Grasshopper Problems in Yacutia (Eastern Siberia, Russia) Grasslands

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ABSTRACT.—The zone of natural Yacutia grasslands is situated between 60-64°N and 130-135°E. Vegetation of the meadow-steppe occupies vast glades dispersed in woodlands. These glades are inhabited by a dozen grasshopper species, three of which (*Chorthippus albomarginatus*, *Aeropus sibiricus*, and *Omocestus haemorrhoidalis*) are of economic importance. Most (up to 98%) of the grasshopper population consists of *C. albomarginatus*, which can produce mass outbreaks in years with deficient rainfall. Overgrazed pasture grasslands are particularly subject to grasshopper depredation. A recent outbreak took place in 1986-87, and an upsurge was observed in 1992. Prospective control strategies are under discussion—including rotational grazing, grassland management, and effective utilization of appropriate chemical measures on limited areas based on phenology forecasts. Special consideration is given to the search for and possible utilization of alternative control agents.

Locusts and grasshoppers are pests of major economical importance in the countries of the former USSR: in the late 80s and early 90s of the twentieth century, they were controlled by insecticide treatments on the surface more than 4 million ha annually. In Russia, the annual average area of anti-locust and grasshopper treatments usually does not exceed 300,000 ha. However, in years of heavy outbreaks, it can reach (as it did, for example, in 1993) more than 600,000 ha.

A remarkable zone in Russia where grasshoppers systematically inflict damage is Yacutia, a vast region situated in the northeastern part of Siberia between 55° and 75°N and 107° and 162°E. It extends over 3,103,000 km^2 (more than one-fifth of the entire area of Russia). The greatest part (80%) of Yacutia is covered by coniferous forest, the taiga, where the larch, *Larix gmelini* predominates. However, in the central area, the landscape is characterized by the alternation of forests and natural glades with grassland vegetation of a meadow-steppe type that is unique for this boreal region. It is in this zone, which is intensely exploited for cattle and horse breeding—the main occupation of Yacutians—that the principal sites of grasshopper outbreaks are concentrated.

Natural Conditions, Climate and Vegetation

The area of frequent grasshopper outbreaks in Central Yacutia is situated on the plain on both banks of the Lena River (Fig. 1). Its northern border passes between 61° and 63°30'N and in this respect, the Yacutian zone of grasshopper outbreaks has no analogues, either elsewhere in Eurasia or in North America. The climate is extremely continental: the lowest winter temperatures are −66°C, with a mean for January of −43.2°C; the highest summer ones are +40°C, with a mean for July of +18.7°C. Thus, the range for the mean temperatures is more than 60°, and exceeding 100° for the extremes. Precipitation is low: averaging annually about 250 mm, with summer rainfall of 160-180 mm. The frost-free period is short, varying from 90 to 100 days. Summer is characterized by very long sunny days (maximal photoperiod in June is 18 h, 20 min).

Glades in taiga colonized by grasshoppers are saucer-like depressions of thermokarst origin. In the middle of these depressions there are usually one or more shallow ponds with mineralized water. The area of a given glade varies from 2 to 3,000 ha but most frequently 100-300 ha. Soil is of a meadow-steppe, black alkaline type with a thin humus horizon. It forms the so-called seasonal cryogenic ground (melting in summer) which is in fact the upper layer of permafrost that can be hundreds of meters thick. Natural climax vegetation of the glades is of short-grass meadow-steppe type, dominated by the grass *Puccinellia tenuiflora*. Other grasses in this short-grass meadow steppe are species of *Poa*, *Festuca*, *Hordeum*, *Koeleria*, and *Alopecurus*. Other plants present include sedges (Cyperaceae), rushes (Juncaceae) and species of the dicotyledonous families (Asteraceae, Fabaceae, Ranunculaceae, Caryophyllaceae, and others).

