

Biology of European flying squirrel *Pteromys volans* L. (Rodentia: Pteromyidae) in the North-West of Russia

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ABSTRACT. Biology of European flying squirrel in the North West of Russia is studied. Original data on habitats' distribution, shelters, nutrition peculiarities, daily activity, reproductive period, juvenile's development at stages of postnatal ontogenesis, parental behavior, and locomotion peculiarity are given. The species is distributed sporadically at the western border of the natural habitat and has obvious tendency to decrease. The main reason of flying squirrel population decrease is forest final harvest at vast territories. On the initiative of the authors the flying squirrel is included into the Red Data book of the Leningrad Province.

KEY WORDS: *Pteromys*, North West of Russia, biology, behavior, locomotion, protection.

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Биология обыкновенной летяги *Pteromys volans* L. (Rodentia: Pteromyidae) на Северо-Востоке России

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РЕЗЮМЕ. Изучалась биология обыкновенной летяги на северо-востоке России. Приведены оригинальные данные о биотопах, убежищах, особенностях питания, суточной активности, размножении, постнатальном онтогенезе молодых особей, родительском поведении и особенностях локомоции. Вид спорадически распространен на западной границе ареала и уменьшается в численности. Основная причина сокращения численности популяций летяги - вырубка лесов на большой территории. По инициативе авторов летяга включена в "Красную Книгу" Ленинградской области.

КЛЮЧЕВЫЕ СЛОВА: *Pteromys*, Северо-Восток России, биология, поведение, локомоция, охрана.

Introduction

European flying squirrel (*Pteromys volans* Linnaeus, 1758) (Figs. 1–3) is the only representative of the numerous family of flying squirrels (Pteromyidae) in Russia. It inhabits areas of southern taiga and conifer deciduous forests of Eurasia (Ognev, 1935, 1938). The species natural habitat appears on the map like a spike. Its acute angle covers the territory of Fennoscandia, which includes Baltic States, Norway, Finland, and such Russian administrative units as Karelia, Leningrad, and partly Novgorod and Pskov provinces. The species spreads to the east up to the Pacific coast of Eurasia. Subspecies *P. volans volans* L. 1758 inhabits the North West of Russia (Gromov & Erbaeva, 1995). In the second half of the XX century the western border of the European flying squirrel area suffered great changes. Nowadays there are no flying squirrels in northern Finland (Kaikusalo, 1973; Hokkanen *et al.*, 1977; Hokkanen, 1996), Sweden, Poland (Gorner & Hacethal, 1987; MacDonald & Barrett, 1993). In Baltic States flying squirrel can be found, first of all, in the North East of Estonia (to the North West of Chudskoe Lake), in some places near to the town of Piarnu and in 25 km distance from Tallinn (Aul *et al.*, 1957; Hallanaro,

2001). Nowadays a special "flying squirrel" sanctuary was founded in the North East of Estonia for study of biology of this species. It can be said for sure that flying squirrels inhabits north-eastern and eastern regions of Latvia but also sporadically distributed in Estonia (Taurins, 1982). In Lithuania most likely there are no flying squirrels; at least in the XX century none was found there (Balciuskas, 1988). The situation is a little better in Finland, though the territory occupied by the species is gradually decreasing. According to the data presented by Finnish zoologists (Eronen & Paakkonen, 1996; Hokkanen, 1996), flying squirrels dwell in separate areas in the west and southwest of the country and its population consist of 50 thousands breeding individuals.

In the North West of Russia the flying squirrel is common though its population is considerably decreasing. Big forest cutting territories present serious hazard for its existence. In accordance with the previous years registration data we define the species population as equal to 35000. Information on biology of the European flying squirrel in our region can be found mostly in faunistic reports, which give no detailed description of the species ecology (Savinov & Lobanov, 1958; Novikov *et al.*, 1970; Airapetyants *et al.*, 1987). It is difficult to take the species preservation and rehabilitation measures without having clear idea of its way of living.

Material and methods

The article is based on the original material, which includes long-term (1961–2002) observations of the European flying squirrel biology and spreading in the North West of Russia, mainly in Leningrad, Vologda and Novgorod provinces, made by the authors. Totally over 70 individuals were studied, among them living in natural environments. Species biology was studied by the method of lifetime observation, both in natural biotopes and in open-air cages in various areas of Leningrad Province. Peculiarities of reproductive period, parental behavior, formation of exterior characteristics, locomotive and behavioral reactions in postnatal ontogenesis were examined.

