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Rodents in Urban Ecosystems of Russia and the USA

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Abstract

The chapter discusses the distribution and biology of major groups of rodents that are most likely to be encountered in urban areas in Russia and the USA. Emphasis is made on the factors affecting the abundance of these animals and the likelihood they will invade human dwellings. Commonalities between analyzed geographic areas include a dominance of Norway rats (*Rattus norvegicus*) and house mice (*Mus musculus*), which have historically colonized urban ecosystems, globally. These species were introduced into the USA much later than to the European and Asian parts of Russia and some differences in their ecology were noticed between two countries. The wild rodents that occupy urban territories can represent many other species. Species compositions are influenced by rodent communities in natural habitats surrounding cities. The striped field mouse (*Apodemus agrarius*) and the East European vole (*Microtus levis*) are common in cities of the European part of Central Russia, the striped field mouse and the reed vole (*Microtus fortis*) can occasionally occupy some urban territories in the south of Russian Far East. The rodents that periodically invade urban territories in the USA include the New World rats and mice (*Neotoma*, *Peromyscus*, and *Sigmodon*), *Microtus* voles, and tree and ground squirrels. Differences in the terminology related to describing invasive species used in Russia and the English-speaking countries are discussed.

Urban rodents present a great risk to human health, especially to people whose health is already compromised (Battersby et al., 2008). Though the epidemiology of many rodent-borne diseases in urban environment remains ill-defined, numerous studies have shown that rodents can be infected with a large variety of infectious and parasitic agents. During the last decades we have seen a rise in human diseases that are associated with rodent reservoirs and their presence can have serious implications for public and veterinary health (Meerburg et al. 2009). In additions to being reservoirs for zoonotic diseases, urban rodents historically present threat to food supplies and are important competitors with humans for food where they live together. Rodents within human settlements are also seen as pest because of their destructive behaviors that can cause economic losses and lead to structural damages. To develop an effective control strategy, the true rate, locations of infestations, ecological characteristics of urban rodents, and some other risk factors need be assessed. As David Davis (1951) stated 60 years ago, because of the economic and epidemiologic importance of reducing urban rat populations, these efforts rarely provided data of value for science and also rarely reduced the pests except temporarily. The subject of this review is the characteristics of an ecologically diverse group of rodents, for which their urban environment is common, between Russia and the United States. Rodents became human neighbors at the very

early stage of human civilization; however, during last century city developments dramatically extended habitats within urban territories suitable for rodents and this process reached the global scale. The process of invading urban habitats by rodents continues and creates dramatic changes in rodent diversity within urbanized territories.

Terminology and differences in terms between Western and Russian literatures

Though it was not our initial intention to go deeply into semantic issues of specific categories that unify all rodent inhabitants in urban areas, there is a serious reason to start this paper by discussing some terminology before we concentrate on specific groups. This is especially important because of some traditional differences in describing urban rodents between Russian and US scientists. Among rodents occupying urbanized territories, it is easy to distinguish two major groups. One group represented by two species of *Rattus* rats (*Rattus norvegicus* and *R. rattus*) and house mice (*Mus musculus*), which are highly adapted to survive within urban landscapes and can be found throughout the world. The other group is represented by rodent species that may be found within city limits, but do not show a long history of living in close proximity to humans, most of them are more common outside of human dwelling and are adapted to a natural environment.

In the western literature, the most common term for the first group is 'commensal rodents' while the second is 'non-commensal rodents'. For example, in the book recently published by the World Health Organization and entitled 'Public health Significance of Urban Pests' (2008), there are two chapters 'Commensal rodents' and 'Non-commensal rodents and lagomorphs'. In the first of these chapters, the authors (Battersby et al., 2008) stated that "rats and mice are thought of as commensal rodents because of their close association with human activity. In ecological sense, the term commensalism refers to a symbiotic condition in which one participant benefits while the other is neither benefited nor harmed. Etymologically, commensalism refers to a sharing of one's table. These rodents benefit from their association with people in that they share dwelling with human occupants and, metaphorically speaking (though sometimes literally), eat from the same table. *People, however, not only do not benefit from an association with these rodents, but they also may in fact suffer harm*" (italic here is ours). The mentioned contradiction was noticed by other biologists as well and is one of the reasons why the term 'commensal' was not widely adapted among Russian and Eastern-European zoologists. Instead, in these countries more common definition for such rodents is 'synanthropic rodents' (Kucheruk, 1965, 1988; Kucheruk and Karaseva, 1992). The term 'synanthropic' indicates that these animals are inhabitants of human settlements or 'ecologically associated with humans'.

An application of the term 'synanthropic rodents' in Russian literature on rodent ecology has two meanings: in strict sense, when it was restricted to the rodent species, which were unintentionally introduced to new territories from the areas of their origin (Tikhonova et al. 2001, 2006; Rechkin et al., 2001); and in a wider sense, when it was applied to all rodents that can occupy urban habitats while maintaining their connection to natural biotopes (Kucheruk, 1965, 1988; Kucheruk and Karaseva, 1992). Calling all

these rodents as ‘synanthropes’, the prominent Russian zoologist Valent Kucheruk proposed to distinguish so-called ‘true’ synanthropes versus ‘semi-synanthropes’. In this sense, the term ‘true’ synanthropes are close to the term ‘commensal’ used in the western literature.