Principal Economic Species

More than 30 grasshopper species have been reported from Yacutia (Miram 1933; Bey-Bienko and Mistchenko 1951; Karelina 1961). Species composition and density vary in different habitats depending on the type of vegetation. Forest edges with their dense cover of grasses and forbs are rich in species (> 20) but not in numbers of individuals; however, in the grasslands of natural glades, especially in those severely affected by grazing, the number of species does not exceed 10 or12, but they have the highest grasshopper densities. The most abundant and the most important economically is the White-Striped Grasshopper, *Chorthippus albomarginatus* (De Geer, 1773), forming the bulk (up to 98 %) of the grasshopper population. It is followed by other gomphocerines, *Aeropus sibiricus* (L., 1767) and *Omocestus haemorrhoidalis* (Charpentier, 1825). These two species are also capable of periodic outbreaks. Other species—*C. brunneus* (Thunberg, 1815), *C. fallax* (Zubovsky, 1899-1900), *Arcyptera fusca* (Pallas, 1773), *Podisma pedestris* (L., 1758); *Melanoplus frigidus* (Boheman, 1846), *Podismopsis jacuta* Miram, 1928; *Bryodema tuberculatum* F., 1775, *Chrysochraon dispar* (Germar, 1831-1835), and *Euthystira brachyptera* (Ocskay, 1826) — hardly ever exceed a small percentage of the grasshopper community and are rarely observed to produce high numbers.

Storozhenko (1991) provided keys to identify the subspecies of *Chorthippus albomarginatus* and showed that they are geographically separated from one another. In Yacutia, *C. albomarginatus* is represented by the nominate subspecies, *C. albomarginatus albomarginatus*.

Biology of *Chorthippus albomarginatus* in Yacutia

This short description is based on the works of Karelina (1957, 1960, 1961), supplemented by our own observations (1988-1992). As for all other local grasshopper species, *Chorthippus albomarginatus* is univoltine, hibernating in the egg stage, which makes up the major part (up to 10 months) of the annual cycle. Hatching occurs at the beginning of June. Hopper development comprises four instars and lasts 24–30 days. Uvarov (1977) remarked that in other regions this period is nearly twice as long, *e.g.*, 42–59 days in Holland (Lensink 1963) or about 50 days in

England (Richards and Waloff 1954). Though mean temperatures during hopper development are similar (11–16°C in Holland, 16°C in England and 18°C in Yacutia), the highest maximum temperatures and very long summer days in Yacutia significantly accelerate this process. Hopper density can reach some thousands per m² in the first instars and gradually declines towards the end of hopper development when insects are more evenly distributed throughout the habitat. Nevertheless, densities of late-instar nymphs of hundreds per m² are very common.

Adults first appear at the end of June. After 4 to 9 days of sexual maturation, adults copulate, and two days after the first copulation, females begin laying eggs. The number of eggs in an egg-pod is 4–10, more often 8–10 (Tcherniakhovsky 1986): Every female lays an average of 8 (maximum 16) egg-pods, for a total of some 150 eggs per female during the reproductive period which lasts 30–40 days. The intervals between the successive ovipositions are about 2.8 days, as compared to 3 to 4 days in W. Siberia or N. Kazakhstan where the duration of the reproductive period is two months or more (Kadzevitch 1935, Berezhkov 1956). Adults reconcentrate on the oviposition sites, and egg-pod densities of 300/m² are frequent. Known to be sedentary in other zones of its distribution, *C. albomarginatus* can produce short distance (for some km), downwind, swarm flights between the glades in Yacutia (Karelina 1961), with flights taking place when grasshopper numbers become so great that food shortages occur. Rubtzov (1935b) observed some effects of high (up to 150 individuals/m²) density on adult coloration and morphometrics in E. Siberia; in Yacutia, however, with maximum adult densities reaching 1000/m² and more, observations failed to show similar effects.

Among biotic factors affecting the numbers of this species in Yacutia, the fungus *Entomophtora grylli* (Fres.) Nowak is the most important, sometimes causing wholesale hopper mortality. Of 16 species of fungi identified by Leskov (1990) from the corpses of field-collected *C. albomarginatus*, this fungus was responsible for the death of 92% of the hoppers. However, maximal activity of fungal pathogens concurrent with the widespread epidemics of grasshoppers is observed mostly on the decline of the curve of their population, whereas at the peak of mass outbreak, the effect of these pathogens on the reduction of host numbers is virtually negligible (Nurzhanov and Latchininsky 1987).

