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Male dimorphism in the European earwig (*Forficula auricularia*) from woodlands and grasslands in a middle-Russian city (Kaluga, Russia)

Victor Aleksanov

Abstract
Males of the European earwig, *Forficula auricularia*, are dimorphic in forceps length. Long-forceped (macrolabic) and short-forceped (brachylabic) males are considered as alternative reproductive tactics.
Above 1500 specimens were collected with pitfall traps and shelters from 26 samples in Kaluga and surroundings, about 200 km southwest from Moscow, in the north of Middle-Russian Upland. About 46 % of specimens were macrolabic in total. Brachylabic males prevailed in woodlands, macrolabic males prevailed in grasslands. Gardens had intermediate proportion of long-forceped specimens. There were no significant differences between earwigs collected in various patches of habitats. There was no obvious seasonal dynamics of forceps length. Forceps length distribution was stable a year to year in the most of plots. In some habitats samples earwigs from pitfall traps were compared with samples from shelters in tree crowns.

Keywords: Male dimorphism, earwigs, *Forficula auricularia*, urban habitat, Central Russian Upland

Introduction

The forceps length in males of the European earwig *Forficula auricularia* L., 1758 shows dimorphic variability: there are long-forceped (macrolabic) and short-forceped (brachylabic) males. Now these morphs are considered as status-dependent alternative reproductive tactics (Tomkins & Simmons 1996, Tomkins 1999) [12, 9]. Long-forceped males appear only under favorable nutritional conditions and have a large body size, but many large males grown under favorable conditions have small forceps (Tomkins & Simmons 1998, Tomkins & Simmons 1999, Tomkins 1999) [13, 14, 9]. There is a genotype-by-environment interaction that determines the morph frequency in a population (Tomkins, 1999) [9]. Morph frequency and delimiter of morphs strong vary between populations (Tomkins, 1999, Tomkins & Brown, 2004) [9, 10].

Male dimorphism in the European earwigs has a long history of studying. There were a lot of manipulative experiments (Radesäter 1993, Simmons & Tomkins, 1996, Styrsky & Van Rhein, 1999, Tomkins & Simmons 1996, Tomkins & Simmons 1998, Tomkins & Simmons 1999, Walker & Fell 2001) [6-8, 12-15]. An extensive field samples were obtained in the United Kingdom (Bateson & Brindley, 1892, Tomkins & Brown, 2004) [1, 10] and in the east part of the Russian Plain - Perm region (Diakonov, 1925, Huxley, 1927) [2, 4], measurements of the forceps length were also done in earwigs sampled in Sweden (Radesäter, 1993, Forslund, 2003) [6, 3] and in United States of America where *F. auricularia* is introduced species (Lamb, 1976, Walker & Fell, 2001) [5, 15]. Tomkins and Brown (2004) [10] compared island and mainland populations of *F. auricularia* in the United Kingdom. Current works about the forceps length do not compare different habitats in one locality and do not inspect seasonal and perennial dynamics of earwig dimorphism. Ground-dwelling and tree-dwelling specimens were not compared in forceps length. Data about dimorphism of *Forficula* in central part of Russian Plain are absent. Now entomologists (Wirth *et al*., 1998) [16] divide *F. auricularia* into two taxons – a recyclic taxon from regions with middle climate and a monocyclic taxon from north and east regions. So material about forceps length of this species in different parts of its area is important to confirm theoretical models of male dimorphism and to describe pattern of geographical variation.

Therefore the aim of paper was to describe forceps length and morphs frequency of *Forficula auricularia* in woodland and grassland habitats in a middle-Russian city (Kaluga), to compare these from surface and crowns in gardens, to watch seasonal and annual variation.

Materials and methods

Earwigs were sampled during 2003-2011 with pitfall traps. A trap was a plastic glass (85 mm mouth diameter, with 4% formalin). Traps were exposed since May to November but males of earwigs were obtained since July to November. Kaluga city is located 150 km southwest of Moscow, in the north of the Central Russian Upland, in zone of temperate broadleaved forests. Sufficient samples of earwigs were obtained from 16 sites which can be divided into three groups: 1) small broadleaved deciduous woodlands with high crown cover (further - woodlands); 2) gardens and parks with mixture of cultivated and wild-growing trees, bushes and herbs (further - gardens); 3) grasslands (Table 1).

