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Margaletić, Josip

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RODENTS AND THEIR HARMFUL EFFECTS ON TUROPOLJSKI LUG (TUROPOLJE GROVE) AND ON CROATIAN FORESTS

MIŠOLIKI GLODAVCI I NJIHOVA ŠTETNOST U TUROPOLJSKOM LUGU I U DRUGIM HRVATSKIM ŠUMAMA

JOSIP MARGALETIĆ

Department of Forest Protection and Wildlife Management, Faculty of Forestry, University of Zagreb, Svetošimunska 25, HR – 10 000 Zagreb

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The natural and artificial regeneration of a stand, as well as the production of plant material in forest nurseries, is directly influenced by numerous biotic and abiotic factors. Several species of murids (family Muridae, Rodentia) which belong to two subfamilies, mice (subfamily Murinae) and voles (subfamily Arvicolinae), can be distinguished among biotic factors as pests of forest seeds, shoots and young plants. In the lowland forests of Croatia three species of mice are present (the yellow necked field mouse – *Apodemus flavicollis*, the common field mouse – *Apodemus sylvaticus* and the striped field mouse – *Apodemus agrarius)*, and six species of voles (the bank vole – *Clethrionomys glareolus*, the common vole – *Microtus arvalis*, the field vole – *Microtus agrestis*, the water vole – *Arvicola terrestris*, the European pine vole – *Microtus subterraneus* and the Alpine pine vole – *Microtus multiplex.* The population density of these rodents changes during a year, but also in a period of several years. In years when there is a high density of population, the damage to forestry can be catastrophic. Research on the population dynamics of rodents, which is important for the measures and methods of contemporary forest protection to be carried out successfully, was done during 1995 and 1996 in Turopoljski Lug (Forest Office of Zagreb). Modified methods of a minimum square with snap traps, "Y" methods and methods of linear transect were used. Computer data processing was done by a statistical method of linear regression, by a method of calculating the population density of animals over a surface unit by the total catch of animals and by a method of calculating the relative population density. This paper deals with the harmful effects of rodents in Croatian forests in the period from 1980–1995 and the amount of harm caused to the seeds of pedunculate oak and to forest sprouts by small rodents during periods of different population dynamic densities.

Key words: lowlands forests, rodents, population density, forest seeds, forest sapling, forest regeneration

INTRODUCTION
UVOD

The decay of some trees and groups of forest trees and whole stands has been known throughout the history of forestry. In some areas of the Republic of Croatia (Gorski Kotar, around Zagreb, central Posavina), the drying of stands has reached high proportions.

Forests of pedunculate oak with broom *(Genisto elatae-Quercetum roboris* Ht. 1938) (Prpić et al. 1988) are among the most damaged forest communities. The main reason for the drying of lowland stands is seen by Prpić (1977) in the decrease of the level of underground water caused by extensive hydromelioration. Natural and artificial regeneration of stands, as well as the production of plant material in forest nurseries, is directly influenced by numerous biotic and abiotic factors (Spaić & Glavaš 1988). Rodents can be distinguished among biotic factors as pests of forest seeds, seedlings and young plants. They constantly cause minor damage in forests. In years of high population density, the damage can significantly increase and inflict high losses to the forest economy (Vajda 1974). It is known that rodents can do damage in all kinds of forests (mountain, seaside, highland and lowlands). In Croatia, the greatest damage was noted in lowland forests of pedunculate oak (the report – Diagnostic Prognostic Services of the Institute of Forestry of Jastrebarsko for the period 1980–1994). Rodents frequently have a decisive role in the production of germinable seed of pedunculate oak. In some cases, the whole crop of acorn in a pedunculate oak stand can be completely destroyed by rodents, particularly in years of high population density (Spaić & Glavaš 1988). Their harmful effect in forest communities of pedunculate oak is particularly significant in years of a decrease in the acorn crop (Crnković 1982).

The negative effect of rodents is even more emphasised if they cause damage to seeds and plant material which are used in the regeneration of forests where there is an intensive process of drying. Several economic factors should be considered when dealing with damage in artificial regeneration (costs of collecting forest seeds, costs of plant production in forest nurseries, costs of afforestation, costs of protection of young growths). The material means that forest operative units invest in the regeneration of a stand could be lost in a short time if there is a high population density of rodents on the region that has to be regenerated. Freshly cultivated plants and forest seeds of high quality become an important source of food for these animals. The problem of rodents in forest protection has not been sufficiently studied. Detailed research on this group of pests in the forestry of Croatia has not been done.

Successful control of increased population densities of rodents is impossible without good knowledge of their morphological and physiological features, their food habits, reproduction, as well as the ecological factors that influence members of the community. Unprofessional procedures in this domain can have unpredictable negative consequences for the forest ecosystem and the animal species which live in it and which are not to be controlled. Monitoring the population dynamics of these pests is of considerable importance for measures and methods of contemporary forest protection to be successfully carried out. Using direct or indirect methods, forest science can considerably decrease the damage caused by rodents. The main aim is to create high-quality prerequisites for the successful regeneration of the forest stand, either natural regeneration or artificial acorn introduction, i.e. forest plants. Numerous methods to reduce the high population densities of pests have recently been used in order to complete this task (preventive, mechanical, chemical and biological methods). In order to consider the problems of rodents in pedunculate oak forests more efficiently, it was necessary to examine in detail the community structure according to species, to determine their population density, the intensity of the damage done to forest seeds and young plants, and to recommend protective measures.

In order to examine the quantity of the damage done by rodents to forest seeds (the acorn of pedunculate oak) it was necessary to find a stand which was richly fruitful. To determine the damage done by small rodents on young growths, the aim was to find a stand where artificial regeneration was made by plant material and on which research on the quality and the quantity of the mentioned pests was planned. These conditions were fulfilled in the forests of the Management Unit Turopoljski Lug. Turopoljski Lug is situated 30 km SE of Zagreb. The Management Unit is 4333.6 ha, and forms the west part of the Panonian lowland. The altitude of the Management Unit Turopoljski Lug is between 97 and 109 m. According to Köppen's classification, this area belongs to the "mediate warm and rainy 'cfwbx' type of climate" (Prpić et al. 1994). The precentagés of the main tree species are: 77 % *Quercus robur*, 8 % *Alnus glutinosa*, 8 % *Carpinus betulus*, 4 % *Fraxinus excelsior*, 1 % *Fagus sylvatica* and 2 % others. The whole unit is considered as a forest-management area of regular forests. Field research was done in the central part of the Management Unit in subcompartments 58a, 59a, 62a, 75a, 90a, 98a.

RODENTS (RODENTIA)
GLODAVCI (RODENTIA)

Discussing this group of mammals, some authors (Vajda 1974, Delany 1974, Kowalski 1976, Spaić & Glavaš 1988, Kovačić 1988, Trilar 1991, Matić & Skenderović 1993, Baltić 1995, Glavaš et al. 1996) use various names for them like: "forest rodents", "rodents", "tiny rodents" and "small rodents".

The expression "small mammals" (Micromammalia) is mostly used in literature for species of Mammalia in which the weight of adult members is greater than 2 g and less than 120 g (Delany 1974). This group of mammals includes: moles, soricids, squirrels, voles, mice etc.

BIOLOGICAL FETURES OF RODENTS
BIOLOŠKE OSOBINE MIŠOLIKIH GLODAVACA

Rodents are mammals with characteristic front (upper) incisors. Their body is cylindrical (Kowalski 1976). They are very nimble, cautious and react quickly. Their paws usually have five toes with claws. The tail is usually well developed and covered with horny scales or hairs. *A. flavicollis* and *Myoxus glis* have the longest tail among the rodents (Kowalski 1976). Their jaw is strong in its rear part, so food is mixed with circular movements. There is one pair of incisors in the upper and the lower jaw (incisiva) and three pairs of molars (molara). Some of them have premolars (premolare). Their incisors are very sharp, as they are coated with enamel only from the front. The incisors are used for gnawing food and other materials. In order to keep them adequately long, they are forced to use them daily as they constantly grow, and in that way they are worn away. These animals do not have canines. Most of these mammals are active by night, in contrast to those species who live in cold areas and mostly take their food during the day. Some of them collect food for colder days by making stocks in special stores. Digging activity is well developed in many species. Small rodents have a relatively short life span. Most of them do not live longer than 2.5 – 3 years. The mass of crystalline lens and the length of the skull are proportional to the age of the animal (Gurnell & Knee 1984). The most precise data on the age of the individual is obtained by measuring these parameters.

Reproduction
Razmnožavanje

The reproduction of rodents and the growth and development of offspring depend on the influence of several factors, among which the characteristics of the climate, particularly the outer temperature, are very important. The potential for reproduction is very high. Females can have a litter several times a year. In moderate and cold climatic areas, reproduction stops during the winter. The average number of young in each litter is 2 to 8. The gestation period of a female lasts over 20 days. The time from their birth to complete sexual maturity is 2–4 months. Young voles mature sexually very early, much sooner than they reach their full growth (Kowalski 1976). The young are born with closed eyelids, closed auditory canals and without fur. After 7–12 days the fur completely covers the body, while the eyelids and auditory canals open between the age of 10 and 12 days. The young suckle and depend on their mother until approximately 20–25 days of age. In most mammals, a female is not ready for new fecundation until breast-feeding stops, while in rodents a female can mate and become pregnant the same or the next day after giving birth.

One of the important activities of the adults, particularly females, is building a nest. It is a place for rest, a shelter from natural enemies and the place where the young are raised. A nest can serve as a store of gathered food. Males take little care of the offspring. The strongest males mate with females (Thor & Carr 1979). In taking care of the offspring, a female becomes very aggressive in cases where there is danger for the young or she skilfully and quickly hides them in a safe place (Meehan 1984).

The growth of the young depends a great deal on the kind and quantity of food accessible to mothers during the gestation period and lactation. Wehmer & Jen (1978) proved that a reduction of 25 % of food during the gestation period causes a decrease in lactation and also a decrease in weight of the litter. The light also influences the reproduction, development and growth of certain species of rodents. The young born at the end of spring or at the beginning of summer mature sexually more quickly than those born during the autumn and winter.

THE ROLE OF SENSE ORGANS
ULOGA OSJETILA

The sense of smell has an important role in the reproduction of rodents, in the raising of offspring, in finding food, in their relationship with animals of the same or different species and so on. According to Bowers & Alexander (1967) these mammals can sense the smell of other animals and can unmistakably distinguish members of the population. With their sense of smell, female small rodents can distinguish their offspring from the offspring of other females (Moor 1981). Male mice attack other males of an unfamiliar smell which come to their colony for mating.

The smell of other animal species can also influence the behaviour of rodents. Some species of mice suffer a genuine shock when they sense the smell of the urine of a cat or some other predator. The attraction to or repulsion from the smell of other animals of the same or different species can be used as one of the possibilities of controlling the population density of rodents. Research directed at finding and producing attracting and repelling devices has been very intensive during recent years.

One of the most important senses of these animals is mechanoreception. Sense hairs are distributed on the back and sides of the body and the snout. The safe movement of this animal in the dark is possible following its tactile introduction to the objects in the environment. By removing sense hairs, sensibility to touch is considerably decreased and the animal loses its ability to orientate itself in space (Taylor & White 1978).

The sense of sight has a relatively small role in most small rodents. Some of these animals can see well at night. Most species from the genera *Apodemus, Mus* and *Rattus* can clearly identify objects up to a distance of 15 m (Sloane et al. 1978).

Their hearing is well developed. They can register sound above the limit of man's hearing ability (20 kHz). Apart from registering ultrasound waves, rodents can also produce them (Watts 1980), and they use them in their mutual communication. Ultrasound has a significant role in their sexual behaviour. Newborns also produce ultrasound waves in order to attract their mother's attention (Smith 1979).

The sense of taste in small rodents has mostly been researched in the genus *Rattus*, and it has been established that rats register four tastes, like man: sweet, salty, sour and bitter (Brouwer & Hellcant 1973).

FOOD HABITS
PREHRANA

Most rodents are polyphagous animals. The quality of food is very important for their normal growth and development. The lack of certain nutritious components can cause various kinds of avitaminosis, rachitis etc. Baits used to catch these animals, which consist of food tasty to man, are not always necessarily attractive to rodents. A combination which could be used as a universal nutritious base for making poisonous baits has not been found. Plant food or a thick cloth with grease in which bacon and onion were fried is particularly attractive to members of the genus *Apodemus* and some species of voles and, due to its efficacity, it is frequently used in baiting them. Water is an important factor in the nutrition of rodents. While researching the nutrition of rodents, Knote (1982) noticed that if mice eat food with a constituency of only 12 % moisture and no water, they die after 3–4 days. Members of the genera *Apodemus, Microtus* and to some extent *Mus* drink relatively small quantities of water. If the outside temperature drops, their need for food increases.

FACTORS IN THE INCREASE OF POPULATION DENSITY
ČIMBENICI POVEĆANJA GUSTOĆE POPULACIJE

Population density is the number or the biomass of the members of a species on a surface unit in a given time (Androić 1970). Many factors contribute to an increase in the population of rodents. These factors can be grouped in four basic groups (Androić et al. 1981):

1. The population density and physiological condition of the population

The possible increase in number depends on the population age structure, behaviour and physiology of its members, on the relation of sexes in the population, social relations within the population, competition within the species, genetic predisposition and on the birth-rate and the death-rate.