All observations were photographed and video filmed; voice signals were recorded. Feeding information was obtained by watching tamed animals eating at natural habitats; besides, animal living in open-air cages was offered various natural fodder to find out the attractiveness and seasonal preference of feeding objects. Diurnal activity was studied by visual observations of inhabited shelters and registration of all departures and returns. We used not only our own observations but also information on encounters with flying squirrels received from different parts of the region.

Habitats

Flying squirrels inhabits various types of forest, preferring coniferous woodlands with elements of hardwood. In Estonia and Finland the animals live in fir-woods with admixture of birches and aspen (Greve, 1909; Siivonen, 1956; Kaikusalo, 1973). Studies of the last years show that flying squirrels can be met at the forest edges near woodcutting areas, tilled fields, recreation zones (Eronen, 1996). It is stipulated by cutting of large quantity of old mature forest in central regions of Finland. Finnish specialists also think that distribution of this species in their region is limited by great number of owls and absence of alder-trees (Sulkava & Sulkava, 1996a, b).

According to the observations, made in Leningrad, Vologda and Novgorod provinces, flying squirrel habitats are mature high mixed forests with dominant conifers and large amount of hardwood both in the first and second tiers, such as aspens, birches, alder-trees, and willows (Novikov *et al.*, 1970). In undergrowth fir-tree, rowan-tree, bird cherry tree, buckhorn are frequent, among bushes there are raspberry-canes, black and red currant. Mosses, fallen foliage, grass, berry-fields form the topsoil. Crown density at territories inhabited by flying squirrels is approximately 60%. Evidently, one of the main factors making the territory suitable for the species existence is variety of hardwood, which provides the animals with seasonal change of food, and old fir-trees and defective aspens serving as shelters. Similar ecotopes are characteristic of the whole northwestern part of the species area. It is confirmed by observations



Figure 1. European flying squirrel *Pteromys volans volans* Linnaeus, 1758.

of Marvin (1959) in Karelia, Savinov & Lobanov (1958) in Vologda Province and Serzhanin (1961) in Byelorussia. In Leningrad Province flying squirrel ecotopes are spread irregularly. In some places there can be up to four colonies at 3-km route, in other similar woodlands there are traces of them for the space of several kilometers. Reasons of such distribution of the species on the woodland are not clear yet. Most likely it is connected with low population density. Flying squirrels are often met in the north, northeastern and eastern parts of our region. They are not numerous in the west and southwest. Altogether we can name 64 places in Leningrad Province, where within the last 50 years ecotopes of this species were found (Airapetyants & Fokin, 2002).

Shelters

At the Russian North West as well as in other parts of the area flying squirrels usually make their shelters in hollows, though sometimes they settle in frost-clefts, natural cavities in half-rotten wood and in forsaken squirrel nests. Practically always they choose hardwood, aspen is the most preferable, birch and alder are less preferable. Animals seldom choose pine hollows, evidently because of wood gumminess. We found 28 shelters, 25 of them were located in aspens, two in birches and only one in a pine. 80% of the shelters were at 3–5 m height. According to Timm's information in Estonia the distance from the ground to a hollow inlet in most cases did not exceed 4–6 m. In Finland it was, as a rule, 3–6 m (Kaikusalo, 1973). Nests are mainly located in hollows, pecked by big motley woodpeckers. It should be noted that the direct dependence of the species well being on big hollows in these woods is clearly evident all

