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Short Communication



Ecological genetics of beetles of the genus *Adalia*: dynamics of population of *A. bipunctata* restructuring in Arkhangelsk in conditions of global warming

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ABSTRACT

The dynamics of the composition of the *Adalia bipunctata* L. population in Arkhangelsk for 21 years has been studied. The proportion of black individuals decreased by almost 2 times; the average annual temperature at the same time increased from 1.92° to 2.95°. A comparison of the population composition with the average annual temperature showed that the proportion of black individuals in the population is negatively correlated with the average annual temperature. The observed change in population composition is probably the effect of global warming.

Keywords: *Adalia bipunctata*; melanism; population; temperature; global warming.

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Краткое сообщение

Экологическая генетика жуков рода *Adalia*: динамика перестройки популяции *A. bipunctata* Архангельска в условиях глобального потепления

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АННОТАЦИЯ

Изучена динамика состава популяции *Adalia bipunctata* L. в Архангельске на протяжении 21 года. Доля черных особей снизилась почти в 2 раза; среднегодовая температура в то же время возросла с 1,92° до 2,95°. Сопоставление состава популяции со средней годовой температурой показало, что доля черных особей отрицательно коррелирует со среднегодовой температурой. Наблюдаемое изменение состава популяции является, вероятно, эффектом глобального потепления.

Ключевые слова: *Adalia bipunctata*; меланизм; популяции; температура; глобальное потепление.

Как цитировать

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BACKGROUND

Global warming, which has been observed during the last half-century, has an unavoidable impact on genetic processes in populations of various organisms. However, in order to assess the effects of global warming, long-term monitoring of the same population is required, as well as easily detectable markers of genetic processes occurring in the population. These criteria are met by two-spotted ladybug (*Adalia bipunctata*) populations. This species lives throughout Eurasia, from France to Kamchatka and from Norway to Armenia. Geneticists have been studying several populations of this species for the past 100 years. Two-spotted ladybug populations are polymorphic in an easily detectable morphological trait, which is under clear genetic control [1, 2].

One of the authors of this paper spent 20 years studying the composition of an *A. bipunctata* population in Arkhangelsk. The study revealed a directed change in the population composition, which is likely the result of significant climate warming. Our findings and statistical analysis are presented below.

The study aimed to confirm the impact of climate change on the composition of an *A. bipunctata* population in Arkhangelsk.

METHODS

A. bipunctata L. species (Coccinellidae, Coleoptera) were collected in Arkhangelsk (64°33', 40°3'), primarily on Troitsky Avenue and the Dvina River embankment, on Tatarian honeysuckle (*Lonicera tatarica*), willow (*Salix* spp.),

and caragana (*Caragana* spp.). Insects were collected during the imago and pupa stages. In samples with a significant proportion of pupae, phenotypes were assessed separately for insects collected during the imago stage and those that emerged from pupae. Insect phenotypes were determined according to Lusi [1, 2].

Information on the climate of Arkhangelsk and its changes was taken from www.meteoblue.com [3]. The composition of the studied population was compared with data on the average annual temperature in Arkhangelsk. Results were processed using Excel's built-in functions.

RESULTS AND DISCUSSION

The composition of the *A. bipunctata* population in Arkhangelsk in different years is presented in Table 1. Table 2 shows the calculated trend-based average annual temperature for the year of sample collection. There was a significant increase in the average annual temperature over the study period ($y=0.048x-95.82$, $R^2=0.334$, $p=0.00003$). Over 21 years of observation, the proportion of black morphs in the population decreased significantly (Table 2). The graph in Fig. 1 shows a linear relationship between this decrease and the increase in average annual temperature ($y=-23.71x+94.24$; $R^2=0.950$, $p=0.0002$).

The *A. bipunctata* population in Arkhangelsk (Table 1) had a relatively high percentage of black morphs (6-pustulata and 4-maculata morphs), along with the regular presence of a rare morph named *pantherina* by Lusi [2]. We never encountered this form in Moscow, and it is extremely rare in Saint Petersburg. One of the authors

Table 1. Composition of the *Adalia bipunctata* population in Arkhangelsk in different years

Таблица 1. Состав популяции *Adalia bipunctata* Архангельска в разные годы

Year of sample collection	Stage	Number (n)	Morphs				
			typ	pan	pust	mac	other
2003	Imago	170	87	1	18	62	2
2005	Imago	126	64	5	25	31	1
2005	Pupa	144	78	1	22	40	3
2010	Imago	264	155	2	16	88	3
2010	Pupa	42	20	1	6	14	1
2011	Imago	165	94	1	10	60	—
2011	Pupa	72	40	1	10	21	—
2012	Imago	179	113	2	17	46	1
2014	Imago	117	75	—	17	22	3
2024	Imago	92	62	8	4	18	—

Note: typ, typica; pan, pantherina; pust, 6-pustulata; mac, 4-maculata; прочие — other.
Примечание. typ — typica, pan — pantherina, pust — 6-pustulata, mac — 4-maculata, прочие — черные особи с не проявленным или необычным узором из красных пятен.