2. Climatic conditions

Favourable climatic conditions are an important factor in the increase of the population density. These are determined by temperature, humidity, precipitation and the distribution of these factors during the year.

3. Habitat and food sources

Rich ground vegetation, particularly in neglected and weedy habitats, is an important food source. The presence of herbaceous and granular food sources is a condition for the nutrition of the population. The establishment of natural cycles in the fructification of ligneous plants is successfully used to estimate the possible increase in the size of the rodent population in forest stands.

4. Natural enemies and diseases

Numerous predators (fox, marten, polecat, wild cat, buzzard, hawk, owls, crows, etc.) and epidemics of infectious diseases are important factors in regulating the rodent population. Epidemics usually appear when the density of populations is high and cause their sudden decrease.

RODENTS AS POTENTIAL VECTORS OF ZOONOSES
MIŠOLIKI GLODAVCI KAO POTENCIJALNI PRIJENOSNICI ZOONOZA

Rodents are a constant "reservoir" of various zoonoses and when their number increases, they can transmit them to men and domestic and wild animals (Fališevac 1976). These diseases are divided into several groups according to the agents:

1. diseases caused by bacteria (tularaemia, leptospirosis, plague, salmonellosis, tuberculosis, etc.);
2. diseases caused by viruses and rickettsiae (rabies, haemorrhagic fever, lymphatic choriomeningitis, etc.);
3. diseases caused by mycoses (various forms of dermatomycosis and trichophytosis, e.g. flavus, sporotrichosis, etc.);
4. diseases caused by protozoa (sarcocystis, amebiasis etc.);
5. diseases cause by parasites (coccidiosis, leishmaniosis etc.).

Turopolje is a natural focus of tularaemia, leptospirosis and rabies (Borčić et al. 1976, 1986, 1987).

SPECIES OF POTENTIALLY HARMFUL RODENTS IN THE MANAGEMENT UNIT TUROPOLJSKI LUG
VRSTE POTENCIJALNO ŠTETNIH MIŠOLIKIH GLODAVACA U GOSPODARSKOJ JEDINICI TUROPOLJSKI LUG

In the forest stand of Turopoljski Lug there are several species of rodents (family Muridae) (Meštrov 1986), which in years of high population density cause great damage to forest seeds and young plants. They belong to two subfamilies: mice (Murinae) and voles (Arvicolinae).

The subfamily Murinae includes 122 genera and 529 species (Wilson & Reeder 1992). Three species which belong to the genus *Apodemus* are distinguished in this subfamily as pests of forest seeds in the oak lowlands forests of Turopoljski Lug (Meštrov 1986). These species are:

1. *Apodemus flavicollis* (Melchior 1834);
2. *Apodemus sylvaticus* (Linneus 1758);
3. *Apodemus agrarius* (Pallas 1771).

The subfamily Arvicolinae includes 26 genera and 143 species (Wilson & Reeder 1992). According to the research of Meštrov (1986), the following species of voles (subfamily Arvicolinae) live in the forests of Turopoljski Lug:

1. *Clethrionomys glareolus* (Schreber 1780);
2. *Microtus arvalis* (Pallas 1778);
3. *Microtus agrestis* (Linnaeus 1761);
4. *Microtus subterraneus* (de Selys-Langchamps 1836);
5. *Microtus multiplex* (Fatio 1905);
6. *Arvicola terrestris* (Linnaeus 1758).

RODENTS IN FOREST ECOSYSTEMS
MIŠOLIKI GLODAVCI U ŠUMSKIM EKOSUSTAVIMA

In already damaged forest stands, which include our pedunculate oak forests in northern Croatia (Prpić et al. 1988), rodents become significant pests and are controlled preventively to save the regeneration of forests. However, we must not forget that they are a natural part of forest ecosystems. Their natural role in forests is complex and important for forests to keep their biological diversity and balance. Turček (1968) already noticed this and he systematised their influence on the forest ecosystem:

- on the microclimate of windfall leaves and uppermost layers of soil;
- on the nature of soil, its aeration and humification;
- on the flow of inorganic and organic matters;
- on the decay of organic matters;

- on the structure of the stand, both of ground growth and of trees;
- on spreading plants by the spreading of seeds;
- on the population density of some harmful insects;
- on the preservation of the population of various forest predators whose main food are rodents;
- on the succession on clearings.

RODENTS AND THEIR HARMFUL EFFECTS ON CROATIAN FORESTS IN THE PERIOD FROM 1980-1995
MIŠOLIKI GLODAVCI I NJIHOVA ŠTETNOST U HRVATSKIM ŠUMAMA OD 1980. DO 1995. GODINE

Mice and voles cause damage to forests by eating forest seeds, gnawing barks and roots. Mice (subfamily Murinae) can be particularly distinguished as pests of forest seeds and can completely destroy seedings in forest nurseries or disable the natural regeneration of forest areas. This form of damage in lowland forests is mostly done by the species *Apodemus flavicollis* and *Apodemus sylvaticus* (Androić et al. 1981). Rodents dig long corridors underground by which they frequently undermine young plants in forest nurseries and forest stands, and they gnaw young plants and the roots of forest trees. Some of them can climb, so they gnaw the bark of fully grown trees. Most frequently they gnaw the bark of young plants 2–15 years old. They completely gnaw through young plants and ring the older ones or gnaw them on the sides. When they multiply, they cause real waste in cultures and forest nurseries. Forest areas offer abundant food to rodents, good conditions for reproduction and hibernation, as well as protection from natural enemies. Forest areas rich in ground (grassy) vegetation are particularly suitable for these mammals. They are particularly abundant in forests which are bordered by fields and meadows. In autumn mice migrate to border forests. These mammals rarely gnaw roots. Such damage is mostly caused by *Arvicola terrestris*. According to the report of the Croatian Board for Aspens (1995), in 1988 this pest destroyed about 150 ha of willow and aspen culture, gnawing in the winter months the bark of the offshoots of trees underground or immediately above the ground. This occurred in the localities of Erdutski Rit and Bjelobrdski Rit. Efforts to establish the number and to control this species were not successful.

In the period from 1980–1994, the biggest damage from rodents was noted in 1994 over an area of 3,947.51 ha, while considerable damage was registered in 1989 (2,905 ha), in 1990 (2,596.10 ha) and in 1993 (2,293.87 ha). In the period from 1980-1988 damage was very small. For the years 1991 and 1992, the Diagnostic Prognostic Service of the Institute of Forestry of Jastrebarsko does not have precise data on damaged areas due to the war in the Republic of Croatia. Control of these pests on the field in the period from 1980-1994 was most frequently done by chemical methods using various rodenticides.

The extent of damage for 1995 was examined by carrying out a survey in all forest offices of the public enterprise "Croatian forests". The aim of the survey was to obtain high-quality data on the harmful effects of rodents in forest stands of Croatia in 1995 (areas of damaged forest stand, the season when the damage appeared, the species of the pest, the population density of the pests, methods of control, etc.).

According to the data from all forest offices of the public enterprise "Croatian forests", damage on forest areas caused by rodents in 1995 was registered on 3,795 ha.

Most of the damaged forest areas in 1995 were registered in the area of the Forest Office of Vinkovci, while on the areas of the Forest Office of Buzet, the Forest Office of Gospić and the Forest Office of Senj, damage was not registered.

Damage caused by rodents during 1995 was mostly done in autumn, winter and early spring. Damage was mostly done on forest seeds (acorn), young growth and young plants in the communities of pedunculate oak. In the beech stand, damage on forest seed was registered in the Forest Office of Ogulin (Forestry Josipdol) and the Forest Office of Nova Gradiška (Forestry Slavonski Brod). In the stand of the sessile oak, damage on the forest seed was registered only in the area of the Forest Office of Našice, while damage by small rodents on the seeds of the bay oak was registered in the Forest Office of Split (Forestry of Sinj).

The age of damaged forest stands varies and ranges from one to 130 years, depending on whether damage was done on young plants (plants at an age from one to ten years) or on forest seeds (where the age of the stand is most frequently over 70 years). According to the results of the survey, damage to the bark of young plants is mostly done by voles (subfamily Arvicolinae), while damage to forest seeds was done by mice (subfamily Murinae).

Establishment of the population density of rodents in 1995, according to the results of the survey, was done in several Forest Offices: the Forest Office of Vinkovci, the Forest Office of Bjelovar, the Forest Office of Požega, the Forest Office of Sisak and in the Forestry of Đurđevac (the Forest Office of Koprivnica).

In the forestry of Croatia in 1995, the most frequent method of controlling rodents in increased numbers was a chemical method, and among rodenticides, the most frequently used were "Faciron" and "Brodilon", while "Ratox", "Antikolin" and "Arex" were rarely used.

The control of rodents (deratization) includes various preparations and preliminary work which has to be done before carrying out the control in practice. An elaboration of the plan of control, informing people, as well as testing the efficacy of the deratization are some of the tasks which require the presence of professional staff on these occasions. Most of the Forest Offices in which high numbers of rodents were established asked for the help of professional staff in carrying out deratizational measures (veterinaries or scientists whose subject of research is small mammals). High-quality processes of deratization resulted in the decrease of damage in almost all localities. On the area of the Forest Office of Sisak, after the control of pests was carried out, damage decreased by 80 %, while on the areas of the Forestry of Križevci and Slavonski Brod, deratization was not as successful as expected, which can be the result of low-quality control. From the account of the problems of rodents, it is obvious that further research into these areas is necessary in lowland forests, and this is described further in the paper.

METHODS
METODE RADA

In research so far, already-known and elaborated methods of biological study have been used. Most of them are described in the scientific papers of the authors who examined species of the family Muridae in a similar way (Zejda & Holišova 1971, Kovačić 1988, Kirkland et al. 1990, Trilar 1991, Zukal & Gaisler 1992, Kirkland & Sheppard 1994). In this study, the intensity of damage on young plants and forest seeds was established by individual methods.

During the research, the used methods were divided into three groups:

a) The field methods of establishing the population density and sampling of rodents
   1. Modified Standard Minimum Method with snap traps (Zejda & Holišova 1971, Pelikan 1971);
   2. "Y Method" (Kirkland et al. 1990, Zukal & Gaisler 1992, Kirkland & Sheppard 1994);
   3. Linear transect (Androić et al. 1981, Crnković 1982).

b) Field methods of establishing the intensity of damage
   1. Collecting of fallen acorns;
   2. An analysis of the damage of forest plants.

c) Laboratory methods
   1. Determination and treating of morphometric features of the caught animals (Niethammer & Krapp 1978, 1982);
   2. Examination and analysis of collected acorn;

d) Mathematical methods of determining the population density
   1. Multiple Regression Method (Poole 1974);
   2. The method of calculating population density on the surface unit (Zukal & Gaisler 1992);
   3. Relative population density determined by the method of linear transect (Androić et al. 1981, Crnković 1982);
   4. Comparison of population density of rodents calculated by different methods (t-test, Pranjić 1986).

ESTABLISHING THE POPULATION DENSITY AND SAMPLING OF ANIMALS
TERENSKE METODE ZA UTVRĐIVANJE BROJNOSTI I UZORKOVANJE ŽIVOTINJA

Taking measures for timely rodent control in order to decrease the intensity of damage to young plants and forest seeds is only possible with a periodical analysis of the population density of these animals. For that purpose, several methods are used, which, according to Tapper (1976), can be divided into three main groups. They are primary, secondary and tertiary methods. By primary methods, animals are sampled in an area of a precisely determined size ("Capture–recapture method", "Y Method", "Standard Minimum Method"), while by secondary methods the animals from an incompletely defined area are sampled (linear transect). All methods which do not sample animals are tertiary methods and the density of population is determined indirectly through signs of the animals' activities, like counting traces or droppings (Bider 1968, Lord et al. 1970, Lidicker 1973). The advantages of tertiary methods are that they do not influence the population, require very little equipment and sometimes only one coming to the field is enough. Their main disadvantage is obtaining exact relations with the actual density of the population, achieving only relative values. In this study, three methods were used by which the population density of small rodents in the forests of Turopoljski Lug was determined.

Standard Minimum Method consists of establishing the number of the population collected in the catching places of a particular area. This method was suggested by Grodzinski et al. (1966), involving the catching of animals over a period of five nights in an area of 5.76 ha. Traps are placed within a staked out "square" on precisely defined catching places. According to the suggestion of Grodzinski et al. (1966), the square consists of 16 x 16 catching places at a mutual distance of 15 m. Two snap traps are placed in each catching place (a total of 512 traps). According to Zejda & Holišov (1971) and Pelikan (1971), the 16 x 16 square in catching places is too big, as the same results are achieved with a smaller square of 8 x 8 in catching places on an area of 1.44 ha. For success in this method, it is important that the conditions of catching are the same, i.e. that all members of the population have the same chance of being caught, that at the time of catching, deviations of mortality are slight, that there are no immigrations and emigrations of animals in the period of catching and that the weather conditions are approximately the same.