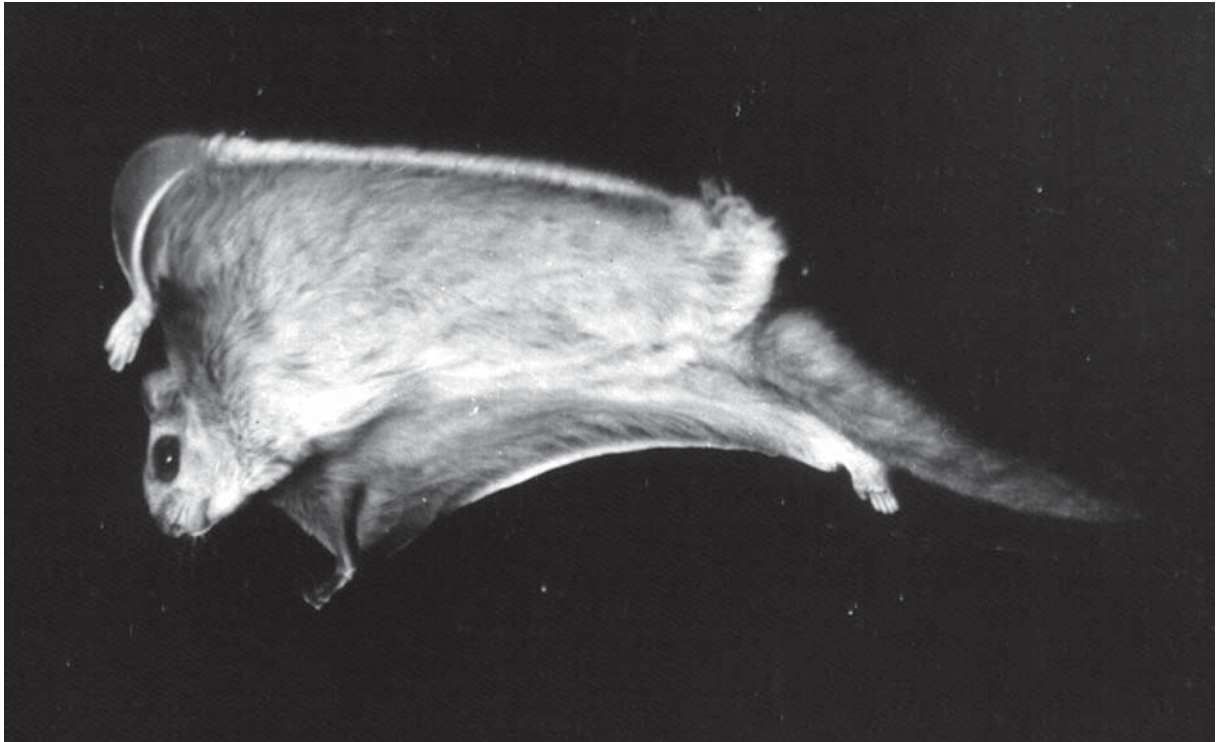


Figure 2. Gliding flying squirrel.

over the North Western part of the species natural habitat, as was noted previously by Siivonen (1956, 1972). The same was observed in Finland and Estonia (Y. Timm, pers. com.). It is also correct for the territories researched by us: all flying squirrel hollows (both inhabited and neglected ones) found by the authors, were pecked by big motley woodpeckers. Meanwhile in Altai and Transbaikalia flying squirrels settle in hollows made by white back woodpeckers (Borodulina & Blagosklonov, 1951), at the Far East of Russia — by black woodpeckers (Smirnov, 1982). Flying squirrels evidently prefer hollows made by big motley woodpeckers because of entrance moderate size that prevents penetration of squirrels and martens into the hollow. The entrance diameter, according to observations in our region, vary from 3 to 5 cm, according to observations made by Estonian zoologists, it can be 2–3 cm (Tasa *et al.*, 1975). One animal, as a rule, can have several hollows, which it uses depending on weather conditions and its reproductive state. Number of hollows likely depends on number of hollow trees in the area. Traditional division into temporary and permanent ones does not suit flying squirrel hollows, as they are used in dependence of numerous environmental factors, so it makes more sense to select brood ones among them, at least such a definition is unambiguous. Animals live in their nests either alone or in couples and families. Most comfortable are hollows with one or two nearby fir-trees, which conceal the hollow entrance. However, we found an aspen, standing at the forest road edge quite in the open space, which is the shelter of a female flying squirrel. It uses it for many years to breed litter. Inside the shelter there is

a pavement made of moss, dry grass, and chips. In brood and winter shelters there is always a ball shape nest with a small hole on the top. Various materials are used for its construction: splintered bast, vegetable rags, moss, hanging lichen, feathers, vegetable and animal fluff. According to observations done in Leningrad Province, lichen *Usnea barbata* is a necessary component. Animals gather it on the nearest trees. We have described in detail the nest interior previously (Airapetyants, 1963). If there are not enough hollow trees animals can settle in artificial nesting-places. Scores of times we found flying squirrels in starling-houses, which we hanged to attract garden dormice. According to our observations golden-eye (garrot) houses are most suitable for flying squirrels, because entrance hole is smaller, or shelters made of hollow aspen stumps (not less than 50 cm in length and 30 cm in diameter) manufactures especially for flying squirrels. Such hollows are used in Leningrad Province. According to our experience the animals feel comfortable in such shelters. Most frequently they attract young animals during the separation period. In Finland artificial owl nestling places are hanged for this purpose (Kaikusalo, 1973). Inhabited dwellings of flying squirrels are easily found in late autumn or early winter, at these seasons excrement accumulations appear near the stem directly under the hollow or favorite “fodder” aspens. Amount of excrement can show how often the dwelling is used and how many dwellers inhabit it. Permanent winter dwellings most frequently are used in spring and summer for breeding. It should be noted that American flying squirrels *Glaucomys volans* (Linnaeus, 1758) and *G. sabrinus* (Shaw, 1801) build and use

