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Some Aspects of Interrelations between Terrestrial Ecosystems and the Changing Climate

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Abstract—Issues of interrelations between climate and land ecosystems (mainly, their basic component: vegetative land cover) are considered in the paper. The hysteresis effect, which manifests itself in the dynamics of biome boundaries, is described on both a global and a regional scale and based on data analysis of the primary production of aboveground phytomass and evaporability. The work helps reveal centers of interannual stability of the onset of phenological events throughout the territory of European Russia and study regularities in their shifts during the vegetation period. The interannual temporal variability in the onset of natural events is shown to remain within the range of climatic variables. It is established that the temporal patterns for the onset of many spring events have advanced to earlier dates over the past decades (whereas those for autumn events have shifted to later dates) and the vegetation periods have extended, e.g., by more than ten additional days in the northern part of European Russia. However, phenological responses to global warming show differences across regions and groups of organisms, which evidences that the biota responds as a whole to present-day climate changes in different ways.

Keywords: climate change, terrestrial ecosystems, territory of European Russia, phenological phenomena, changes in phenological indicators.

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CLIMATE AND BIOME BOUNDARIES

The fact of close interrelations between climate and vegetation is recognized by everybody. Various climate classifications (by Berg, Alisov, Ivanov, Keppen, Penck, Budyko, Grigoriev, and others) correspond, to one degree or another through systems of indices and indicators, to the distribution of major vegetative formations or natural zones, which are also generally identified by type of vegetation (climate types of tundra, savanna, or taiga; permanently humid or dry/humid climate; Arctic, temperate, or equatorial climate, etc.). These spatial–functional interrelations are represented under bioclimatic schemes (by Holdridge and similar schemes by Keppen, Thornthwait, and Box) and in many related works (Bazilevich et al., 1986; Zubov, 1978; Parfenova and Chebakova, 2009; Puzachenko and Skulkin, 1981; Usol'tsev, 2003; Monserud, 2003).

Thousands of years were required for the creation of the dynamic climate–vegetation equilibrium, while its present-day state, particularly in the Northern Hemisphere, has been established under the influence of conditions existing in the observed interglacial period. It is important to note that, not only does climate determine the type of vegetation, but latter produces a significant effect on climate formation by regulating the processes of energy and mass exchange, drainage, evaporation, and the total balance of the underlying surface; apart from this, the role of vegetation is important in the formation of atmospheric gas composition and redistribution of precipitation. Studies on the power of terrestrial ecosystems to regulate their moisture exchange with the atmosphere have shown that these processes are more developed in forest communities (the moisture-exchange regulation indicator is equal to 2.5) and less developed in steppe communities (1.5) and agrocenoses (1.2) (Minin, 1991). Present-day climate warming, which has resulted mainly from organic fuel burning (as many scientists believe and as adopted by international documents: the UN Framework Convention on Climate Change (UN FCCC), the Kyoto Protocol), can also be referred to the phenomenon associated with the effect of vegetation (albeit prehistoric) on climate.

Considering the above-mentioned facts, as well as the inertness of both climate and, to a greater degree, vegetation, we cannot anticipate a simple response of zonal vegetation to the observed warming. For example, we cannot expect an active advance of biome boundaries toward the north; changes in species composition, in particular, principal forest-forming or edificator species; changes in productivity parameters; etc., as would follow from the above-mentioned popular bioclimatic schemes. Studies show that these schemes correlate to the real territorial distribution of vegetation with an accuracy ranging from 35 to 58%; therefore, vegetation dynamics predictions based on the above schemes need to be approached with caution (Vedyushkin, 1995). It should be noted that the mean per century shift rate for zones of woody species is limited to tens of kilometers (Velichko, 1992). Therefore, potential shifts in vegetative zonal boundaries will certainly be far behind the present-day rates of climate change.