The population density of rodents is calculated by a method of linear regression. Results of the use of the minimum square method have shown that the first day's catch was the biggest and that it decreases during other days (Grodzinski et al. 1966). In the field research, snap traps with a wooden base, a "Museum Special" type, and snap traps with a metal base were used. The "Museum Special" trap proved to be of better quality in the field than metal ones, for three reasons:

1. a wooden base is more resistant to atmospheric influences (particularly humidity) in comparison to traps with a metal base which tend to corrode;
2. when killed, the animal's skull is not damaged, as the length of the spring enables it to catch the animal behind the head. The whole skull is used to determine the species of the caught animal;
3. the preparation of the bait for this type of snap trap is faster and simpler.

For the "Museum Special", a mixture of oat cereals and canned sardines was used as bait. For the metal snap traps, a thick cloth (about 1 cm^2) dipped into oil in which onion and bacon were fried was used as bait. Such baits are efficient without having to be replaced (they keep their smell to catch rodents for several months). They are frequently used in practice, thanks to their efficiency. The catch of animals on the study area lasted five nights. The date of the catch, the name of the trial surface and the symbol of the catching place on which the catch was registered were noted. Further treatment of animals (determination, measuring of length and weight) was done in the laboratory of the Croatian Natural History Museum in Zagreb. In the period from April 1995 to November 1996, a study area was activated four times (April 1995, and May, June and October 1996).

The "Y Method" is the latest method of determining the population density of rodents. Kirkland and Sheppard (1994) used it in their research of the population dynamics of terrestrial mammals in the forests of North America.

The aims of using this method in Turopoljski Lug, were to examine its efficiency in determining the population density of rodents in lowland pedunculate oak forests and to compare the obtained results with the results of the population density of rodents obtained by other methods. The "Y" method is based on catching small terrestrial mammals in pitfalls filled with water. The catch is done on a surface area of 0.735 ha (Zukal & Gaisler 1992, Kirkland & Sheppard 1994). The "Y" method is included in a group of primary methods of determining the population density of small mammals. Kirkland & Sheppard (1994) caught small mammals with the "Y" method in a period of 10 hunting nights. Zukal & Gaisler (1992) established that to calculate the density of populations, only the results of the first five nights of catching can be taken into consideration, due to the edge effect and the immigration of animals from the surrounding area.

Due to the great influence of weather changes on the activity of animals (Bider 1968) and also on the catch of animals by the "Y" method and the minimum square method, in the period of research (April 1995 and May 1996), the air temperature was measured daily, and rain, snow and clouds were registered (Table 9). Temperature was measured by a digital thermometer at 7.30. The "Y" method showed very good results in the years of a high population of animals (Zukal & Gaisler 1992). Apart from the population density of rodents, it can also determine the population density of other animals that live on the ground surface (insects from the family Carabidae, frogs, insectivorous species, salamanders, etc.). The disadvantages of the "Y" method are:

1. a lot of time spent on preparing a plot on the field;
2. frequent damage to partitions by big game, wind, snow, etc.

The "Y" method was applied in April 1995 and in May and October 1996 in a forest community *Carpino betuli-Quercetum roboris*, subcompartment 98a. Consideration was given to the choice of its microlocation. Two study areas were placed on the field with a richly developed layer of shrubbery. According to Vraneš (1972), rodents more frequently stay on such a habitat than on fields with a poorly developed layer of ground growth and shrubbery. The surfaces were placed at a distance greater than 100 m which prevents the catch of animals from a neighbouring surface. The study area for the "Y" method was placed in the same section and with the same plant community as the described study area with snap traps, in order to compare the results of the animal catch by these two methods.

Ten pitfalls were placed from the central point in three directions at an angle of 120° (the shape of the letter "Y", according to which the method was named). The three containers in each direction were completely buried so that their upper edge was level with the soil at a distance of 5 m. The length of one line of the "Y" was 15 m.

Metal containers were used with a diameter of 12 cm and 20 cm deep. To prevent the filling of containers with water above the recommended level during rain, they were pierced on the side, at a depth of 10 cm. 25–30 cm high partitions were put between the catching containers, which were buried 3–5 cm in the ground, to prevent animals passing under them and serving to direct animals towards the vessels. PVC bands were used which were tightened by wooden sticks one metre high. The containers were filled with water to prevent the escape of the animals and in order to kill them by drowning. The surfaces were visited for five days (Zukal & Gaisler 1992) early in the morning.

The method of linear transect is included in the group of secondary methods of determining the population density of small mammals. The absolute population density cannot be determined by this method, but only relative relations. Its advantage is that within a short time the population density of animals over a larger area can be researched. The traps and the bait as described in the standard minimum method were used. Snap traps were placed in a straight line, at a distance of five metres. The traps were inspected in the morning. 50 or 100 traps were placed in the chosen direction. The population density of rodents was determined by this method 10 times: in spring (1x) and in autumn (4x) 1995 and in spring (1x), in summer (1x) and in autumn (3x) 1996. A hunting transect was activated in subcompartments 58a, 59a, 62a, 75a and 90a. The obtained results were compared with the results of the population density of rodents obtained by other methods.

The population density of small mammals was expressed by the percentage of the catch of animals in relation to the total number of placed traps. If the catch is 1–2 % - the density of population is low; if the catch is up to 10 % - the population density is moderate; the values of 30–60 % are obtained with an increased population density; a catch bigger than 80 % means that there is heavy infestation (Androić et al. 1981). If the number of animals on the area is increased, the animals should be controlled.

MATHEMATICAL METHODS
MATEMATIČKE METODE

Relative and absolute methods of determining the population density were used. Results of a higher quality (Delany 1974) are obtained in their combined use.

Multiple Regression Method
Statistička metoda linearne regresije

To process the sample obtained by the method of the minimum square, the Multiple Regression Method of the programme Statistica (Stat Soft; 1994) was used. The Multiple Regression Method is based on the presumptions that:

1. Values of the independent variable are fixed and measured without mistakes;
2. Values of the dependent variable are on the ordinate;
3. For the values of the independent variable, the values of the dependent variable are independently and normally distributed;
4. The distribution of points around the regression line is equal on both sides (Pool 1974).

The purpose of the method is to determine the dependence of one variable (X) on the other variable (Y), in which the value "Y" corresponds to each value "X". If there is a dependence between them, then the points with co-ordinates "X" and "Y" are on the regression line. Its existence can be shown by the expression: Y = a + bX, where: X = an independent variable (a cumulative catch of animals during previous days); Y = a dependent variable (a catch of animals per day); a = segment on the ordinate; b = the line gradient.

The segment on the ordinate ("a") represents the value of the function b=0 and is calculated by the expression: a = Y – bX, where: Y is the arithmetic mean of the number of animals per number of days, X is the arithmetic mean of the cumulative catches per number of days.

The line gradient (the regression coefficient, "b") represents the relation between variables "X" and "Y" and is calculated:

$$b = \frac{\Sigma xy}{x^2} \qquad \Sigma xy = \Sigma X_i Y_i - \frac{(\Sigma X_i)\cdot(\Sigma Y_i)}{n}, \; i=1,2\ldots n$$

$$\Sigma x^2 = \Sigma X^2 - \frac{(\Sigma Xi)^2}{n}, \ i=1,2\ldots n$$

n = number of catching days

The Multiple Regression Method for the estimation of the population size is used in such a way as to calculate the parameters of the regression line "a" and "b" according to the daily catch (values on the ordinate) and cumulative catches of the previous days (values on the abscissa). The degree of dependence of values "X" and "Y" is expressed by the correlation coefficient, and is calculated:

$$r = \frac{N\cdot(\Sigma XY)-(\Sigma X)\cdot(\Sigma Y)}{\sqrt{[N\cdot(\Sigma X^2)-(\Sigma X)^2]\cdot[N(\Sigma Y^2)-(\Sigma Y)^2]}}$$

Variables X and Y are in linear correlation for $-1 < r < 1$. If the correlation coefficient ("r") is closer to the absolute unit, the correlation is higher. The number of animals on the plot is represented by a point in which the regression line intersects the abscissa axis (Y = 0). An adequate approach for research of the population density of rodents requires a regular catch of animals in the field (Delany 1974).

The method of calculating on a surface unit
Metoda preračunavanja na jedinicu površine

In order to compare the results of the minimum square method (the area of 1.44 ha) and the "Y" method, the catch of animals from both "Y" plots was regarded as a single plot catch (the area of 1.47 ha because they were added). In that case, the areas of catch by the study area method and by the "Y" method were almost identical.

The results of the catch obtained by the "Y" method on five hunting nights were regarded as the total animal catch. The number of caught animals on the surface was the real number of animals on that surface (Zukal & Gaisler 1992). The number of animals from the surface was converted into the number of animals on one hectare according to the expression:

$$N/ha = \frac{10.000\cdot N/p}{P}$$

where:
N/h = the number of animals on one hectare;
N/p = the number of animals on a trial surface (two "Y");
P = the surface in m^2 (14,700 m^2).

t-test

To compare the calculated values of the number of rodents on one hectare according to the "Y" method and the multiple regression method (Table 8), a t-test was used. It was used with small samples ($n_1<30$ and $n_2<20$) to examine the difference between the arithmetic means which follow t-distribution (Pranjić 1986). The aim was to establish if there was a significant difference in the obtained results between these two methods. As a zero-hypothesis, it was assumed that there was no difference between N/haY and N/haKV, i.e. Ho; N/haY = N/haKV. In that case, the following expression was used:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{n_1+n_2}{n_1 \cdot n_2}}}$$

where:

$\bar{x}_1$ = arithmetic mean of the elements from samples "1" (the number of animals per one hectare in the seasons of catch calculated by the multiple regression method);

$\bar{x}_2$ = arithmetic mean of the elements from samples "2" (the number of animals per one hectare in the seasons of catch calculated by the "Y" method);

n_1 = number of elements in sample "1";

n_2 = number of elements in sample "2";

s = standard deviation.

To calculate standard deviation, the following expression was used (Pranjić 1986):

$$s = \sqrt{\frac{\Sigma(x_i - \bar{x}_1)^2 + \Sigma(x_j - \bar{x}_2)^2}{n_1+n_2-2}}$$

x_i = the elements of sample "1";

x_j = the elements of sample "2".

FIELD METHODS OF DETERMINING THE INTENSITY OF DAMAGE
TERENSKE METODE UTVRĐIVANJA INTENZITETA OŠTEĆENJA

Determination of the intensity of damage is one of the parameters in the estimate of the population density of rodents in a forest stand. The damage they cause is present in the form of gnawing on seeds and on young plants in the form of two parallel shallow grooves 1–2 mm wide (personal measuring on the field). If the colour of the gnawed place is light, it is new damage. Vajda (1974) emphasises that mice are mostly the pests of forest seeds, while voles mostly do damage to young plants (saplings and seedlings).

Collecting the fallen acorn
Skupljanje otpaloga žira

Fallen acorn was collected every 14 days to establish the intensity and dynamics of damage to forest seeds from small rodents. Collected acorns from 5 study areas which were of the size 3 x 3 m each served as a sample. The choice of location for collecting was mostly under the crown of the trees which had the richest fruit. Also of interest was if the catch of rodents influenced the quantity of damage and if seeds were collected outside the study area on the part of the stand 100 m away from its edge, where there was no catch. The date of the taking of the sample, the number of the section and the name of the trial surface on which the seeds were collected were noted.

An analysis of the damage of forest plants
Analiza oštećenosti šumskih sadnica

The intensity of damage to young plants in subcompartment 58a was determined. Damage was noticed on young plants in the form of gnaws on a large number of plants in the lower part of stems. According to the bite marks, it was obvious that they were done by rodents. A darker colour of the gnawed place meant that damage was older than a year. The size of damage proved that at the time of its appearance, the population density of the animals on the field was increased. On this site, linear transects were placed to continue following the population density of rodents and to observe the dynamics of the appearance of new damage on young plants. Plants were examined on seven surfaces 5 x 5 m in size in order to follow the intensity of new gnaws on them. The intention was to include as large a number of plants as possible in the research. The height of a stem and the height of the damage on all the plants within the surfaces were noted (a total of 430 pieces). The measurements were written in the field form. The percentage of the damage for each plant was calculated:

$$\text{the dama ge of the plant} = \frac{\text{the height of the damage}}{\text{the height of the plant}} \times 100$$

Due to various intensities of damage, the results were arranged in five groups:
0 – undamaged plant;
1 – partially damaged plant (individual, shallow gnaws);
2 – a plant damaged from 0–5 %;
3 – a plant damaged from 5–10 %;
4 – a plant damaged more than 10 %.

Plants on the marked surfaces were examined in the period May–November 1996, six times all together.

LABORATORY METHODS
LABORATORIJSKE METODE

Determination and treatment of morphometric features of the caught animals
Determinacija i obrada morfometrijskih osobina ulovljenih životinja

The caught animals were sorted according to the experimental plots and the dates of catch and were placed in containers with 75 % alcohol. The animals were determined using the books Niethammer & Krapp (1978, 1982). The following parameters of the animals were measured: the body weight, the length of the body and tail, the length of the tail, the length of the hind foot without claws and the length of the ear. The body weight was measured using the scale "Pesola" to an accuracy of 0.5 g, and the length with a ruler to an accuracy of 0.5 mm. The sex and the approximate age of the caught animals were determined. The treated animals were labelled. All the samples were deposited in the collection of mammals of the Croatian National History Museum in Zagreb.