There is another pair of terms that sometimes is applied for urban rodents such as ‘alien’ or ‘invasive’ species versus ‘native species’. This terminology reflects that *R. norvegicus*, *R. rattus*, and *M. musculus* are not native to the most part of Earth except some Asian regions and invaded all continents except Antarctica through human activities. These rodents are distributed all over the world principally through occasional introductions and becoming established in human settlements. The integrity of their distribution is determined mainly by transport connections and freight traffic. In the past, the distribution depended mainly on cart traffic and ship navigation. The latter was a leading factor for crossing ocean barriers. In the modern world, the role of automobile and air transport is growing. These notions were suggested in the global strategy on invasive alien species (*A Global Strategy...*, 2001; *100 of the World’s Worst Invasive Alien Species...*2001). However, accepting the term ‘alien species’ as a wide notion and using this term in this paper and elsewhere, we also think that the state of being alien always manifests itself at the population level (each species has an area where it is local). The state of being alien is always regional. One of the clear signs of being alien is expansion of the area both due to displacement of borders and by introduction of animals to areas where formerly representatives of this species were absent (Dgebuaдзе, 2000). Colonizing some regions a long time ago, the invasive species become so common there that an application of the term “alien” to them seems odd (Khlyap and Warshavsky, 2010).

‘Peridomestic animals’ is a term that is widely used in epidemiology and zoology. It is used to describe animals, which though not domesticated, live in close proximity to humans. Rats are sometimes used as an example of peridomesticity, however, it is not a so obvious description of indoor rats compared with rats living adjacent to buildings. This distinction becomes important in the epidemiology of zoonotic diseases because the extent of contact between humans and peridomestic animals (some rodent species along with other wildlife and domestic animals) that serve as potential carriers of pathogens such as *Yersinia pestis* or hantaviruses influence the likelihood of transmission.

Specific characteristics of urban territories as an environment for rodents

Rodents living in urban environments often show specific adaptations. An urban area is characterized by closely located buildings and other human features, and by higher human [population density](#) compared to areas surrounding it. Urban regions may be [cities](#) and [towns](#), but usually are not [rural](#) settlements such as [villages](#) and [small](#) clusters of houses. Sometimes it is not easy to define from ecological perspectives urban areas, especially in suburban parts. It is also important to remember that ecological conditions in urban territories vary among countries such as Russian and the USA as well as within each country.

Within urban territories land surface temperature is commonly higher and humidity lower compared to surrounding natural habitats (= urban heat island). Another important aspect is the extent of sites that are not suitable for rodents, such as roads and squares covered by asphalt or concrete within urban areas. The habitats that can be potentially occupied by rodents are commonly separated from one another and this tends to fragment rodent populations within urban sites. As a result, rodent species that adapt to urban habitats need to survive periods of restricted movement but likely need some portion of their lives when long distance dispersal (allowing recolonization of available habitats) occurs. There are exceptions such as rodents occupying large green areas such as parks, and cemeteries. Habitats suitable to rodents within urban areas can roughly be classified as 1) buildings, 2) human created features outside buildings, and 3) resembling natural habitats. The latter can be created by humans or to be remnant habitat patches survived during an urban development. Specifics of these habitats vary greatly depending on history and geography. The lowest rate of rodent diversity is usually observed inside buildings and the highest rate is common within patches resembling natural habitats.

Rodents experience the most stable conditions inside buildings. Among factors affecting invasive ecology of rodents are architectural peculiarities such as construction materials, presence of empty spaces between walls, damage (holes) in walls; and accessibility to food. Access to food waste, such as garbage dumps, is an especially important factor. For their movement, urban rats tend to use existing features, but also can create burrow systems, which cause additional damages to house.

Movement between suitable habitat patches may either be directly across the surface, through underground features created by people, such as drains, or by the animals themselves or by unintentional transportation by people, with cargo. In industrialized countries rats are often found in considerable numbers within the sewer system of cities (Lund, 1994). This is sometimes their main refuge in modern situations where slums are no longer present and where efficient refuse removal operations make it difficult to find food sources above ground.

Among habitats outside buildings, we emphasize a role for lawns and roadsides for distribution of urban rodents. Such areas can be exposed to intensive burrowing by rodents. Some authors stressed an importance of railroads for invasion of rodents inside urban territories (Tikhonova et al., 1997). Having settled in urban areas, rats and mice may secondarily expand to recreational zones (Zjigarev, 2004) and via favorable biotopes disperse to other human settlements (Kucheruk, 1965, 1988).

When considering urban rodents we also need to evaluate the roles that predators play in influencing the distribution of rodents. Inside and near buildings rodents may become prey for stray and outdoor cats and dogs (Glass et al 2009), and in areas resembling natural habitats, there is a wider range of potential predators including foxes, weasels, ferrets, martens (Karaseva et al. 1999), as well as raptors. A special study in forested areas within Moscow during the period of 1975-1996 revealed a presence of weasels, stoats, foxes, and to a lesser degree polecats and martens. In many US cities, the expansion of foxes, coyotes, skunks, raccoons and other wild mammals has become more evident during last decades. Birds of prey represent over 70% of all predator

attacks on rodents (Nour et al. 1993), but their importance (especially nocturnal raptors) likely decreases in areas close to human houses. Finally, pest control can significantly reduce and in some cases completely eliminate rodents in cities and towns (Lambropoulos et al., 1999; Rylnikov, 2010). Regardless of these limiting factors, expansion of urban areas provides some rodent species with all they need to survive and thrive.

Biological traits of urban rodents

The synanthropic rodents possess a unique set of ecological and ethological adaptations enabling them to exist in proximity to people. Biological traits of synanthropic rodents enabling them to be neighbors of man were firstly formulated for the house mouse by Tupikova (1947). Later, these efforts were expanded by other Russian zoologists to other species (Sokolov and Karaseva, 1985; Meshkova and Fedorovich, 1996; Karaseva et al., 1999; Kotenkova, 2000; Kotenkova, Munteanu, 2007; Khlyap and Warshavsky, 2010; Bobrov et al., 2008). Among specific traits for obligate synanthropic rodents, the authors identified that they : 1) can easily penetrate into new territories; 2) are capable of quickly colonizing new territories; 3) are able to live in close proximity to each other; 4) are capable of rapid population growth; 5) can live in strongly fragmented space, e.g. in houses separated by streets or in suitable fragments of undeveloped territories; 6) are omnivorous but can switch to a very restricted kind of food; 7) prefer high calories food but can starve for long periods of time; 8) can freely travel with transport vehicles and therefore became widely distributed and overcome oceanic barriers.