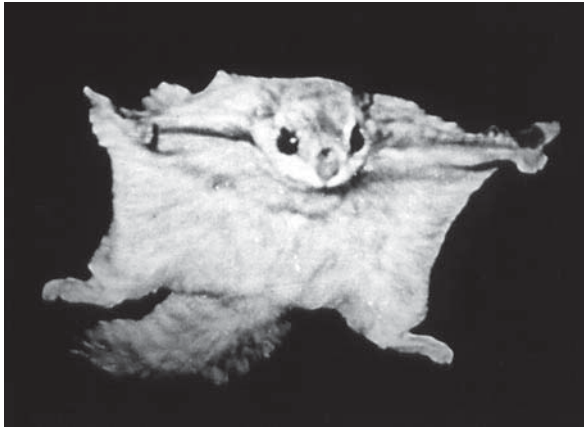


Figure 3. Gliding flying squirrel.

habitats practically in the same way. The difference is that American species in summer time use open (out of hollow) nests (Goertz *et al.*, 1978). Our flying squirrels seldom make such nests; at least we have never found them. Kaikusalo (1973) found several ones in Finland. Meanwhile, according to the data, collected by Kudryavtseva (1994), in the North East of European part of Russia flying squirrels often settle in old neglected squirrel shelters. We think it can be explained by large quantity of flying squirrels and lack of natural shelters.

Seasonal and daily activity

Flying squirrels are active all the year round. In nasty nights with heavy rains, or in winter during heavy snowfalls, when the night temperature is lower than -30°C , animals can stay in their shelters without leaving them even for natural functioning. Sometimes in bad weather flying squirrels leave their shelters only for urination and defecation, but not for feeding.

According to our observations in Leningrad Province and to data of Finnish researchers (Siivonen, 1956; Airapetyants, 1963; Kaikusalo, 1973), at the northwestern border of the natural habitat, flying squirrels are active mainly at nighttime. However, active time duration and activity in dark/light periods depend on season and reproductive state of an individual. Materials obtained in Leningrad Province (our data) and in central Finland (Hokkanen *et al.*, 1977), practically coincide. It indicates to similar type of flying squirrel activity in this part of the natural habitat.

In late autumn and winter months, when dark period of day is very long in this region, animals stay out of shelter for 3.5–9.5 hours, which is less than night duration (16 hours). During this period they can visit their shelters many times.

In November–February two peaks of activity can be seen: soon after midnight and at daybreak. They leave the nest much later than sunset; even the same individuals can vary the departure time greatly. In autumn and winter feeding time duration is the same for males and females.

Starting from March flying squirrels often leave their shelters in daytime. At this period there is no exact

dependence of out-of nest activity on solar radiation. It is evidently connected with the temperature. Animals, kept in indoor enclosures or open-air cages, behave in the same way. In March we often saw flying squirrel footprints on the snow between trees. Running distances varied from 5–6 to 10–12 m. During White Nights period animals leave their homes simultaneously with sunset (sometimes a little bit earlier) and come back finally an hour or hour and a half before dawn. At this time most females have litters, so they eat long, though periodically for a short while they visit nests with juveniles. Visit frequency probably depends on remoteness of feeding area and juveniles' age. Thus, in enclosures food search and eating take less time (food is located not far from shelter), and animals visit their posterity more frequently. As juveniles become older the female spends more time outdoors. In spring and summer the same individuals leave shelters in the evening practically at the same time (difference can be 1–10 min). According to the data of the Finnish zoologists mentioned above, if the dark period duration is less than 6 hours, flying squirrels in central Finland are equally active in day and night time, and the time spent outdoors exceeds the time period between sunset and sunrise. Difference between day and night peaks of activity is 12 hours. In Leningrad Province flying squirrels are mostly active at night (it is stated both by direct observations and circumstantial evidences), though sometimes, as it was said above, they feed in daytime for a short time. The ceremonial of feeding withdrawal is similar to that of loir *Glis glis* Linnaeus, 1766 (Airapetyants, 1963). At first they look out several times from the hollow inlet. The intervals between looks can vary from 2 to 15 min. An animal is looks around and listens to, then very quickly slips out from the hollow entrance and climbs the stem up or to the nearest branch. After committing physical needs (big quantity of excrements is collected on the same branch), a flying squirrel runs to the tree crown, where it starts eating.