Examination and analysis of the collected acorn
Pregled i analiza skupljenoga žira

The treatment of the samples of pedunculate oak was done immediately after they had been brought from the field. This consisted of counting seeds in the sample and in determining the number of seeds damaged by rodents and other biotic factors (insects and fungi). By examining the acorns in October and November 1996, the dynamics and the intensity of damage to forest seeds caused by small rodents was followed. An acorn on which the described damage was visible was separated and further analysed. Its length and width was measured using a slide calliper and an eyepiece estimate of the damage was made. The name of the damaged part of the acorn was noted (basal, top or a central part). The separated fruit was further analysed in order to establish if there was some other visible damage from other pests, apart from gnaws *(Cydia* spp., *Balaninus* spp., fungi, etc.). In this way, it was possible to answer the question: "Do rodents more frequently damage healthy seeds or do they damage seeds "attacked" by other pests?"

RESULTS
REZULTATI

THE DAMAGED CONDITION OF FOREST SEEDS
OŠTEĆENOST ŠUMSKOGA SJEMENA

The size of the damage by rodents on forest seeds was determined by a detailed examination of the collected acorn of pedunculate oak from the study area. Damage was easily noticeable and was in the form of characteristic shallow bite marks of various intensities.

Seeds were also damaged by various kinds of fungi and insects from the genus *Balaninus* and the genus *Cydia*. The biology of the mentioned insects is closely connected with the oak seed. Larvae emerge from the seeds by biting with strong mandibles through the exit hole from the interior of the acorn. For species of the genus *Balaninus* (ordo Coleoptera), the exit hole is round, while for leaf roller moths (ordo Lepidoptera) (Hrašovec 1993) it is oval.

Seeds attacked by fungi were also separated from the samples. The damaged acorn had a dense net of hyphae which covered its cupule and wall. The results of the analysis of the damage of seeds are shown in Table 1. In the research on the size of damage on seeds, a total of 4,817 pieces of pedunculate oak acorn were examined. Analysis determined that 82.90 % of the seeds in the sample were healthy, while the rest were damaged by the following agents: rodents 2.35 %, acorn weevil *(Balaninus* spp.*)* 6.70 %, leaf roller moths *(Cydia* spp.*)* 6.29 % and fungi 1.76 %. Figure 1. shows the dynamics of damage on pedunculate oak acorns by rodents.

Figure 1. The dynamics of damage by rodents according to the surfaces on the samples of the pedunculate oak seed (October–November 1996)
Slika 1. Dinamika štete od mišolikih glodavaca po plohama na uzorcima sjemena hrasta lužnjaka (listopad–studeni 1996)

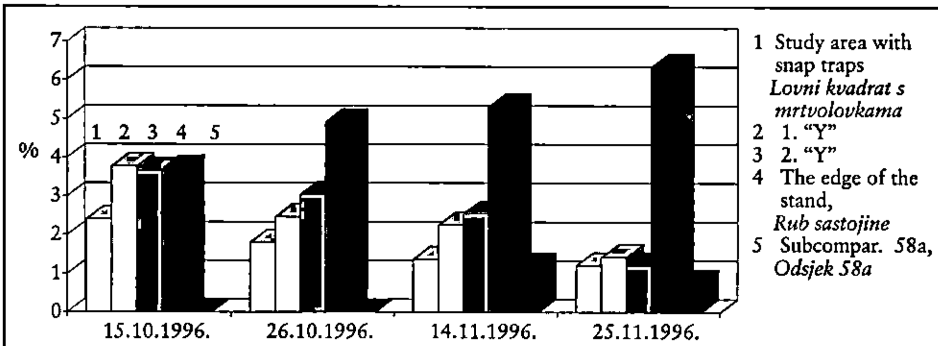


Table 1. The damaged condition of the pedunculate oak acorn by biotic factors
Tablica 1. Oštećenost žira hrasta lužnjaka od biotskih čimbenika

A trial surface *Pokusna ploha*	The quality of the seed *Kakvoća sjemena*	The sample collected on *Uzorak skupljen dana* 15.10.1996.		The sample collected on *Uzorak skupljen dana* 26.10.1996.		The sample collected on *Uzorak skupljen dana* 14.11.1996.		The sample collected on *Uzorak skupljen dana* 25.11.1996.	
		pieces. *kom.*	%	pieces *kom.*	%	pieces *kom.*	%	pieces *kom.*	%
Study area with snap traps (subcomp. 98a) *Lovni kvadrat s mrtvo-lovkama (odjel 98a)*	healthy *zdravo*	197	79.12	178	80.18	186	84.55	211	85.08
	damaged by rodents *oštećeno (glod.)*	6	2.41	4	1.80	3	1.36	3	1.21
	damaged by *oštećeno* (*Balaninus* spp.)	18	7.23	15	6.76	13	5.91	11	4.44
	damaged by *oštećeno* (*Cydia* spp.)	21	8.43	19	8.56	18	8.18	14	5.64
	damaged by funghi *oštećeno (gljive)*	7	2.81	6	2.70	-	-	9	3.63
	Total *Ukupno*	249	100.00	222	100.00	220	100.00	248	100.00
The first "Y" (subcomp. 98a) *Prvi "Y" (odjel 98a)*	healthy *zdravo*	187	78.24	168	82.76	158	88.76	175	82.94
	damaged by rodents *oštećeno (glod.)*	9	3.77	5	2.46	4	2.25	3	1.42
	damaged by *oštećeno* (*Balaninus* spp.)	22	9.21	14	6.90	8	4.49	19	9.00
	damaged by *oštećeno* (*Cydia* spp.)	16	6.69	10	4.93	6	3.37	14	6.64
	damaged by funghi oštećeno (gljive)	5	2.09	6	2.95	2	1.13	-	-
	Total *Ukupno*	239	100.00	203	100.00	178	100.00	211	100.00
The second "Y" (subcomp. 98a) *Drugi "Y" (odjel 98a)*	healthy *zdravo*	203	82.52	169	85.79	172	87.31	216	87.10
	damaged by rodents *oštećeno (glod.)*	9	3.66	6	3.04	5	2.54	3	1.21

	damaged by *oštećeno* (*Balaninus* spp.)	19	7.72	12	6.09	11	5.58	15	6.04
	damaged by *oštećeno* (*Cydia* spp.)	14	5.69	10	5.08	7	3.55	11	4.44
	damaged by funghi *oštećeno (gljive)*	1	0.41	-	-	2	1.02	3	1.21
	Total *Ukupno*	246	100.00	197	100.00	197	100.00	248	100.00
The edge of the stand (subcomp. 98a) *Rub sastojine (odjel 98a)*	healthy *zdravo*	248	83.50	226	79.30	176	85.02	163	86.24
	damaged by rodents *oštećeno (glod.)*	11	3.71	14	4.91	11	5.31	12	6.35
	damaged by *oštećeno* (*Balaninus* spp.)	14	4.71	17	5.96	7	3.38	8	4.23
	damaged by *oštećeno* (*Cydia* spp.)	16	5.39	21	7.37	11	5.31	6	3.18
	damaged by funghi *oštećeno (gljive)*	8	2.69	7	2.46	2	0.98	-	-
	Total *Ukupno*	297	100.00	285	100.00	207	100.00	189	100.00
Subcomp. 58a *odjel 58a*	heathy *zdravo*	241	79.80	288	78.90	207	82.47	224	85.17
	damaged by rodents *oštećeno (glod.)*	-	-	-	-	3	1.20	2	0.77
	damaged by *oštećeno* (*Balaninus* spp.)	29	9.60	37	10.14	16	6.37	18	6.84
	damaged by *oštećeno* (*Cydia* spp.)	23	7.62	29	7.95	21	8.37	16	6.08
	damaged by funghi *oštećeno (gljive)*	9	2.98	11	3.01	4	1.59	3	1.14
	Total *Ukupno*	302	100.00	365	100.00	251	100.00	263	100.00

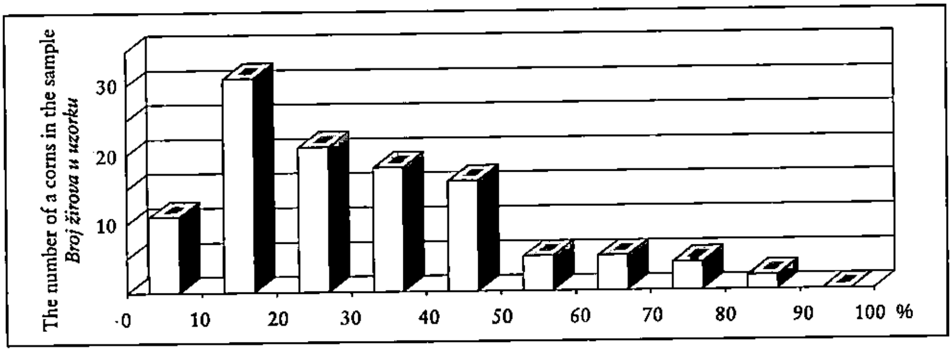
In the first collection of seeds (15.10. 1996), the condition of acorns damaged by rodents was almost equal and ranged from 2.41% to 3.77 % (Figure 1). In a forest stand under normal management, such a size of damage is considered as acceptable. In the sample collected from the trial surface in subcompartment 58a, not a single damaged sample of acorn was found, which was repeated in the next collection two weeks later and which is an indirect indicator that the number of rodents in the subcompartment 58a was small.

On analysing the seeds from the surfaces of both "Y" and the study area (subcompartment 98a) collected approximately two weeks after first coming to the field (26.10. 1996), a noticeable decrease in seeds damaged by rodents was found in the samples. The decrease in the quantity of damaged seeds continued until the end of November 1996.

The results of the analysis of the collected material from the edge of the stand on which there was no catch of animals were different. Checking samples from that surface, an increase in damaged seeds from 3.77 % to 6.35 % was noticed.

A damaged part was estimated on each separated acorn and visible bites by rodents (a sample of 113 pieces) were viewed with an eye-piece. The damage was expressed as a percentage in relation to the size of the seed (Figure 2).

Figure 2. The percentage of the damaged condition of the seed in a sample
Slika 2. Postotna oštećenost žira u uzorku



In the examined sample there were 31.21 % of acorns with an estimated damage of 10-20 % of the total area, while 14.17 % of the seeds had an estimated damage higher than 50 % of the total size. In the same sample, an examination was made on which part of the acorn (base, middle or the top part) was mostly attacked by rodents (Figure 3). The examination showed that 59.77 % of seeds were damaged on the basal part, 28.32 % on the top part, while 11.91 % were damaged in the middle part. When analysing the sample of seed damaged by rodents, it was also examined if there was damage by other pests (*Balaninus* spp., *Cydia* spp. fungi, etc.) apart from that by rodents. The aim of this research was to determine whether rodents more frequently attack healthy, undamaged acorn, or if they prefer damaged seeds already attacked by other pests. The results of the analysis of the samples are shown in Figure 4.

It was established that 73.45 % of the sample was damaged only by rodents. Damage by other biotic factors on this portion of the samples was not noticeable.

Figure 3. The damaged condition of parts of the acorn
Slika 3. Udio oštećenosti dijelova žira

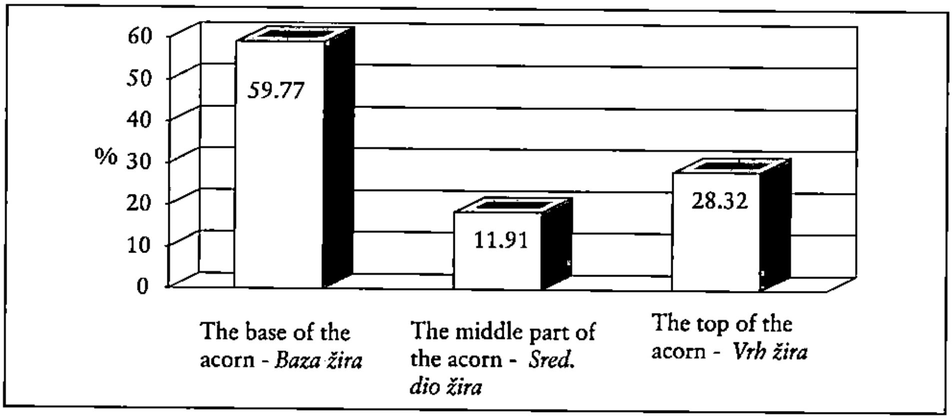
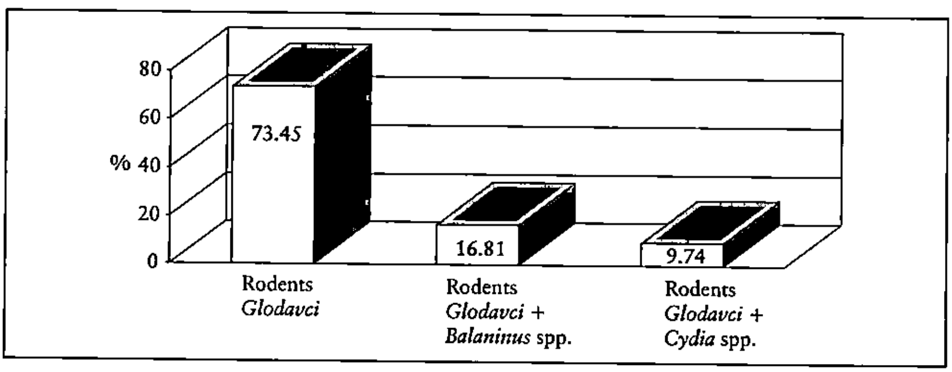


Figure 4. The damaged condition of the acorn by biotic factors
Slika 4. Oštećenost žira od biotskih čimbenika



On 16.81 % of the samples, apart from gnaws by rodents, exit holes of insects from the genus *Balaninus* were visible, while on 9.74 % of the acorn sample, apart from gnaws by rodents, exit holes by insects from the genus *Cydia* were visible. Rodents most frequently damaged acorn which had not been attacked by acorn weevil and leaf roller moths. It was not noticed that rodents had damaged any acorn which had previously been infected by fungi.