Table 1: Characteristics of study sites.

Name	Type	Geographic coordinates in WGS 84	Tree	Herb	Cultiv ation	Comments	Years
Eco-biological center (EBC):	garden	N54°30'30" E36°15'48"	1	1	1	An old garden (0.48 ha) surrounded with urban public and residential buildings in city center	2003, 2004, 2006, 2011
a) tree-cover sites			apple garden, small early-stage broadleaved woodland				
b) yard			grassy patches enclosed buildings and artificial surface				
Kaluga state university (KSU)	garden	N54°30'34" E36°16'24"	1	2	0	a small (0.13 ha) public garden surrounded with buildings; solitary pear and apple trees	2011
Radiotelecenter (RTC)	garden	N54°31'18" E36°15'48"	1	1	0	a small (0.2 ha) park with dense herb layer and solitary tall broadleaved deciduous trees disposed in line	2006
Podgornaya	garden	N54°30'59" E36°17'05"	1	1	1	with apple trees, currants, vegetables and flowers, it is located in small (0.84 ha) array of gardens which disposed in gully and surrounded with buildings	(2006, 2007, and 2009)
Olgovsky	garden	N54°34'21"; E36°17'54"	1	1	1	with apple trees, currants, vegetables and flowers located in a large (154 ha) array of gardens in urban periphery	2009
Suburban garden 1	garden	N54°36'27" E36°27'44"	1	1	1	with apple trees, currants, vegetables and flowers located in an array of gardens 28.7 ha square	2004, 2006-2009
Suburban garden 2	garden	N54°36'37", E36°27'45"	1	1	1	with apple trees, currants, vegetables and flowers located in an array of gardens 22.2 ha square	2004, 2007, 2009
Suburban garden 3	garden	N54°36'60" E36°27'46"	1	2	0	with dense grass cover and solitary apple trees, currants, and flowers located in periphery of the array of gardens adjacent to grassland and broadleaved forest	2009
Medical center (MC)	woodlan d	N54°30'21" E36°17'07"	2	0	0	small (0.16 ha) anthropogenic unmanaged broadleaved deciduous woodland	2006
Berezuy woodland	woodlan d	N54°30'33" E36°14'45"	2	0	0	small (4.34 ha) natural-growing broadleaved deciduous woodland on east slope of gully surrounded with public buildings	2003, 2004
Central Park woodland	woodlan d	N54°30'21" E36°14'42"	2	0	0	small (1.4 ha) natural-growing broadleaved deciduous woodland on south slope near central park	2003
Zhyrovsky woodland	woodlan d	N54°30'29" E36°16'3"	2	1	0	small (3.6 ha) natural-growing broadleaved deciduous woodland on gully surrounded with residential buildings	2003
Birch woodland	woodlan d	N54°30'25" E36°18'45"	1	1	0	small (0.86 ha) early-stage birch woodland remote from buildings	2010
Urban grassland	grasslan d	N54°30'26" E36°18'51"	0	2	0	unmanaged mesic grassland adjacent to the birch woodland remote from buildings	2010
Rural grassland in south from Kaluga	grasslan d	N53°43'57" E35°42'20"	0	2	0	unmanaged non-flood mesic grassland	2000
Rural grassland in east from Kaluga	grasslan d	N54°26'52" E36°31'19"	0	2	0	unmanaged non-flood mesic grassland in Valley of Oka River	2001

Notes: Tree: 0 – no trees, 1 – crown cover less than 70%, 2 – crown cover more than 70%. Herb: 0 – vast areas without herbs, 1 – sparse cover, 2 – dense cover. Cultivation: 0 – non-cultivated sites, 1 – cultivated sites.

Microhabitat distribution of earwigs was inspected in suburban gardens during 2007-2009. A lot of earwigs was sampled in further types of microhabitats of garden 1: 1) non-arable patch under apple covers; 2) annual-tilling patch near currant bushes under periphery of apple cover; 3) regularly tilling patch under periphery of apple cover. Patches near plum trees and near apple trees were examined in garden 2.

