SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA
[AGRICULTURAL BIOLOGY], 2015, V. 50, № 2, pp. 137-151 ISSN 2313-4836 (Online)

Advances and challenges. Reviews

UDC 6359.009:632.6/.7:591.54(470.342)

doi: 10.15389/agrobiology.2015.2.137rus
doi: 10.15389/agrobiology.2015.2.137eng

THE INFLUENCE OF CLIMATIC ANOMALIES ON THE ANIMALS IN MIDDLE LATITUDES OF THE EAST OF THE RUSSIAN PLAIN

A.N. SOLOV'EV, T.G. SHIKHOVA, E.I. BUSYGIN

Prof. B.M. Zhitkov Russian Research Institute of Game Management and Fur Farming, Russian Academy of Agricultural Sciences, 79 ul. Preobrazhenskaya, Kirov, 610000 Russia, e-mail biomon@mail.ru
Received April 14, 2014

Abstract

With a steady climate change increases the risk of weather anomalies. The droughts, forest fires, winter frosts become more frequent that affects the abundance and diversity of animals, including commercial species and crop pests. The deviation of timing of the phases of ontogeny from multiyear is a sensitive indicator of the state and the processes of ecosystems. In order to identify the features of the biota response to extreme weather conditions we studied the reaction of animals of the East Russian Plain (Kirov Region) to weather anomalies of cold winter in 2009-2010 and the hot summer of 2010 according to phenological (1890-2013 years) and phytosanitary (2000-2013 years) monitoring of 52 species *Clitellata*, *Bivalvia*, *Gastropoda*, *Insecta*, *Aves*, *Mammalia*. The observations were carried out on the territory of the boreal ecotone with different changes of hydrothermal regime within Vyatsko-Verkhnekamsk District of the Volga Region. The phenological monitoring carried out by a standard technique involving public opinion poll from permanent correspondents. We analyzed the date of the seasonal phases of development: the end of winter diapause, the beginning of oviposition, hatching of eggs, the emergence of the imago insects; spring arrival, the beginning of the breeding cycle, autumn departure of birds and others. In 2010 the survey of additional information on phenology of biological objects was conducted by method of questioning of permanent observers in 23 geographical locations of the Kirov Region. We examined the impact of agroclimatic conditions for the development of pests within permanent control areas of Kumenskii Hospital District Department of the Federal Phytosanitary Service during the active vegetation. Long frosts below –35 °C were pessimal and sublethal for different stages of ontogenesis in *Leptinotarsa decemlineata*, *Aelia acuminata*, *Agrotis segetum*, *Oscinnella frit* and others. Extreme summer heat above 30 °C and drought were pessimal for *Phyllotreta vittula*, *Leptinotarsa decemlineata* and sublethal for eggs and larvae of *Oscinnella frit*, *Aelia acuminata*, *Elateridae*, but contributed to the early emergence of *Apion apricans* adults. Exceeding monthly average air temperature at the 1 °C resulted in advancing the timing of microthermal insects development by 1.9 days and advancing the arrival dates of near migrant birds by 1 day in April, and in advancing the timing of mesothermal insects development by 1.3 days and advancing the arrival dates of distant migrant birds by 1.4 day in May. The 100 °C excess of the effective temperature in May led to emergence of *Oscinnella frit*, *Leptinotarsa decemlineata*, *Pieris brassicae* adults 2.9-3.8 days ahead of due time. In June it resulted in larvae emerging 2.7-4.8 days ahead of due time, and in July their adult summer generation occurred 1.6-1.7 days earlier. Negative impact of pests on crops in abnormal seasons can be reduced by spring crops sowing in early summer, while winter rye should optimally be sowed in later date. In the conditions of mid-latitude of Eastern European Plain the temperatures below –40 °C in winter and long heat up to 40 °C with a summer drought are within the adaptive capacities of the regional biota. Their influence does not cause irreversible consequences in the functioning of wildlife, particularly animals, including pests.

Keywords: animals, phenological events, climatic anomalies, the Russian Plain.

With the steady climate change over the past few decades, the risks of the development of weather anomalies increase [1-5]. For the period of instrumental weather observations, ten of the warmest years, according to the World Meteorological Organization (Switzerland), have been in the twenty-first century. The most differentiated response of the natural environment to climate warming has been noticed in and forecast for the high latitudes [6-11]. Changing climate trends bring about complex in their direction and intensity changes in the seasonal rhythms of ecosystems in different natural zones and landscapes [12-21]. Climatic factors have different biota impacts defining the state of populations [22-25], the reproductive cycle [23, 26], the patterns of distribution [23, 27] and migrations [26, 28, 29], and the phenology of species [25, 26, 30-34].

At the turn of the twenty-first century, the frequency of blocking patterns in the atmosphere (stationary anticyclones) increased, droughts, forest fires and other adverse phenomena became more frequent [35]. The year 2010 was one of the warmest, with the extremely hot summer in the European part of Russia [35-38]. All the seasons were abnormal: the frosty winter of 2009 to 2010 ranked the 8th amongst the coldest years, the spring became the warmest, the summer broke the heat record, and the autumn was very warm (the 5th among the warmest years). The abnormal heat and drought (for more than 50 days) were considered the largest natural disaster caused by meteorological factors [36, 39]. Previously observed weather anomalies were not so extreme [40-43].

The regional responses to the 2010 extreme weather conditions in the biocenoses and agroecosystems of the European part of Russia have been reflected in a number of works, in particular the condition of the plant component of the biota [44-46], the reaction of fruit and berry crops [47-49], the yields of cereals [50] have been studied. The specifics of the impact of the extreme summer heat together with the prolonged drought and the winter frosts of 2010 on the animals in the central and southern areas of the Russian Federation have been described [40, 41, 51-54]. The weather and climate anomalies adjust in a certain way the cycles of the long-term dynamics of populations affecting, first of all, organisms with mobile and ephemeral types of population dynamics such as small rodents, insects, etc. [55], many of which cause damage to the agricultural production. In warm years, part of the insect population can bring an additional generation therefore the outbreaks of forest and agricultural crop pests are possible [32, 56-58].

At the organism level, the thermal anomaly effect is known to manifest itself in the deviations of the onset of ontogenesis phases from the long-term average dates, which is used as a complex sensitive indicator of the status and response of the biota to the changing environment. At the geographical population level, each biological species adapts to the range of local weather and climate factors in their seasonal dynamics. The combination of seasonal phenomena, the control and regulation mechanisms, and the limits of possible deviations in the timing and duration of seasonal development phases are considered allelically determined characteristics (properties) of species defining their adaptation ranges.