THE DAMAGED CONDITION OF FOREST PLANTS
OŠTEĆENOST ŠUMSKIH SADNICA

In subcompartment 58a, in a forest community of *Genisto elatae-Quercetum roboris*, the intensity of damage by small rodents on new growth was studied. Research began in spring 1996 (in May) on seven surfaces. In order to examine precisely the dynamics of damage, with the aim of defining the period of its most frequent appearance, five field measurements were taken, during which a total of 2,580 forest plants (a total of 430 plants x 6 examinations) were treated. In the first examination of plants (May 1996) all noted damage by rodents was older than a year (autumn 1994 and winter 1994/95). On that occasion no new damage was noticed. Either no gnaws or gnaws of various intensities (plants without damage, partially damaged plants and completely damaged plants) were observed. Figure 5 shows the percentage of damaged plants in the sample on the surfaces. On all surfaces, more than 50 % of damaged material was recorded. The smallest percentage of damaged plants after the first examination was registered on surface 1, amounting to 58.42 %, while the most damaged plants in the sample were registered on surface 2 (97.38 %). On other surfaces, the damage of plants was between 80 % and 95 %.

Table 2 shows the analysis of damage of plants after the first examination in spring 1996 and according to the described categories of damage (see "Methods" section). Plants with a percentage of damage between 5 % and 10 % (degree of damage 3) (Table 2) were the most frequent. The second examination of plants on the study area (July 1996) did not show any new damage.

During the examination of young plants in the middle of October 1996, new gnaws by small rodents on surface 4 (one piece of damage), surface 6 (two pieces of damage) and surface 7 (two pieces of damage) were noticed. All were noted on plants which were already damaged. Rodents gnawed undamaged parts of bark up to a height of 10 cm from the soil surface. During the fourth examination of samples (26.10. 1996), no gnaws were noticed on any plant. In the middle of November 1996, new damage was noticed only on two plants on surface 7. The amount

Figure 5. The damaged condition of plants on surfaces 1–7
Slika 5. Oštećenost biljaka na plohama 1– 7

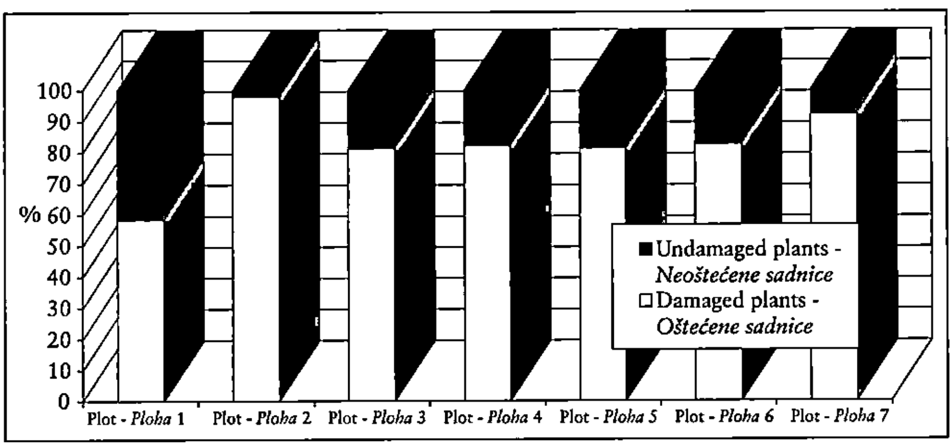


Table 2. The population density of plants on plots according to the degrees of damage
Tablica 2. Brojnost biljaka na pokusnim plohama po stupnjevima oštećenosti

N° of the plot *Broj plohe*	The degree of damage *Stupanj oštećenosti* 0		The degree of damage *Stupanj oštećenosti* 1		The degree of damage *Stupanj oštećenosti* 2		The degree of damage *Stupanj oštećenosti* 3		The degree of damage *Stupanj oštećenosti* 4		Total *Ukupno*	
	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%
1.	42	41.58	32	31.69	3	2.97	8	7.92	16	15.84	101	100.00
2.	1	2.13	8	17.02	5	10.64	21	44.68	12	25.53	47	100.00
3.	6	18.75	8	25.00	3	9.38	9	28.12	6	18.75	32	100.00
4.	10	17.86	16	28.57	4	7.14	18	32.14	8	14.29	56	100.00
5.	6	18.75	3	9.38	5	15.63	15	46.88	3	9.36	32	100.00
6.	8	17.39	10	21.74	7	15.22	14	30.43	7	15.22	46	100.00
7.	9	7.76	7	6.03	38	32.76	50	43.10	12	10.35	116	100.00
Σ	82	19.07	84	19.54	65	15.12	135	31.39	64	14.88	430	100.00

of newly damaged plants in this examination was 0.47 %. With the examination of samples at the end of November 1996, new damage was noticed only on one plant of common ash on surface 1. The measured gnaw was partial, 7.4 cm long.

In the period from July to November 1996 (not taking into consideration the first examination in May 1996), among 2,150 examined plants, new damage by rodents was noticed on eight plants. The estimate of damage on plants, as an indirect method of determining the number of rodents on this site, indicated a low population of mentioned animals.

THE POPULATION DENSITY OF RODENTS
BROJNOST POPULACIJE MIŠOLIKIH GLODAVACA

In the forests of Turopolje, the following species of rodents were determined: *Apodemus flavicollis, A. sylvaticus, A. agrarius, Clethrionomys glareolus, Microtus arvalis* and *M. agrestis.*

THE POPULATION DENSITY OF RODENTS CALCULATED BY MULTIPLE REGRESSION METHOD
BROJNOST MIŠOLIKIH GLODAVACA IZRAČUNATA METODOM LINEARNE REGRESIJE

Four species of rodents were caught, with a total of 39 animals (Table 3).

Table 3. The catch of rodents by the minimum square method according to species and dates of the catch

Tablica 3. Ulov mišolikih glodavaca metodom minimalnoga kvadrata po vrstama i datumima ulova

The date of the catch *Datum ulova*	The catching day *Lovni dan*	*Clethrionomys glareolus*	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Microtus arvalis*	ΣΣ
20.04.1995.	1	1	7	–	–	8
21.04.1995.	2	–	1	–	–	1
22.04.1995.	3	–	4	–	–	4
23.04.1995.	4	–	–	–	–	–
24.04.1995	5	1	2	–	–	3
Σ		2	14	–	–	16
03.05.1996.	1	–	2	–	–	2
04.05.1996.	2	–	–	–	–	–
05.05.1996.	3	–	–	–	–	–
06.05.1996.	4	–	–	–	1	1
07.05.1996.	5	–	–	–	–	–
Σ		–	2	–	1	3
11.07.1996.	1	–	3	–	–	3
12.07.1996.	2	–	2	–	–	2
13.07.1996.	3	–	1	–	–	1
14.07.1996.	4	–	–	–	–	–
15.07.1996.	5	–	–	–	–	–
Σ		–	6	–	–	6
23.10.1996.	1	–	5	–	–	5
24.10.1996.	2	–	4	–	–	4
25.10.1996.	3	–	2	–	–	2
26.10.1996.	4	–	–	–	–	–
27.10.1996	5	–	2	1	–	3
Σ	–	–	13	1	–	14
ΣΣ	–	2	35	1	1	39

The dominant species was *A. flavicollis* (89.75 % of the catch). 5.13 % of the caught animals belonged to the genus *C. glareolus*, while the *A. sylvaticus* and *M. arvalis* amounted to 2.56 % of the total sample. Table 4 shows the results of the daily and the cumulative catch of animals per season of catches. The population density of rodents per surface (1.44 ha) for each season of catch was calculated by the method of linear regression. Converting the obtained results to a surface of one hectare, the population density of animals per hectare was calculated. These results are shown in Table 5.

Table 4. The account of daily (X) and cumulative catches (Y)
Tablica 4. Prikaz dnevnih (X) i kumulativnih (Y) ulova po sezonama izlova

The season of the catch *Sezona izlovljavanja*	April *Travanj* 1995	April *Travanj* 1995	May *Svibanj* 1996	May *Svibanj* 1996	July *Srpanj* 1996	July *Srpanj* 1996	October *Listopad* 1996	October *Listopad* 1996
x - daily catch *x - dnevni ulov* y - cumulative catch *y - kumulativni ulov*	X1	Y1	X2	Y2	X3	Y3	X4	Y4
Day *Dan* 1	8	0	2	0	3	0	5	0
Day *Dan* 2	1	8	0	2	2	3	4	5
Day *Dan* 3	4	9	0	2	1	5	2	9
Day *Dan* 4	0	13	1	2	0	6	0	11
Day *Dan* 5	3	13	0	3	0	6	3	11

Table 5. The population density of rodents on the plot (N/p) and on one hectare of the surface (N/ha) calculated by the multiple regression method
Tablica 5. Brojnost mišolikih glodavaca na pokusnoj plohi (N/p) i na jednom hektaru površine (N/ha) izračunata metodom linearne regresije

The season of the catch *Sezona izlovljavanja*	N / p	N / ha
April *Travanj* 1995	15.24	10.58
May *Svibanj* 1996	2.65	1.84
July *Srpanj* 1996	6.40	4.44
October *Listopad* 1996	15.54	10.79

THE POPULATION DENSITY OF RODENTS CALCULATED BY THE "Y" METHOD
BROJNOST POPULACIJE MIŠOLIKIH GLODAVACA IZRAČUNATA "Y" METODOM

The population density of the rodent population was investigated using the "Y" method in spring 1995 and in spring and autumn 1996. On both "Ys" five species of rodents were caught in a total of 34 animals (Table 6). *A. flavicollis* (67.65 %) was dominant. *C. glareolus* and *A. sylvaticus* were each present in 5.88 % of the sample while 11.76 % of the caught animals belonged to the species *M. arvalis*. *M. agrestis* was present in the sample at a rate of 8.87 %. Using the "Y" method, the number of animals were caught on 2 plots of a total area of 1.47 ha (N/p) per each catch season. Converting the obtained results to the surface of one hectare, the population density of rodents per hectare was determined (N/ha) (Table 7).

Table 6. The catch of rodents by the "Y" method according to species and dates of the catch
Tablica 6. Ulov mišolikih glodavaca "Y" metodom po vrstama i datumima ulova

The date of the catch *Datum ulova*	The catching day *Lovni dan*	*Clethrionomys glareolus*	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Microtus arvalis*	*Microtus agrestis*	ΣΣ
13.04.1995.	1	1	1	–	–	–	2
14.04.1995.	2	–	1	–	–	–	1
15.04.1995.	3	1	1	–	1	–	3
16.04.1995.	4	–	5	–	1	–	6
17.04.1995	5	–	1	–	1	–	2
Σ		2	9	–	3	–	14
03.05.1996.	1	–	–	–	–	–	–
04.05.1996.	2	–	–	–	–	–	–
05.05.1996.	3	–	–	–	–	–	–
06.05.1996.	4	–	–	–	–	2	2
07.05.1996.	5	–	–	–	–	–	–
Σ		–	–	–	–	2	2
23.10.1996.	1	–	9	2	1	1	13
24.10.1996.	2	–	4	–	–	–	4
25.10.1996.	3	–	–	–	–	–	–
26.10.1996.	4	–	–	–	–	–	–
27.10.1996	5	–	1	–	–	–	1
Σ	–	–	14	2	1	1	18
ΣΣ	–	2	23	2	4	3	34

Table 7. The population density of rodents on a plot (N/p) and on one hectare (N/ha) calculated by the "Y" method

Tablica 7. Brojnost mišolikih glodavaca na pokusnoj plohi (N/p) i na jednom hektaru (N/ha) izračunata "Y" metodom

The season of the catch *Sezona izlova*	N / p	N / ha
April *Travanj* 1995	14	9.52
May *Svibanj* 1996	2	1.36
October *Listopad* 1996	18	12.24

The arithmetic means of the population density of rodents per hectare by t-test (Table 8) determined by the multiple regression method and the "Y" method was compared.