The dependence between the equilibrium type of vegetation and cyclic–dynamic climate conditions is obviously a variable value. Well-substantiated predictions for the response of vegetation to climate changes should include this variability, which is naturally formalized under the concept of hysteresis. We commonly understand this concept as the noncoincidence of quasi-equilibrium trajectories of a system in the case of a direct or reverse change in parameters.

In our case system (S) is interpreted as a vegetative cover with stable conditions of $S(p)$ types of vegetation (biomes), characterized by definite production P; the parameter p is defined by climate (evaporation from water surface or evaporability, E). It is obvious that for each vegetation type of S there are values of climatic parameters, existing and realized on the earth's surface, at which a given type cannot survive. It is also clear that there are points with the same values of E in different vegetation zones. Therefore, the conditions for the realization of spatial hysteresis (which is present on the earth's surface where the equilibrium vegetation is indefinitely determined by climatic factors) are satisfied. The real situation at the biome boundary within a hysteresis zone depends on both climatic and other factors, first of all, paleogeographic ones.

Studies at the local scale have shown that a hysteresis zone is unavoidably present among vegetation communities if the environment-forming role of their dominant species is great enough (Vedyushkin, 1992). Bufferness manifests itself in the unchanged position of a boundary until changes in external parameters (temperature, precipitation, etc.) exceed certain limits. However, if an impact proves strong enough for a sharp shift in a boundary to take place, the latter does not regain its former position after external environmental conditions return to their initial state even upon completion of relaxation processes (irreversibility).

Boundaries between communities where dominant species are not strong edificators do not have the properties described above. The boundary in this case is unclear and smooth, a hysteresis zone is absent, and the boundary reversibly follows changes in environmental conditions (with a possible delay for the time of relaxation).

As we have already mentioned, the environment-forming role of vegetation manifests itself with all its apparentness at the macroscale, and biomes therefore possess a strong enough environment-forming capacity to exclude a mixture of biomes at the same place. It follows that the case of a smooth change in boundaries on the level of biomes is unrealizable. Abrupt boundaries can be explained by both hysteresis and changes in environmental conditions (relief and other changes). However, "jumps" in production and differences in vegetation types on adjacent plots of land, when external conditions remain unchanged, point to the presence of hysteresis.

CLIMATE AND VEGETATION PRODUCTIVITY

Interrelations between annual vegetation production and evaporability on the territory of the former Soviet Union were studied within the approach outlined above (Kolosov and Minin, 1992; Minin, 1991). We received assessments of dominant changes in aboveground phytomass production due to water surface evaporation (evaporability) changes for the period 1951–1987 and revealed two zones of indefinite dependence (hysteresis) that were adjacent to boreal forests in the north and south. The southern zone is typified as more powerful (Vedyushkin et al., 1995). In contrast to the real position of the boundaries between the biomes, the boundaries of the hysteresis zones are clearly determined by climatic conditions and will definitely be prone to changes (they will shift toward the poles in the general case) under possible global warming. However, changes in the boundaries will begin only with sufficiently strong climate warming (the threshold effect).

When we are dealing with climate–vegetation interrelations, the issue of ecosystem "memory" of past climatic conditions deserves our particular attention. This problem can be considered by the example of primary production in the most informative way, using multiyear observation series. As for the contribution of various meteo-parameters for the current and preceding years to the harvest of aboveground phytomass in mowed vs. unmowed steppe in the Central Black Soil Reserve (for the period 1964–1985), the highest coefficient values of correlation with harvest were demonstrated in both cases by the cumulative precipitation of May–June and July–November of the preceding year for the unmowed steppe and by that of July–August of the preceding year for the mowed steppe. However, the preceding-year autumn temperature conditions proved in both cases to be more important than the current-year spring thermal conditions and the preceding-year precipitation (Minin et al., 1993). It is important to note that the production of some ecological groups (legumes, mosses, sedges, old fields, and litter layer) did not reveal the same close correlation with precipitation as that of gross phytomass, cereals, or forbs. Stronger effects on their productivity are evidently produced by intracenotic factors (such as competition). However, the summary production of steppe vegetation communities was very closely correlated with climate.