The potential for rapid population growth by rodents in anthropogenic biotopes is a key aspect for these species. It is not accidental that prominent representatives of synanthropic animals—the black rat and the house mouse—are included on the list of the 100 most dangerous invasive alien species (*100 of the World's...*, 2000). Many other dangerous alien species are similar to synanthropic rodents in their biology. For example, Ehrlich's review (1989) identified a similar list of properties for successful invaders to that described by Tupikova (1947): large native range; abundant in original territory; 'r' tendency of a species to disperse in a given environment; broad diet; short generation cycle; capacity for shifting between r- and k-strategies; high genetic variability; ability to aggregate; females able to colonize alone; larger size comparing to related species; associated with people; able to function in a wide range of environmental conditions.

Norway rats

Among more than 60 species of *Rattus* genus, only two species: Norway or brown rats (*Rattus norvegicus*) and black or roof rats (*R. rattus*), have colonized urban ecosystems globally for a historically long period of time. Other species, such as *Rattus exulans* may be associated with humans, but are less common in urban areas. Black and Norway rats are characterized as historically introduced species, cosmopolitan in their distribution, and alien by their introduction to places where they did not inhabit previously, and mostly living inside houses or using other man-made features. These two species are distributed throughout the world principally through occasional introductions. The extent of their range is determined mainly by transport connections and freight traffic. In the past, the distribution depended mainly on cart traffic and ship navigation.

The latter was a leading factor for crossing ocean barriers. In the modern world, the role of ground and air transport is increasingly growing. However, this happens more rarely than occasional introductions. In many regions, the network of the area of true synanthropic species depends on the density of settlements.

The Norway rat is one of the most common and dominant rodents in the most cities and small towns in both Russia (especially in its European part) and the USA (especially in eastern North America). Though this species is believed to have originated from the plains of Northern China, it has spread to all continents, except Antarctica and with rare exceptions these rats live wherever humans live, particularly in urban areas (fig. 1). The question of when Norway rats became commensal with humans remains disputed, but as a species they have spread and established themselves along routes of human migration and now live almost everywhere humans do. The Norway rats colonized the southern Far-East Russian (Primorsky Krai, Amur region and Transbaikalia) in the Late Pleistocene - Holocene (Milutin, 1990), may have been present in [Europe](#) as early as 1553 and occupied the European part of Russia in the 17th century. Invasion of Norway rats to some parts of Russia continued during the last decades of 20th century, most notably their penetration to the north along the Yenisey River and Lena River reaching Chukotka (Kucheruk, 1990).

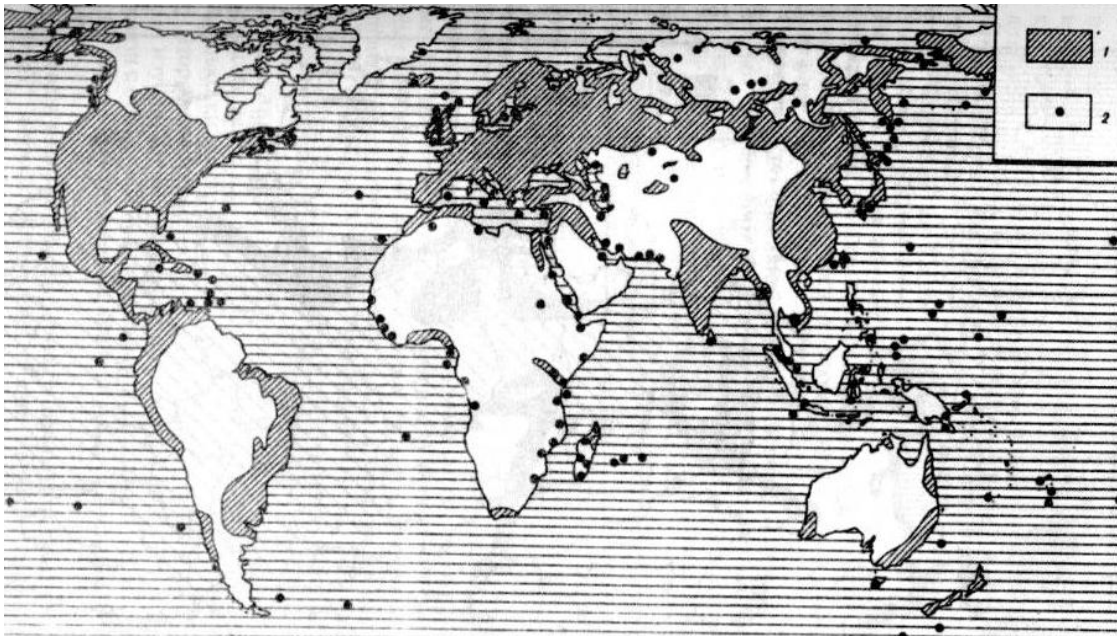


Figure 1. Range of *Rattus norvegicus* (after Kucheruk, 1990). Shaded parts (1) are areas of continuous distribution of the rats and dots (2) indicate separate findings.

In Russia, the distribution of Norway rats depends on density of human populations. These rats are practically absent in regions where less one person per square kilometer. In the European part, this species is absent in the middle of Kolskiy peninsula, between Mezen River and Pechora River, and in Bolshezemelnaya tundra. Significant parts of Eastern Siberia and Western Siberia are still free from rats. In the Russian Far East,

brown rats are reported mainly in urban centers located along transport lines, including seaports (Kucheruk, 1990).

Norway rats reached North America much later - between 1750 and 1775 (Nowak, 1999; Silver, 1927). This can explain one of the differences in ecology of *R. norvegicus* between Russia and the USA such as a more common occupancy of natural habitats by the rats in some parts of Eurasia compared to America. Within the territory of Russia, the degree that rats are restricted to urban environments can vary greatly depending on environmental conditions. In the north-eastern parts of Russia, these rats are strictly synanthropic; in the northern part of European part of Russia Norway rats can migrate to natural habitats during the summer; while in central and southern part of Russia they can live in the natural habitats throughout the year. There Norway rats prefer damp environments, such as river banks, reeds, bamboo, and fields of rice (Kucheruk, 1990; Rylnikov, 2010).