Earwigs from crowns were sampled with shelters in August 2007 in three suburban gardens. A shelter was a piece of cloth exposed on tree branch. Shelters were placed in apple trees and currant bushes, in garden 2 also in plum trees.

Forceps were measured from a middle point of their base (lines that forceps joint to the ultimate tergite) in a straight line across the curve to the tip. Measurements have been conducted at 0.1 mm with stereomicroscope with ocular micrometer. Total 1551 specimens have been measured. Also total abundance of earwigs and operational sex ratio were noted in each sample. Total abundance of earwigs was estimated as number of specimens per 100 traps in day. Brachylabic and macrolabic morphs were distinguished based on a bimodal frequency distribution of the forceps length – a bin with the lowest frequency and all those larger than it were assigned to the macrolabic morph (Bateson & Brindley, 1892, Huxley, 1927, Lamb, 1976, Tomkins, 1999) [1, 4, 5, 9]. To discriminate differences between habitats and seasons in the forceps length we use non-parametric Kruskal-Wallis and Mann – Whitney test. STATISTICA 7.0 was used to survey results.

Results

The forceps length of males of *F. auricularia* had a strong bimodal distribution in every sample of earwigs from Kaluga (Figures 1-12). It varied from 2.5 to 9.9 mm. In total delimiter of morphs was 5.1 mm, mode of brachylabic males laid around 4 mm, and mode of macrolabic males laid around 7 mm. About 46 % of males were macrolabic in total. Proportion of macrolabic males varied from 14 to 86 % in every sample (Figure 14). Macrolabic specimens prevailed in 6 samples from 27.