Average egg losses due to very low winter temperatures usually do not exceed 15 % (Karelina 1961) or 20 % (Pankratova 1992), being higher on the hillocks with thinned snow cover. On the contrary, eggs seem to be less resistant to high summer temperatures when 24–40 % of them can perish from desiccation should the rainfall be deficient.

Economic Importance

During its life-period, which lasts 40–60 days in Yacutia, one individual of *C. albomarginatus* consumes from 1.60 g (Karelina 1960) to 2.98 g (Rubtzov 1932) of fresh food. The voracity of grasshoppers living in dense bands is much higher than of those in scattered populations. Assuming that average density in the band is 300 individuals/m² and that the mean surface occupied by the band is 200 m², it is easy to calculate that such a band would destroy nearly 0.2 t of vegetation throughout its life. These figures perhaps even underestimate the real damage, because the maximal hopper density is known to be of several thousand individuals/m² and the surface occupied by a band frequently exceeds 3,000 m² (Karelina 1961). Popov (1987) shows that an average hopper band destroys from 40–100% of vegetation on its way, the rate is higher in the case of poor plant cover. Karelina (1960) points out that the dense bands of *C. albomarginatus* cut the grass even below the ground level, explaining why restoration of vegetative cover progresses very slowly, demanding several years on sites suffering from grasshopper damage.

Yacutia grasslands are utilized either as natural pastures (nearly 600,000 ha) or as hayfields (over 700,000 ha). The productive capacity of such hayfields is not very high, varying from 0.4–1.3 t of hay per ha (Skriabin and Karavaev 1991). It depends essentially on the amount of atmospheric precipitation in the vegetative period and decreases to 4 or 5 times in drought years, which are known to be favorable for grasshopper pullulations. Taking into account that the production of natural grasslands forms nearly 90% of forage in the region (Skriabin and Karavaev 1991), the vital importance of keeping grasshopper populations below the economic threshold becomes evident. In outbreak years, grasshoppers frequently attack grain crops—wheat, rye, and barley—of

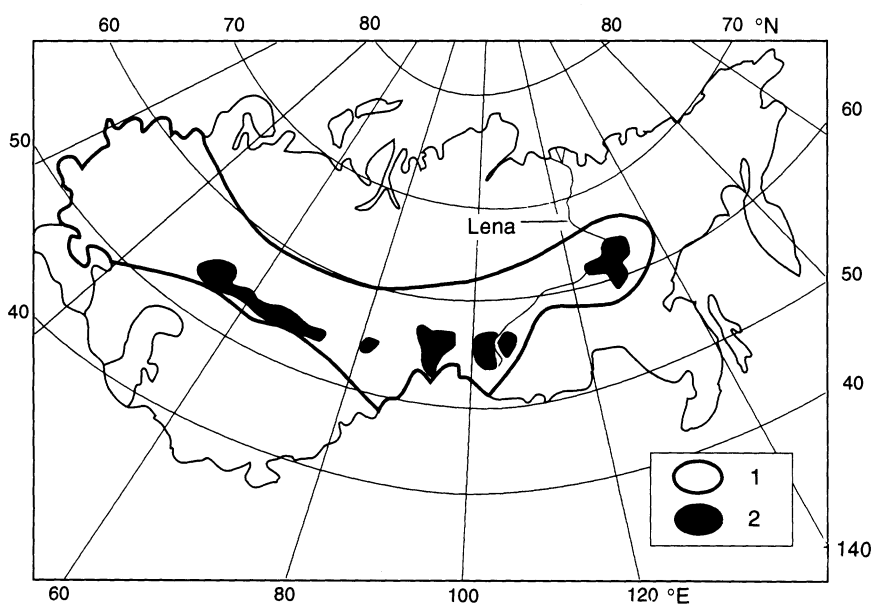

Fig.1. Distribution range and areas of frequent outbreaks of *Chorthippus albomarginatus albomarginatus* in the former Soviet Union (modified after Rubtzov 1935a and Storozhenko 1991). **1**, Distribution range. **2**, Areas of frequent outbreaks.