Table 8. The population density of rodents on one hectare according to seasons of the catch calculated by the "Y" method (N/haY) and the multiple regression method (N/haKV). "x" denotes the arithmetic mean N/ha Y and N/haKV

Tablica 8. Brojnost mišolikih glodavaca na jednom hektaru po sezonama izlova izračunata "Y" metodom (N/haY) i metodom linearne regresije (N/haKV); "x" označava aritmetičku sredinu N/haY i N/haKV

The season of the catch *Sezona izlova*	N/haKV	N/haY
April *Travanj* 1995	10.58	9.52
May *Svibanj* 1996	1.84	1.36
October *Listopad* 1996	10.79	12.24
$\bar{x}$	7.74	7.71

The calculated "t" (t_{izr} = 0.007) was compared with the "t" tabular (t_{tab}= 4.303) for the reliability limit of 0.05 and the number of the degree of freedom n = 2. As $t_{izr} < t_{tab}$, it could be concluded that the zero-hypothesis was acceptable, i.e. the population densities of rodents calculated by the multiple regression method and the "Y" method were statistically significantly different from each other (Ho; N/haY = N/haKV). The results of the measurement of the weather conditions are shown in Table 9.

Table 9. Weather conditions in the forest community of the pedunculate oak and hornbeam (subcompartment 98a) according to the sampling days
Tablica 9. Vremenske prilike u šumskoj zajednici hrasta lužnjaka i običnoga graba (odjel 98a) po danima uzorkovanja

The date of the sampling *Datum uzorkovanja*	Cloudiness *Oblačnost*	Precipitation *Oborine*	The air temperature *Temperatura zraka* °C	The soil temperature *Temperatura tla* °C
13.04.1995.	cloudy *oblačno*	rain *kiša*	9.2	8.7
14.04.1995.	cloudy *oblačno*	rain, snow at night *kiša, noću snijeg*	6.4	6.2
15.04.1995.	cloudy *oblačno*	rain at night *noću kiša*	4.9	6.6
16.04.1995.	cloudy *oblačno*	rain *kiša*	8.4	6.9
17.04.1995.	fair *vedro*		7.7	7.7
20.04.1995.	partly cloudy *poluoblačno*	rain at night *noću kiša*	9.0	9.7
21.04.1995.	cloudy *oblačno*		12.0	11.1
22.04.1995.	fair *vedro*		9.1	10.7
23.04.1995.	fair *vedro*		9.9	10.7
24.04.1995.	cloudy *oblačno*	rain *kiša*	8.6	9.8
03.05.1996.	cloudy *oblačno*	rain at night *noću kiša*	8.2	9.1
04.05.1996.	fair *vedro*		7.6	9.4
05.05.1996.	fair *vedro*		11.5	9.2
06.05.1996.	cloudy *oblačno*	rain at night *noću kiša*	12.7	11.3
07.05.1996.	fair *vedro*		9.6	10.3

In Figures 6, 7 and 8 measured air temperatures, registered precipitation and the catch of animals per sampling day are shown. The dates of the catch were placed on the abscissa and the number of caught animals and air temperature on the ordinate. The biggest number of rodents was caught on plots (study area and two "Ys") in the period when it was raining or immediately before rain.

DETERMINING THE RELATIVE POPULATION DENSITY OF RODENTS BY THE LINEAR TRANSECT METHOD
ODREĐIVANJE RELATIVNE BROJNOSTI MIŠOLIKIH GLODAVACA METODOM LINEARNOGA TRANSEKTA

The population density of rodents by the linear transect method was checked in forest communities *Genisto elatae-Quercetum roboris* Ht. 1938 (subcompartments 58a and 62a) and *Carpino betuli-Quercetum roboris* Rauš 1969 (subcompartments 59a, 75a and 90a). The transects were in the same forest communities in which the squares were placed and where the "Ys" were done. The catch of animals lasted one night. Research of the population density of animals by the linear transect method was started in spring 1995 by placing 100 snap traps (transect I) next to the edge of subcompartment 90a (pedunculate oak and a hornbeam forest). On checking the transect the next morning, it was found that animals were caught in eleven traps. Among the caught animals the dominant species was *C. glareolus* (seven animals). The result is logical, as the red-backed vole most frequently lives on habitats with little water and rich grassy vegetation (Androić et al. 1981) and a

Figure 6. The account of the catch of rodents, the air temperature, rain and snow according to the sampling days by the "Y" method in April, 1995
Slika 6. Prikaz ulova glodavaca, temperature zraka, kiše i snijega po danima uzorkovanja "Y" metodom u travnju 1995. godine

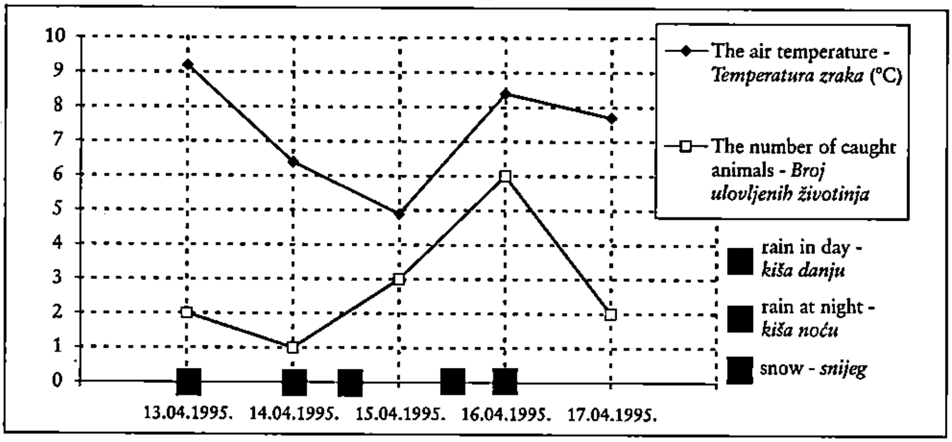


Figure 7. The account of the catch of rodents, the air temperature and rain according to the sampling days by the minimum square method in April, 1995
Slika 7. Prikaz ulova glodavaca, temperature zraka, kiše i snijega po danima uzorkovanja metodom minimalnoga kvadrata u travnju 1995. godine

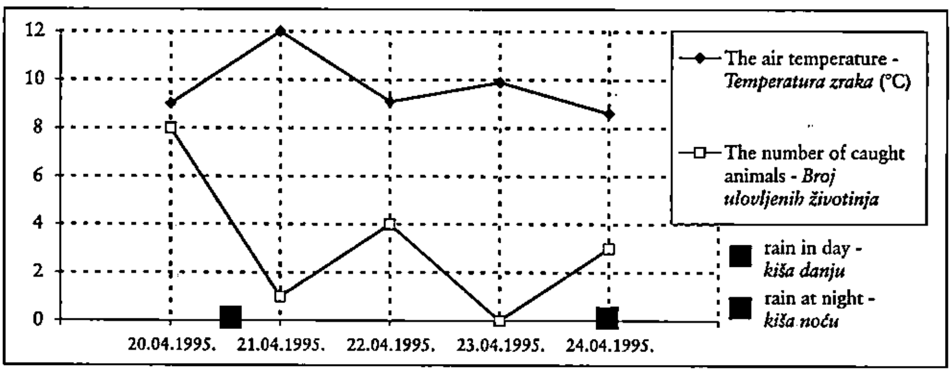
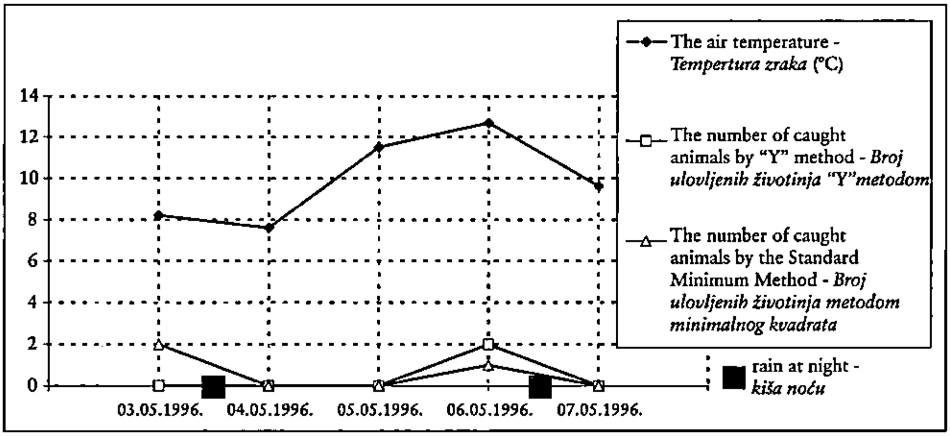


Figure 8. The account of the catch of rodents, the air temperature and rain according to the sampling days by the minimum square and the "Y" method in May, 1996
Slika 8. Prikaz ulova glodavaca, temperature zraka, kiše i snijega po danima uzorkovanja metodom minimalnoga kvadrata i "Y" metodom u svibnju 1996. godine



transect was placed on such a field. *A. flavicollis* (two animals) and *A. sylvaticus* (two animals) were also caught in transect I.

The next time the population density of rodents was checked was in autumn 1995, when two parallel transects were placed about 200 m from each other, in subcompartments 75a (transects II and III) and 62a (transects IV and V) in which various plant communities are prevalent (pedunculate oak and hornbeam forest in subcompartment 75a and pedunculate oak and broom forest in subcompartment 62a). To avoid the edge effect on rodents, transects were placed 50 m from the edge of the stand. Four species of rodents (17 specimens) were caught. An analysis of the catch area showed that each species lived on a particular microhabitat. In the transects placed in a community of pedunculate oak and hornbeam, the dominant animals were *A. flavicollis* (88 % of the catch), while the rest were *C. glareolus*.

Eight animals were caught in two other transects (transects IV and V) placed in the forest community of pedunculate oak and broom (section 62a). In each transect 50 traps were placed. All the animals were caught in transect V.

The percentage of caught rodents in transect V was 16 %. The dominant animal was *A. agrarius* (62.5 %), while the rest of the sample included *M. agrestis* (37.5 %). The result of the catch shows the presence of various species of rodents in certain forest communities. In the community *Carpino betuli-Quercetum roboris*, two species were noticed: *A. flavicollis* and *C. glareolus*, while in the forest *Genisto elatae-Quercetum roboris* Ht. 1938, *A. agrarius* and *M. agrestis* were caught.

The third determination of the population density of rodents was done by the linear transect method in May 1996 by placing 100 snap traps in the catching line in subcompartment 58a (forest community *Genisto elatae–Quercetum roboris*). No animal was caught. Two months later, a catching transect was put on the same place (transect VII). Only one *A. flavicollis* and one *M. arvalis* were caught. In autumn 1996, three new catching transects (VIII, IX and X) were activated, and at the same time the population density of the mentioned pests was investigated by the "Y" method and the minimum square method. Animals were not caught by catching transects VIII, IX, X.

DISCUSSION
RASPRAVA

According to the data of the Diagnostic Prognostic Service of the Institute of Forestry of Jastrebarsko and the author's personal survey over several years, in all Forest Offices of the public enterprise "Croatian Forests", damage has been noticed on the forests seeds and young plants in Croatian forests over an area of several thousand hectares. The relation of the number of animals in the countryside and the amount of damage they can cause is proportional (Vajda 1974). The greatest intensity of damage was registered in lowland pedunculate oak forests. In order to prevent this in time, it is necessary to regularly check the population densities of the causes of the damage in the field. Three different methods were used to examine the population density of rodents in the forests of the Management Unit Turopoljski Lug during two subsequent years. Absolute and relative population densities of rodents were calculated in the forest communities *Genisto elatae-Quercetum roboris* and *Carpino betuli-Quercetum roboris*. In May 1996 the lowest absolute population density was registered in the community of pedunculate oak and hornbeam using the "Y" method (N/ha = 1.36), and the highest in October of the same year (N/ha = 12.24). The dominant species was *A. flavicollis*, as the habitat on which the study area for this method was placed completely suited this species (a great quantity of windfall leaves and poorly developed shrubbery) (Vraneš 1972).

Very similar results were obtained for the population density of rodents in the same region by the multiple regression method. The lowest absolute population density of rodents was also determined in May 1996 (N/ha = 1.84). The result corresponds to Vajda (1974) and Androić et al. (1981) who emphasise that the population density of rodents in spring is smaller than in autumn. During the winter months the mortality of animals increases due to the effects of low temperatures and a lack of food (Delany 1974). In July 1996, a lower increase in the population density of animals (N/ha = 4.44) was noticed. Three months later the population density reached its highest value (N/ha = 10.79). Comparing by a t-test the results of the population density determined by the "Y" method and the minimum square method, it can be concluded that there is no significant difference between them, with a degree of reliability of 95 %. If the catch is analysed according to species, differences can be noticed. In spring 1995, two animals of the species *C. glareolus* were caught by both methods. In comparison with Kovačić (1988), this number is minimal considering the usual population density of that species in this area. The population density of the *C. glareolus* in the forests of this management unit was 26 animals per hectare in April 1984 (Kovačić 1988). The highest density of population of this species was noticed in November 1983 (N/ha = 138) (Kovačić 1988).

In the period of almost two years, no *M. agrestis* were caught on the study area, while in catching containers placed in a "Y" in the same period, three animals of that species were caught. Similar results were obtained with *M. arvalis* and *A. sylvaticus*. On the study area one animal of each type was determined, while in both "Ys" *A. sylvaticus* were caught and four *M. arvalis* (Table 3 and Table 6). *A. flavicollis* was the most numerous species on the plots. The catch dynamics of the *A. flavicollis* shows that the most numerous catches were in spring 1995 and autumn 1996. The greatest catch was always registered on the first three nights.