Table 2. Composition of the *Adalia bipunctata* population in Arkhangelsk and average annual temperatures in the years of collecting
Таблица 2. Состав популяции *Adalia bipunctata* Архангельска и среднегодовые температуры в годы сборов

Year of sample collection	Number (n)	Black morphs, %*	Average annual temperature, °C
2003	170	48.2 (40.52–56.01)	1.92
2005	270	45.2 (39.15–51.33)	2.02
2010	306	41.8 (36.24–47.58)	2.26
2011	237	42.6 (36.24–49.18)	2.31
2012	179	35.8 (28.74–43.25)	2.36
2014	117	35.9 (27.24–45.29)	2.46
2024	92	23.9 (15.63–33.94)	2.95

*The left and right limits of the 95% confidence interval (Fisher’s exact test) are shown in parentheses.
*В скобках указаны левые и правые границы 95% доверительного интервала (точный тест Фишера).

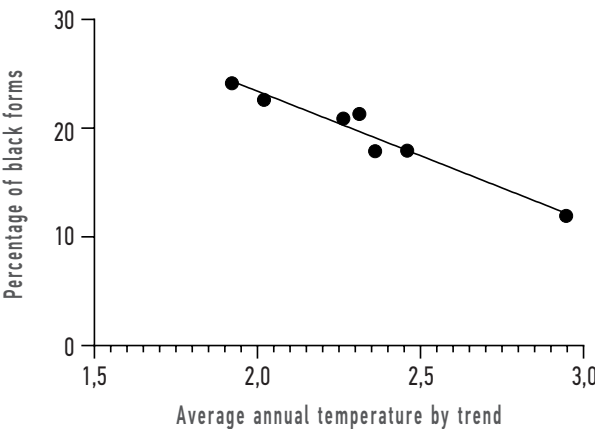


Fig. 1. The dependence of the population composition of *A. bipunctata* in Arkhangelsk on the average annual temperature.
Рис. 1. Зависимость состава популяции *A. bipunctata* Архангельска от среднегодовой температуры.

had previously performed a genetic analysis of the elytra pattern characteristic of this form [4], which, like other variations in elytra coloration and pattern, is determined by one of the alleles of the gene *S*.

The observed changes in the composition of the *A. bipunctata* population in Arkhangelsk coincided with the reorganization of populations in several other cities. The decline in the proportion of black morphs in the *A. bipunctata* population in Saint Petersburg began in the early 1980s [5]. Subsequently, the proportion of melanists in the two populations in Saint Petersburg gradually decreased until 2018–2019 [6]. Similar changes in the gene pool were reported in the Netherlands [7], Bergen (Norway) [8], and Yalta (Crimea) [6]. Because of its widespread occurrence, this phenomenon can be linked to global warming, which has become particularly noticeable in the last half-century. To confirm the impact of global climate change on the composition of *A. bipunctata* populations, it is important to assess changes in gene pools of other populations where a high proportion of melanists was previously observed. The population in Arkhangelsk, the composition of which has been studied

by one of the authors since 2003, meets these criteria. Table 2 presents the results of these observations, which showed a clear, almost twofold decrease in the proportion of black morphs over the past 20 years.

Experimental findings show different responses of black and red *A. bipunctata* morphs to solar radiation [9] and, at least in some populations, greater reproductive success of black morphs compared to red ones during the summer period [10].

CONCLUSION

The study findings support the hypothesis that temperature increases cause changes in the composition of *A. bipunctata* populations. To confirm our hypothesis, it is desirable to continue observing various geographically distant *A. bipunctata* populations. In this context, of particular interest are several populations in Southern Europe (Marseille, France; Ostia (Rome), Italy), where one of the authors discovered an unusually high percentage of melanists for Western Europe several decades ago [11, Table P1].

ADDITIONAL INFO

Authors' contribution. All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study. Personal contribution of each author: I.A. Zakharov, experimental design, collecting and preparation of samples, writing the main part of the text; A.V. Rubanovich, data analysis.

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Competing interests. The authors declare that they have no competing interests.

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ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией. Личный вклад каждого автора: И.А. Захаров — концепция и дизайн исследования, сбор и обработка материалов, написание текста; А.В. Рубанович — анализ полученных данных.

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