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INTRASPECIFIC VARIATION IN WING SHAPE OF *DOLICHOPUS PLUMIPES* (DIPTERA, DOLICHOPODIDAE)

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Abstract

A study of 128 specimens of *Dolichopus plumipes* from 9 geographical regions was conducted to evaluate the interpopulation variation in wing shape. The wing shape was described by 7 morphometric characters. The shape variation was examined using principal component analysis and t-test. The wing length and related characters were found to differ in shape between the western, eastern, northern and southern specimens. Correlation and regression analysis showed that geographic variation in wing length was strongly associated with longitude; and a significant linear component was revealed.

KEY WORDS: Diptera, Dolichopodidae, wing, interpopulation variation

Introduction

Recent studies in population ecology have shown that morphological variability in all taxonomic levels can provide data for use in evolutional, environmental and taxonomical studies (Violle *et al*., 2011). In particular, the magnitude of intraspecific variation should be used as a measure of the dispersion of morphometric characters (Vasiliev, 2005). It is important to examine the range of intraspecific variations to study an adaptive optimum of a morphological trait. The study of the variability in intraspecific level can provide data on the evolutionary path of a species.

Significant differences in wing shape and quantitative traits are related to geographical location and temperature selection. Most studies have focused on Diptera species, because flight plays an important role in survival and is the force affecting the evolutionary path.

Cline variation in the wing shape of *Drosophila serrata* (Malloch,1927) was found by Hoffmann and Shirriffs (2002). Griffiths *et al.* (2004) have described significant differences among Australian populations of

Drosophila birchii Dobzhansky & Mather, 1961, but in this case the wing shape components were not associated with latitude. Imasheva *et al.* (1995, 1996) found significant differences in wing shape and size between populations of *Drosophila melanogaster* Meigen, 1830, and these differences have strong a correlation with temperature. Laboratory experiments have shown that intraspecific differences in the structure of the wings can be associated with temperature (Cavicchi *et al*., 1985, 1991).

In our study, we focused on interpopulation variability of wing shape in *Dolichopus plumipes* (Scopoli, 1763), which is a fairly common species in the Palaearctic Region. Dolichopodid flies are active predators, and flight plays an important role in their life cycle, for example, in pursuit and courtship behavior (Land, 1993 a, b). Morphometric characters of wing are widely used in the taxonomy of the family Dolichopodidae for the compilation of keys on generic and specific levels, as well as in the study of the phylogeny of the family. Therefore, a detailed study of their intraspecific variability allows for a deeper analysis of evolutionary trends.

Materials and methods

The study of 128 males of *D. plumipes* from nine populations was conducted in order to analyze interpopulation variability. Material for the present study was taken from the collection of the Department of Ecology and Systematics of Invertebrate Animals of Voronezh State University. The collection of the Zoological Institute of the Russian Academy of Science (St. Petersburg) was also considered. We have studied specimens collected from the following territories: environs of Petropavlovsk-Kamchatskiy and the Bering Islands (Kamchatskiy Territory), Magadanskaya Province, Kustanayskaya Province, Lipetskaya Province, Krasnodarskiy Territory, Latvia, Voronezhslaya Province, environs of Lviv (Ukraine).

In examining the morphology of the wing structure, right wings were placed on a glass slide and covered with a cover glass. The morphometric characters were measured under a MBS-9 microscope (Lytkarino Optical Glass Factory) at magnification 40 with an ocular micrometer of 100 divisions. Measurements were converted into millimeters. The following characteristics were selected for the measurements: length of costal section between wing base (point 1 on Fig. 1) and meeting point of vein R_1 with costa, length of costal section between veins R_1 and R_{2+3}, R_{2+3} and R_{4+5}, R_{4+5} and M_{1+2}, length of posterior cross-vein (dm-m), total length and width of the wing (Fig. 1).

Principal component analysis (PCA) was conducted in order to allocate the characters accounting for more than 50% of the variance. Then ANOVA was used to quantify the relative amounts of variation caused by intra- and interpopulation variability.

Since the selected variables had normal distribution, mean and standard deviations were computed to describe them. Comparison of the morphometric characteristics of the groups was based on the significance of differences using the Student's t-test at a significance level of 0.95.