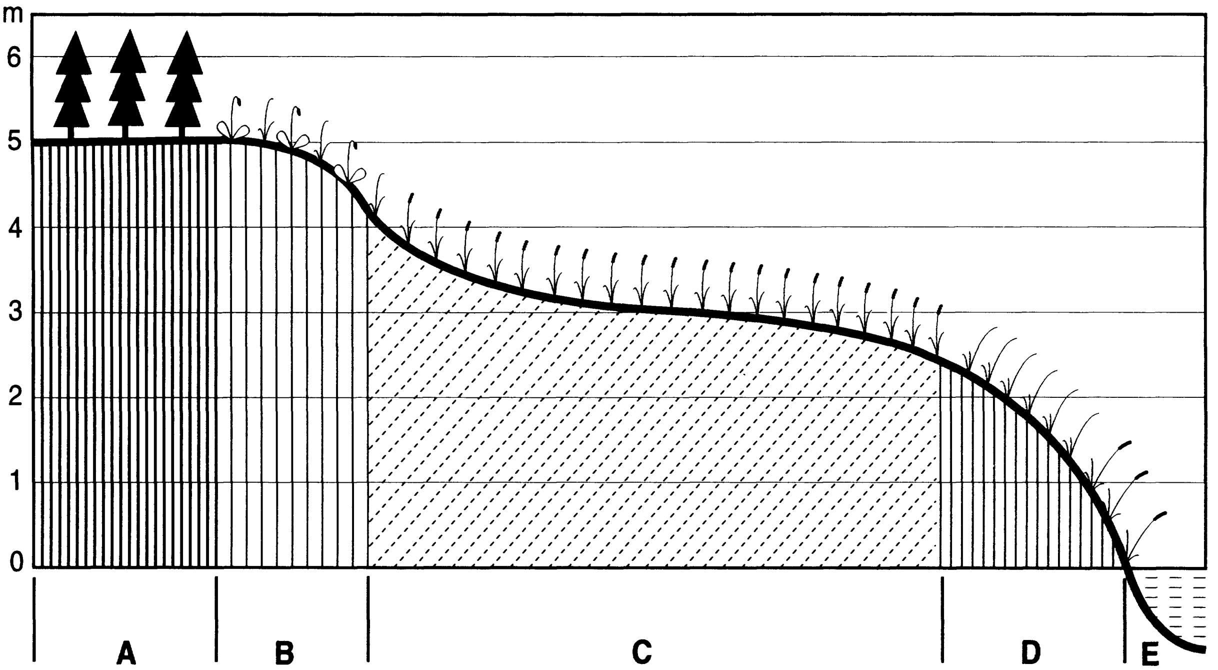

Fig. 2. Scheme of the distribution of vegetation in Yacutia glades (see text). A, Coniferous forest; B, Xerophilous belt; C, Mesophilous belt; D, Hygrophilous belt; E, Pond

which is over 100 000 ha are grown in Yacutia. For example, during the outbreak of 1947-1949, these pests totally destroyed 200,000 ha of hayfields and crops and lowered the average yield of cereal crops to 50% (Karelina 1961).

Meteorological Factors Contributing to Outbreak Formation

Karelina (1961) showed that upsurges in numbers of *C. albomarginatus* in Central Yacutia are always connected with insufficient rainfall and high summer temperatures. Massive outbreaks coincide with a 20–40% reduction in rainfall and an increase of 0.5–1.5°C in the mean temperature of the warm period (April to October), as compared with normal values. The probability of outbreaks is augmented, if such conditions are maintained during successive years. Low humidity is unfavorable for fungal and microbial pathogens and raises the survivorship of embryos, hoppers, and adults.

Since drought periods are frequent in Central Yacutia, local grasshopper outbreaks are regularly take place every 2–4 years, the extensive mass outbreaks occur every 8–10 years and continue for 2 or 3 years. The last outbreak was observed in 1986-87, and an important upsurge took place in 1992. Though *C. albomarginatus* occurs commonly throughout the wooded meadow-steppe of Eurasia (Uvarov 1977), the Yacutian area—with its particular ecological conditions making outbreaks more frequent and severe than elsewhere—is clearly distinctive (Rubtzov 1935a, *cf.* Fig.1).