In our observations we estimated the influence of the climatic factors of the abnormal winter and the following positive summer anomalies in the east of the European part of Russia, on the plains of Vyatka-Verkhnekamsk area of the Volga woodlands within the boreal ecotone characterized by an increased gradient of changes in the hydrothermal parameters.

In our estimations we analyzed the timing of the seasonal development phases in 52 species of animals from seven classes (*Clitellata*, *Bivalvia*, *Gastropoda*, *Arachnida*, *Insecta*, *Aves* and *Mammalia*), 21 orders and 41 families (by recording the end of the diapause, the beginning of oviposition, the emergence of larvae and imagines in insects, and the arrival, the beginning of the nesting, the departure, etc., in birds) in Kirov Region during the abnormal seasons of 2010. The timing of the phenological activities was compared with the long-term average values obtained by processing the regional phenological monitoring data for 1890-2013 received from a constant network of correspondents using a uniform procedure and program including 286 seasonal phenomena, with 103 of them on 64 zoological objects [59]. We determined how much later (+) or earlier (–) the events happened relative to the long-term average date (in days). Additional information on the condition of biological objects in 2010 was gathered from phenologists-observers by a survey. A total of 25 questionnaires on 23 geographical settlements in Kirov Region were processed.

The influence of weather conditions on the development of agricultural pests was studied in the stationary agroecosystems of the in Kumenskii District Division of the Federal Phytosanitary Control Service, with every-five-day surveys of the areas in 2000-2013. The abundance of insects and damages to plants were evaluated by standard methods [60].

The data were statistically processed using Microsoft Excel 2003 and Statistica v. 10.0.

With longitudinal length of 570 km and latitudinal length of 440 km, the average total area of Kirov Region in the Volga Region is 120.7 thousand km^2 (56°3′ -61°4′ N, 41°17′ -53°56′ E). It is situated within the boreal thermal belt lacking heat but with excess moisture, where the latitudinal zonation is mostly driven by the solar thermal factor [61]. The climate is moderately continental with prolonged cold snowy winters and moderately warm summers (with average temperatures of –15 °C in January and +18 °C in July). The frost-free period is about 120 days. The winds are predominately western. The annual rainfall in the north of the Region is 600-700 mm, with 400-500 mm in the south. In June, July and August, the moistening in the greater part of the region is usually moderate and sufficient, particularly the G.T. Selyaninov's hydrothermal factor (HTF) is 1.0-1.3, and only in the northern areas it is excessive with HTF of 1.4-1.5 [62]. The wildlife is represented by typical zonal faunal complexes of middle and southern taiga subzones, as well as of broadleaved-coniferous forests.

In 2010, the European East suffered from extreme temperatures with the yearly range of 80 °C (from –40 °C in February to +40 °C in August) together with a prolonged drought.

The winter of 2009-2010 was mostly cold and very cold, with the average temperature 0.5-2.0 °C below the normal and the sum of negative temperatures 105-285 °C higher than the long-term value. For a long time the temperatures were very low (below –40 °C in February, reaching to –44 °C on the surface of snow cover). By the end of the winter the frozen layer of soil was 7-25 cm thicker compared to the normal value. Early spring of 2010 began 9-11 days ahead of an average date and was warm. In 3rd decade of April, the daily average air temperature was steadily higher than 5-10 °C, while the monthly average for May, 15.7 °C, had been the highest in Kirov for the last 100 years. From June 21 till August 18, because of a blocking anticyclone above the Region, the weather was extremely hot, with daily average temperatures 3.5-11.0 °C higher than normal (Fig. 1), atmospheric and soil droughts, and dry hot winds (HTF was below 0.5).

From the beginning of June, the moisture reduced to critical level (less than 10 mm of productive moisture in the plow layer and less than 50 mm in 1 m layer of soil). Such droughts, for six to eight decades, in the region were only observed in 1972 and 1981.

At the end of June—beginning of August 2010, the temperature increased above the absolute summer maximum (40 °C). From August 12 the air temperature began to decrease and in the second half of August morning frosts (from 0 to –6 °C) were recorded everywhere. The first half of autumn was warm and dry but the weather was changeable with frequent rains in the second half. The warm period ended November 18 (3-4 weeks later), being 27-35 days longer on average [6].

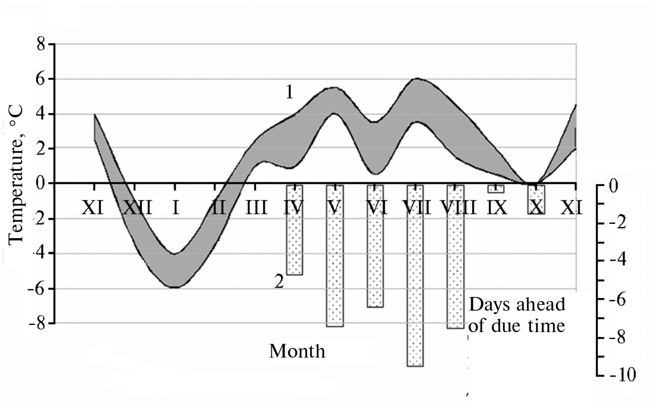

Fig. 1. The range of the temperature anomalies in Kirov Region (1) and the average values of zoophenological anomalies in Kirov (2) in 2010

Unlike in other hot summers, the monthly average temperatures were higher than the long-term average values during all the vegetation period in 2010.

The effective temperatures sum ($\sum_{эф.\ t°}$) was higher than the long-term average values, e.g. in May by 132.5 %, in June by 58.4 %, in July by 60.7 %, in August by 34.2 %, and in September by 32.9 %.

The climatic anomaly of 2010 was characterized not only by maximum temperature increase over the monthly average values but also by the record-breaking length — from the second half of spring till the second half of autumn including the whole vegetation period and shifting the onset of the phenological phases of plant development to earlier dates (up to 18 days) [44].

Any persistent climatic trend is known to influence the trophic factor, the physiological state and the reproductive function of animals [32, 57, 58]. Other conditions being equal, the temperature factor, primarily, defines the duration of separate phases in organism development. The thermal limit of the organism activity at +5 °C is very conventional, e.g. for the frit fly *Oscinnella frit* L. it is +8 °C at $\sum_{эф.\ t°}$ = 400 °C, while for the winter cutworm *Agrotis segetum* Den. et Schiff. it is +10 °C at $\sum_{эф.\ t°}$ = 1000 °C [64]. Poikilothermic animals, for each development phase of which there is a certain range of favorable temperatures or the temperature optimum for their maximum fertility and survival, are the most sensitive to the temperature factor.