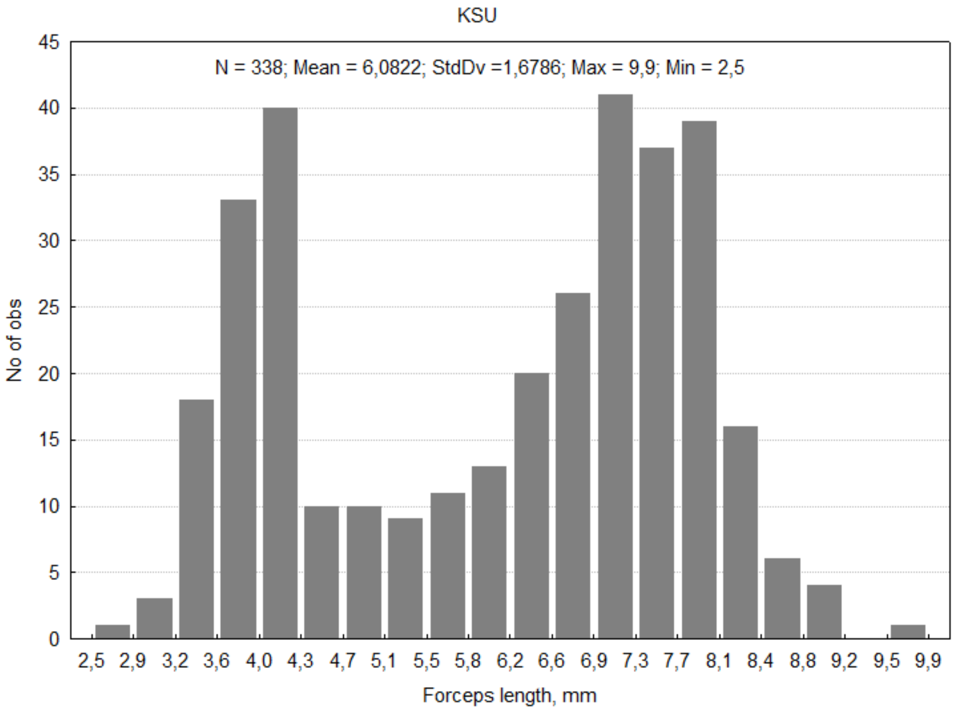

Fig 1: Forceps length distribution in Kaluga State University

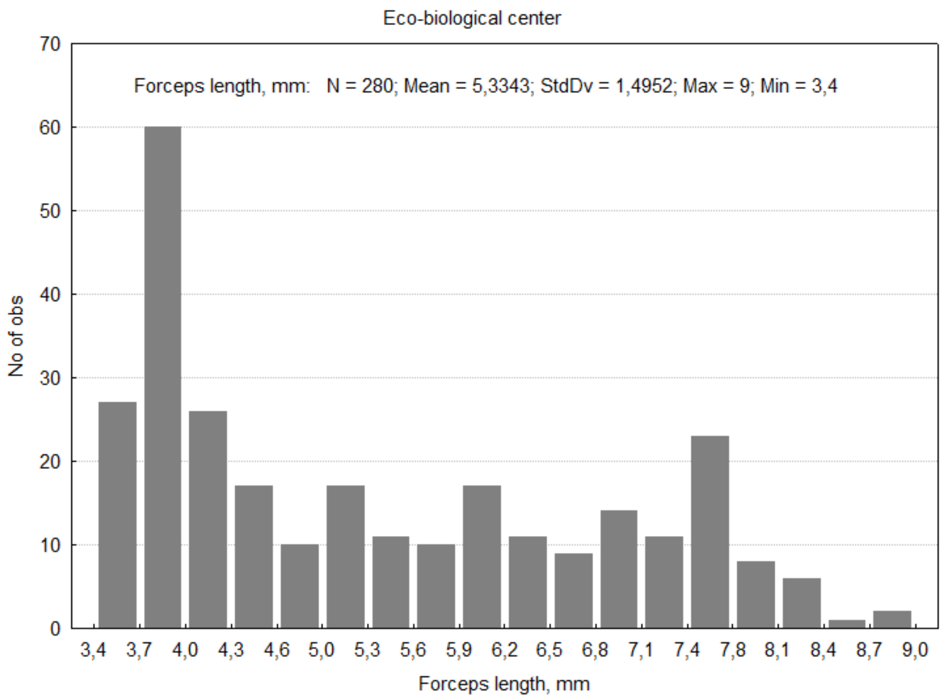

Fig 2: Forceps length distribution in Eco-biological center

