THE BIOLOGY OF MICROTINE CYCLES

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INTRODUCTION

Striking increases in rodent populations have been recorded since Biblical times. Such plagues and the resultant economic losses have engaged the attention of scientists for years. More recently, and from the viewpoint of economic zoology, attention has been directed to these phenomena of cycles with their resultant change of population levels. Mass increases in a species are obvious, and have excited the interest of biologists periodically, so that an extended literature has resulted. Periods of scarcity of any species are far less noticeable, and accordingly are seldom recorded.

Microtine (short-tailed field mice or voles) species exhibit a regular periodicity in their cyclic behavior. A study of this subject is justified because of the damage to agriculture caused by these animals, particularly at the height of the cycle. By their destruction of fruit trees, hays, cereals, and garden truck, the annual loss runs into millions of dollars. A careful study of a cycle might well elucidate the factors responsible for the plague, and, if it does not suggest remedial measures, it might at least indicate some possibility of forecasting periods of optimum density. Thence practical control measures for the anticipated hordes of mice can be inaugurated.

REVIEW OF LITERATURE

Few detailed observations of cycles have been recorded. Lantz (4) records a number of instances which clearly show the cyclic tendency of Microtus, but apparently was not cognizant of fluctuating populations and their periodic recurrence. Elton (2) and Middleton (5) observed vole cycles in Great Britain, Collett in Norway, mentioned by Elton and his coworkers (2), while recent studies in the Union of Soviet Socialist Republics by Vinogradov (12), Pidopiichka, according to Vinogradov, and Plater-Plochotzkij (7) suggest a cyclic tendency among microtines.

PERIODICITY OF CYCLES

All available evidence points to a 4-year cycle. Lantz (4) presents considerable data, gleaned from circulars distributed to orchardists, that Microtus was abnormally abundant in 1863, 1883, and 1887. During the summer of 1888 mice were notably scarce, following 2 years of abundance. Their numbers were again high in Ohio in 1890. Mice were extraordinarily abundant in 1903 and once more, after a notable
decrease, became abundant in the spring of 1906. One correspondent wrote of "remembering four to five seasons out of the past twenty-five when the pest was very, very numerous. It seems almost incredible how all of a sudden they come and then seemingly disappear.”

Elton and his coworkers (2) and Middleton (5) give much evidence of the existence of a 4-year cycle in British voles. In Norway, Collett, according to Elton et al., presents data suggestive of a 3½-year cycle for Microtus agrestis. Vinogradov (12) has attempted to establish a 10-year cycle in the Union of Soviet Socialist Republics, these outbreaks occurring in the year ended with a 3 (i.e. 1763, 1933). His data, chiefly of a historical report, and not based on field work, rather suggest a much shorter period. Pidoplichka, as reported by Vinogradov (12), disputes a 10-year cycle in Russian voles, and shows that a maxima can be reached in 2½ years. Plater-Plochotzkij (7) indicates a short cycle for M. pelliceus, possibly of 3 or 4 years.

The investigators of Great Britain and the Union of Soviet Socialist Republics thus postulate a cycle in voles approximating 4 years. These data favor studies of the writer, which indicate a similar periodicity in northeastern United States. While the peak of a cycle usually terminates at the end of 4 years, increasing populations is not of necessity a gradual one. Under ideal conditions mice may reach plague proportions in 3 years. Similarly, populations at the peak of a cycle may not assume alarming proportions and do not always cause widespread destruction.

Extensive trapping records, quadrat studies, close field observations, and the records of county agricultural agents indicate that mice were extremely abundant in New York State during the winters of 1919–20, 1923–24, 1927–28, 1931–32, and 1935–36. G. C. Oderkirk, district agent of the United States Bureau of Biological Survey, writes (in litteris June 26, 1936) that in Illinois and Indiana population highs occurred in the general periods 1923–24, 1927–28, and 1931–32. Oderkirk further observed that mice were again very abundant in this area during the winter of 1935–36.

METHODS

The studies here recorded are based chiefly on field and laboratory observations on the field mouse (Microtus pennsylvanicus pennsylvanicus (Ord.)) in the Ithaca, N. Y., locality. Field notes are available from 1924 to 1936, but most of the data are based on intensive studies extending from the spring of 1933 until the fall of 1936. A total of 4,000 animals were examined, equally divided as to sex, and representing all ages. The distribution of the collections by months was sufficient to give reliable data.