Sometimes having reached the top, the animal immediately glides to another tree and thus gets to the main feeding area. If in the nest there is juvenile brood, a female will linger in the crown to wait for juveniles. The juveniles appear 5–20 min after mother's departure. They also spend some time on the "toilet" branch, then run to the crown to their mother. First independent feedings of young juveniles are not durable, as a rule, animals stay in "their" tree; later they gradually expand their sphere of activity. By two-month age they have explored the mother's territory; duration of outdoor activity of three-month juveniles is practically the same as that of adult animal.

Feeding and fodder procuring

Flying squirrel feeding in the North West of the natural habitat is the same in all regions; it is likely because of habitat similarity. In Finland (Siivonen, 1956; Sulkava & Sulkava, 1996a, b), in Estonia (Aul *et al.*, 1957) as well as in our region animals eat leaves, buds,

twigs and aments of alder, aspen, birch, willow, pine's and fir's needles and cones, berries, like red currant, raspberries, bilberries, wild strawberries. Lichen *Usnea barbata* is a very important fodder in all seasons, at least in Leningrad Province. Among wood species aspen is most widely used by flying squirrels. It plays a special role for animals in the North West of Russia. Seed fodder, as noted in the literature (Airapetyants, 1963; Egorov, 1971; Kudryavtseva, 1994) and shown by observation on captured animals, does not constitute a significant part of the animal ration. Flying squirrels eat green scales of fir and pine-cones in the same way as red field voles do, they eat seeds only at early stages of ripening. It should be noted that flying squirrels, kept in enclosures, easily get used to eating sunflower seeds, oat flakes, sometimes, not often, "cedar nuts", but still traditional fodder (twigs and leaves) is preferable. According to our observations in Leningrad Province (Airapetyants, 1963), animals, starting from the first days of June till the mid August, eat mainly aspen leaves and sprout rind. At the same time they eat berries gladly. At the end of summer leaves do not attract animals any longer. At that time they prefer rind, cone scales, milky ripe seeds and lichen. According to information of Finnish zoologists (Makala, 1996a, b) they simultaneously start to reserve birch and alder aments. Flying squirrels hide reserves mainly in secondary shelters: frost-clefts loose rind, cavities from fallen twigs, artificial nests. In enclosures they make stores in deserted nestling boxes, cracks and rarely in inhabited nests. In natural conditions some fodder kept in winter shelters is used as reserve for bad weather. Starting from September animals gladly eat axillary "sleeping" buds of bilberries, fir-tree and pine needles and rind. In winter the main food is aspen branches (buds and rind), buds of other hardwood and lichen. In early spring pine buds and needles constitute a large part of flying squirrel ration. At the beginning of May animals eat young birch aments (80% from all kinds of fodder), aspen and alder buds, as well as buds and leaves of these trees and rowan trees. Thus, the first thing that attracts attention is that there is a distinct seasonal change of feeding objects in flying squirrel ration. Moreover, the mentioned interchange of fodder is observed by captured animals, from a variety of natural fodder offered to them, they choose, first of all, those which they eat at this season at liberty.

Established seasonally is characteristic for the species in all part of the natural habitat, but according to published information, usage of fodder differs. Thus in eastern parts of Russia flying squirrel ration includes more birch than aspen; in Sikhote-Alin Range the ration consists of hazel sprouts, leaves, buds and rind of maple, rowan-tree, alder (Salmin, 1938). In Baikal region flying squirrels eat cedar nuts, fir-tree and silver fir seeds (Zonov & Mashkovskii, 1977). Beech nuts, acorns, fir seeds, wild fruit and mushrooms prevail in the ration of ecologically similar species, the North American flying squirrel *Glaucomys sabrinus* (Rue, 1975).

In places, where flying squirrel eat in aspens, soil under trees is thickly covered with cut and gnawed

around leaves. Leave blades have torn edges made by rodent's incisors. Meanwhile leave blade ribs often remain untouched. In summer time such leave remains can testify flying squirrel presence and can be used for their registration. An animal eats about 80 birch and aspen leaves daily. It cuts much more leaves but some of them for unknown reason are not eaten. As a rule a twig cut by an animal is 7–8 cm long; holding it with its forepaws and rotating it quickly, an animal gnaws the rind on spiral.

In pine and fir needles only mesophyll is eaten, thus every needle appears to be opened, the remaining epidermis is used as bedding or dropped to the ground. Observations of captured animals show that daily norm of eaten needles is about 100 g.