Present-day studies on the stability of ecosystems in terms of their resilience (or elasticity), or their potential to restore their structure and functions after suffering damage, have shown that grassland ecosystems realize this process rather quickly (Titlyanova, 2009). Thus, after the removal of loading, the species composition is restored to the native stage in 10–15 years (if grazed plots were heavily trampled, the restoration period may last 30–40 years); the parameters of the biological cycle—storage of green aboveground and belowground phytomass—are restored in 3 years, while for old fields and the litter layer it is 10–15 years; the level of primary production, close to the zonal one, is restored in 6–10 years; the structure of the biological cycle requires 5–6 years. The "memory" of grass communities can probably be assessed using the indicated time intervals.

Clearly, we can also speak at the level of biomes of their "remembering" climatic conditions over a sufficiently lengthy period of time, which is actually the parameter that characterizes their inertness or the "scale" of hysteresis. An analysis of the correspondence (or differences) between the observed and the optimal natural vegetation (ecosystems in an extended sense) for the existing climatic conditions will make it possible to assess the degree of inertness effect in ecosystems in relation to climate changes.

CLIMATE AND FLORISTIC DIVERSITY

Floristic diversity is an important characteristic for describing the state of vegetation. The geographical pattern of this diversity across the territory of eastern Europe is subordinate to its natural zonal patterns. The increasing diversity trend is oriented northeast–southwest. The highest values of floristic richness are observed in the zone of broadleaf forests and forest steppe. Low values are recorded in the tundra zone, in desert and semidesert areas of the Cis-Caspian Lowlands, and in dry steppes of Ukraine (Kozharinov and Morozova, 1997). Calculation of the Kendall tau correlation coefficients between the climatic parameters and floristic diversity of the eastern European territory allowed us to reveal the most important climatic characteristics (air temperature in April and August, the sum of temperatures above 5 and 10°C, total precipitation in April, number of days with thaw in March, etc.). These indicators can serve as the basis for the assessment of vegetation dynamics in terms of floristic diversity under climate changes.

INTERANNUAL VARIABILITY OF CLIMATIC PHENOLOGICAL INDICATORS

In temperate latitudes two types of states are clearly expressed in the interannual dynamics of nature: the summer vegetation peak and the winter dormancy period. Between these polar states, we can distinguish a succession of many annual events: snow thawing, arrival and nesting of birds, the onset of blossoming, leaf-out of trees, seed and fruit ripening, leaf yellowing and seasonal leaf-fall, etc. Available data on the onset of seasonal events in nature over a long period of time allow us to assess, on the one hand, the multiyear regime of hydrometeorological conditions and, on the other hand, specific patterns in the intra- and interannual dynamics of landscapes, ecosystems, and their components. An integrated study of temporal variability in climatic and biological parameters allows us to obtain a clearer picture of the hierarchy behind natural processes and phenomena and evaluate the potentially destructive role of anthropogenic factors in its structure. Knowledge of probability values in the parameters and amplitudes of variances makes it possible also to approach more soundly the solution of the problems associated with the resistance of the biosphere and its individual components to anthropogenic impacts.

With the aim of studying the adjoint interannual climate–biota variability, our work was based on materials on the onset dates of 29 events in the living and nonliving world (arrival of first starlings and rooks, onset of blossoming of the bird-cherry tree and rowan tree, stable passages of average daily air temperatures in spring and autumn over threshold values, first and last light frosts in the air and on the soil, etc.) for more than 300 locations over a nearly thirty-year period. The total number of data series was close to 5500 (Minin, 1991).