In 1932 11 areas more or less defined by natural boundaries, were mapped. These areas, all supporting a microtine population, varied from one-half acre to 12 acres. Trapping was commenced in 1932, with snapback traps which were replaced in 1933 largely by traps designed to take the animals alive. From the spring of 1934 to the fall of 1936, trapping was conducted in every month.

In the larger areas, where snapback traps were placed, trapping was conducted for a week with 100 traps. The traps were all baited with oatmeal flakes (the most attractive of many baits tried). An area is thus quickly rendered free of mice, more than four-fifths of them
being trapped in the first 2 days. Unpublished data of the writer usually indicate that the home range of Microtus is very small, usually encompassing an area not exceeding 2,000 square feet. Thus trapping in the center of a 10-acre tract (while not depleting the population excepting in the middle of the area) will give a fair index to the population level for different years. Traps set at 10-pace intervals through the area (such stations being marked with permanent stakes) is another method which has proven satisfactory. Traps are set within 1 or 2 feet of the stakes and are thus easily recovered.

In areas up to 3 acres the mice caught alive were counted, marked, and released after the area had been trapped a week. This method, conducted similarly over a 4-year period, indicates roughly the fluctuations in the mouse population for the different areas under observation. Obviously some of the areas were better suited to mice than others and accordingly supported a larger population. All that were continuously studied for 3 or more years show a marked increase in mice from the fall of 1932 to the spring of 1936.

**MOUSE POPULATIONS**

Microtine numbers vary in any one locality from year to year. When at their peak, the voles frequently exist in incredible numbers; shortly after periodic decline few may be found. Piper (6) estimated 8,000 to 12,000 mice per acre during the Nevada plague of 1907. The fields were riddled with their holes, which were scarcely a step apart. Pidoplichka recorded few mice in an area of the Union of Soviet Socialist Republics in 1925; by 1927 their numbers had reached 6,000 per hectare. Fortunately, the eastern United States has never experienced such hordes, but the rise and fall of murine populations is none the less apparent to one who follows these from year to year. Townsend (11) estimated the population of Microtus in Central New York as 2 to 67 per acre in various habitats. From his studies, he believed Microtus was more abundant in 1933 than in 1934.

Estimates of population per acre based on trapping records over a 4-year period are indicated in figure 1. To substantiate these estimates, several areas were selected and thoroughly trapped. The populations actually existing in such areas agree essentially with the estimates based on a week of trapping.

Studies indicate a mouse population in the spring of 1933 ranging from 15 to 40 per acre depending on the habitat. Other factors being equal, larger areas produced higher populations per unit area than did the smaller areas. A gradual increase in the population occurred, with losses during the winters when no breeding was apparent. This increase culminated in apparent optimum densities of mice in the winter of 1935-36. Populations of 160 to 230 mice per acre were reached. At Ticonderoga, Essex County, N. Y., Lyle W. Johnson saw from 2 to 8 mice about each tree in his orchard during late November. Later, while removing mulch, he saw 3 to 4 mice per tree and estimated the mouse population during early December as 200 to 300 mice per acre. These populations are similar to those observed by Elton et al. (2), who indicate that voles reached densities of over 100 per acre, but probably less than 200 per acre on the Scottish border during the spring of 1934.
Population density of voles may be indicated by amount of fresh dung over unit areas. The droppings are characteristically green when fresh, and are usually deposited in little piles at irregular intervals along the runways. Less often they are scattered promiscuously along the trails. If suitable areas of sufficient size (3 to 10 acres) be selected, and counts of pellet middens be made in a uniform manner at regular intervals, some index to periodicity in population levels will be available. Spacing the counts at 10- or 20-foot intervals will eliminate the unconscious choice of likely stations.
A wire circle 20 inches in diameter was dropped at 20-foot intervals, 100 counts being made for each investigated area. Monthly records thus secured substantiated the trapping records and indicate a sharp decrease in mouse numbers in many areas from the winter of 1935–36 to the summer of 1936 (table 1).