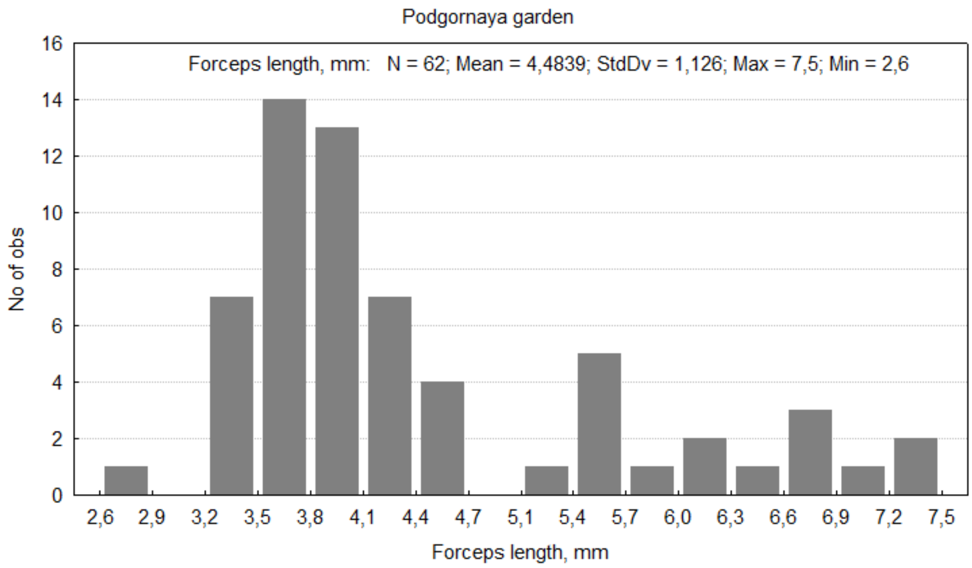

Fig 3: Forceps length distribution in Podgornaya garden

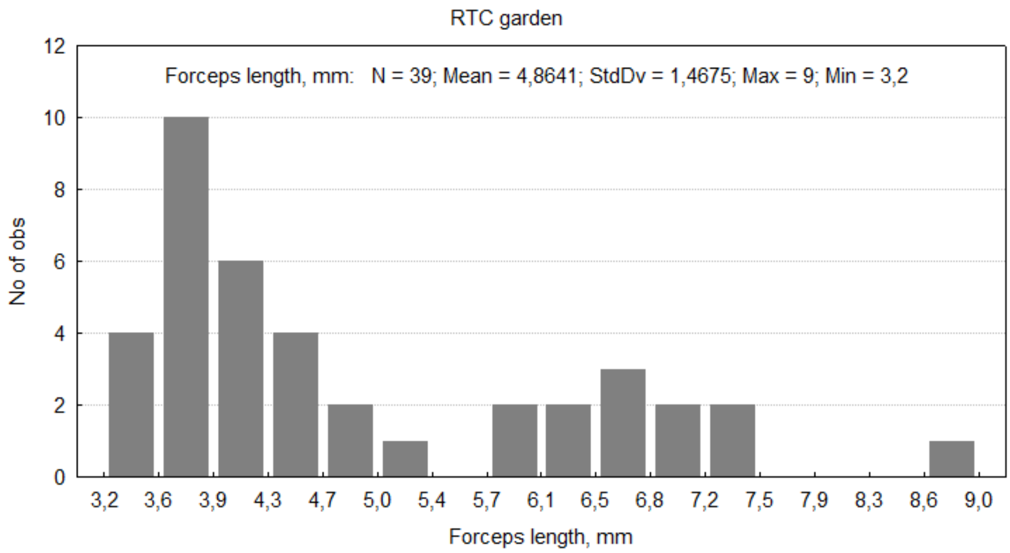

Fig 4: Forceps length distribution in Radiotelecenter

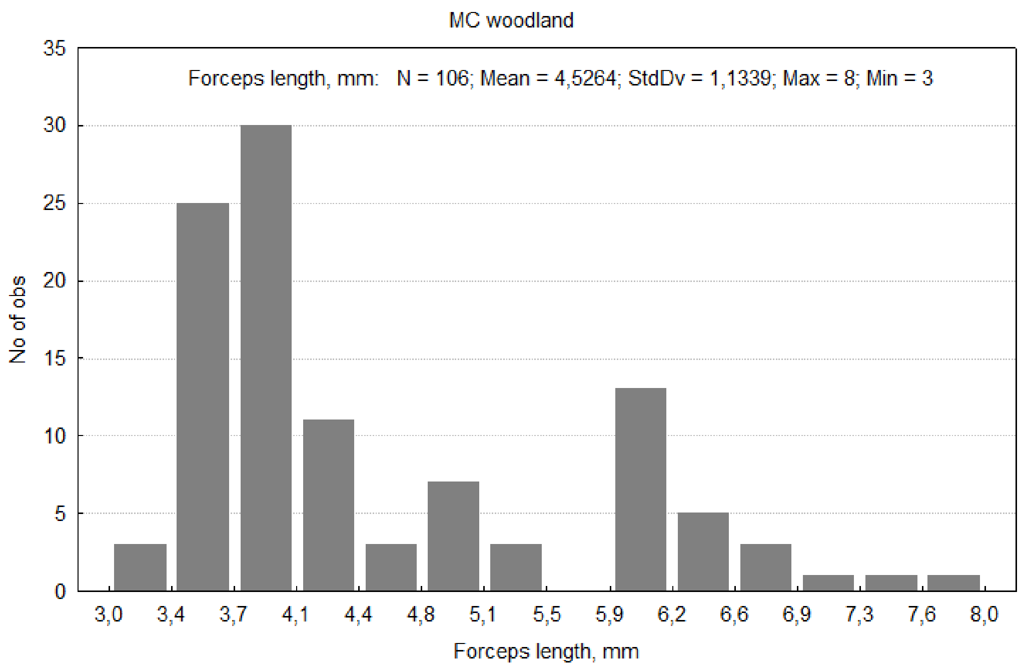