It should be noted that homoiothermic animals, the optimum range for which is so narrow that even the slightest changes in temperature could bring about a strong (sometimes teratogenic) effect, are the most sensitive to the temperature factor.

In the early spring, zoo-phenological phenomena started at their usual time (±3 days); in April their onset was slightly earlier (1-8 days) than the average dates. The winter insect diapause finished 5-12 days earlier than the average dates, which is consistent with the 4-9 days earlier transition of the daily average temperature over +5 °C. All zoo-phenological phenomena started 2-16 days earlier than usual in May too. This trend continued till the end of summer (see Fig. 1).

In the early April, the negative zoo-phenological anomalies (earlier onset of events) were –3 days on average (from 0 to 7 days), after the middle of April they were –7 days (from –2 to –14 days). The positive April temperature anomaly of 3.47 °C (122 % of the norm) caused the earlier onset of the life phases in animals for –4.7±3.7 days on average; the May anomalies (5.2 °C or 149 %

of the norm) shifted the dates 6.4±4.1 days ahead of due time.

The accumulation of the sum of effective temperatures by the end of June (up to 158 %) was the reason of even earlier (–6.4±4.2 days on average) dates in animal development. The temperature reached its maximum in July (125 % of the norm) and the average values of zoo-phenological anomalies increased up to –9.5±6.4 days. Summer phonological phases in insects started up to 14 days ahead of the average dates.

When the daily average air temperature anomalies were less than 3.9 °C, the deviation of the onset of zoo-phenological events from the long-term average started to decrease too, and when the temperature anomaly decreased to 0.08 °C, it moved to the positive (delay) area.

Invertebrata. The frosty winter 2009-2010 with little snow, the dry spring and summer drought of 2010 caused increased die-offs of eggs and caterpillars of many insect species. There were almost no pests on apple trees and berry shrubs, no larvae in macromycetes. Many invertebrata, e.g. earthworms (*Lumbricidae*), had summer diapause. At the same time, the hot weather favored the development of larvae and early emergence of young beetles of the clover seed weevil *Apion apricans* Hrbst.

The flying and oviposition of the common rustic *Mesapamea secalis* L. were observed during the winter plant emergence period in August-September. Caterpillars of the common rustic emerge when the daily average temperature is below +5 °C, therefore, over the last few years, when Septembers were warm, they started to appear in October or, more often, in spring, and their main injuriousness to the winter plants has shifted to the spring. In the autumn of 2010, there were about 1.2 insects/night in the insect traps or 57.2 % of the long-time average (1.7 insects/night). During the drought, some chrysalides died in the upper layer of soil before butterflies emerged. The ratio between males and females was 1:1.2, with the long-term average of 1:1.4 ($\sigma = \pm 0.36$, $n = 8$), the female fertility was 116 eggs on average (83 % of the long-term average).

High daily average temperatures (above +5 °C) in the 3rd decade of September and in October prevented emergence of common rustic caterpillars and they were only registered in the beginning of November when their food, i.e. young winter plants, appeared. After the drought of 2010, the fertility of common rustic females grew to 136 eggs per a butterfly (97.1 % of the long-term average) in the autumn of 2011, with the ratio between the male and female insects restored to the long-term average.

In spring of 2011, the number of caterpillars was low (15.0 % of the average value), with 0.4 % of the winter rye plants damaged (15.0 % of the average). On the winter crops, the common rustic imagoes were found after August 22, they continued flying in September and the butterfly number was 1.3 insects/night (62.0 % of the long-term average). Caterpillars emerged even in October at the population density of 34.5 % compared to the long-term average with the damage to the winter rye being 0.3 %.

The warm weather in the first half of May 2010 was favorable to the development of the barley flea beetle *Phyllotreta vittula* Redt., which started causing damage to the first summer crops (the damage to the leaves was 1-2 points at the pest number 11.5 insects/m^2, being 14.0 % more than the long-term average). Extremely high temperatures (more than 30 °C) and the summer drought inhibited this pest, the eggs laid in soil were drying out, therefore in the autumn of 2010 the colonization of the winter crops by the barley flea beetle was 1.9 % of the long-term average. We did not observe leaves of the winter crops damaged by this pest. The population of the barley flea beetle in the winter crops continued to decline in 2011 too, and after the dry and hot weather in the second half of the summer of 2011 the number of insects in the winter rye was the same as in the year before (Fig. 2, A).

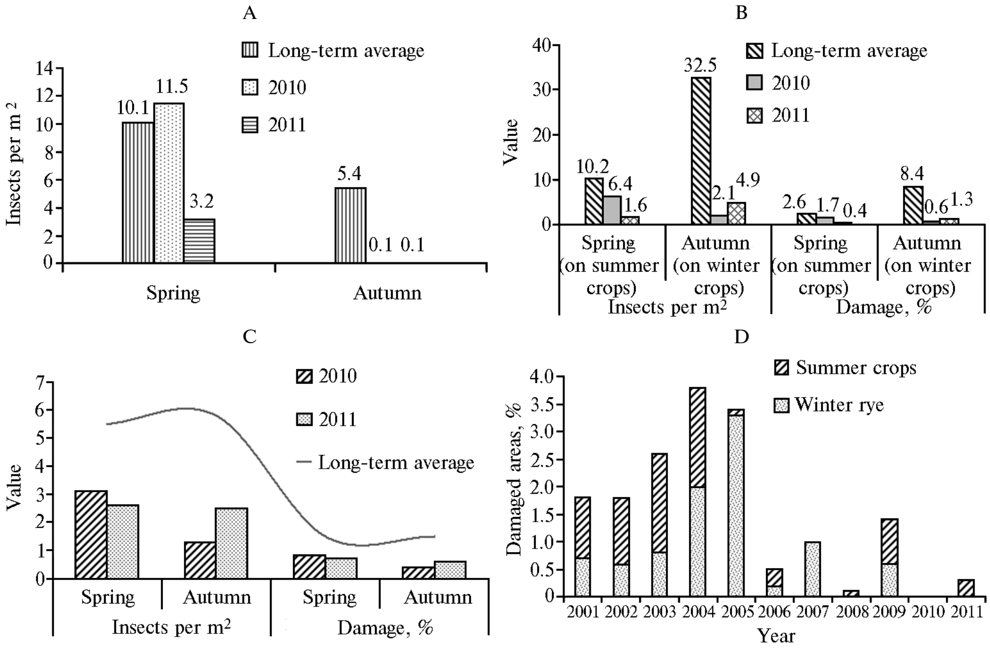

Fig. 2. Population of harmful insects and damage they cause to the agricultural crops (A-B), as well as the percentage of the invaded area (Г) during the extreme summer seasons: A — barley flea beetle *Phyllotreta vittula* Redt., B — frit fly *Oscinnella frit* L., C — wireworms *Elateridae*, D — bishop's mitre shieldbug *Aelia acuminata* L. (Kirov Region)