**Table 1.—Fecal counts as an indicator of mouse abundance in a 12-acre field at Ithaca, N. Y.**

[Percentage of 100 stations showing fresh droppings at time indicated]

<table>
<thead>
<tr>
<th>Date</th>
<th>Percentage of stations with fresh droppings</th>
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<th>Percentage of stations with fresh droppings</th>
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<th>Percentage of stations with fresh droppings</th>
<th>Date</th>
<th>Percentage of stations with fresh droppings</th>
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</thead>
<tbody>
<tr>
<td>1934</td>
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<td>1936</td>
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<td>March... 24</td>
<td>November... 65</td>
<td>May... 92</td>
<td>March... 89</td>
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<td>April... 30</td>
<td>December... 48</td>
<td>June... 78</td>
<td>April... 69</td>
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<td>July... 83</td>
<td>May... 21</td>
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<td>June... 43</td>
<td>September... 91</td>
<td>September... 23</td>
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<td>July... 40</td>
<td>October... 83</td>
<td>October... 29</td>
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</tr>
<tr>
<td>August... 33</td>
<td>January... 62</td>
<td>November... 98</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>September... 58</td>
<td>February... 55</td>
<td>December... 94</td>
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<tr>
<td>October... 69</td>
<td>April... 86</td>
<td>September... 27</td>
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<td>October... 31</td>
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</tbody>
</table>

1 At 80 stations.

**FACTORS RESPONSIBLE FOR CYCLIC INCREASE**

Both biotic and abiotic factors contribute toward population oscillations. Among the biotic factors which permit increasing populations of small rodents might be mentioned a dearth of predators, parasites, and disease. Abiotic conditions favoring increase are physical and are mainly concerned with favorable climatic conditions such as mild winters or those with much snow, and wet summers. Rigorous winters with little snow and dry summers are reflected in a reduced population.

Obviously any change in the reproductive behavior of a species that would tend toward increased populations should be indicated during the waxing of a cycle. Actually, population densities are augmented by acceleration of the breeding rate, increased number of young per litter, and prolongation of the breeding season.

**ACCELERATION OF THE BREEDING RATE**

Microtine rodents are the most prolific breeders of all mammals. Their litters follow one upon another in rapid succession. Bailey (1) reared 13 litters from a single female *Microtus* within a year, while the writer had one female that produced nine litters in 8 months. It is not known how long the mice stay in heat, but observations on captives indicate that the period is extremely short, perhaps a few hours. The oestrous period normally follows parturition. Fruitful copulation is thus possible immediately after the young are born. It is not uncommon to collect gravid nursing individuals. Repeatedly females are trapped that give evidence of very recent parturition, a bloody discharge being yet apparent. Ostensibly these promiscuous individuals are ready and willing to accept a male. Frequently a copulation plug is present when the uteri are yet distended following...
partus. It thus seems apparent, from field observations, that one mating follows another in rapid succession when the two sexes are abundant enough to make this condition possible.

During periods of low population densities, the chances are greatly lessened of a female in oestrous meeting a fertile male. Such females might repeatedly pass the critical oestrous period before a successful mating occurs. This would lessen the rate of breeding.

Long familiarity with the appearance of breeding mice has enabled the writer to determine, from wild-caught specimens, whether or not they were lactating, and, if lactating, the approximate age of the nursing young. It was thus possible to determine, in pregnant individuals, by an examination of the teats, whether they were or were not nursing. If a high percentage of the nursing mice were gravid, it would indicate young were being produced exceptionally fast. If, on the other hand, few lactating mice were pregnant, it would appear that young were not being produced at an excessive rate.

Table 2 indicates the acceleration in the breeding rate from the fall of 1933 until the summer of 1936. It will be noted that during the period of mortality (March to June 1936) breeding was not materially affected, only a decrease in litter size being apparent. This is in contrast to the observation of Preble (8) who found during an epidemic among snowshoe rabbits a great curtailment in the breeding activities in the Athabasca-MacKenzie region in 1905. Local epidemics in widely scattered areas of New York (Westchester, Seneca, and Tompkins Counties) occurred from late March into the early summer of 1936.