Land-Use Systems and Grasshopper Distribution within the Glades

The intensified exploitation of natural Yacutian grasslands as pastures in the twentieth century has led to heavy overgrazing and trampling of the ground cover. As a result, the fragile fertile soil horizon has become seriously damaged, and the dense natural climax grass vegetation has been gradually replaced by weeds (*Agropyron repens, Brassica campestris, Fallopia convolvulus, Axyris amaranthoides*) and ruderal plants (*Chenopodium album, Artemisia jacutica, Polygonum viviparum, Cirsium setosum*), forming a poor ground cover. This process creates favorable conditions for grasshopper expansion, since the sites with sparse and mosaic vegetation are rapidly colonized and readily utilized by females for oviposition.

A characteristic feature of local methods of cattle and horse breeding—widely utilized in the past until approximately 1930—was the abundance of corrals or pounds around the small ranches in the glades where livestock was kept during warm season. Having been continuously manured by cattle, these sites with degraded plant cover offered, along with the overgrazed pastures, excellent conditions for egg-laying. Karelina (1961) insists that such ancient corrals are the main sources of the swarm formation in the glades. However, our recent investigations demonstrate that presently the situation has changed. Since the 1930s, most of these corrals have been abandoned because of breeding being concentrated in immense collective farms. Sometimes it is difficult even to find the ancient corrals now, because their sites have become almost uniformly covered by grass. Only the density of *O. haemorrhoidalis* is still 10–20% more prevalent on the locations of abandoned corrals than elsewhere in the glade, reveals their former whereabouts.

Study of grasshopper populations in glades with four principal kinds of land-use (pasture, hayfield, fallow, cultivated field) shows that cultivated field (cereal crops) and hayfield (irrigated meadow), with their regular and dense plant cover, are free from grasshoppers except for the margins. In contrast, fallow land, with its sparse ruderal vegetation, and pasture that has undergone intensive grazing pressure, are extremely heavily populated. Further investigation in a typical pasture glade has detected a noticeable spatio-temporal pattern of grasshopper distribution within the three different belts of vegetation distinguished according to the degree of humidity (Fig. 2). It appeared that the maximal hopper densities of *C. albomarginatus* (up to $350/m^2$ for the first and $80/m^2$ for the last instars) were concentrated in the middle (mesophilous) belt of vegetation that occupied 60–80% of the glade surface. Covered essentially by *Puccinellia tenuiflora*, this middle belt is an excellent refuge for hoppers, which find favorite food and shelter there. On the patches of bare ground resulting from overgrazing, the females of *C. albomarginatus* can lay eggs.

However, oviposition takes place more frequently in the outer (xerophilous) belt situated close to the forest border. The poor vegetation consists of grasses: *Hordeum brevisubulatum*, *Poa angustifolia*, *P. pratensis*, and *Agropyron repens*; sedges: *Carex duriuscula*, and *C. melanocarpa*; and forbs: *Sanguisorba officinalis*, *Potentilla stipularis*, *Thalictrum simplex*, and others. This belt occupies the peripheral 10-20% of the glade area and provides optimal thermic conditions for embryonic development in spring; hatching begins here 4-6 days earlier than in any other part of the glade. Soon after hatching, hoppers migrate from the periphery into the center of the glade, where parcels of more abundant vegetation (feeding sites) are situated mainly in the middle zone. The inner (hygrophilous) belt around the pond in the centre occupies 10-20% of the glade surface and is covered mostly by tall grasses: *Scolochloa festucaceae*, *Beckmannia syzigachne*, *Glyceria triflora*, and *Alopecurus arundinaceus*; sedges: *Carex rhynchophysa*, *C. aquatilis*, and rushes: *Juncus* spp. It is seldom frequented by grasshoppers, except for the end of their life-period, when fresh food is lacking in other belts. The proportion of belt areas is not stable: in the dry years, the extent of the middle and outer zones increases, and nearly all of the glade is inhabited by grasshoppers; in the wet years, grasshopper habitats are restricted to the peripheral xerophilous zone. Some specific differences in grasshopper distribution are also observed: while the highest numbers of *Chorthippus albomarginatus* hoppers are found in mesophilous belt, the habitats of *Aeropus sibiricus* are restricted mainly to xerophilous forest margins (maximal density of 25/m^2 for young hoppers). As for *Omocestus haemorrhoidalis*, it is usually more numerous in sites where land is substantially modified by human activities, *e.g.*, around the corrals (maximal density of 32/m^2 for second-instar hoppers).