These series were treated using alignment coordinate networks, including the pattern of distribution, calculation of quantiles and basic statistical methods (Kolosov and Liseev, 1987; Minin, 1991), and mapping the difference of quantiles with a 5% support; as a result, the centers of stable interannual regimes in the manifestations of phenological events were found on the territory of European Russia (TER). The results revealed regularities in shifts of the centers of stability during the vegetation period across the region (from the Lower to the Middle Volga, when average daily temperatures in spring surpassed the 0°C mark; to the center of the TER, when the temperature surpassed 5°C; then the Baltic countries and Belarus, when the temperature surpassed 10°C; and again the southern regions of the TER, when the temperature surpassed 15°C). Correlations between the variability values for the onset dates of biotic and abiotic events were calculated. Thus, the average amplitude of the onset dates for pheno-phenomena over a statistically average period of 20 years amounted to 27 days for birds, 29 days for plants, 37 days for the dates of exceeded threshold values, and 41 days for the dates of the first and last light frosts in the air and on the soil. It was revealed that the most narrowed onset dates (the "narrow channel" effect) were those for phenological events in the period when the average daily air temperature exceeded 5°C in spring (average amplitude was 31 days) and when the temperature increased up to about 10°C (average amplitude of dates for "spring height" phenomena was 25 days during this period); also among the most narrowed were the dates when autumn temperatures surpassed the 10°C mark (amplitude was 34 days) (Minin, 1991, 1994).

The most unstable temperature passages were over the 0 and 15°C marks in spring (37 and 45 days, respectively) 15 and 0°C marks in autumn (37 and 40 days).

Based on an analogous methodology, a study of the interannual variability of productivity and climatic parameters showed on the example of mowed vs. unmowed steppe that the multiyear variability of biological parameters remains, on the whole, within the variability of climatic values (cumulative precipitation, dates of stable passage of average daily air temperature over the 10°C mark in spring, etc.). In the case with harvests, increased variability and going beyond the "external framework" were recorded for the mowed steppe and likely associated with anthropogenic interference (phytomass removal), which especially affected the variability of mortmass (Minin, 1994).

The specificities revealed in the character of adjoint variability in climatic and biological parameters point to the readiness of biological objects and structures of various ranks for a very broad range of external environmental changes. Considering the revealed regularities, we can state that the genetically predetermined vegetative development program, for example, in plants, is practically always realized in the present-day climatic conditions and may be unrealized only in rare anomalous years or along zonal boundaries. We believe that the probability of a two- or threefold repetition of anomalous years actually capable of seriously affecting the populations is even lower, and we can reiterate that we should not expect quick directed responses of vegetation to one or another serious climate change.

PHENOINDICATION OF CLIMATE CHANGES

In recent years the interest in multiyear phenological data series as a source of information about the interannual dynamics of plant populations and ecosystems has significantly grown in view of climate changes in Russia and abroad (Kupriyanova, 2000; Minin, 2000; *Sezonnaya zhizn'* ..., 1980; *Fenologicheskie nablyudeniya* ..., 1982). A considerable volume of phenological data has been accumulated in Russia on especially guarded natural territories within the Letopis' prirody (Chronicles of Nature) program. A logical extension of the work on the multiyear data analysis under the Chronicles of Nature Program was the competition project announced by Russia's representative office of the World Wide Fund for Nature (WWF); this called for conducting work on data analysis of past and present-day climatic changes and their relevant effects in nature reserves (*Vliyanie izmenenii* ..., 2001), as well as the preparation of regional climatic passports (*Regional'nye izmeneniya* ..., 2003).

European countries are now actively integrating their national phenological networks and unifying observational and analytical methods for handling multiyear series (*Growth Stages* ..., 1997). The timing of the onset of flowering phenomena in plants, which advanced by 6–7 days or more during the second half of the 20th century in the temperate latitudes of the Northern Hemisphere, is now widely used as a phenological indicator (Gordienko and Minin, 2006; Minin, 2000; Minin, 2007; Penuelas and Fitella, 2001). According to the observational data analysis results obtained by the network of international phenological gardens (IPG) throughout Europe in the period 1959–1993, the average increase in length of vegetation period by the linear trend equation was 10.8 days, due to the earlier onset of vegetation in spring and its later end in autumn (Menzel and Fabian, 1999).