For the preliminary analysis, the morphometric characters of specimens from extreme points in latitude (Magadanskaya Province and Krasnodarskiy Territory) and longitude (the Bering Islands and environs of Lviv) were taken. Then the morphometric characters were examined for longitudinal and latitudinal patterns with regression analyses. Statistical analysis was performed using Statistica 10.

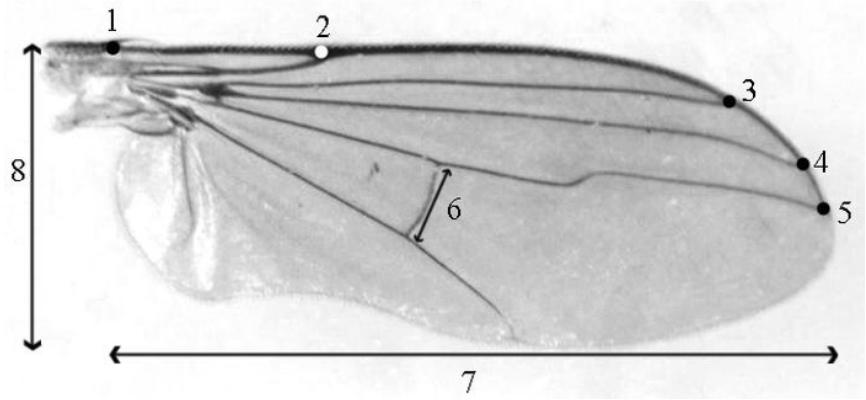

Figure 1. Parameters of the wing selected for study: 1-2 – length of costal section between the wing base and meeting point of costa with R_1; 2-3 – length of costal section between R_1 and R_{2+3}; 3-4 – length of costal section between R_{2+3} and R_{4+5}; 4-5 – length of costal section between R_{4+5} and M_{1+2}; 6 – length of posterior cross-vein; 7 – length of the wing from base to apex; 8 – width of wing in its widest part.

Results

PCA showed two dominant components accounting for more than 50% of the variance. The first component (PC1) accounted for 36.1% of the variance and was associated with wing length (7), length of costal section between the wing base and meeting point of costa with R_1 (1-2) and length of costal section between R_1 and R_{2+3} (2-3) (see Fig. 1). The second component accounted for 16.6% of the variance and was correlated with the length of the posterior cross-vein (6).

Table I. The effect of inter- and intrapopulation variability on wing shape of *D. plumipes* (results from ANOVA). MS – mean square, df – degrees of freedom, F – F-criterion, P – significance levels.

Character	Effect	MS	df	F	P
Base – R_1	Interpopulational	8.26	8	46.30	<0.0001
	Intrapopulational	0.18	119		
R_1 – R_{2+3}	Interpopulational	2.36	8	5.57	<0.0001
	Intrapopulational	0.42	119		
R_{2+3} – R_{4+5}	Interpopulational	0.24	8	2.72	<0.01
	Intrapopulational	0.09	119		
R_{4+5} – M_{1+2}	Interpopulational	0.56	8	7.37	<0.0001
	Intrapopulational	0.08	119		
dm-m	Interpopulational	0.18	8	3.17	0.003
	Intrapopulational	0.06	119		
Length	Interpopulational	10.72	8	16.08	<0.0001
	Intrapopulational	0.67	119		
Width	Interpopulational	2.18	8	10.27	<0.0001
	Intrapopulational	0.21	119		

Single-factor ANOVA showed that wing-shape differences are present among species from different geographical regions. These differences were related to all studied characters except the length of costal section between R_{2+3} and R_{4+5} and the length of the posterior cross-vein (Table I).

We found significant differences between specimens from the extreme points of longitude (the Bering Islands and environs of Lviv) and latitude (Magadanskaya Province and Krasnodarskiy Territory) in the following characteristics: wing length and length of costal section between the wing base and meeting point of costa with R_1 (Table II, Fig. 2, 3). Differences between other characters were not statistically significant. The results of the t-test showed that eastern and northern flies have longer wings than western and southern flies.

Table II. Mean wing length and length of costal section between the wing base and meeting point of costa with R_1 of *D. plumipes* from four extreme geographical regions.