Described for a typical pasture glade, a similar situation can be generalized for all pasture glades suffering from overgrazing. Moreover, it has proven to be valid also for most hayfields (except irrigated meadows) because of uncontrolled erratic movements of livestock between unfenced glades. The entire Yacutian grassland area, therefore, is actually subject to potential grasshopper depredation, the situation being aggravated by extensive cattle raising.

Control Measures

Agrotechnical Procedures. Karelina (1957, 1961) was the first to emphasize the importance of agrotechnical ecological methods of grasshopper control in Yacutia. She argued for rotational grazing and pasture amelioration, aimed at reducing the grazing pressure in areas most frequently damaged by grasshopper infestations. In the hayfields, early scheduling of grass cutting (before mass egg-laying) is essential, because after grass has been cut, the shortage of food greatly affects egg production: nearly half of ovarioles degenerate, causing 80–90% reduction in female fecundity.

One very effective means of meadow amelioration is irrigation that results in the creation of a tall, dense grass stand unfavorable for grasshoppers. However, the proportion of irrigated meadows is not high (less than 10%) because of technical difficulties: the water of numerous small ponds is not suitable for irrigation purposes, as it provokes rapid salinization of soil. It is necessary to add such measures as fall ploughing in areas of oviposition and subsequent reseeding of these areas by grasses. Since some forage grasses (*Koeleria gracilis*, *Hierochloe glabra*, *Helictotrichon schellianum*) and grain crops (oats) are scarcely damaged by *C. albomarginatus* (Karelina 1961), introduction of naturally resistant cultivars can also be recommended for local agricultural practice as suggested by Hinks and Olfert (1992) for North American temperate regions.

Chemical Control. Though the role of agrotechnical measures is pivotal in preventive long-term grasshopper control (Uvarov 1977), the rapid and effective chemical interventions in case of heavy outbreak are still unavoidable (Tzyplionkov 1970). Unfortunately, the immediate advantages of direct insecticide control have made it a panacea in the eyes of local authorities, and, in fact, grasshopper control in Yacutia is now almost entirely chemical. In outbreak years, annual treatments are carried out on more than 50,000 ha. The area is subject to treatment if the adult density exceeds 2–3 individuals/m^2 (Tzyplionkov 1970). The dust of hexachloran (HCH) with an application rate of 15–17 kg a.i./ha and the emulsifiable concentrate of parathion methyl at an application rate of 0.16–0.4 kg a.i./ha are most commonly utilized. Equipment used for dusting and spraying is manufactured in Russia and Ukraine. Treatments are terrestrial and full-volume (300-400 l/ha in case of spraying with parathion methyl). Hopper mortality varies from 70 to 92%. Recently, trials of ULV spraying by malathion (0.8 l/ha) showed promising results (hopper mortality over 95%). Malathion was also applied in the form of an aerosol with the controllable dispersion generator equipment. Hopper mortality in some of such treatments reached 90–95% but the insecticide derivation depended entirely on weather (especially wind) conditions.

The study of grasshopper distribution within the habitat indicates that, in most cases, it is not necessary to treat the entire area of the glade: control measures should be concentrated in the middle belt, the area most frequented by the insects. This would result in an economic use of pesticide and reduce chemical stress on the environment.

The main difficulty in the organization of chemical control of grasshoppers in Yacutia is the wide dispersion of small areas to be treated. Together with a poor state of the local lines of communication, it makes rapid and effective insecticide intervention nearly impossible. Because of the short period of hopper development, the problem of appropriate placing and timing of control operations is very important. In this respect, the forecasting of development of spatio-temporal structure of grasshopper populations—*e.g.*, on the basis of predictive phenology modelling that is widely utilized in the monitoring of North American grasshopper species in similar rangeland conditions (Kemp 1986,1987; Kemp and Onsager 1986)—would be of great use in the choice of strategy and tactics for grasshopper control. On the other hand, the effect of insecticide treatments on non-target organisms seems to be especially hazardous in Yacutia, where areas of anti-locust treatments coincide with ecotonal zones (steppe-forest-lake) of maximal life concentration. Special studies of side-effects of grasshopper control on flora and fauna of the glades have not been conducted yet, but our numerous observations indicate that important mortality of some groups of animals (*e.g.*, fishes, ground-nesting birds, and terricolous insects) is often caused by such treatments. The possibility that pesticides degrade in soil more slowly than in more southern regions and that their products accumulate in the upper layer of permafrost (due to its "conservation effect") also cannot be ignored, especially in the case of persistent HCH.