Norway rats colonized urban areas practically through all US states. The outdoor Norway rat population in residential neighborhoods in Baltimore, Maryland, was estimated around 48,000 rats (Easterbrook et al., 2005). A survey of 1,363 residents of Baltimore City found that 64% of respondents observed rats in streets but only 6% saw rats inside residences (Childs et al., 1991). This difference reflects the rat's tendency to burrow under structures in this region. The northern Rocky Mountain States were last remaining sections of this country where much territory was wholly free of rats. According to Silver (1927), rats were reported in Denver in 1886 and by 1907 they were reported in most of the large towns of Colorado. The studies in five states (Colorado, Idaho, Montana, Utah, and Wyoming) conducted from 1947 through 1955 showed that rats were present in each of the above listed States (Harmston and Wright, 1960). In the central Great Plains Norway rats were often associated with agricultural activities and the urban areas that supported them (Bee et al. 1981) and in recent years have become less abundant. The first appearance of rats in Alaska is unrecorded, but as Rausch (1969) stated, the rat became established soon after the arrival of Europeans. It was a report of Norway rats traveling on Russian ships in 1828, and infestation increased steadily. In the early 1940s hundreds of U.S. military ships routinely visited the Aleutians and the rat infestation grew during this time. Since 1950s, presence of Norway rats in Alaska were reported by Clark (1958), Manville and Young (1965), and Haas (1986).

In the USA, the Norway rats are mostly restricted to man-made environments, within urban areas, especially at more northern latitudes. Cities like New York are particularly attractive places for rats because of its aging infrastructure, high moisture and poverty rates. Rats are very comfortable living in alleyways and residential buildings, as there is usually a large and continuous food source in those areas (Sullivan, 2003). They commonly occupy areas around warehouses, stores, slaughterhouses, and docks, although most commercial sites are required to maintain rodent control efforts. Thus, populations are often largest in high human density residential areas. The rats build their nests in burrows along the outside the walls of homes or in various clumps of vegetation. Norway rats may also construct their homes under buildings, beneath the edges of sidewalks, concrete patios, along stream banks, around ponds, and in garbage dumps. In more southern regions of the USA, Norway rats also can live away from

human populations in more rural areas such as marshes and grasslands (Davis, 1953; Glass et al. 1989; Glass et al. 1998).

Though Norway rats can disperse long distances, investigations of marked animals demonstrated that they tend to live within small individual territories that sometimes does not exceed one building (Sudeykin, 1976). A study in Baltimore, Maryland demonstrated that most rats remained within 25 m of the burrows during an evening's foray (Glass et al 1989) and genetic analyses using microsatellite probes showed that rats were assigned to the city block of their capture, indicating strong site fidelity and that rats from one block could be genetically distinguished from rats in the block across the street. (Gardner-Santana et al, 2009). There was evidence of some infrequent, long-distance movement within the city as several rats were assigned to areas 2-11.5 km away (Gardner-Santana et al, 2009).

Norway rats are usually active at night and are good swimmers, both on the surface and underwater. Unlike *R. rattus* they are not especially good climbers though they can climb rough surfaces and tend to inhabit the lower floors of multistory buildings. Norway rats dig well, and often excavate extensive burrow systems (Davis 1953).

This rat is a true omnivore and will consume almost anything (Schein and Orgain 1953). Rats require a substantial amount of grain in their diet. In general, the number of rats is directly proportional to the amount of food, e.g. 10g of food supports one rat (Davis, 1951). Foraging behavior is often population-specific, and varies by environment and food source ([Fragaszy and Perry, 2003](#); [Glass et al 1989](#)), e.g. rats living near a hatchery in [West Virginia](#) caught fingerling fish (Cottam et al. 1948). In urban environments the [life span](#) of rats can be up to four years though more than 90% barely manage one (Davis, 1953; Glass et al 1989; Rylnikov, 2010). A yearly mortality rate was estimated around 95% with predators and interspecies conflict contributing to such high rate (Davis, 1948). Norway rats live in large hierarchical groups, either in burrows or subsurface places such as sewers and cellars.

Black rats

The black rat (*Rattus rattus*) originated in India or [Southeast Asia](#), and spread to the [Near East](#) and [Egypt](#), and then throughout the [Roman Empire](#), reaching [England](#) as early as the 1st century (Engels, 1999). This species appeared not later than the Neolithic Age on the north-eastern coast of the Black Sea. During the 5th century they were introduced north to the Baltic Sea through trade routes along Dnepr River and Don River (Kucheruk, 1991). At that time and later, this species has been introduced through human travel overseas to all continents. Black rats are most often found in large numbers in coastal areas because of the way the species is spread by people via sea ships (Kucheruk and Lapschov, 1994). During the Middle Ages populations of black rats were common in Moscow and other large cities in the Central part of Russia and outbreaks of plague occurred in these regions (Nikolaev, 1968). In 1346–1350, one third of the human population in Europe perished from the plague and black rats were claimed to be the main source for this pandemic (McNeill, 1976).

Black rats are generally found in any area that can support its mainly vegetarian diet. Because *R. rattus* is an excellent climber and often lives in high places, it can be

found in the top floors of buildings or in attics. Even though it can be found near water, this species rarely swims and unlike its close relatives, rarely finds a home in sewers or in aquatic areas.