Sometimes in literature information appear about flying squirrel rapacity, they are accused of bird's egg-laying destruction, aggression towards juvenile and adult birds (Rakhilin, 1968; Telegin, 1970). Egorov found remains of red field voles in stomachs of four animals. All mentioned cases took place in Trans-Ural region, it is possible that in some areas animal fodder is used, but in our region we have not observed such cases. Captured flying squirrels peacefully shared enclosures with budgerigars and small sparrow birds, they have never been seen attacking birds. Meanwhile animals occasionally get into traps for minks and martens, where meat is baited as attraction. We offered floury cockchafer larvae, cockroaches, ant pupae to captured animals but they never touched them. In residential areas there are "favorite" trees, where flying squirrels eat. During night trips animals visit these trees without fail, so it is possible to foresee their route and wait for them under these feeding places. It makes easier to watch the behavior of eating flying squirrel. High undamaged trees with big crowns attract animals most of all. Here they can eat for a long time, then covering distance with several gliding jumps, they move for the next feeding place.

Reproductive period

Reproductive period (the individual life period from the beginning of heat till juveniles' departure from a family) in our region begins in the middle of March and ends at the end of August or beginning of September. Judging from our observation population of northwestern part of the habitat has two reproductive peaks: at the end of March and in April–May. So the first dates of juveniles' mass birth are in the beginning of May, the second are in June. Finnish zoologists (Siivonen, 1972; Kaikusalo, 1973; Makala, 1996a, b) have similar data for Finland. They think that major part of broods appear in May (67% according to Makala, 1996a, b). The difference is that in Finland one third of females reproduce repeatedly, while in Leningrad Province, according to observations of the same individuals, flying squirrel females have only one brood per season (Airapetyants *et al.*, 1987). Some cases of repeated reproduction are presupposed in Estonia (W. Timm, pers. comm.). It

is possible that the second brood can appear if the first one perishes at the early stages of postnatal ontogenesis. Two reproductive peaks established for our region are connected with later participation of young animals in reproduction. We noticed the same with the captured animals. When on heat animals are active at daytime, they often run on the ground, leave frequent urine marks on the snow. Excited animals follow each other with specific buzzing and squeak, the sounds we have never heard from them during other periods of life. A male persistently follows a female in oestrus, making numerous attempts to copulate, but at the first stages of courting, it as a rule, is rejected; a female imitates aggression, attacking the partner, trying to bite it. We watches animals, clutched at each other, roll on the ground with strident squeal and loud snarling. The female was in heat state, it excited the male and stimulated active pursuit. After copulation flying squirrels put themselves into order, tidy up themselves, licked anogenital area, had rest and started everything from the very beginning. Such excitement, associated with copulation, lasts one or two days and take place in the second part of oestrus. Later on, animals can share the same nest till juveniles' birth, or the male can leave joint nest to seek another female in oestrus, if the population density is high. As our observations show, most often the male remains in his area, the joint use of shelter depends on the female's "mood".

According to our observations of captured animals, pregnancy (at exact knowledge of copulation date) lasts 40–42 days. There can be 1–4 cubs in the brood, most often there are 2–3. Young females, according to Kaikusalo (1973) information, have the least number of cubs (1–2), the same as old ones; optimal reproductive age is at second and third year of life (2–4 cubs). In Leningrad Province we found five broods consisting of 2 or 3 juveniles.

All six females which gave birth in captivity had two cubs. As in the most of sciuriform rodents, flying squirrel cubs have very long period of postnatal ontogenesis. Such factor as eye opening proves this. Cubs of the species under study open eyes at the age of 28–31 days. If to divide postnatal period into four stages, as we suggested (Airapetyants & Fokin, 1986), then stages of juvenile flying squirrel development can be described as following.

I stage. From birth till the age of 12–13 days. By the end of this stage cubs have dark thick fur (this stage of scalp development is conventionally named by us "velvety" stage), the furrow separating eyelids is well seen, there are dark circles around eyes, toes and fingers are completely separated. Lower incisors are well seen through the film, there are prominent knobs on the places of upper teeth. At this age cubs can crawl well, but only forward extremities propulsive, stomach practically is not raised from substratum. Meanwhile cubs can crawl along the inner wall of the hollow, clutching with hand and foot nails. Being frozen outside the nest they make series of staccato sounds - "weeping of abandoned baby" (according to terminology by Eisenberg, 1968). Average cub body mass at this age is 21–22 gr., body length

is equal to 47% of body length of an adult flying squirrel.