In Yacutia, two main trends in the progress of chemical control may be outlined: the modernization of pesticide application technique and the improvement of pesticide assortment. Recent introduction of ground ULV-spraying of synthetic pyrethroids (fenvalerate) may be considered as the first step in this direction. Naturally, it is imperative that further progress in this field should be accompanied by careful investigation of the environmental impact of grasshopper chemical control.

Perspectives for Microbiological Control. One of the most promising areas of the progress in acridological control is the utilization of efficient natural agents. With its numerous small isolated grasshopper populations, Yacutia seems to be an excellent trial site for experimenting in this field. Recently, the screening of microbiological pathogens provoking grasshopper epidemics in Central Asia and Yacutia was accomplished by the specialists of VIZR. The main results of this research are described in our previous publications (Nurzhanov and Latchininsky 1987; Latchininsky and Launois-Luong 1992). The following fungal pathogens were proposed for possible utilization in grasshopper control: *Entomophtora grylli* (Fres.) Nowak, *Cephalosporium lefroyi* Horne, and *Beauveria bassiana* (Bals.) Vuill. (Leskov 1990, Ogarkov 1990); *Beauveria tenella* (Siem.) Delacr. (Nurzhanov 1989, Gogolev 1990); *Metarhizium anisopliae* (Metsch.) Sorok., *Verticillium lecanii* Zimm., and *Paecilomyces farinosus* Brown (Nurzhanov and Pavliushin 1990). Some of them were subsequently field tested. Gogolev (1990) reported the mortality of 71.1% of second-instar hoppers of *C. albomarginatus* in Yacutia on the eighth day after treatment by suspension of spores of *B. tenella* of the strain originally obtained by Nurzhanov (1989) from *Locusta migratoria migratoria* (L., 1758). In the experiments of Ogarkov (1990) on the complex of grasshopper species (*C. albomarginatus, A. sibiricus*, and others) in E. Siberia, hopper mortality on the eleventh day after treatment with dry spores of the local strain of *B. bassiana* varied from 47.2 to 84.8%. As for other groups of pathogens, encouraging results were obtained by Danilov and Karpova (1990) who reported the mortality of 96% of hoppers of *C. albomarginatus* three days after laboratory treatment with nematodes *Steinernema carpocapsae*. However, as in the case of fungal pathogens, development of nematodes depends entirely on weather conditions posing almost insurmountable problems for their introduction in practical grasshopper control. To summarize, the range of pathogens — potential candidates as grasshopper control agents — is rather broad, including microorganisms of four groups: fungi, nematodes, bacteria, and protozoans (Latchininsky and Launois-Luong 1992), but the following phases of research (selection, purification, and mass production of virulent strains) depend largely on the high-quality equipment and demand solid financial support that is scarcely achievable in the present period of deep recession in the countries of the former USSR.

CONCLUSIONS

This brief review of the current grasshopper situation in Yacutia shows that the conditions for mass multiplication of these pests are created mostly by human activities. The over-intensive exploitation of the fragile grassland ecosystem in specific local conditions has led to the persistence of grasshopper damage in Yacutia. This chronic problem is aggravated, when the meteorological background is favorable for plague development. A possible solution is a balanced strategy of grasshopper control based on a number of preventive long-term agrotechnical and ecological procedures aimed at reducing the surface of patchy, mosaic habitats preferred by the pests and restoring the damaged plant cover. Direct control measures could be justified in the case of heavy outbreaks; progress in this field includes the modernization of pesticide assortment and the improvement of methods of application. The possibility of utilizing of grasshopper enemies as natural control agents, being of special interest in particular regional conditions, demands further investigation.

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