Fig 5: Forceps length distribution in MC woodland

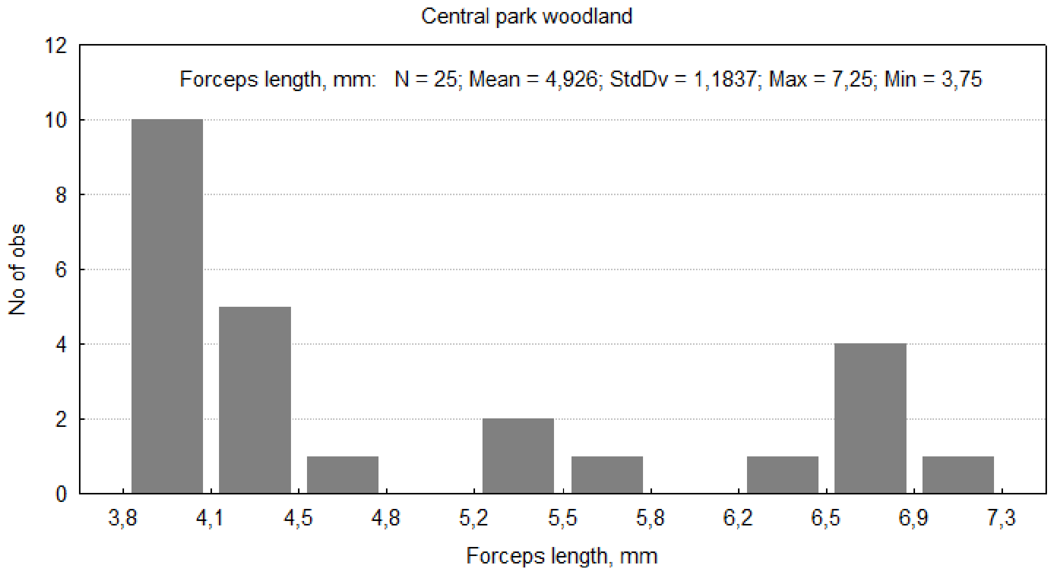

Fig 6: Forceps length distribution in Central park woodland

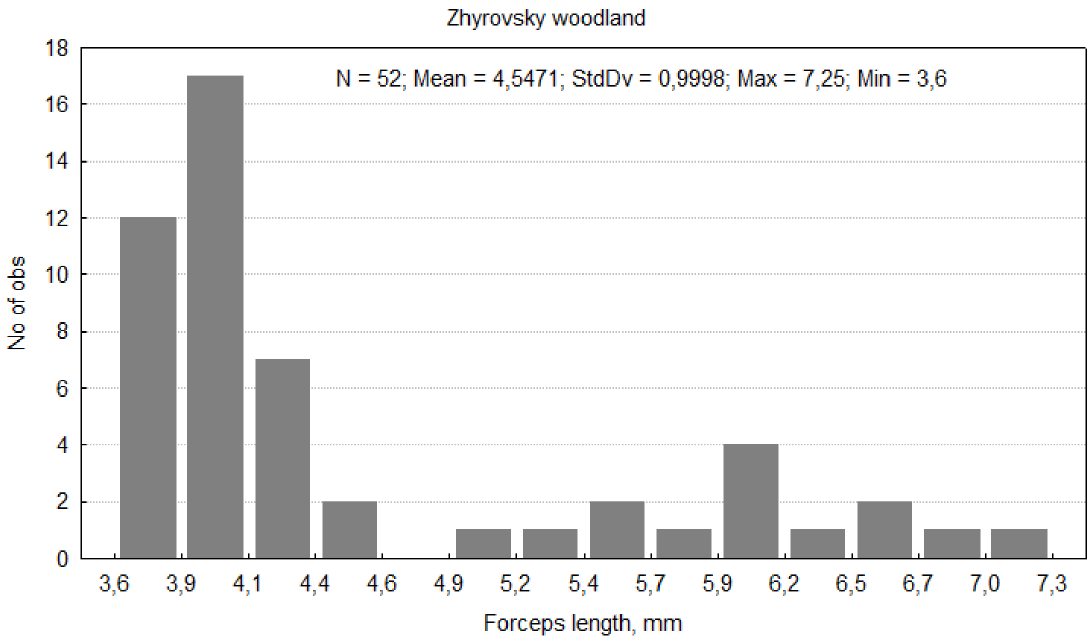