In the second half of January and the first half of March of 2010, with a thin snow cover and low temperature at the level of tillering node of winter crops, larvae of the frit fly *Oscinnella frit* L. were noticed to die, including well fed ones. Warm and dry weather promoted mass flying of imagines in the winter crops and their migration to the emerged summer crops beginning from May 13 (6 days earlier than the average date). The density of larvae in the winter crops was 1.7 times less than usual. With early colonization of crops by the larvae of the frit fly, mostly main, more productive, stems of plants were damaged (1.7 % or 65.4 % of the long-term average value).

The abundance of the frit fly increased in the 2nd generation when the larvae fed in the oat caryopses. In 2010, the 2nd generation developed on the oat plants in the first half of July but exceptionally hot and dry weather caused death of eggs and larvae. A total of 0.6 % of plants were damaged (3.0 % of the monthly average), with the larvae density 55 times less than usual, i.e. the number of adult pests decreased too. In the autumn of 2010, the frit fly started colonizing the emerged winter rye but cold weather with prevailing north-west and north-east winds and periodic rains made it difficult for pest imagoes to disperse. The density of larvae was 15 times less than average and the plant damage was 14 times less than usual.

In 2011, mass flying of the frit fly and their migration to the summer crops was delayed from May 11 to May 15 because of colder weather and night frosts of up to – 5 °C. Cold weather in May 2011 decreased the population of this pest in the summer crops even further. The frit fly larvae started emerging in the first five days of June and their abundance was 16.0% of the long-term average; 0.4% of summer crops were damaged (15.0% of the long-term average damage value). With the abundance of 0.5% of the long-term average, the 2nd generation of larvae only damaged 0.2% of plants (1.0% of the long-term average). In the warm autumn of 2011, the frit fly laid eggs in the winter rye longer than usual, the abundance of its larvae was 15.1%, and the percentage of damaged plants was 15.5% of the long-term average values (see Fig. 2, B).

The favorable combination of warmth and wetness from the 2nd decade of May till the 2nd decade of June contributed to high activity (dispersal, breeding) of the click beetles *Elateridae* and their larvae, which started actively feeding on the emerged summer crops. The summer figures on the abundance of this insect species in the summer crops and the damage to the plants were 1.3 times lower than the mean annual, with even more reduction observed by the autumn: abundance on the winter rye was up to 22.0%, the percentage of damaged plants was up to 27.0% relative to the long-term average levels (see Fig. 2, C).

Prolonged atmospheric and soil drought in June, July and August suppressed the activity of the click beetle larvae. In summer they migrated to the deeper soil horizons and were not seen in the clean fallow fields. The winter crops damaged by them started to be detected only in September when the wireworms *Elateridae* entered the root layer. In July, the hot weather combined with the persistent drought caused death of eggs and the 1st instar larvae in the top layer of heavy loamy soils. Cool and rainy weather in the autumn of 2010 made it difficult for the pests to disperse on the emerged winter crops. Because of death of younger instar larvae after the drought of 2010, the abundance of larvae and the damage to the plants during the vegetation period of agricultural crops in 2011 remained much lower compared to the long-term average values (see Fig. 2, C). The abundance of wireworms in the summer crops was 25.5 %, with the damage to the plants 23.0 % of the average values.

The frosty winter of 2009-2010 with little snow and the following hot and dry summer had an adverse effect on the development of the bishop's mitre shieldbug *Aelia acuminata* L. restricting pest population and preventing increase in its colonization area, which were observed in the previous years. During all the vegetation period in 2010, the population of the shieldbug was minimal, and it was noticed neither during the route surveys nor while cutting the winter and summer crops with an insect net. In 2011, this shieldbug was not found until the preharvesting period and only on the summer crops (0.3 insects per 100 sweeps of the net) (see Fig. 2, D).

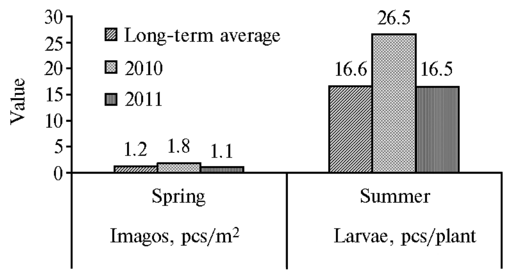

Fig. 3. The number of Colorado beetle *Leptinotarsa decemlineata* Say imagoes and larvae the in years with weather anomalies (Kirov Region).

The cold winter of 2009-2010 had an adverse effect on the Colorado beetle *Leptinotarsa decemlineata* Say. The population of the overwintered beetles was very small; they were totally missing on some potato fields. In severe winters, the mortality of these beetles was 2-3 times higher on heavy soils than on the light ones [65, 66]. The beetles cannot penetrate deeply into the heavy soils prevailing in the northern half of the Region and hibernate in the 25-40 cm layer. During the period of observations, with a thin snow cover and severe frosts, the soil temperatures reached –7 °C and most beetles died. That is why, despite the big population of larvae in 2009, the abundance of overwintered imagoes was just a little higher (Fig. 3). In the spring of

2010, in most southern areas of the Region, adult beetles, as well as their eggs, appeared on the surface 3-4 days ahead of due time, with the eggs starting to hatch 4 days earlier. At the same time, the females, which finished their diapause later, continued laying eggs. In hot July, the larvae of the Colorado beetle were feeding intensely, new generations were emerging in big numbers and, as a result, there were larvae of all the instars on the potato fields and part of them pupated. On July 15, there were 9.2 insects more per a colonized potato plant and there were 8 % more colonized plants than usual. From July 21, 2nd generation of beetles started to appear, and from July 25 (the due date) a large scale appearance started with 2.6 beetles per plant and the colonization of 0.3 % of potato plants. With the onset of the heat and drought in July, the beetles burrowed into the soil becoming temporary dormant.