The effect of climate changes on the condition of the biota throughout Russia can be analyzed based on the materials provided by nature reserves (*Vliyanie izmenenii* ..., 2001), as well as on climatic passports for ecoregions (*Regional'nye izmeneniya* ..., 2003).

Considerably warmer spring and summer months, as well as longer frostless periods, have been recorded over the past 50 years in the Barguzin Nature Reserve. However, the moistening regime has remained practically unchanged, pushing further climate aridization. A slowdown or cessation of warming was recorded in the 1990s. Correspondingly, shifts in the life cycles of some plant and bird species were expressed in earlier onset dates of vegetation, earlier arrival of birds, and longer vegetation periods. No changes were detected in the species with later onsets of vegetation and flowering. Climate changes do not seem to produce any effects on mammals.

Over the last century, average January temperatures in the Altai–Sayan region have shown a 3–4°C increase, whereas summer temperatures have increased not at all or only slightly. The daily temperature variation amplitudes have decreased, while the summary amount of precipitation has remained at practically the same level. The timing of the onset of spring ice drifting on some rivers (the Enisei, Abakan, Tuba) has shifted to earlier dates since the 1920s (by 1–2 days for every 10 years), and the dates for autumn ice formation have demonstrated an analogous trend. Spring phenomena in plants have responded by shifts to earlier dates, but not everywhere (the onset dates of flowering in the bird-cherry tree have remained the same in the Minusin Basin since the mid-1960s). The onset dates for summer-associated phenomena have either remained the same or begun to be delayed. There are records of the advance of the upper forest boundary to higher altitudes across the Sayan Mountains. Mallards have started to arrive 13–16 days earlier, while there are records of the later arrival of starlings.

The mean January temperature in the Chukotka Peninsula markedly decreased in the second half of the 20th century, while the amount of precipitation shrank. In contrast, the July temperature increased. During the past century, a shift of forests to the north was recorded in the Anadyr' and Khatanga basins, although the latter may be evidence of the general trend of expansion of the tundra to polar deserts and overgrowth of the tundra by sparse forest.

Winter warming has also been recorded in the Taimyr Peninsula (winters in the 1990s were regularly 2°C above the norm). On the whole, the January temperatures have increased by 1.5–2.0°C over the past 50 years, whereas the July temperature has even decreased by 1°C. The amount of precipitation used to change insignificantly. No directed changes in the state of the ecosystems have been revealed across the peninsula.

On the whole, weather became somewhat colder in the Kola Peninsula over the 20th century, which was reflected in the varying nature of phenological responses. According to the Lapland Nature Reserve, no reliable trends were detected for the majority of events over the period of 1930 to 2001. The destruction of snow cover in forests started to delay by almost a week, while its autumn installation was recorded 10 days earlier, which is evidence of cooling to some extent. Correspondingly, autumn events in the birch tree, for example, came a week earlier, whereas the dates for the spring events remained practically the same; bears analogously started to enter hibernation 5 days earlier in the fall.

In Il'men Nature Reserve (the eastern foothills of the southern Urals), winters and springs have become warmer; the biota has responded rather intensely but, at the same time, variably. Since 1980 the inflammability of the forest has increased. Over the past 20–30 years, the spring events in plants have been tending toward earlier onsets, whereas birds have been observed to respond weakly. The onset of blossoming in the rowan tree and dog rose now occurs on later dates. At the same time, the autumn phenophases have begun to occur 7–18 days earlier.

In Taganai National Park (uplands of the southern Urals), climate warming and moistening were recorded, which led to better survivability of undergrowth and shoots in the winter period, improvement in the conditions of growth, and development of woody plants at the uppermost limit of tree growth. This was expressed in the relatively fast advance over the last century of the upper border of low forest to higher altitudes into the mountains, up to 60–80 m vertically and up to 500–600 m along the slope. The alpine and tundra-related vegetation was sharply reduced and the biodiversity of highlands shrank, so that alpine-tundra-like communities may disappear from the territory of the national park in the next 50 years.