Character		**The Bering Islands**	**Environs of Lviv**
Base – R_1	Average, mkm	119.67	74.29
	Standard deviation	9.74	5.94
	T-test (significance)	11.86 ($P < 0.00001$)	
	df	42	
Wing length	Average, mkm	339.35	314.86
	Standard deviation	18.25	9.30
	T-test (significance)	3.44 ($P = 0.001$)	
	df	42	
		Magadanskaya Province	**Krasnodarskiy Territory**
Base – R_1	Average, mkm	108.75	84.00
	Standard deviation	2.60	5.37
	T-test (significance)	11.47 ($P < 0.00001$)	
	df	12	
Wing length	Average, mkm	302.25	288.33
	Standard deviation	6.80	15.46
	T-test (significance)	2.29 ($P < 0.05$)	
	df	12	

Wing length correlated moderately with longitude ($r = 0.55$). Length of the costal section between the wing base and the meeting point of costa with R_1 correlated strongly with longitude ($r = 0.81$). Regression analysis showed a significant linear component in both cases. The angular coefficient (b±SE) of the linear relationship between the length of costal section measured from wing base to the meeting point of costa with R_1 and longitude is 0.81±0.05 ($P < 0.00001$). The angular coefficient (b±SE) of the linear relationship between the wing length and longitude is 0.55±0.07 ($P < 0.00001$). The linear components of these relationships suggest wing elongation in a direction from west to east (Fig. 4).

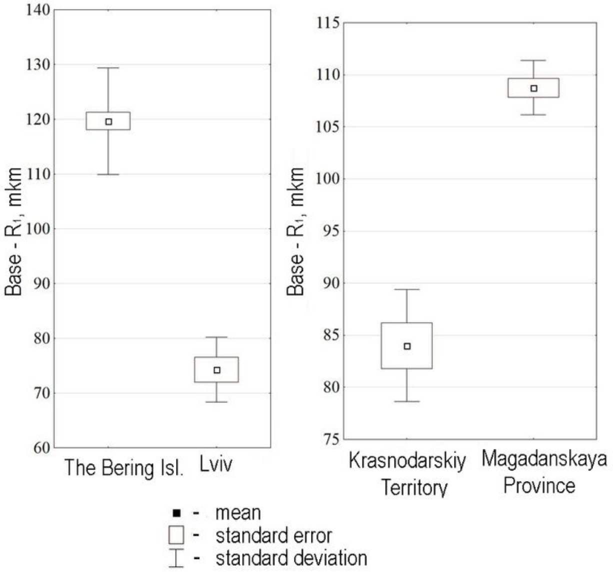

Figure 2. Means, standard errors and standard deviations of length of costal section between the wing base and meeting point of costa with R_1 of *D. plumipes* in the Bering Islands, environs of Lviv, Magadanskaya Province and Krasnodarskiy Territory.

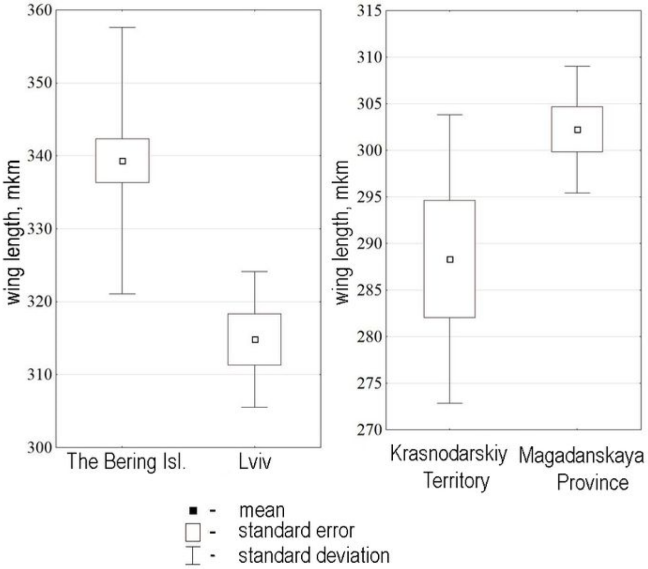

Figure 3. Means, standard errors and standard deviations of wing length of *D. plumipes* in the Bering Islands, environs of Lviv, Krasnodarskiy Territory and Magadanskaya Province.