Fig 7: Forceps length distribution in Zhyrovsky woodland

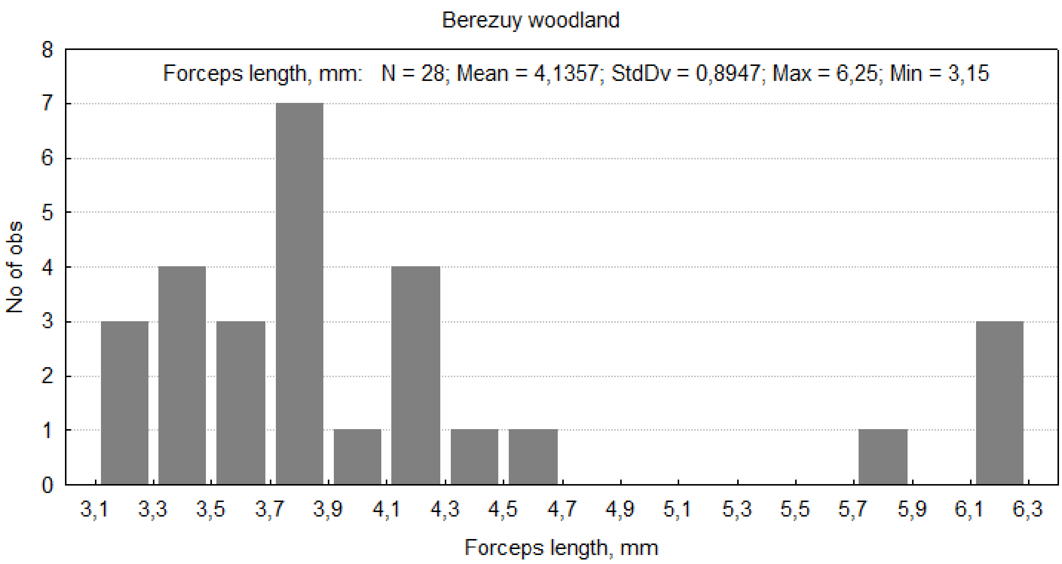

Fig 8: Forceps length distribution in Berezuy woodland

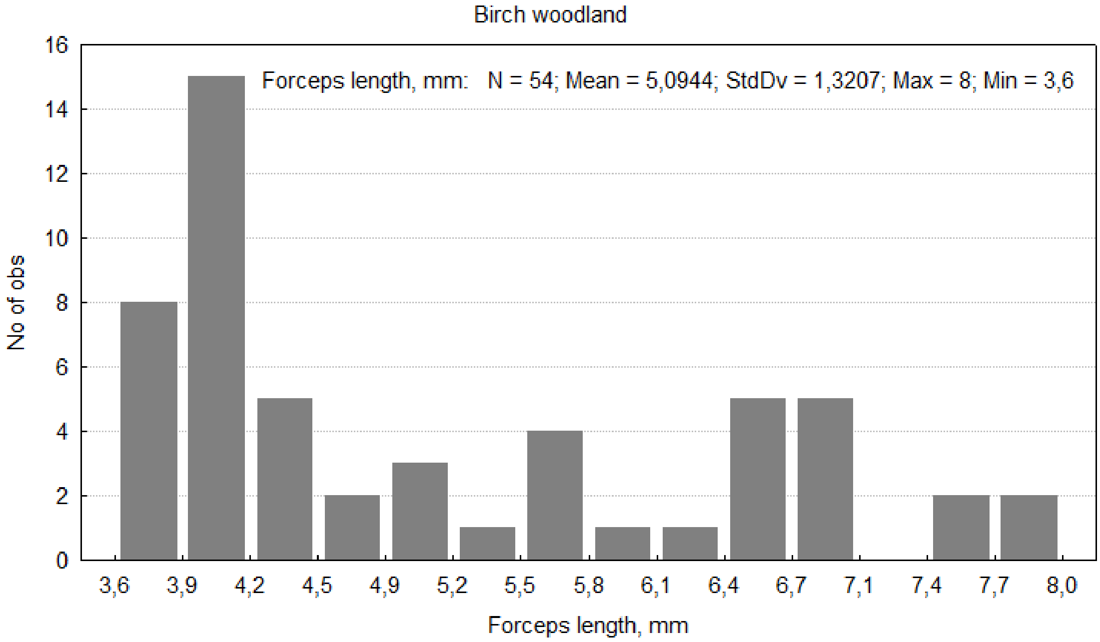

Fig 9: Forceps length distribution in Birch woodland