When the air temperature is 30 °C, eggs of the Colorado beetle dry out and die. But the ecological flexibility of its populations is different, that's some are more resistant to droughts, while others are tolerant to toxic chemicals or to frosts, which makes the species extremely capable of surviving in adverse conditions [65, 67, 68]. In the central and southern areas of the Region, the summer generation of the Colorado beetle did not appear until September, when the heat slackened. But in some areas, despite the settled hot and dry weather fatal for the larvae, imagoes were observed to emerge in big numbers in the second half of the summer of 2010, when the population of the beetle reached 160 % of the long-term average. In the vegetation period of 2011, the number of imagoes, and later the larvae of the Colorado beetle, was 92 % lower and the damage to the potato was 20 % lower compared to the average.

In 2010, the ticks *Ixodidae* appeared very early and were active all the summer. The first bites of people by the tick in Kirov were noticed on April 6 (the average date was April 11 ±9.8 days, n = 9). In most northern areas the number of *Ixodidae* ticks noticeably reduced, but in certain places they were incredibly active in May. At the end of August to September of 2010, we observed bursts of activity of the *Dermacentor* ticks when they emerged from the summer diapause, which was longer because of the hot and dry weather.

The summer generation of the most common species of pierid (the cabbage butterfly *Pieris brassicae* L.) was very small. We only observed 1-2 butterflies on cabbage heads, with totally absent caterpillars, which develop at 20-25 °C. It was only after the heat slackened and the air became more humid in autumn (in September—October) that these butterflies could be noticed in some areas. Many pierids prefer cruciferous plants (cabbage, colza, turnip, etc.). Their population can be limited both by strong frosts in winter (the chrysalids overwinter on the soil surface) and hot dry weather in summer.

Dry weather in the spring noticeably decreased the populations of diptera insects, such as the black flies *Simuliidae*, the biting midges *Ceratopogonidae*, the mosquitoes *Culicidae*, the horse-flies *Tabanidae*. On the bigger part of the territory of the region, mosquitoes and horse-flies appeared only for a short time and in small number. Mosquitoes remained abundant (4-5 points) in big swamps and in the lake and marsh wetlands in the northern and central areas of the Region. Horse-flies were abundant in the wet areas of the bogs. Black flies in great numbers were only observed once in the summer. Their abundance (4-5 points) was predominantly noticed in the taiga area.

The land mollusks (slugs and snails) can only be active in the narrow temperature range; they die or go into diapause when the temperature is above 30 °C. After the drought of 2010, the abundance of small gastropod species of litter layer (*Zonitidae*, *Discidae*, *Euconulidae*, *Cochlicopidae,* etc.) did not change, but the populations of molluscs living on leaves, such as *Bradybaena* *fruticum* (Mull.), *Euomphalia strigella* (Drap.), *Succinea putris* (L.), *Oxyloma pfeifferi* (Ross.), reduced by 25-33 %.

Vertebrate. *Birds.* In the spring of 2010, the first short-distance migrants such as the starling *Sturnus vulgaris* L., the northern lapwing *Vanellus vanellus* (L.), the gulls (*Larus canus* L., *Larus ridibundus* L.), the mallard *Anas platyrhynchos* (L.), the white wagtail *Motacilla alba* L., arrived 2-5 days ahead of due average dates. In the second half of April, the first flying past flocks of the common crane *Grus grus* (L.) and geese *Anser* spp. were registered 6 days (n = 21) and 9 days (n = 26) earlier than usual. Long-distance migrants, particularly the barn swallow *Hirundo rustica* L., the thrush nightingale *Luscinia luscinia* L., the common swift *Apus apus* (L.), the corncrake *Crex crex* L., arrived 6-10 days earlier compared to the average dates. All the birds arrived in a very short time, and the nesting started 10 and more days earlier than usual. The rooks *Corvus frugilegus* (L.), the starlings, the barn swallows did not nest in some villages, but in certain areas (provided the habitat conditions remained unchanged) the second ovipositions of the barn swallow and very late (beginning of September) mallard hatchings were observed.

The early arrival of birds in spring meant the early dates of their departure in autumn since the migratory state of birds is sensitive to temperature fluctuations. It is controlled by the long-term system of autonomous timing, which is triggered in the beginning of the period of photoperiodical stimulation in spring [69]. The autumn departure of partially migratory birds is stimulated by the worsening situation with food, but the true migrating birds leave their nesting areas before the situation becomes unfavorable when the secondary (signal) factors trigger bird's physiological processes which bring it into the migratory state.

The steady warm weather in autumn hinders the migratory state in weakly migrating allotrophic short-distance migrants (the starling, the mallard, etc.). In autumn, the first flying away flocks of common cranes near Kirov were observed on September 12, or 8 days later than the average date (September 4 ±6.7 days, n = 20), with the last ones departing 10 days earlier than usual. The rooks departed on their usual dates (+2 day, σ = ±3.0, n = 24), with starlings and mallards delaying in the conditions of warm autumn (Table).

Last dates of bird departure in 2010 (Kirov)

Species	Years, n	Deviation from the average date in 2010, days
Apus apus	27	–9
Grus grus	20	–10
Sturnus vulgaris	16	+11
Corvus frugilegus	24	+2
Anas platyrhynchos	13	+35

With the abnormally late freezing of water bodies in 2010, the departure date of last mallards was the latest in all the history of observations. The last birds departed, on average, 3.8±6.5 days later in October.

Mammals. Forest fires caused summer migrations of bears *Ursus arctos* L., elks *Alces alces* L., wild boars *Sus scrofa* L., which were gathering in the areas not affected by fire. Small water bodies getting shallow and drying out significantly worsened the habitat of semiaquatic mammals. Beavers *Castor fiber* L., when possible, migrated from small drying out water bodies to deeper ones at the end of summer and beginning of autumn. There was no massive mortality among the beavers but their population decreased: according to the records, in 2010 in the Vyatka River floodplain conservation area [71], it was 51 % of the long-term average (209±74, n = 17). Compared with 2009, in Kirov Region, there was a decrease in the beaver population by 2.4

%, in the otter *Lutra lutra* L. and muskrat *Ondatra zibethicus* L. populations by 8 %, in the boar *Sus scrofa* L. population by 15 %, and in the wolf *Canis lupus* L. population by 25 % (63).