II stage lasts 16–18 days and ends with eye opening. By its completion cubs are covered with rather long light gray hair, including all kinds of undercoat and arista hair. Acoustic ducts are opened by the 20-th day. Lower incisors are 2 mm long, the upper ones will be appear by 27–28-th day of life. Wing membrane is covered with soft short hair. Cubs can wash themselves, investigate hollows, crawling on inner walls, hang at one back leg. They move at pace on horizontal surfaces, make first attempts to jump, pushing with all four paws simultaneously. "Weeping of abandoned baby" by the end of this stage is substituted by hollow murmur, hiding reaction at fright or at hazard disappears, cubs try to escape. We were witnesses a female, disturbed by us, left a hollow in a half rotten birch stub and three cubs practically fell out of the hollow following her and awkwardly jumped into different directions. We have to note that as a rule it is impossible to make a family leave shelter in a live sturdy tree. If a female tries to carry over her cubs, they assume a "transportation pose": roll themselves in a ball, bending paws, head and tail under the body. By the end of the first month of life juvenile flying squirrels start to react to rattling sounds of the brood mates. Straight away from the eye opening cubs make first attempts to peep out of the hollow: during 2–3 min the cub looks around, then disappears in the shelter depth. Body mass of juvenile flying squirrels is about 50 g, body length is about 60% of that of adult animals (14–21 cm). Rolling reaction, helping to collective heat regulation, remains; stable body temperature is 36–36.5°C establishes by the end of the second stage of the ontogenesis.

III stage is characterized with complete formation of all exterior features and behavioral reactions. It finishes with the family absolute disintegration. Cubs at this stage are three months old. Young generation leaves parents' territory; at first animals keep close to the nest area, then they settle apart, occupying free forest areas.

Two months old flying squirrels have practically the same hair color as adult ones. They start leaving the nest, investigate nest tree (spending outside the shelter 10–20 min) at the age of 40–45 days. Usually at first withdrawals cubs run on branches following their mother's heels. Only after the female "flies away" to feed, cubs return to the nest. Locomotion is already perfect enough, juveniles have mastered all paces, and by 1.5 months age they can make gliding jumps. At first the extension of such jumps does not exceed 20 m, but it increases every day and at the age of 50 days juvenile flying squirrels feed independently, flying from one tree to another and exploring the feeding area. Our observations show that such first withdrawal lasts not more than half an hour. Its extension is about 50 m, an animal practically does not linger at every tree, it eats one or two birch or aspen leaves. On the third day a juvenile flying squirrel stayed on feed trees up to 10 min, so feeding time was a little bit over an hour. It is interesting to note that fodder seeking route is usually stable, that is why we could guess the place of the next stop and pass from one tree to another.

Juvenile animals as well as adult ones have their favorite trees, where they stay long. So we watched closely one 50-day old female. On her 500 m long feeding route there were 142 trees (28 fir-trees, 34 pines, 66 birches, 2 rowan trees and 12 aspens) where it landed and stopped. It stayed and ate long only at four aspens. Every night the animal followed this route till the moment when it finally left its parents' territory. It is interesting to mention that a male from the same brood, habitually followed the mother, completely repeating her feeding route. This animal left the nest area 10 days earlier than his sister. According to the data provided by Kaikusalo (1973) and Makala (1996), in Finland separation of juvenile animals takes place on 43–45th day after the first withdrawal from the nest, i.e. by three months age. Our information for Leningrad Province completely coincides with this. Rakhilin (1968) thinks that in the Eastern Siberia the juveniles remains with parents till the next spring. By the end of the III stage juvenile flying squirrels have body mass about 70–80 g. Body length is 80% from that of an adult animal.

Locomotion

One of the most astonishing features of flying squirrel is its ability to gliding (Figs. 2, 3) which is repeatedly discussed in the literature (Ding, 1959; Polyakova & Sokolov, 1965; Gupta, 1966; Rue, 1975; Smirin & Popova-Bondarenko, 1977). Here we present some of our original data on gliding in the European flying squirrel.

The gliding cycle in European flying squirrel includes succession of stages from start of flight to completing of flight on the tree trunk or, less common, on tree branches and very rarely landing on the ground. An intensive shove by hind extremities provides start acceleration sufficient for a guided gliding in a descending trajectory. The physical parameters of animals, notably the correlation of the body mass and total surface of belly, tail and spread wing membrane, vary considerably in the taxonomically rich family Pteromyidae (Thorington & Heaney, 1981). So called scale effect determines either high gliding speed (giant flying squirrels *Petaurista*, woolly flying squirrels *Eupetaurus*), or amazing gliding maneuverability (small and middle sized *Glaucomys*, *Pteromys* and *Hylapetes*).