Table 2.—Percentage of nursing mice that were gravid as an index to the rate of breeding

<table>
<thead>
<tr>
<th>Month</th>
<th>1933</th>
<th>1934</th>
<th>1935</th>
<th>1936</th>
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<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
<td>Percent</td>
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<tr>
<td>January</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>February</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>March</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>April</td>
<td>20</td>
<td>15.0</td>
<td>22</td>
<td>13.6</td>
</tr>
<tr>
<td>May</td>
<td>8</td>
<td>37.5</td>
<td>15</td>
<td>60.0</td>
</tr>
<tr>
<td>June</td>
<td>15</td>
<td>75.3</td>
<td>24</td>
<td>83.3</td>
</tr>
<tr>
<td>July</td>
<td>7</td>
<td>71.4</td>
<td>19</td>
<td>73.7</td>
</tr>
<tr>
<td>August</td>
<td>28</td>
<td>75.0</td>
<td>38</td>
<td>78.9</td>
</tr>
<tr>
<td>September</td>
<td>21</td>
<td>38.1</td>
<td>14</td>
<td>42.8</td>
</tr>
<tr>
<td>October</td>
<td>16</td>
<td>37.5</td>
<td>10</td>
<td>26.0</td>
</tr>
<tr>
<td>November</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>December</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

INCREASED NUMBER OF YOUNG PER LITTER

Larger litters during the ascendancy of the cycle augment the mouse population. The number of young per litter ranges from 1 to 11. The average number, based on data from females taken in every month of the year, and over a 4-year period (1933-36), is 5.07. Embryo counts of necessity do not give an exact criteria of the young produced. Resorption of embryos frequently occurs, especially in the period approaching the peak of the cycle, or at its culmination. Young are occasionally still-born in captivity, and
this undoubtedly occurs also in the wild state. Yet sufficient embryo counts made over a period of years do indicate whether the number per litter is increasing or decreasing. Increased litter size was apparent in each of the corresponding months from 1933 until 1935 (fig. 2). With mice dying, probably from an epizootic, during the spring of 1936, a decrease in litter size followed. Thus the average number of embryos for July 1936 was 4.5, the corresponding month in 1933, 1934, and 1935 it was 6, 6, and 6.2, respectively.

PROLONGATION OF THE BREEDING SEASON

The breeding season of cyclic rodents varies from year to year, depending largely on the density of population. Field mice commonly breed in central New York from mid-March until mid-November. Except during the third or fourth year of the cycle, the mouse numbers usually have not reached excessive proportions and the mice do not customarily breed during the winter months (December to February). In the year of greatest mouse abundance, cold weather curtails winter breeding greatly, yet a fair proportion of the animals continue to produce young throughout the winter. A considerable decrease in the litter size and frequency of breeding during the winter is, however, apparent. There was no indication of cessation of breeding during the winter of 1935–36 as was evident in the previous two winters (fig. 2). Following a period of reduced mouse populations in the spring and summer of 1936, it became evident that a smaller share than usual of the surviving mice were breeding.

FACTORS RESPONSIBLE FOR DECREASE IN NUMBERS

Abiotic factors, such as climatic conditions, might conceivably have a limiting effect upon animal populations. Biotic factors, such as abundance of predators or parasites and disease, might likewise account for an appreciable toll.
CLIMATIC CONDITIONS

Climatic conditions apparently exerted little influence in minimizing a steady increase of the murine population from the winter of 1932 until 1935. Snow acts as protection for mice, both by discouraging predators and by excluding frost from the ground. Mice were extraordinarily abundant in central New York during the winter of 1931-32, yet in the area under investigation there were but 6 days during December, January, and February in which more than 2 inches of snow remained on the ground. After a sharp decrease in numbers, mice began to increase during the winter of 1932-33, yet on only 15 days of the entire winter did snow remain on the ground to a depth of 2 inches.

Similar conditions prevailed during the winters of 1933-34 and 1934-35. The mice showed greatest increase in the fall and early winter of 1935 and continued abundant until late spring of 1936. Prolonged periods of deep snow during the winter undoubtedly helped the mice to increase. On the other hand, prolonged dry periods limit the increase. Reports from the Midwest had indicated that the peaks in mouse population occurred synchronously with those in the East during 1923-24, 1927-28, and 1931-32. While the voles were again abundant in Michigan, Indiana, Illinois, and Wisconsin during the winter of 1935-36, they were still abundant in this area during the summer of 1936. The prolonged drought at this time may have delayed appearance of the peak.

Orchardists frequently attribute mouse abundance and consequent damage to prolonged periods of heavy snowfall. In central New York during the winter of 1930-31 snow remained on the ground from mid-December until mid-March, yet mice were not abundant nor was there any considerable damage. A similar situation prevailed during the winter of 1922-23, yet mice were not particularly abundant and little damage resulted. A combination of prolonged periods of deep snow synchronous with peaks in mouse population usually cause severe damage.