Kovačić (1988) registered the maximum population density of the species *A. flavicollis* in the Turopolje forests in December 1983 (N/ha = 88), and the minimum in April 1984 (N/ha = 6). Analysing the population density of all rodents together put the maximum number in November 1983 (N/ha = 209), and the minimum in February 1984 (N/ha = 20) (Kovačić 1988). The population density of the rodent community follows the population dynamics of the dominant species *C. glareolus* and *A. flavicollis*. This fact was also confirmed by the results of this study in which the population density of the community follows the population dynamics of *A. flavicollis*. Having compared the calculated maximum population density of that community with Kovačić (1988), it was concluded that the population density of animals during the present research was very small. It was 10-15 times smaller than in the period from July 1983 to June 1984 (Kovačić 1988). The same conclusion was reached on the small population density of rodents on the mentioned area by the linear transect method. An analysis of the relation of the number of caught animals and determined species in comparison with other used methods showed that the catch of animals in one night by this method was insufficient to learn completely about the composition of the community of small mammals. In the transect three species of rodents were determined. The highest relative value of the population was determined in transect IV in the community of *Genisto elatae-Quercetum roboris* (subcompartment 62a) in November 1995 when a catch was registered in 16 % of the snap traps. The most abundant was *A. agrarius*. The result of the catch at linear transects IV and V is at first sight illogical. Both catching lines were placed on the same habitat, so it was expected that the catch in them would be approximately the same. However, the outcome was the result of the different placing of the traps. In transect V, snap traps were placed in protected places (in baréd litter, under tree-stumps, in microdepressions, etc.), while the snap traps in transect IV were placed in unprotected places on the surface of windfall leaves. A decision on control is made according to the number of caught animals in the transect. Control is not necessary if the percentage of caught rodents is under 20 % (Crnković 1982). If the catch is between 20 % and 30 %, the control can, but need not, be done, depending on whether there is artificial or natural afforestation, which depends on whether there are young plants and forest seeds on the field which have to be protected. When animals are caught in 30 % of the snap traps, the pests must be controlled. According to Androić et al. (1981), the relative number of animals from 30 % to 60 % is a sign of an increased number of animals, while Delany (1974) considers the situation in which animals are caught in 80 % of the traps as a true indicator of a high population density of rodents in the forest.

Factors which influence the choice of microhabitat of certain species of small mammals are the quantity of light in lower layers of a stand, the presence of ground vegetation, the level of underground water and the length of periods of flood (Price 1978, Dueser & Hallet 1980). According to Vraneš (1972), *A. flavicollis* mostly lives on drier areas with poorly developed shrubbery and a great quantity of windfall leaves. However, *C. glareolus*, apart from on the edges of the stand, lives on forest areas rich in shrubbery. The results in the catching transects during spring 1995 and summer 1996 in the forest community *Carpino betuli-Quercetum roboris* completely correspond in number and species of caught rodents to the results of the "Y" method and the minimum square method. There are no differences in the community *Genisto elatae-Quercetum roboris* linear transect method done in May and July 1996. By comparing the catch of animals by various methods in subcompartments 90a and 98a (the community *Carpino betuli-Quercetum roboris*) in autumn 1995, the differences in results are significant. At that time, the highest population density of animals was registered by the minimum square method and the "Y" method. In the simultaneously placed transects IX and X in subcompartment 90a, no animals were caught. The cause might be a heterogeneous microdistribution of populations in the forest or the possible unfavourable climatic influence on the percentage of the catch. Tracing the population densities of rodents is possible only by catching animals over several days (Kovačić 1988, Trilar 1991, Zukal & Gaisler 1992). Comparing the catch in the transects with the values at which Crnković (1982) defines control in the field to be necessary, it was concluded that it was not necessary to control the rodents during last two years in the Management Unit "Turopoljski Lug". Even the highest percentage of caught animals in linear transects (16 % - in the section 62a in autumn 1995) was under 20 % of the catch, at which point Crnković (1982) recommends that rodents be controlled.

The dynamics of the catch of animals depends on the influence of temperature and precipitation. Following the effects of these parameters, it was established that most rodents were caught in the rainy period or immediately before it, when the activity of rodents is increased (Figures 10, 11, 12). According to the research of Bider (1968), at this time the activity of animals increases. Analysing the damaged condition of the seed of the pedunculate oak, it was determined that the highest percentage of the damaged acorn was 6.35 % per sample on the edge of vegetation. The increase in damage occurred because the acorn became an important source of food for rodents after the end of vegetation, and their population density on this surface was not reduced by the catch. A small increase in damage on forest seed on the edge of the stand is not disturbing. In the years of the low population density of rodents, damage caused by them to the crop of acorn is negligible. Rodents mostly damage the healthy acorn not attacked by other pests (insects). Most gnaws by rodents were noticed in the basal part of the acorn. The high percentage of damage to the base part has a logical explanation, since it is known that an acorn is thinnest at that part (Hrašovec 1993). The greatest damage to the pedunculate oak seed was done by *A. flavicollis*, as these species were the most abundant among the caught animals.

An important task is to regenerate devastated forest stands. Numerous authors have written about determining the most suitable kinds of trees and methods of regenerating areas devastated by the drying of pedunculate oak *(Quercus robur* L.) in Croatia (Dekanić 1977, Matić 1989, 1993, 1994, Prpić et al. 1994, Matić et al. 1994, Oršanić et al. 1996). Examining the new growth of autochtonous kinds of trees that appear on surfaces devastated by the drying of pedunculate oak communities and knowing the biological features, ecological demands and economic features of trees, Matić (1989) concludes that pedunculate oak, common ash and alder are three basic kinds which should be used in the regeneration of these forests.

Due to the great mosaicism of the decay of pedunculate oak which takes place in Turopoljski Lug at a higher or smaller intensity on almost the whole surface (Prpić et al. 1994), the regeneration of the forest by a natural or an artificial method should take place in numerous compartments (9, 13, 20, 32, 38, 58, 59, 60, 61, 62, 74). The choice of the method of regeneration, as well as the choice of the kinds of trees, was made according to the estimate of the future biotope and the future structure of the stand, which would guarantee its stability. On a specific plate-like field on which dryings of great quantity were noticed, artificial regeneration was done by planting pioneer species of trees (alder, common ash) which have the common task of creating conditions in the soil and on the soil for the pedunculate oak which belongs here. Plant material used in the regeneration of the stand is frequently exposed to the attack of numerous pests. Intensities of damage by small rodents on the plants are distinguished in 3 categories: plants without damage, partially damaged plants, and completely damaged plants. Partial damage means a shallow, discontinued gnawed surface on the bark several centimetres long. Such damage does not represent a great danger for the physiology of a plant, as gnaws heal up in a short time. The consequences of partial gnaws are indirect, as a gnawed place serves as the entrance for numerous fungi to the host plant, causing its disease (Glavaš 1984, 1984a, 1989, Glavaš & Halambek 1992). Complete damage was defined as a continuous, deeply gnawed region of various length in the lower part of a stem.

When damage was done (it is assumed that it was in winter 1994/95), the population of rodents was very high. At that time, the control of rodents ought to have been done by one of the methods of contemporary forest protection, in order to avoid the consequences which we witness today.

In May 1996 old gnaws of various intensity were determined in the lower parts of the plants on all seven study areas. According to the colour of the gnawed places, it was concluded that voles caused the damage in late autumn 1994 and during winter 1994/1995. The damage was probably done by *M. agrestis* or *M. arvalis*, while the habitat and the way of damaging the plants completely correspond to these species. In linear transects (transects VI and VII) *A. flavicollis* and one *M. arvalis* were caught. The smallest percentage of old damaged material (58.42 %) was registered on surface 1, while the majority of plants (97.87 %) were damaged on surface 2. According to the quantity of damage and the time of its appearance, the population density of the rodents was very high. From July to November 1996, new damage was noticed on only 1.86 % of forest plants, which is negligible. The absence of new damage in July 1996 was expected, as during vegetation rodents use other food sources (herbaceous plants, insects, earthworms, forest fruit, etc.). If the obtained result is compared with the low population density of rodents which was established at that time on that site by a linear transect method, then this is logical. One of the indirect methods of defining the population density of small mammals in the field is by following the intensity of damage on seeds and young plants (Vajda 1974). From the result of the damaged conditions of plants, it could be noticed that the population density of rodents was very small and that it was not necessary to control them.

Control measures to reduce the population density of rodents are taken because of the epidemiological danger and damage that these rodents can do during periods of high population densities. Knowing the characteristics of the majority of the species of these pests (high reproduction potential, the possibility to adapt to various conditions of life and types of habitat, euryvalence in relation to numerous factors of the environment, etc.), the problem of controlling their population density with the use of preventive or direct measures is a very complex task. Preventive measures are particularly significant in the control of rodents and are taken with the aim of decreasing the quality of the habitat on which the rodents live. For that purpose, various methods of tillage (plowing, earthing up), the management of forest order, weed control, etc. are taken. The unprofessional management of forest order creates conditions for high population densities of animals. The use of repellents is also included in preventive measures in the control of rodents. The potential repellent must have an irritating effect through the sense of smell and not through the sense of taste. According to this personal survey and the data of the Diagnostic Prognostic Service of the Institute of Forestry of Jastrebarsko, repellents were not used in Croatian forestry in the period from 1981–1995 as preventive measures against rodents.

Various mechanical methods are also frequently used in the control of small rodents. They include catching animals by placing hunting containers and using various traps (snap traps and livetraps). These measures are very expensive, since a great deal of time, material means and labour force are necessary for their use on large areas. They are therefore not economically justified.

By organising the prognostic service in all Forest Offices of the public enterprise "Croatian Forests" and by regularly monitoring the dynamics of the population density of rodents, the expenses of forest cultivation would be rationalised, and at the same time, the damaging effects on the rest of forest fauna would decrease.

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MIŠOLIKI GLODAVCI I NJIHOVA ŠTETNOST U TUROPOLJSKOM LUGU I U DRUGIM HRVATSKIM ŠUMAMA

SAŽETAK

Mišoliki (sitni) glodavci pripadaju grupi biotskih čimbenika koji utječu na kakvoću prirodne i umjetne obnove šumskih sastojina, te na proizvodnju mladih biljaka u rasadnicima. Redovito žive u šumama gdje stalno čine sitnu štetu na šumskom sjemenu i mladim biljkama. U godinama kada se prenamnože, šteta može znatno porasti i nanijeti šumskom gospodarstvu velike gubitke. Mišoliki glodavci čine štetu u svim tipovima šuma. U Hrvatskoj je najveća šteta od njih zabilježena u nizinskim šumama hrasta lužnjaka. Ovi sisavci često imaju odlučujuću ulogu u produkciji klijavo sposobnoga sjemena hrasta lužnjaka. Štetno djelovanje osobito im je naglašeno u godinama smanjena uroda žira. Negativni učinak još im je izraženiji ako su štetu počinili na sjemenu i sadnicama kojima su obnovljene šume zahvaćene sušenjem. U nekoliko mjeseci mogu biti izgubljena znatna materijalna sredstva koja je šumarska operativa uložila u obnovu posušenih sastojina (troškovi skupljanja šumskoga sjemena, troškovi proizvodnje sadnica u rasadnicima, troškovi pošumlja-

vanja i zaštite mladih biljaka) ako se na tim terenima glodavci prenamnože. Šumarska je znanost u mogućnosti umanjiti štetu od njih primjenom različitih posrednih ili neposrednih metoda (uzgojni radovi, te mehaničke, kemijske i biološke metode suzbijanja) namijenjenih redukciji njihovih prenamnoženih populacija. Cilj je stvoriti bolje preduvjete za prirodnu ili umjetnu obnovu šumskih sastojina. Uspješno suzbijanje povećane populacije mišolikih glodavaca nemoguće je bez dobroga poznavanja njihovih morfoloških i fizioloških osobina, kao i ekoloških čimbenika koji u manjem ili većem stupnju utječu na dinamiku njihove populacije. Nestručno izvedena deratizacija može izazvati negativne posljedice za šumski ekosustav i životinjske vrste koje obitavaju u njemu, a nisu cilj suzbijanja. Praćenje dinamike populacije mišolikih glodavaca veoma je važno za uspješno provođenje mjera i metoda suvremene zaštite šuma. Detaljna istraživanja ovih sisavaca u hrvatskom šumarstvu dosada nisu rađena.

Utvrđivanje brojnosti mišolikih glodavaca i intenziteta štete koju uzrokuju na šumskom sjemenu i mladim biljkama obavljeno je u šumama GJ Turopoljski lug kojom gospodari JP "Hrvatske šume" (Uprava šuma Zagreb, Šumarija Velika Gorica). Gospodarska se jedinica ubraja u šumskogospodarsko područje jednodobnih šuma, a nalazi se 30-ak kilometara jugoistočno od Zagreba. Površina gospodarske jedinice je 4333,6 ha. Na ovom području prevladava nizinski reljef. Hidrološke prilike koje vladaju u GJ Turopoljski lug vrlo su važne za uspijevanje hidrofita, ponajprije hrasta lužnjaka (*Quercus robur*), poljskoga jasena (*Fraxinus angustifolia*), crne johe (*Alnus glutinosa*), domaćih topola (*Populus* spp.) i vrba (*Salix* spp.). Fitocenološka istraživanja šumske vegetacije Turopoljskoga luga pokazala su da u normalnim prilikama ove sastojine imaju svojstva, sastav i strukturu tipičnih nizinskih šumskih ekosustava Pokuplja i Posavine. Glavne su šumske zajednice: šuma hrasta lužnjaka i običnoga graba (*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969), šuma hrasta lužnjaka i velike žutilovke (*Genisto elatae-Quercetum roboris* Ht. 1938) i šuma poljskoga jasena s kasnim drijemovcem (*Leucoio-Fraxinetum parvifoliae* Glav. 1959), dok šumska zajednica crne johe s trušljikom (*Frangulo-Alnetum glutinosae* Rauš 1968) zauzima tek nekoliko hektara.