Mortality among animals. The synergistic effect of adverse meteo and trophic factors was eliminating for a number of species. In many species it lowered the tolerance of populations to pathogenic organisms and predators, which cause, in particular, few cases of death among mountain hares *Lepus timidus* L. caused by the bites of ticks in southern and central areas, as well as deaths of beavers, badgers *Meles meles* L. and hoofed animals (boar, elk, roe deer *Capreolus capreolus* L.) caused by wolves. The effect of abiotic factors on overwintering nonmigratory species was exacerbated by the lack of food caused by the weather conditions and leading, in particular, to freezing of starving young boars born in that year.

In July, in the middle of the drought, mortality among the moles *Talpa europaea* L. was observed. Fish died in winter because water bodies were frozen solid, and in summer because they dried out or because of the increased temperature of water, particularly in the small tributaries of the Vyatka River, dead burbot *Lota lota* (L.) and even ruffe *Gymnocephalus cernuus* (L.) were seen. Dried out water bodies caused massive mortality among big bivalve molluscs *Unionidae*, as well as death of semiaquatic mammals (otters, muskrats, beavers).

Thus, in the conditions of Vyatka-Verkhnekamsk southern taiga area, frosts below –20 °C in the late autumn-early winter with no snow and prolonged winter frosts below –35 °C were pessimal, sublethal, and sometimes lethal for a number of invertebrates, including agricultural pests (Colorado beetle, bishop's mitre shieldbug, winter cutworm, frit fly) causing death in the diapause at different ontogenesis stages (eggs, larvae, imagoes). With the progression of positive temperature anomaly in the warm season, the onthogenesis phases in invertebrates started abruptly, up to 16 days earlier than the long-term average dates. The onset of invertebrate (insects) development phases in the corresponding thermal groups ahead of the average dates was in line with deviation of the dates of daily temperatures stable transition over +5, +10, +15 °C from the long-term average ones. The monthly average air temperature rise by 1 °C results in 1.9 days earlier onset of the development stages in microthermal invertebrates and 1 day earlier arrival of short-distance migrant birds in April; and in 1.3 days earlier development of mesothermal invertebrates and 1.4 days earlier arrival of long-distance migrant birds in May. When the increment of the effective temperature sum is 100 °C, it results in earlier phenological phases in pests, i.e. 2.9-3.8 days earlier appearance of the imagoes of frit fly, Colorado beetle, cabbage butterfly in May, 2.7-4.8 days earlier emergence of larvae in June, and 1.6-1.7 days earlier flying of the summer generation of the imago in July.

Worsened food sources of insectivorous birds, especially those feeding on the wing (swifts, swallows), drying out swampy areas serving as feeding stations for common cranes, sandpipers and some other species because of the summer drought stimulate early departure of migrating birds, primarily of true oligophagous migrants, to the wintering grounds. In a warm autumn, big groups of partially migrating heterotrophic species of birds may linger in the middle latitudes for an unusually long time.

Extremely high air temperatures (above +30 °C) and the drought in July and August were pessimal for a number of agricultural pests, suach as barley flea beetle, cabbage butterfly and even for such a thermophilic and ecologically flexible pest as the Colorado beetle; and sublethal and lethal for slugs, eggs and larvae of the frit fly, click beetles, bishop's mitre shieldbugs. The summer drought limited the reproduction of these invertebrates.

High injuriousness of the frit fly and the barley flea beetle manifests itself only on the emerged summer crops, well developed plants are damaged less. That is why when these pests develop very early and fast in the conditions of elevated temperatures in spring, it is practical to finish summer crop sowing earlier and in a very short time working double shifts.

In a warm prolonged autumn, to avoid mass frit fly and common rustic colonization on the emerged winter rye, the sowing should be done in the optimal later time. When there is no emerged winter rye, these pests colonize unsuitable lands or perennial grasses, predominantly with crop stands.

With hot weather and fast development of clover seed weevil larvae, imagoes emerge earlier, and the population of beetles wintering in clover fields is the biggest in such seasons. Therefore the yield from these fields is only suitable as forage. It is the first year yield that should go for seeds.

The population of the wireworm cannot be regulated. The only measure is to decrease the areas with perennial grasses dominated by the couch grass *Elytrigia repens* (L.) Nevski, the aboveground parts of which are preferred by adult click beetles, with the roots preferred by their larvae.

Thus, in the conditions of the moderate continental climate in the middle latitudes of the European East, extreme negative winter temperatures of up to –40 °C and prolonged heat of up to +40 °C combined with a summer drought are within the adaptation limits of the regional biota, including agricultural pests.

Acknowledgement

We thank Yu.V. Anisimov, A.A. Golovina, N.M. Deryabina, T.M. Doronina, S.Yu. Efremov, K.V. Kiseleva, S.N. Kladov, N.A. Klestov, N.B. Kirpikova, L.S. Kokoulina, E.A. Леонову, Z.V. Mertvishcheva, N.D. Metelev, O.A. Moraleva, L.A. Nabatova, D.P. Potapova, G.G. Pugacheva, G.I. Repin, V.A. Rusakov, T.A. Sandakova, N.V. Churina, V.P. Shamova, G.I. Yuferov, our correspondents from Kirov Phenological Center for the results of the observations.

REFERENCES

1. Schwartz M.D., Reiter B.E. Changes in North American spring. *International Journal of Climatology*, 2000, 20(8): 929-32 (doi: 10.1002/1097-0088(20000630)20:8<929::AID-JOC557>3.0.CO;2-5).
2. Kondrat'ev K.Ya., Demirchyan K.S. *Vestnik RAN*, 2001, 71(11): 1002-1009.
3. Gruza G.V., Ran'kova E.Ya. *Izvestiya RAN. Fizika atmosfery i okeana*, 2003, 39(2): 1-20.
4. Houghton J. *Global warming. The complete briefing*. Cambridge, GB, 2009.
5. Schonwiese C.-D., Janoschitz R. *Klima-Trendatlas Europa 1901-2000*. Berichte Inst. Atmosphäre Umwelt, Univ. Frankfurt/M., Germany, 2008.
6. Kolomyts E.G. *Ekologiya*, 2006, 6: 429-440.
7. Hickling R., Roy D.B., Hill J.K., Fox R., Thomas C.D. The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology*, 2006, 12: 450-455 (doi: 10.1111/j.1365-2486.2006.01116.x).
8. Rahmstorf S., Schellnhuber H.J. *Der Klimawandel. Diagnose, Prognose, Therapie*. Germany, Munchen, 2007.
9. Kislov A.V., Grebenets V.I., Evstigneev V.M., Konishchev V.N., Sidorova M.V., Surkova G.V., Tumel' N.V. *Vestnik Moskovskogo universiteta. Seriya 5: Geografiya*, 2011, 3: 3-8.
10. *Ekologo-geograficheskie posledstviya global'nogo potepleniya klimata XXI veka na vostochnoevropeiskoi ravnine i v Zapadnoi Sibiri: Monografiya* [Ecogeografic effects of global warming in XXI century on the East European Plain and in Western Siberai: monograph. N.S. Kasimov, A.V. Kislov (eds.). Moscow, 2011.
11. Kasimov N.S., Kislov A.V., Baburin V.L. *Ekologiya i zhizn'*, 2012, 8: 72-77.
12. Menzel A. Trends in phenological phases in Europe between 1951 and 1996. *International Journal of Biometeorology*, 2000, 44(2): 76-81 (doi: 10.1007/s004840000054).
13. Minin A.A. *Fenologiya Russkoi ravniny: materialy i obobshcheniya* [Phenology of the Russian