In Pechero-Ilych Nature Reserve (northern Cis-Ural area), warming also interfered, in general, with the spring–winter period. However, the phenological responses in the living world proved to be diversified. For many species the vegetation period even shrank on account of stronger shifts in timing to earlier dates in autumn than in spring. There were also records of newly emerged species of flora and fauna.

No apparent climatic and phenological changes were detected in the Caucasus Nature Reserve.

On the whole, the spatial patterns of phenological trends in various events in the nature of European Russia are also inhomogeneous. A conducted analysis of the trends (by the linear trend equation) in the onset dates of phenophases in some tree species over the period 1966–1995 (Minin, 1998) allowed us to reveal a group of specificities.

Shifts in the onset of leaf unfolding on the birch (*Betula pendula* Roth. (*B. verrucosa* Ehrh.)) are prominent in the region's north and reach 5 to 10 days or more (the trends are in general statistically reliable within a 95% confidence interval). At the same time, a zone of well-expressed positive trends is shaped in its southwest, while a small-gradient field with values of 0...+5 days (the trends are unreliable) is localized in the region's center. Thus, no unambiguous and ubiquitous evidence has been found to confirm this species' expected response to global warming.

According to the data by (Voskova, 2005) for the phase of first leaf unfolding on the birch over the 1970 to 2000 period of observations under an analogous methodology, a latitudinal position was typical of the isolines for the absolute values of shifts to earlier dates, ranging from 1 day in the region of Lipetsk and Tambov to 8 days in the region of Vologda (the shift value fields for these periods in Voskova and Minin's materials are, on the whole, similar enough). However, the later onset dates of blossoming for the bird-cherry tree (*Padus avium* Mill.) are characterized by more definite negative trends. This trend is particularly expressed in the north and northwest, where the shifts in date values are 10–15 days or more in absolute values (Minin, 1998). A zone of weakly expressed positive trends is repeated in the southwest, whereas a zone of weakly negative trends is repeated in the center. A somewhat later onset of blossoming in the rowan tree (*Sorbus aucuparia* L.) is usually characterized by negative trends in the region's northwest and weakly positive trends in its west and southwest. Despite the predominant trend toward a shift in the onset date for blossoming of the small-leaved linden (*Tilia cordata* Mill.) to earlier dates in the majority of places, this shift does not exceed 4 days except in the northern part of the territory in question, where its absolute value reaches 6–7 days.

On the whole, the trend isoline fields for onset dates of phenomena are sufficiently close, which is evidence that a common factor shapes these trends. Apparently, this may be the warming-oriented changes in the meteorological conditions of spring months.

Stable passage of the average daily air temperature in spring over the 10°C mark serves as a climatic indicator, which is close in idea and dates to the phenomena being discussed. However, there is no full coincidence in the structures of phenological parameter value fields with the positions of A coefficient isolines by the linear trend equation for the data series from the paper by (Mirvis et al., 1996) on stable passage of air temperatures in spring over the 10°C mark. Apart from this, as shown by the analysis of linear trends for the blossoming onset dates of the bird-cherry tree at different field stations (Vologda, Vyatka, Nerekhta, Kineshma), with the experience of long series of observations (for over 50 years), the *A* values for a long-term period for the same station are lower according to absolute value than for the last period of time and the trends are not statistically reliable.

A weakly expressed trend toward later dates is characteristic of the phenomenon of leaf-fall end in the birch (Voskova, 2005). The absolute shift value increases by the trend equation from 1 to 6 days in the south–northeast direction.

Spatial distribution analysis of the trends in dates for phytophenological phenomena across the central part of the Russian Plain, along with the analysis of changes in the lengths of the birch vegetation period for 1970–2000, allowed researchers to reveal some specific features (Voskova and Minin, 2005).

On the whole, this period is characterized by the trend toward a longer vegetation period in the birch (to 10 or more days to the north of 56°N). This increase occurred in the north due predominantly to the stabilized earlier dates for spring phenomena, while across the rest of the territory in question it is due to the shift in leaf-fall ending dates for later ones; the trend values (including the spring events) do not exceed 5 days to the south of 53°N.

