* fruiting bodies found cached at Spadeadam and Wauchope Forest (57 out of 58) is most likely a reflection of the great abundance of these species at this time of year. During our survey most of these were found in trees next to rides or the forest edge. Given the observed occurrence of fruiting bodies throughout the forest, possible explanations are better drying conditions and more squirrel activity near the edge of plantations. Edge trees are known to produce larger cone crops relative to trees growing inside (Phillipson, 1987) and it is therefore possible that squirrels spend more time there foraging.

A large proportion of the caches found during the study appeared short lived and the majority of fruiting bodies observed on the transects had disappeared after 2 weeks. As a food store these caches are clearly vulnerable to intra- and interspecific competitors as well as weather conditions (e.g. heavy wind, frost) and cache recovery rates may therefore vary.

The minimum estimate of 42.23 fruiting bodies cached within an average home range would constitute approximately 525–714 kJ (using a mean wet weight of 8.15 g, an estimate of 90% water content and 15.96–21.84 kJ/g dry weight; Grönwall & Pherson, 1984). This is equivalent to the energetic requirements of a red squirrel (330–420 kJ) for 1–2 days (Grönwall, 1982). A more detailed study is required to determine the relative importance of fungi in the diet of red squirrels and the ecological relationship between fungi and squirrels, such as their possible role as spore dispersal agents (Kotter & Farentinos, 1984).

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# The denning behaviour of feral ferrets (*Mustela furo*) in a pastoral habitat, South Island, New Zealand

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**Abstract**

This paper describes the denning behaviour of 24 feral ferrets *Mustela furo* on farmland, East Otago, South Island, New Zealand. One hundred and ninety seven dens were located and radio-collared ferrets were found to share dens simultaneously with other ferrets on 7.4% of 706 radio-tracking events and used dens that had been previously used by other ferrets (sequential den sharing) on 44.3% of occasions. In this particular study, ferrets were exhibiting a higher degree of sociality than has been recorded in other solitary mustelid species and therefore may not be adhering to the model of intrasexual territoriality thought to apply to other mustelid species. Den sharing may be a mechanism by which bovine tuberculosis *Mycobacterium bovis* is transmitted within ferret populations. Over 80% of the sequential den sharing occurred within 14 days, well within the survival span of *M. bovis* bacilli. Denning of infected ferrets in haybarns may pose a risk of transmission of *M. bovis* to livestock from hay.

## INTRODUCTION

Little is known about the biology and ecology of the feral ferret *Mustela furo* in New Zealand even though it supports the largest population in the world (Nowak & Paradiso, 1983). Ferrets have been implicated in the decline of some endemic species (Murphy, 1996). and recently there has been debate about the role and importance of ferrets as vectors of bovine tuberculosis (Tb; *Mycobacterium bovis*) to livestock in New Zealand. High prevalences of infection have been found in ferret populations, tuberculous ferrets have been found throughout Tb-infected areas and in association with infected livestock, and the observed pathology suggest that ferrets are potentially infectious to other animals (Walker, Reid & Crews,