Plain: data and analysis]. Moscow, 2000.
14. Kozharinov A.V., Minin A.A. V sbornike: *Vliyanie izmeneniya klimata na ekosistemy* [In: Effects of climate changes on ecosystems]. Moscow, 2001: 17-23.
15. Peñuelas J., Filella I. Phenology — responses to a warming world. *Science*, 2001, 294: 793-795 (doi: 10.1126/science.1066860).
16. Chmielewski F.-M., Rotzer T. Response of tree phenology to climate change across Europe. *Agricultural and Forest Meteorology*, 2001, 108: 101-112.
17. Delbart N., Picard G., Toan T.L., Kergoats L., Quengan S., Woodwand I., Dye D., Fedotova V. Spring phenology in Boreal Eurasia over a nearly century time scale. *Global Change Biology*, 2008, 14(3): 603-614 (doi: 10.1111/j.1365-2486.2007.01505.x).
18. Thuiller W., Lavergne S., Roquet C., Boulangeat I., Lafourcade B., Araujo M.B. Consequences of climate change on the tree of life in Europe. *Nature*, 2011, 470(7335): 531-534 (doi: 10.1038/nature09705).
19. Insarov G.E., Borisova O.K., Korzukhin M.D., Kudeyarov V.N., Minin A.A., Ol'chev A.V., Semenov S.M., Sirin A.A., Kharuk V.I. V sbornike: *Metody otsenki posledstvii izmeneniya klimata dlya fizicheskikh i biologicheskikh sistem* [In: Assessment of the impact of climate change on physical and biological systems]. Moscow, 2012: 190-265.
20. *Phenology and slimate shange.* Xiaoyang Zhang (ed.). Croatia, 2012 (doi: 10.5772/2146).
21. *Phenology: an integrative environmental science.* M.D. Schwartz (ed.). Springer, Netherlands, 2013 (doi: 10.1007/978-94-007-6925-0).
22. Parmesan C. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution and Systematics*, 2006, 37: 637-669 (doi: 10.1146/annurev.ecolsys.37.091305.110100).
23. Musolin D.L., Saulich A.Kh. *Entomologicheskoe obozrenie*, 2012, 91(1): 3-35.
24. Visser M.E., te Marvelde L., Lof M.E. Adaptive phenological mismatches of birds and their food in a warming world. *Journal of Ornithology*, 2012, 153(1): 75-84 (doi: 10.1007/s10336-011-0770-6).
25. Cahill A.E., Aiello-Lammens M.E., Caitlin F.M., Hua X., Karanewsky C.J., Ryu H.Y., Sbeglia G.C., Spagnolo F., Waldron J.B., Wiens J.J. Causes of warm-edge range limits: systematic review, proximate factors and implications for climate change. *J. Biogeography*, 2014, 41(3): 429-442 (doi: 10.1111/jbi.12231).
26. Ahas R. Long-term phyto-, ornitho- and ichtyophenological time-series analysis in Estonia. *International Journal of Biometeorology*, 1999, 42(3): 119-123.
27. Lenoir J., Gégout J.C., Marquet P.A., De Ruffray P., Brisse H. A significant upward shift in plant species optimum elevation during the 20th century. *Science*, 2008, 320(5884): 1768-1771 (doi: 10.1126/science.1156831).
28. Cotton P.A. Avian migration phenology and global climate change. *PNAS USA*, 2003, 100(21): 12219-12222 (doi: 10.1073/pnas.1930548100).
29. Van Buskirk J., Mulvihill R.S., Leberman R.C. Variable shifts in spring and autumn migration phenology in North American songbirds associated with climate change. *Global Change Biology*, 2009, 15: 760-771 (doi: 10.1111/j.1365-2486.2008.01751.x).
30. Solov'ev A.N., Shikhova T.G. *Materialy Mezhdunarodnoi konferentsii «Ekologiya severnykh territorii Rossii. Problemy, prognoz situatsii, puti razvitiya, resheniya»* [Proc. Int. Conf. «Ecology of the Russian North: challenges, forecasts, development and solutions»]. Arkhangel'sk, 2002: 382-387.
31. Estrella N., Sparks T.H., Menzel A. Trends and temperature response in the phenology of crops in Germany. *Global Change Biology*, 2007, 13: 1737-1747 (doi: 10.1111/j.1365–2486.2007.01374.x).
32. Stefanescu C., Peñuelas J., Filella I. Effects of climatic change on the phenology of butterflies in the northwest Mediterranean Basin. *Global Change Biology*, 2003, 9: 1494-1506 (doi: 10.1046/j.1365-2486.2003.00682.x).
33. Root T.L., Price J.T., Hall K.R., Schneider S.H., Rosenzweig C., Pounds J.A. Fingerprints of global warming on wild animals and plants. *Nature*, 2003, 421: 57-60 (doi: 10.1038/nature01333).
34. Parmesan S. Influences of species, latitudes and methodologies on estimates of phenological response to global warming. *Global Change Biology*, 2007, 13: 1860-1872 (doi: 10.1111/j.1365-2486.2007.01404.x).
35. Mokhov I.I. *Izvestiya RAN. Fizika atmosfery i okeana*, 2011, 47(6): 709-716.
36. Blunden J., Arndt D.S., Baringer M.O. State of the climate in 2010. *Bulletin of the American Meteorological Society*, 2011, 92(6): S1-S266.
37. Semenov V.A. *Priroda*, 2013, 10: 31-41.
38. Popova V.V. *Meteorologiya i gidrologiya*, 2014, 3: 37-49 (doi: 10.3103/S1068373914030042).
39. *Doklad ob osobennostyakh klimata na territorii Rossiiskoi Federatsii za 2010 god* [Report on the climate peculiarities in the Russian Federation in 2010]. Moscow, 2011.
40. *Vliyanie ekstremal'nykh uslovii zimy 1978/79 g. na sezonnoe razvitie prirody Nechernozem'ya v*