Unlike the emigrations of lemmings and gray squirrels, which appear to indicate peaks in the populations of these animals, there is no indication of mass movements of microtines. When the high of a cycle has been achieved, there usually is no territory for the animals to preempt, for all suitable cover is well populated with their kin.

PREDATORS

Carnivorous enemies, such as dogs, cats, foxes, weasels, skunks, hawks, and owls, while undoubtedly preventing local outbreaks upon occasion, can do little to check high populations which are a natural phenomena of the lives of cyclic rodents. The rodent's power of reproduction is so great, that once their numbers have passed a crucial stage, the slow-breeding predators cannot control them. If the outbreaks were extremely local, predators might flock to the area and successfully cope with the situation. Such peaks, in the East, usually occur over an area extensive enough to prevent any concentration of predators at a given point. In the western United States, outbreaks of rodents have usually been of a relatively local nature, and predators then swarm to the locality, taking colossal toll of the mice. Inasmuch as the increase leading to a maxima usually takes
takes place within a single breeding season, or two at the most, there is little chance for carnivores to successfully combat these pests.

**DISEASE AND PARASITES**

All available evidence indicates that disease is the control factor that terminates these mass increases of rodents. Piper (6) has recorded many dead and dying voles after the peak of the Nevada mouse plague of 1907–8. While the mice were ostensibly killed by disease, all attempts to isolate a specific bacterial disease met with failure.

The 1926–27 outbreak in Kern County, Calif., consisted chiefly of the house mice (*Mus musculus*), although meadow mice (*Microtus californicus*) were estimated at 4,000 per acre. According to Selle (10) 200 of these mice, brought into the laboratory, were found to be suffering from symptoms of an infection which caused them to snuffle and their eyes to secrete a yellowish serous fluid. Selle states that more than half the mice were lost in the first month of captivity. The epizootic was likewise studied by Wayson (13) who performed necropsies on many of the morbid microtines, and was able to isolate the causative bacillus of mouse septicemia (*Bacillus murisepticus*) or swine erysipelas (*B. rhusiopathiae*) both of which are considered identical by Preisz (9).

Recently Findlay and Middleton (3), during a period of mortality among wild voles (*Microtus agrestis*) found the only apparent cause of death has been the presence of cysts of a toxoplasm (*Toxoplasma microti*) in the brains. Elton, Davis, and Findlay (2) record a severe epidemic which destroyed many voles, the causative agent being a protozoan (*Toxoplasma*) infection of the brain.

Where great masses of mice assemble following a rapid increase in numbers, the spread of contagious disease is spectacular. A large proportion is quickly destroyed, and few escape the plague. In the eastern United States, where the rodents pass through less spectacular increases, the hordes are more evenly spaced over large areas of suitable habitat and accordingly spread of disease is limited.

That disease was the paramount factor in reducing the 1936 spring population of mice cannot be denied. Edwin H. Buerman, a professional bridge grafter of Williamson, N. Y., grafted trees in western New York daily during June 1936. He informed the writer that while mice were very abundant during the previous fall and winter, few live ones were observed during June. Dead mice, adults and young, were found in their nests on several occasions. Several students of the writer likewise found dead mice in nests during early spring. LeRoy Garnsey of Seneca Falls, N. Y., was in the field constantly during the spring and summer of 1936. He found large numbers of dead mice on his farm, which, upon examination showed no marks or injury of any nature.

Voles taken in late March exhibited symptoms similar to those described by Findlay and Middleton (3). The mice became sluggish, the fur stood on end, becoming damp and slightly oily, and lethargy was pronounced. After incipient drowsiness, a characteristic spasmodic twitching of the neck and shoulders was manifest, the animal soon falling on its side. Watery discharges from the vent and gasping accompanied this final stage, the animals thrusting their hind legs
straight backward. Convulsive activity soon resulted in death. Eleven captives exhibited such clinical symptoms with resultant fatality.

Laboratory analysis of two mice exhibiting convulsive behavior was made by Dr. Alexander Zeissig of the New York Veterinary College. His observations are recorded below.

**Gross examination.**—All of the internal organs appear normal except the liver which in both specimens contained a large cyst near the periphery of the organ. The cysts measured 2 by 1.5 cm and the shape was that of an almond. On opening the cyst what appeared to be the cystic form of a tapeworm was found.