Right after synchronous push of hind limbs the flying squirrel stretch forward and aside the fore limbs and stretch aside the hind limbs, straining the wing membrane (Fig. 2). The road holding on the glidepath is provided by coordinate work of hind limbs and wing membrane musculature. A furry and flattened tail acts as an aerodynamic beam, correcting and optimizing the turns.

The gliding speed of the European flying squirrel is relatively low, 5–7 m/s. At the same time its ability to maneuvering and instantaneous change of gliding direction is striking. The animal easily fly round the obstacles even in the bushy crowns and is able to complete the flight by spiral fly round the tree trunk, which was

frequently observed by us at its nesting tree. The gliding is completing by parachuting phase (Fig. 3). Inasmuch as the animal is landing, as a rule, on the tree trunk it change voluntary the body orientation from horizontal to nearly vertical and somewhat bring together all limbs making the a “parachute” by the wing membrane. The animal touch the trunk by fore and hind limbs almost simultaneously. The limbs act here as shock-absorbers which considerably reduce the impact load on the animal's body at the final gliding phase. The movement in the tree crown is realized either by leaping involving synchronous work of fore and hind limbs, or by trotting gait provided by successive or synchronous work of diagonal limbs. At the same time the animal often run along the branch upside down. Sharp and curved claws allow the animal to climb the vertical trunk by head down.

On the ground the flying squirrel move by gallop, but without carrying-out of the hind limbs forward the line of fore limbs which is hindered by the wing membrane. The flying squirrel tracks on the snow clearly show more widely spread hind limbs compared to the fore limbs. The ground speed of flying squirrel is rather low, no more than 2 m/s.

Enemies and causes of death

The flying squirrels have rather few enemies. They cryptic mode of life, night activity, feeding in high crowns, and quiet gliding make this animal almost inaccessible for most carnivores. The only exception is owls, first of all by hawk owl and barred owl. We observed the hunting of hawk owl for the young flying squirrel, turned out to be unsuccessful. Several times we found remains of flying squirrels eaten by these predators. Rarely flying squirrels become the prey of a marten. However, the real danger for the species is not natural predators but growing man's impact on the territory in the western part of its habitat, which lead to displacement of animals towards to less suitable for live forest parts, with not enough shelters and forage resources. The main role in decreasing of the flying squirrel population is played by the dense felling and disappearance of aspen and birch.

Conclusion

At the present time an obvious tendency to decreasing of territory inhabited by flying squirrel in the western part of its natural habitat is observed. Most likely this tendency will be continued due to growing man's pressure. Universal reduction of native forests on large territories, selective felling of mature fir-trees and aspens, including hollow trunks, put the species to the edge of its possible existence in the not suitable environment. The flying squirrel is quite conservative in its food preferences, which vary little all over its natural habitat. The main foraging object for flying squirrel is aspen, and animals always feed on mature undamaged trees. The aspen can be substituted in our region to a some extent by birch, but only in spring and late autumn seasons. As

many other arboreal mammals, the flying squirrel can not gnaw themselves the hollows in the solid wood. All over their natural habitat they use woodpecker's hollows for nesting. In North-West of Russia the flying squirrels occupy exclusively hollows of greater-spotted woodpecker. In such a way the prosperity of flying squirrels depends on the population of this woodpecker species. Another factor of no small importance contributing to the vulnerability of flying squirrel is its K-strategy of reproduction. Primary monocyclic recurrence of females, long pregnancy (40–42 days) and lactation (42–45 days), low fertility (2–3 offsprings), sexual maturation on the second year of life, do not allow the species to restore the undermined population quickly. Although the isolation of colonies exaggerated by spacious felling prevent contacts between animals. In contrast to squirrels the flying squirrel can not overcome large woodless areas in search for new biotopes because of limited ability to ground locomotion.

For the preservation of flying-squirrel in the North West of Russia and in Leningrad Province in particular, protected reproductive areas should be organized. The destroyed hollow trees should be compensated by artificial nestling boxes and starling-houses. The typical habitats currently lacking the flying squirrel should be populated by animals captured in other areas or animals raised in captivity, with inviolate feeding and behavior stereotypes. In the case when felling on the territory populated by flying squirrel can not be avoided, the following conditions should be observed: 1) felling should be restricted to late winter – early spring in order to made animals individual areas available for animals at the time of rash and birth of offsprings; 2) trees with populated hollows should be saved; 3) some amount of reserve feeding aspens should be kept.

The European flying squirrel is included in the Red Data books of Leningrad Province, Baltic region, and East Fennoscandia (Ingelög *et al.*, 1993; Hokkanen & Fokin, 1998; Airapetyants & Fokin, 2002) and should be protected also in Pskov, Novgorod and Vologda provinces.

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