1979 godu [The impact of 1978/79 extreme winter conditions on seasonal changes in the Nechernozem'e region in 1979]. Moscow, 1981.
41. *Vliyanie neobychnykh pogodnykh uslovii na sezonnoe razvitie prirody v 1983 godu* [The impact of adverse weather on seasonal changes in nature in 1983]. Moscow, 1985.
42. Hansen J., Sato M., Ruedy R. Perception of climate change. *PNAS USA*, 2012, 109(37): 2415-2423 (doi: 10.1073/pnas.1205276109).
43. Perevedentsev Yu.P., Vazhnova N.A., Naumov E.P., Shantalinskii K.M., Sharipova R.B. *Georesursy*, 2012, 6(48): 19-24.
44. Solov'ev A.N., Shikhova T.G. *Vestnik Udmurtskogo universiteta*, 2011, 4: 8-19.
45. Fedotov V.I., Akimov L.M., Kurolap S.A., Matveev S.M., Davydova N.S., Dmitrieva V.A. *Zhara 2010 goda v Tsentral'nom Chernozem'e: posledstviya, prichiny, prognozy* [Heat 2010 in Central Chernozem'e region: consequences, causes, and forecasts]. Voronezh, 2012.
46. Ivanov V.P., Marchenko S.I., Glazun I.N., Nartov D.I., Soboleva L.M. *Vestnik Povolzhskogo gosudarstvennogo tekhnologicheskogo universiteta. Seriya: Les. Ekologiya. Prirodopol'zovanie*, 2013, 1(17): 25-35.
47. Megalinskaya I.Z., Tertitsa T.K. *Trudy Mordovskogo gosudarstvennogo prirodnogo zapovednika im. P.G. Smidovicha*, 2011, 9: 99-105.
48. Echedi I.I. *Plodovodstvo i yagodovodstvo Rossii*, 2011, 2(28): 329-340.
49. Ozherel'eva Z.E., Bogomolova N.I. *Plodovodstvo, semenovodstvo, introduktsiya drevesnykh rastenii*, 2013, 16(16): 123-126.
50. Karlova N. *Ekonomiko-politicheskaya situatsiya v Rossii*, 2010, 10: 54-58.
51. Gryazneva T.N., Rodionova V.B. *Zdorov'e. Profilaktika. Dolgoletie*, 2010, 5(4): 30-32.
52. Babich N.V., Yakovlev A.A. *Zashchita i karantin rastenii*, 2011, 1: 43-44.
53. Kudinov K.A. *Vestnik Volzhskogo universiteta im. V.N. Tatishcheva*, 2011, 12: 51-57.
54. Zakharov A.A., Zakharov R.A. *Zoologicheskii zhurnal*, 2014, 1(93): 92-107 (doi: 10.7868/S0044513414010218).
55. Solov'ev A.N. *Biota i klimat v XX stoletii* [Biota and climate in the twentieth century]. Moscow, 2005.
56. Logan J.A., Régnière J., Powell J.A. Assessing the impacts of global warming on forest pest dynamics. *Frontiers in Ecology and the Environment*, 2003, 1(3): 130-137 (doi: 10.1890/1540-9295(2003)001[0130:ATIOGW]2.0.CO;2).
57. Altermatt F. Climatic warming increases voltinism in European butterflies and moths. *Proceedings of the Royal Society of London. Series B*, 2010, 277: 1281-1287 (doi: 10.1098/rspb.2009.1910).
58. Martín-Vertedor D., Ferrero-García J.J., Torres-Vila L.M. Global warming affects phenology and voltinism of *Lobesia botrana* in Spain. *Agricultural and Forest Entomology*, 2010, 12(2): 169-176 (doi: 10.1111/j.1461-9563. 2009.00465.x).
59. Solov'ev A.N. *Sezonnye nablyudeniya v prirode. Metodika i programma fenologicheskogo monitoringa* [Seasonal monitoring in nature: methods and program of phenological observations]. Kirov, 2005.
60. Berezkin A.T., Bandulevich N.I., Luk'yanova L.G., Matskevich M.N., Shaburova T.N., Kireev V.K., Shumskikh S.I., *Guznova N.P. Kratkaya metodika obsledovaniya ugodii na vyyavlenie vreditelei i boleznei sel'skokhozyaistvennykh kul'tur* [A brief guide to survey for pests and diseases of crops]. Gor'kii, 1985.
61. Kolomyts E.G. *Boreal'nyi ekoton i geograficheskaya zonal'nost': atlas-monografiya* [Boreal ecotone and geographical zonality: atlas-monograph]. Moscow, 2005.
62. Frenkel' M.O., Perevedentsev Yu.P., Sokolov V.V. *Klimaticheskii monitoring Kirovskoi oblasti* [Climate monitoring in Kirov Province]. Kazan', 2012.
63. *O sostoyanii okruzhayushchei sredy Kirovskoi oblasti v 2010 godu (Regional'nyi doklad)* [The state of environment in Kirov Province in 2010: a regional report]. Kirov, 2011.
64. Bei-Bienko G.Ya. *Obshchaya entomologiya.* Moscow, 1980.
65. Zhirmunskaya N.M. *Ogorod bez khimii* [Gardening without chemicals]. St. Petersburg, 2004.
66. Gusev G.V., Yakovlev B.V. *Sbornik rabot po voprosam karantina rastenii*, vypusk 12 [Collected papers on plant quarantine. Issue 12]. Moscow, 1962: 90-97.
67. Taran N.A., Boiko L.A., Gulidova L.A. *Koloradskii zhuk i bor'ba s nim.* Voronezh, 1981.
68. Ushatinskaya R.S. *Koloradskii kartofel'nyi zhuk. Filogeniya, morfologiya, ekologiya, fiziologiya, adaptatsiya, estestvennye vragi* [Colorado potato beetle. Phylogeny, morphology, ecology, physiology, and natural enemies]. Moscow, 1981.
69. Dol'nik V.R. *Migratsionnoe sostoyanie ptits* [Migration state in birds]. Moscow, 1975.
70. Mikheev A.V. *Perelety ptits* [Bird migration]. Moscow, 1971.
71. Shubin S.E. *Trudy Gosudarstvennogo prirodnogo zapovednika «Nurgush» (Kirov)*, 2011, 1: 196-202.