Today the black rat is again largely confined to warmer areas, having been largely driven out by Norway rats in cooler regions and urban areas. The presence of Norway rats is one of the leading factors affecting the distribution and behavior of black rats (Kalinin, 1995). Ecke (1954) recorded a Norway rat invasion through the southwestern part of Georgia, US that almost eliminated the population of black rats in this region. The invasion overran about 1,000 square miles in six years. Similar processes were observed in Russia starting the 2nd half of the 18th century (Kuznetsov, 1930) and during last decades in Tula region (Panina, 1986). In addition to being larger and more aggressive, the change from wooden structures and thatched roofs to bricked and tiled buildings favored the burrowing Norway rats over the arboreal black rats. In addition, Norway rats eat a wider variety of foods, and are more resistant to weather extremes.

Currently, there are two isolated populations of the black rats in the western part of Russia (Pskov region and along Don River from Smolensk region through north of Voronezh region) with occasional reports from cities located on Oka River, Volga River, on the lower reaches of Don River, and on the Black Sea coast of the Caucasus region (Kucheruk, 1991). In the Asian part of Russia, the black rats were mostly reported from sea ports in Primorsky Krai, Sakhalin, and Kamchatka, and sometimes reach mainland cities (Irkutsk region) (Kucheruk, 1994). In the USA, black rats range along the lower half of the East Coast (e.g. [Glass et al. 1998](#)) and throughout the Gulf States upward into Arkansas. They also exist all along the Pacific Coast and are found on the Hawaiian Islands.

Being a better climber than Norway rats, they tend to flee upwards in case of the danger. The home range of *R. rattus* is usually not more than 100 square meters or even smaller. Black rats generally feed on fruit, grain, cereals, and other vegetation. They are omnivorous, however, and will feed on insects or other invertebrates if necessary. Not only does it gnaw through many materials but it ruins more by excreting on the remains of its foraging efforts ([Nowak, 1999](#)). In a suitable environment it will breed throughout the year, with a female producing three to six litters of up to ten young. Females may regulate their production of offspring during times when food is scarce, producing as few as only one litter a year. *R. rattus* lives for about 2–3 years. Social groups of up to sixty can be formed.

House mice

House mouse (*Mus musculus* s.l.) has spread to all continents (fig. 2). Investigations of house mice by using different genetic markers demonstrated that *Mus musculus* represents a complex of closely related forms of different taxonomic ranks (Wilson & Reeder, 2005). Several taxonomic groups of house mice can be identified within the territory of Russia (Yakimenko et al., 2003; Spiridonova et al., 2008). Those include *M. m. musculus* in the west of the Black Sea coast, *M. m. wagneri* in the northern Caspian zone, and *M. m. castaneus* in the south of Russian Far-East. Yonekawa et al. [2003] could not find any *domestic*-type mtDNA in East of Russia before 1996, but now it was

found near Vladivostok and Irkutsk. It was suggested that *M. m. domesticus* was introduced in Russia after 1996, probably via the Vladivostok port and spread around Vladivostok city. The most taxonomic groups of *M. musculus* can hybridize between themselves. Hybrid zones between these groups can be narrow or quite wide [Boursot et al, 1993; Sage et al., 1993; Yakimenko et al., 2000; 2003; Kotenkova, 2002; Spiridonova et al., 2011 and other].

The oldest record of mice of the genus *Mus* on the territory of Russia (Lower Volga region) is dated to the second half of the Middle Pleistocene (Tesakov and Kirillova, 2007), but synanthropic mice *Mus musculus* colonized Europe in the Late Pleistocene (Klein et al., 1987; Lavrenchenko, 1994; Bonhomme et al., 1994). It is possible that, during this period, they might have penetrated to northern latitudes where encampments of ancient hunters and scavengers were discovered (Verpoorte, 2008). However, the scale of these invasions could not have been large. In Russia house mice exist where the density of human populations is above one person per one square kilometer and also where arable land is present. The house mouse (*M. musculus*) is not so demanding in its need for abundant food and water compared to *Rattus* rats. These rodents can be well established in separate buildings and even within an individual apartment.

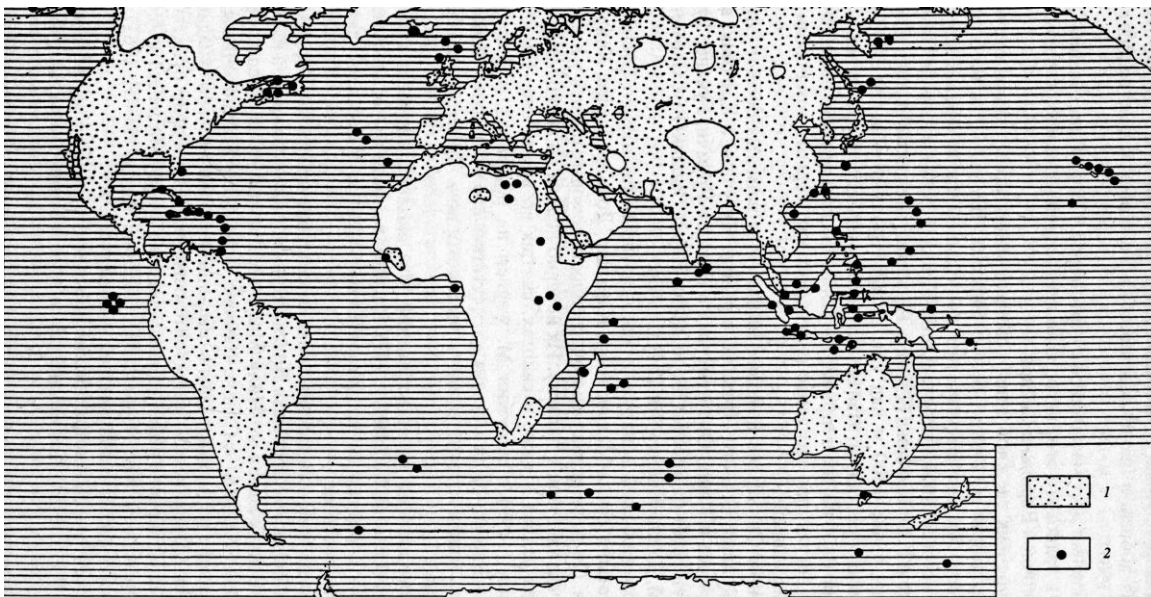


Figure 2. Area of distribution of *Mus musculus* s.l. (after Kucheruk, 1994). Shaded parts (1) are areas of continuous distribution of the house mouse and dots (2) indicate separate findings.