U sklopu istraživanja gustoće populacije mišolikih glodavaca u radu su izneseni opći podaci o njihovim biološkim osobinama (razmnožavanje, uloga osjetila i prehrana). Na povećanje brojnosti ovih sisavaca utječe veći broj čimbenika koji su podijeljeni u četiri osnovne grupe:

1. brojnost i fiziološko stanje populacije (dob populacije, odnos spolova u populaciji, stupanj nataliteta i mortaliteta i sl.)
2. obilježja podneblja (temperatura i vlažnost zraka, vjetar, količina i raspored oborina)
3. stanište i izvori hrane (zakorovljenost staništa, količina i vrsta hrane)
4. prirodni neprijatelji i bolesti (brojnost i vrsta predatora, prisutnost zaraznih bolesti kao čimbenici reguliranja populacije mišolikih glodavaca).

Mišoliki glodavci stalan su izvor različitih zoonoza (tularemija, leptospiroza, kuga, bjesnoća, hemoragična groznica i dr.), a pri povećanoj brojnosti mogu ih prenijeti na čovjeka, te domaće i divlje životinje. Praćenje brojnosti populacije mišolikih glodavaca, te suzbijanje povećane im brojnosti važna je mjera u zaštiti ljudskoga zdravlja i suzbijanju bolesti drugih životinja.

Šume GJ Turopoljski lug nastanjuje više vrsta mišolikih glodavaca (porodica Muridae) koje pripadaju dvjema potporodicama: miševima (Murinae) i voluharicama (Arvicolinae). Iz potporodice Murinae prisutne su tri vrste:

1. *Apodemus flavicollis* (Melchior 1834) – žutogrli šumski miš
2. *Apodemus sylvaticus* (Linneus 1758) – šumski miš
3. *Apodemus agrarius* (Pallas 1771) – poljski miš.

Iz potporodice Arvicolinae prisutne su ove vrste:

1. *Clethrionomys glareolus* (Schreber 1780) – šumska voluharica
2. *Arvicola terrestris* (Linnaeus 1758) – vodeni voluhar
3. *Microtus arvalis* (Pallas 1779) – poljska voluharica
4. *Microtus agrestis* (Linnaeus 1761) – livadna voluharica
5. *Microtus subterraneus* (de Selys-Longchamps 1836) – podzemni voluharić
6. *Microtus multiplex* (Fatio 1905) – alpski voluharić.

Šumske površine pružaju mišolikim glodavcima obilan izvor hrane, povoljne uvjete za razmnožavanje i prezimljavanje, te zaštitu od prirodnih neprijatelja. Osobito im pogoduju šumski tereni bogati prizemnom vegetacijom, te šume koje graniče s poljima i livadama s kojih glodavci u jesen migriraju u granične sastojine. Miševi i voluharice čine štetu u šumi hraneći se šumskim sjemenom, te glodanjem kore i korijenja mladih biljaka. Kao štetnici šumskoga sjemena osobito se ističu miševi (potporodica Murinae) koji mogu potpuno uništiti sjetvu u rasadnicima, ili onemogućiti prirodno pomlađivanje šumskih površina. Prema podacima Dijagnozno-prognozne službe Šumarskoga instituta u Jastrebarskome u razdoblju 1980–1994. godine najveća šteta od mišolikih glodavaca zabilježena je 1994. godine na 3947,51 ha, dok je znatna šteta zabilježena i 1989. godine (2905 ha), 1990. godine (2596,1 ha) i 1993. godine (2293,87 ha). Veličinu štete u hrvatskim šumama u 1995. godini osobno sam istražio provođenjem anketnoga ispitivanja u svim upravama šuma JP "Hrvatske šume". Iz rezultata istraživanja izlazi da je šteta od mišolikih glodavaca u 1995. godini zabilježena na 3794,8 ha. Najveća je šteta bila na području Uprave šuma Vinkovci (1359 ha). Šteta je većinom počinjena u jesen, zimi, te u rano proljeće. Dob oštećenih sastojina je različita i kreće se od jedne do 130 godina, ovisno o tome jesu li oštećenja zabilježena na mladim biljkama (dob do deset godina), ili na šumskom sjemenu (dob je sastojine najčešće iznad 70 godina). Tijekom 1995. godine brojnost mišolikih glodavaca bila je određena samo u UŠ Vinkovci, UŠ Bjelovar, UŠ Požega, UŠ Sisak, te dijelom u UŠ Koprivnica (Šumarija Đurđevac). Te godine u šumama u Hrvatskoj njihovo je suzbijanje najčešće obavljeno kemijskom metodom primjenom preparata "Faciron" i "Brodilon". Provedena deratizacija u većini uprava šuma rezultirala je smanjenjem štete u šumama, npr. u UŠ Sisak, gdje je nakon provedenoga suzbijanja glodavaca šteta od njih smanjena 80 %.

Primijenjene metode tijekom istraživanja podijeljene su u pet grupa:

a) terenske metode utvrđivanja brojnosti i uzorkovanja glodavaca

1. modificirana metoda minimalnoga kvadrata s mrtvolovkama (Zejda & Holišova 1971, Pelikan 1971)
2. "Y" metoda (Kirkland et al. 1990, Kirkland & Sheppard 1994, Zukal & Gaisler 1992)
3. linearni transekt (Androić et al. 1981)

b) terenske metode utvrđivanja intenziteta oštećenja

1. skupljanje otpaloga žira
2. analiza oštećenosti šumskih sadnica

c) laboratorijske metode

1. determinacija i obrada morfometrijskih osobina ulovljenih životinja
2. analiza skupljenoga žira

d) matematičke metode izračunavanja brojnosti mišolikih glodavaca

1. statistička metoda linearne regresije (Poole 1974)
2. metoda preračunavanja na jedinicu površine totalnim izlovom (Zukal & Gaisler 1992)
3. relativna brojnost

e) usporedba rezultata brojnosti mišolikih glodavaca izračunatih različitim metodama

1. t - test (Pranjić 1986).

Standardna metoda minimalnoga kvadrata sastoji se u utvrđivanju broja jedinki populacije skupljanih na definiranim lovnim mjestima površine od 1,44 ha. Izlov životinja pomoću mrtvolovki traje pet noći. Za uspješnost metode važno je da su uvjeti lova isti, tj. da sve jadinke u populaciji imaju jednake izglede da budu ulovljene, da su u vrijeme izlova odstupanja mortaliteta neznatna, da nema imigracija i emigracija jedinki u razdoblju lova, te da su vremenski uvjeti tijekom izlova približno isti. U razdoblju istraživanja od travnja 1995. godine do studenoga 1996. godine lovni je kvadrat aktiviran četiri puta (u travnju 1995. godine, te u svibnju, srpnju i listopadu 1996. godine) u šumskoj zajednici hrasta lužnjaka i običnoga graba (*Carpino betuli-Quercetum roboris*).

"Y" metoda temelji se na izlovljavanju sitnih terestričkih sisavaca pomoću lovnih posuda. Životinje se usmrćuju padom u lovnu posudu napunjenu vodom. Izlov se obavlja na plohi površine 0,735 ha postavljanjem deset lovnih posuda raspoređenih od središnje točke u tri smjera pod međusobnim kutom od 120° (oblik slova "Y") na međusobnom razmaku od 5 m (Zukal & Gaisler 1992, Kirkland & Sheppard 1994). Između lovnih posuda postavlja se pregrada (najčešće traka od PVC visine 25–30 cm). Za ovu metodu postavljene su na terenu dvije pokusne plohe u šumskoj zajednici *Carpino betuli-Quercetum roboris* na međusobnoj udaljenosti većoj od 100 m kako bi se izbjegao ulov životinja s različitih ploha. Izlov životinja trajao je pet noći. Gustoća populacije mišolikih glodavaca "Y" metodom utvrđivana je tijekom istraživanja tri puta (u travnju 1995. godine, te u svibnju i listopadu 1996. godine).

Metodom linearnoga transekta moguće je u kratkom vremenu odrediti približnu (relativnu) brojnost glodavaca na većem području. Na odabranom pravcu postavljaju se mrtvolovke na međusobnom razmaku od 5 m. Lov životinja traje jednu noć. Brojnost mišolikih glodavaca izražava se postotkom ulovljenih životinja u odnosu na ukupan broj postavljenih klopki. Ako ulov iznosi 1–2 %, brojnost populacije je niska; ako je ulov do 10 %, brojnost glodavaca je umjerena; kod ulova od 30 do 60 % brojnost je životinja povećana, dok ulov veći od 80 % znači da je nastupila masovna pojava (Androić i dr. 1981). Suzbijanje je potrebno ako je brojnost životinja na terenu povećana.

Među ulovljenim životinjama determinirane su ove vrste mišolikih glodavaca: *Apodemus flavicollis*, *Apodemus sylvaticus*, *Apodemus agrarius*, *Clethrionomys glareolus*, *Microtus arvalis* i *Microtus agrestis*. Dinamika ulova životinja ovisi o utjecaju temperature i oborina. Prativši međusobni utjecaj tih parametara, utvrđeno je da je većina glodavaca ulovljena u kišnom razdoblju ili neposredno prije njega kada je aktivnost jedinki pojačana (slike 6–8). Metodom linearne regresije izračunata je brojnost glodavaca na lovnom kvadratu za svaku sezonu izlova. Najmanja brojnost glodavaca ovom metodom utvrđena je u svibnju 1996. godine, a najveća u listopadu iste godine (tablica 5). Slični rezultati dobiveni su i "Y" metodom (tablica 7). Usporedivši t-testom rezultate brojnosti glodavaca dobivenih "Y" metodom i metodom linearne regresije (tablica 8), zaključeno je, uz granicu pouzdanosti od 95 %, da među njima ne postoji signifikantna razlika. Dominantna vrsta na lovnom kvadratu i na oba "Y"-a bio je žutogrli šumski miš (*Apodemus flavicollis*). Metodom linearnoga transekta utvrđena je niska do umjerena relativna brojnost mišolikih glodavaca, te je zaključeno da ih u razdoblju istraživanja nije bilo potrebno suzbijati. Analiza odnosa broja ulovljenih životinja i determiniranih vrsta, u usporedbi s ostalim primijenjenim metodama, pokazuje da je kod ove metode ulov jedinki u jednoj noći nedostatan za potpuno upoznavanje sastava zajednice mišolikih glodavaca koje obitavaju na istraživanom terenu.

Utvrđivanje intenziteta oštećenja na sjemenu i mladim biljkama jedna je od posrednih metoda definiranja brojnosti populacije mišolikih glodavaca. Analizirajući oštećenost žira hrasta lužnjaka od ovih sisavaca, zaključeno je da oni najčešće oštećuju zdravi, neoštećeni žir (slika 4). Većina oštećenja zabilježena je u bazalnom dijelu sjemena (slika 3). Pri prvom pregledu oštećenosti mladih biljaka od mišolikih glodavaca u svibnju 1996. godine utvrđene su u donjim dijelovima biljaka grizotine starijega datuma i različita intenziteta. Prema boji oglodanoga mjesta zaključeno je da je šteta nastala u jesen 1994. godine i tijekom zime 1994/95. godine. Velika je šteta (slika 5) pokazatelj da je brojnost populacije glodavaca u to vrijeme bila velika, te ih je tada bilo potrebno suzbijati. Daljnjim praćenjem dinamike nastanka štete (do studenoga 1996. godine) nova su oštećenja zabilježena samo na 1,86 % biljaka. Iz tih rezultata izlazi da je u razdoblju istraživanja brojnost glodavaca u Turopoljskom lugu bila vrlo mala.

Ekonomski je opravdano samo ono suzbijanje mišolikih glodavaca koje se provodi prije početka njihova masovnoga razmnožavanja. Suzbijanje poduzeto u vrijeme kada populacija dostigne svoj maksimum ili prije sloma kalamiteta redovito će promašiti svoj cilj (Vajda 1974). Financijska su sredstva koja se izdvajaju za kemijsko suzbijanje mišolikih glodavaca u hrvatskim šumama velika, a ima primjera da se često troše i u situacijama kad to nije potrebno. Redovitim praćenjem brojnosti mišolikih glodavaca u svim upravama šuma JP "Hrvatske šume" racionalizirali bi se troškovi uzgajanja šuma, a ujedno bi se time smanjili i štetni utjecaji na ostalu šumsku faunu.

Ključne riječi: nizinske šume, mišoliki glodavci, brojnost populacije, šumsko sjeme, šumske sadnice, obnova šuma