**Cultural examination.**—About 0.3 cc of the heart blood was removed under aseptic precautions with a Pasteur pipette and transferred to an agar slant. After several days incubation the medium remained sterile.

**Microscopical examination.**—A smear was made from the heart blood and stained with Wright's stain. No blood parasites were observed.

Unfortunately the small number examined is not indicative nor do the observations preclude the possibility of the presence of a filterable virus.

Blood smears were stained and studied repeatedly during the spring and summer of 1936, but no indication of blood parasites was found.

Inasmuch as the stricken mice exhibited symptoms which suggested cerebral irritations, brains were removed from comatose mice, sectioned, stained, and a thorough study was made for toxoplasms or other contributory disease organisms. None was found.

At the peak of the cycle, and during its decline, bladder worms were found in the liver of approximately one-fourth of the mice. These were determined as the cysticercus, or bladder worm stage, of *Taenia taeniaeformis* Wolffhuegel by E. W. Price, Bureau of Animal Industry, United States Department of Agriculture.

While microtines always support a population of external parasites, ectoparasites were uncommonly abundant during late 1935 and early 1936. Aside from their mechanical irritation and consumption of blood, certain arthropod species are responsible for the transmission of destructive infectious diseases. Ectoparasites were determined by H. E. Ewing, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

The most abundant parasite, a louse (*Hoplopleura a. acanthopus* (Burm.)) was, during this period, much in evidence. More than a thousand were taken from one mouse; it was not uncommon to recover 300 or 400 from single animals during March and April 1936. Mites were likewise abundant, especially *Laelaps microti* (Ewing) and *Atricholaelaps glasgowi* (Ewing). *Laelaps* frequently numbered in excess of 200 per mouse. Two fleas, *Orchopeas leucopus* (Bak.) and *Ctenophthalmus pseudagyotes* Bak., were not uncommon, occasionally six fleas being recovered from one mouse. Fleas and lice persisted on the mice for 20 hours after death of the rodent.

**FORECASTING MOUSE YEARS**

It is highly desirable to know the expectant high in a mouse cycle, for control measures can be inaugurated before severe infestations occur and the resultant loss thus minimized. It has been shown that the highs in mouse populations occur periodically, usually at intervals of 4 years. Past high populations have occurred in the winters of 1919–20, 1923–24, 1927–28, 1931–32, and 1935–36. Extended records
are not available prior to this period, but scattered reports indicate a
regular periodicity of the cycle since 1863.

Assuming there will be no deviation from this frequency, we may
look for the next high in 1939–40 and every fourth year thereafter.
Eternal vigilance and constant warfare should not be relaxed, for local
conditions often permit exaggerated populations to appear before the
anticipated climax to the cycle. Based on observations outlined in
this paper, it was possible to forecast high populations of mice 18
months before their appearance, while the mouse population was far
from numerous. Following extensive warnings and suggested field
practices 1½ years prior to the outbreak, orchardists were able to safe-
guard their trees in part from the most severe mouse infestation New
York has ever experienced.

SUMMARY

Field mice (*Microtus pennsylvanicus*) exhibit variable populations
from year to year. A 4-year cycle has been established for north-
eastern United States. From a low of 15 to 40 mice per acre after
the periodic decline, populations build up to from 60 to 250 per acre
in 3 or 4 years.

Increased population is fostered by three reproductive factors:
(1) An acceleration of the breeding rate; (2) an increased number of
young per litter; and (3) the lengthening of the reproductive season,
which allows for greater numbers of litters per year.

Causes responsible for a decrease in numbers of mice may be abiotic,
such as climatic influences, or biotic, such as diseases, predators, etc.
It appears that murine epizootics occurring when mice have reached
the peak of their abundance, are the primary causative agent reducing
mouse populations. Plagues of mice are often accompanied by
disease of an epidemic nature among these animals.

Forecasting the years of mouse abundance is important, for control
methods may be inaugurated before the expected period of peak
population, and the extent of the damage minimized. Past periods of
great mouse abundance in New York were the winters of 1919–20,
may thus be expected in the winters of 1939–40, 1943–44, and so on.
Increase in mouse populations occur rapidly, so that optimum densi-
ties may be reached in 2 or 3 years following a low. Thus perpetual
vigilance of the agriculturists and especially the orchardists is neces-
sary at all times.

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