There are three 'belt' zones within the territory of the former USSR based on the association between house mice and the natural environment (Tupikova, 1974, fig. 3). In the northern zone, house mice can live only inside buildings. In the second zone, located immediately south, house mice can occupy natural habitats within 1-2 km from urban centers during summer, but they always return to human houses during a cold season. In both above mentioned zones, house mice can survive only in close association with human dwellings and, when people abandon these places, the mice disappear as well (Chabovsky, Dargolts, 1964; Istomin, 1994; Kucheruk, 1994; Shilova, Kalinin, 1994). In the third (southern) zone, including Primorsky Krai, house mice can leave both within urban centers, and in the field and some natural habitats where they can survive a whole year around. Because arable land significantly expanded during 1990s, house mice have practically occupied all territory within the third zone. As a result, the total number of house mice has increased up to a hundred fold during this period (Tupikova et al., 2000; Neronov et al., 2001).

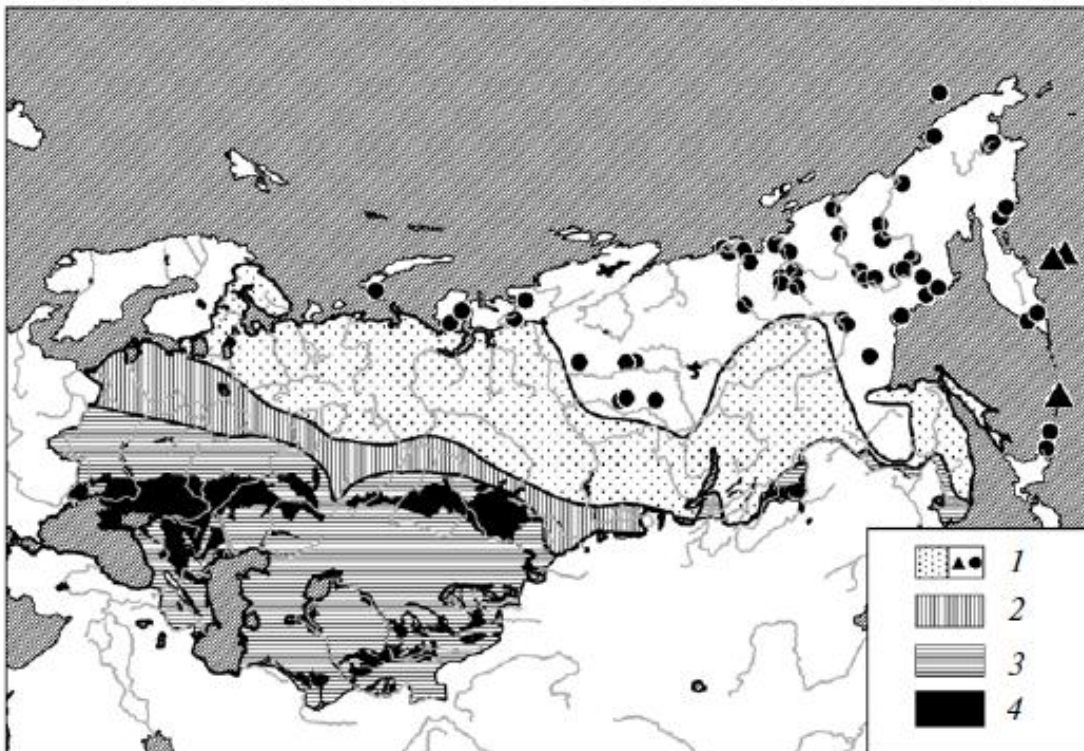


Figure 3. Distribution of house mice in Russia (Tupikova 1947; Khlyap, Warshavsky, 2010): 1) synanthropic populations only; (2) synanthropic populations all year round, agrophilic and exoanthropic in summer only; (3) synanthropic, agrophilic, and exoanthropic populations all year round; (4) as 3, but agrophilic populations prevail. Time of penetration: (all shading and triangles) the area as of the first half of the 20th century; (solid circles) house mice noted in the second half of the 20th century.

In the USA *Mus* shows many similar habitats to those seen in Russia. In urban areas this species is often associated with high density human residential areas, living in the

spaces between common walls and foraging at night within the human habitation. There is substantial clustering of family groups within households of a neighborhood (Childs et al 1992). In the more mild climate of the southern US, house mice will live away from human residences throughout the year, in grasslands and marshes (Korch et al 1989).

Wild rodents within urban territories

Although the most common mammals in urban environments are *Rattus* rats and *Mus* mice, some wild rodents also invade urban territories and can be especially common in areas undergoing development and conversion from rural landscapes to ones that are more urbanized. These species can dominate in areas that are only moderately urbanized and still contain significant patches of natural rodent habitat (Gage and Kosoy, 2008).

Voles are among the most common wild rodents in cities and small towns of Russia and can be found in some US cities as well. Bank voles (*Myodes glareolus*) are common in the deciduous woodland regions of the European part of Russia. Bank voles require ground cover and are found most frequently in hedgerows, banks, roadsides, city parks and other well-vegetated areas, although in the northern reaches of Europe they can be found on relatively open ground, and they have been reported to enter homes. They are often considered pests, because of their habit of stripping bark from small trees, especially larch, elder and young conifers. Among other species of *Myodes*, the northern red-backed vole (*M. rutilus*) can be found in urban and rural areas in Siberia and the Far East of Russia, and southern red-backed vole (*M. gapperi*) can be found in coniferous, deciduous and mixed forests in the western United States.