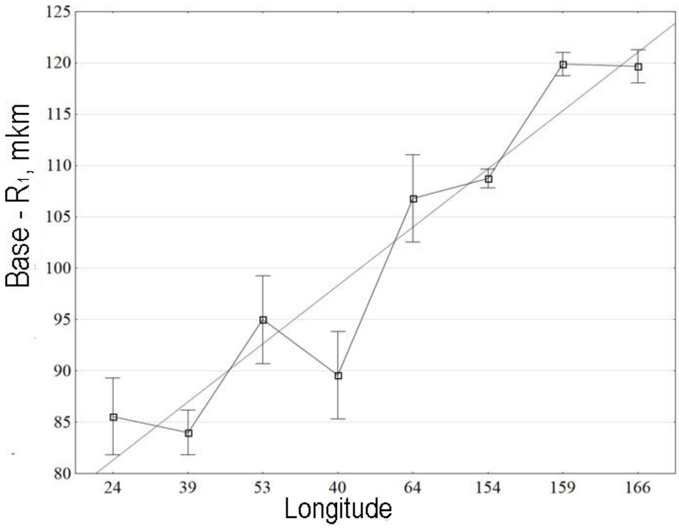

Figure 4. Means and standard errors of length of costal section between the wing base and meeting point of costa with R_1 of *D. plumipes* relating with longitude.

Discussion

A comparison of flies from populations occupying different geographical regions showed that interregional differences in the wing shape are related to wing length and a character associated with it (length of costal section between wing base and meeting point of costa with R_1). Such covariance was usually found between the traits, which are associated in the processes of individual development (Leamy *et al.*, 1997).

A considerable variation in the length of the costal section between the wing base and the meeting point of costa with vein R_1 may be a joint consequence of wing developmental processes and the geometry of the wing. According to genetic studies (Sturtevant & Bier, 1995), in the ontogenesis the prospective veins are considerably wider than the veins that will be formed. Therefore, there is a certain magnitude of vein movement during the ontogenesis. The model for the development of veins divided the formation of veins into two stages. In the first stage, the boundaries of the locations of longitudinal veins are established (Marcus, 2001), and in the second stage, the width of the prospective vein decreases (Sturtevant & Bier, 1995). Thus, the vein displacements have some range of fluctuation. These displacements are small and insignificant if a longitudinal vein and costa meet at a right angle (as in the case with R_{2+3} or M_{1+2}). However, if the longitudinal vein and costa meet at a narrow angle (as in the case with R_1), any small displacement will produce a significant shift of the landmark. Although the interpretation of our results is for the most part hypothetical, the revealed patterns indicate trends of significant intraspecific differences. Previous morphometric studies have shown that the relative length of the R_1 varies among genera and subfamilies; for instance, this character is used as a generic character in the subfamilies Achalcinae and Diaphorinae (Chursina *et al.*, 2014).

Differences in the model of flight are probably one of the main forces affecting the evolution of dolichopodid flies, and it is firstly reflected in the wing structure. Our results indicate geographic patterns in wing shape of *Dolichopus plumipes*. According to the recent aerodynamic studies (Spedding, 1992), the wing length is one of the most important factors of performance in flight. Significant linear association between wing length and longitude suggests that selection might be influencing wing shape. However, this study cannot reveal the mechanism of the wings adaptation to environmental factors. This subject requires additional investigations.

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ВАРИЈАЦИЈЕ ОБЛИКА КРИЛА УНУТАР ВРСТЕ *DOLICHOPUS PLUMIPES* (DIPTERA, DOLICHOPODIDAE)

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Извод

Анализирано је 128 јединки врсте *Dolichopus plumipes* из девет региона са циљем процене међупопулационе варијације у облику крила. Облик крила је описан са седам морфометријских карактера. Варијабилност облика крила је утврђена анализом главних компоненти и Т-тестом. Дужина крила и други карактери се разликују у облику између јединки прикупљених на западу, истоку, северу и југу истраживаног подручја. Анализа корелације и регресије је показала да географска варијација у дужини крила зависи од географске дужине. Такође, уочена је и значајна линеарна компонента.

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