Thus, despite the presence of common coinciding trends toward changes in the onset dates of spring phenomena (stabilization of earlier dates), regional differences do exist. They may be preconditioned by biological specificities in the passage through phenophases by plants. We can suggest that a substantially longer plant vegetation period in the northern zones of the region is associated with their lengthy winter season, whereas the plants' need for a sufficiently long period of winter rest in the central, eastern, and southeastern areas probably weakens the trend toward stabilization of earlier onset dates for spring phases in the birch, bird-cherry tree, and rowan tree.

We also find it very interesting to discuss the data on the multiyear dynamics of dates for phenological events in the animal kingdom against the generally definite trends in the onset dates for phytophenological phenomena. The dates for the arrival of the first starlings (*Sturnus vulgaris* L.) and for the first call of the common cuckoo (*Cuculus canorus* L.) were chosen as a model. The starling is omnivorous and its arrival serves as the indicator for the turn of the winter type of atmospheric circulation to the spring one; the common cuckoo is an insect-eating bird whose arrival, along with the onset of the male birds' lekking, evidences that the summer type of interrelations is already being formed in the biocenoses (Shul'ts, 1981).

In considering the data on the trend fields in arrival dates of the leading starlings over the period of 1968 to 1997 (Minin, 2000), our attention was drawn by the predominance of positive values, which is evidence that the above events have started to come later. This is a delay of 5 to10 days in the center and east of the Russian Plain; in the western part the trend values are nearing zero. The same trend is also traced to a lesser degree on the map of trend values for the date of the cuckoo's first call. Reliable negative trends in both phenomena were recorded only at some localities. We should note that the onset dates for the cuckoo's call and for leaf-out of the birch in the wild almost coincide. Interpreting the above factors by possible changes in the climatic conditions at the places of bird wintering is inconsistent, since these changes are substantially less significant than in temperate latitudes (Minin and Neronov, 1996). In the case of the cuckoo, we may try to interpret the absence of trends in the onset dates of its call by the more significant role of astronomical factors (daylight duration) in the life of birds and by a multistage process in the formation of conditions for the arrival of birds (soil warming, active vegetation, leaf unfolding, mass appearance of insects, etc.). However, it has proven difficult so far to find a logical interpretation for a rather significant and practically ubiquitous delay in the arrival of starlings. This is possibly connected with the fact that a substantial part of the population has begun in recent years to remain for wintering in southern regions and also in the center of the region in large cities. The availability of feed and changes in the nature of migrations are also preconditions for the delayed arrival of starlings in the places of traditional nesting.

Thus, whereas woody species in some regions of the Russian Plain have demonstrated over the past decades a trend toward change in the onset dates of phenological events, which were correlated to a certain degree with the present-day climate warming, birds have either not responded to these changes at all (cuckoo), or their response was the reverse (starling). We obtained a sort of phenological "fork" that at first appeared rather illogical, but it allowed us to express our opinion on the variability in the biota's responses to the external changes being observed. Only individual components of the ecosystems are responding (although with a substantial regional specificity). It is supposed that the present-day climate variations have not yet produced any significant effect on the functioning of the Russian Plain ecosystems. The phenology-based study results add to our conclusions on the variability of vegetation–climate interrelations made in our earlier studies on the nature of spatial relations between the indicators of vegetation cover productivity and evaporability. The biota dampens the directed impacts of external factors (climatic ones in our case) to a certain extent, not revealing any substantial changes in structure and integrity, and its response may not carry any apparent external manifestations for a rather long period of time (or even a reverse response is possible, as in the case of the starling). Obviously, a great number of reverse climatic variations have been experienced by the biota in this manner in the course of evolution. The whole question is how serious the observed present-day climate changes are and how seriously anthropogenic activities have affected the potential of the entire biota and its individual components to resist such overloading.

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