More than 40 species of *Microtus* voles are known to exist. Important species include the East European vole (*Microtus levis*) and common vole (*Microtus arvalis*) in European part of Russia (Kucheruk, 1988; Tikhonova et al. 2001, 2006), reed vole (*Microtus fortis*) in Transbaikalia and the southern Far East, root vole (*Microtus oeconomus*) in Yakutia and narrow-headed Vole (*Microtus gregalis*) in Yakutia and South Siberia. These species also occur in gardens and open woodlands, as they seek out their primary food sources, which consist of grasses, as well as the stems, roots and bark of other plants. At least 17 species of *Microtus* voles occur in North America. Among the most important of these are the meadow vole (*M. pennsylvanicus*), California vole (*Microtus californicus*), prairie vole (*Microtus ochrogaster*), montane vole (*Microtus montanus*) and long-tailed vole (*Microtus longicaudus*). The meadow vole occurs in moist grassy fields and meadows over much of the northern two thirds of North America. The California vole occurs throughout much of California and southern Oregon in low-elevation grasslands, wet meadows, coastal wetlands and open oak savannahs with adequate ground cover (Kays & Wilson, 2002). Muskrats (*Ondatra zibethicus*) are basically large aquatic voles that are native to North America, but have been transplanted to many regions in Eurasia. They occur frequently in ponds and waterways in suburban and largely urban areas both America and Russia. Mountains species of

voles are rarely can be found in towns: *Alticola strelzowi* and *A. barakshin* occur in the in the mountains of Siberia, voles of genus *Chionomys* - in Caucasus Mountains.

Near 13 species of subfamily Cricetinae are known in Russia, 8 of them are found in human settlements. They are: *Cricetulus barabensis* (it is common in settlements of the steppe regions of Buryatia and Chita, and also leads among rodents trapped in the buildings of Tuva and Ubsunursk basins and high mountains of Tuva), *Allocricetulus evermanni*, *Phodopus sungorus*, *Phodopus campbelli*, *Cricetulus longicaudatus*, *Tscherskia triton*, *Cricetulus migratorius*, *Cricetus cricetus*. For example, in Moscow, there is an island population of *Cricetus cricetus* (Karaseva et al., 1999) that is separated from the main part of the area for tens of kilometers to the north. Mice of the genus *Apodemus* can occupy urban centers of Russia in both European and Asian parts. They eat primarily grasses, seeds, nuts, fruits and other plant materials, as well as some insects and snails. Striped field mice (*Apodemus agrarius*) and pygmy field mice (*A. uralensis*) are widely spread and persistent species in some cities of Russia. The striped field mice enter houses, barns and stables and have been reported to colonize highly urbanized areas (Kucheruk, 1988; Tikhonova et al. 2001, 2006); this process is well described in Warsaw, Poland (Andrzejewski et al., 1978). Being highly adaptable, they often occupy gardens and city parks and will enter houses in winter, particularly when house mice are absent. Another species of *Apodemus*, the yellow-necked mouse (*A. flavicollis*) is also common in woodlands, hedgerows, field margins, orchards and wooded gardens. Yellow-necked mice also frequently enter homes as winter approaches, but typically depart by spring. They are known to store caches of nuts in small spaces and under floorboards. In the Russian Far East, these mice replaced with *Apodemus peninsulae* (Kucheruk, 1988). All 3 species of gerbils in Russian can occur in the human settlements. The most important is *Meriones unguiculatus* that is common in the southern of semi-desert part of Tuva (Kucheruk, 1988).

In the USA, native rodent species commonly belonged to the subfamily Sigmodontinae that contains a wide variety of species, including some that occur near human habitations. The most important genera are *Peromyscus* (deer mice and their allies), *Neotoma* (wood rats) and *Sigmodon* (cotton rats). Carlton (1989) recognized 53 species of *Peromyscus*, and all of these are likely to invade human dwellings under certain circumstances (Cahalane, 1961). However, the two species of *Peromyscus* most likely to be encountered by people are the widespread deer mouse (*P. maniculatus*) and white-footed mouse (*P. leucopus*) (Glass et al 1997; King, 1968; Kays & Wilson, 2002). Both species are abundant over large areas of the USA, with the deer mouse occupying all but the south-eastern portion of temperate North America and the white-footed mouse occurring over the eastern half of the continent and in portions of the south-western US. In many respects, including behavior, appearance and general ecology, these mice resemble European species of *Apodemus* mice and can be considered ecological equivalents. *Peromyscus* mice consume a variety of seeds, other vegetable matter and insects. Deer mice are particularly common in grasslands or mixed grass and brush habitats; white-footed mice are more likely to occur in woodland or mixed woodland and brush habitats. Both species will enter homes and other buildings, particularly as winter approaches. Their gnawing near nest entry points on homes or

other structures can cause limited damage to wood siding and their excreta can create an unsanitary situation.

Although wood rats (*Neotoma* spp.) occur in both the eastern and western portions of temperate North America, the diversity of species is greatest in the western half of the continent. Their other name (pack rats) comes from the distinctive nests they build, which consist of large piles of sticks that are often placed at the base of a tree or sometimes next to a man-made wall. Several species of *Neotoma* woodrats are known to build their nests in the walls or crawl spaces of homes, garages or other buildings. The gnawing activities of these rats, as well as the extensive piles of excreta associated with their nests, can result in damage to homes or other property and cause an unsightly mess. Cotton rats (genus *Sigmodon*) are common in grassy and weedy fields in many areas of southern US. The most important species in the temperate regions of the continent is the hispid cotton rat (*S. hispidus*), which is often extremely abundant in thick grassy habitats in the south-eastern and south-central United States (Cameron & Spencer, 1981; Glass and Slade 1980). In many ways, the behavior and ecology of cotton rats resemble those of voles, which are more common in the northern parts of the continent. These similarities include not only types of habitats selected, but also include the construction of grass nests and runways, extremely high reproduction rates and populations that often fluctuate dramatically from year to year. Cotton rats can be destructive to food supplies.

Chipmunks are members of the genus *Tamias*. The Siberian chipmunk (*Tamias sibiricus*), which can be found frequently in parks and towns, is widely distributed in parts of the Russian Federation (the north-eastern part of Europe, Siberia and the far-eastern part). The 22 species of North American chipmunks occur primarily in the mountain forests and nearby sagebrush habitats of the western third of the continent. A single species, the eastern chipmunk (*T. striatus*), occurs abundantly in the deciduous forest regions of the eastern United States and south-eastern Canada, routinely entering yards and gardens in many suburban areas (Mahan & O'Connell, 2005). Some western species occasionally invade homes, where they build nests in attics or wall spaces, sometimes damaging these structures in the process. Invaded spaces are often partially filled with large stockpiles of nuts, pine cones and other edible items. Although chipmunk nesting and hoarding activities can cause some damage, they are of little economic importance. Their primary foods are fruits, nuts, berries, seeds and occasional invertebrates.

Tree squirrels provide a classic example of the successful use of urbanized environments by rodents. In the European part of Russia the red squirrel (*Sciurus vulgaris*), is the most common species of tree squirrel and in the USA common tree squirrels include the gray squirrel and fox squirrel (*Sciurus niger*) in the eastern United States. Both species are common in urban environments, and the latter has been introduced into various cities in the western United States. *Glaucomys* spp (flying squirrels) occasionally invade attics and wall spaces in mountainous areas. Although tree squirrels forage on the ground, they rarely stray far from a tree, where they can flee to safety. These squirrels also can occur at high densities in parks and gardens, raising the likelihood of contact with people.

Another big group of rodents belonging to the family Sciuridae that can occupy urban habitats in the USA and some Asian parts of Russia are ground squirrels (genus *Spermophilus*). Because ground squirrels are large and active during daylight hours, people frequently notice them, and some enjoy having them near their homes, while others consider them destructive and try to eliminate them. North American species of ground squirrels are found primarily in the western grasslands, mountains and deserts, although a couple of species have ranges that extend into the eastern half of the continent. In many instances, these ground squirrels live in wilderness or highly rural areas, but a few species occur regularly near human dwellings and city parks, where they can damage structures, gardens, orchards, crops and other items. Foremost among the ground squirrels encountered in peridomestic environments are two closely related species, the rock squirrel (*Spermophilus variegatus*) and the California ground squirrel (*S. beecheyi*). Rock squirrels occur throughout much of the south-western United States and California ground squirrels are found in many areas of California, western Nevada and southern Oregon. Both species behave similarly and often dig burrows under concrete slabs, woodpiles or other sites near people's homes (Oaks et al., 1987; Jameson & Peeters, 2004). Some have suggested that rock squirrel numbers in the south-western United States have increased as a result of home building and other human activities that provide these animals with novel sources of food (such as pet foods, seeds from bird feeders and water from dripping faucets) and shelter (such as rock piles and walls) (Barnes, 1982). A third species of ground squirrel, the golden-mantled ground squirrel (*S. lateralis*), can occur near human dwellings in mountainous areas of western North America. It is frequently encountered in recreational sites, including heavily used campgrounds in California and adjoining areas, as well as many regions of the Rocky Mountains. Other species of North American ground squirrels also occur occasionally near human habitations, but they generally have limited distribution in urban environments. Within the Russian territory *Spermophilus undulatus* occurs in towns in the Altai and *Spermophilus parryi* in the Yakutia [Kucheruk, 1988]. Prairie dogs are the most common sciurid rodents in some urban areas of the western US, especially in small cities of Colorado, Wyoming, Montana, South Dakota, Kansas, Arizona and New Mexico. Among the five prairie dog species, the black-tailed prairie dog (*C. ludovicianus*) is most likely to occur in close proximity to people, being fairly common in many suburban and even some urban areas, particularly those along the Front Range of the Colorado Rocky Mountains, a region that includes the Denver Metropolitan Area and numerous smaller cities. In some instances, small colonies of this species occur in isolated patches of habitat that are almost completely surrounded by urban development. When living in urbanized environments, prairie dogs can be destructive to shrubs or other plants that are eaten for food or instinctively cropped, White-tailed prairie dogs (*C. leucurus*) are quite abundant and widespread, but also typically live in environments far removed from major urbanized areas (Clark et al., 1971). The closely related Gunnison's prairie dog (*C. gunnisoni*) is found on the Colorado Plateau and surrounding regions of the south-western United States. Unlike the above three species, Gunnison's prairie dogs often establish colonies near human dwellings, such as near Albuquerque, New Mexico.

Within urban areas in Russia there were also reported of members of families Castoridae (*Castor fiber* in Moscow), Dipodidae (*Allactaga sibirica* – Altai, *Sicista betulina* – Moscow), Gliridae (*Muscardinus avellanarius* – Moscow, *Dryomys nitedula* – near Makhachkala, and *Glis glis* – Caucasus).

Urban development clearly creates dramatic changes in rodent communities. The higher level of urbanization, the higher intensity of changes in fauna of rodents within city limits can be observed. Commonalities between analyzed geographic areas include a dominance of Norway rats and house mice, which have historically colonized urban ecosystems, globally. Some differences in their ecology between two countries can be partially explained by the fact that these species were introduced into the USA much later than to the European and Asian parts of Russia. The wild rodents that occupy urban territories in both countries can represent many other species and species compositions are influenced by rodent communities in natural habitats surrounding cities. Various aspects of the biology of urban rodents, such as enormous reproductive potential, feeding behavior and adaptations to city environment contribute to the failure of many rodent control programs, but also grant a necessity to investigate many aspects of biology and ecology of these animals. There is a need for characterization of demographic and population density changes of rodents caused by urbanization and its effect on their diversity, ecology, and behavior patterns, including their dispersal rates. Development of mathematical models based on such information can be useful in predicting expansions of rodent species in areas that were not infested by rodent of these species. The possible effects of climate changes on distribution of urban rodents should be also further investigated.

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