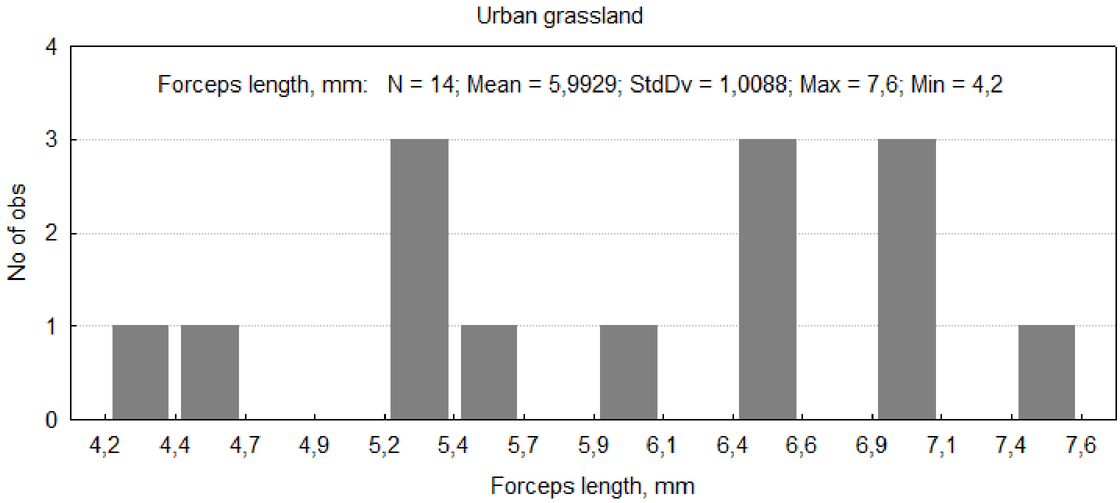

Fig 10: Forceps length distribution in Urban grassland

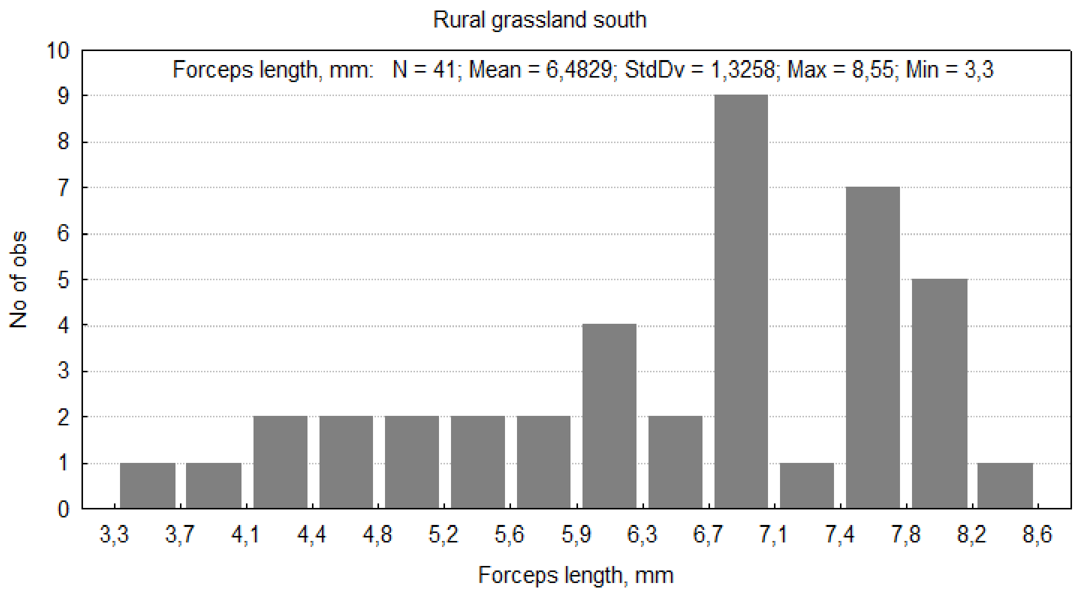

Fig 11: Forceps length distribution in Rural grassland in south from Kaluga

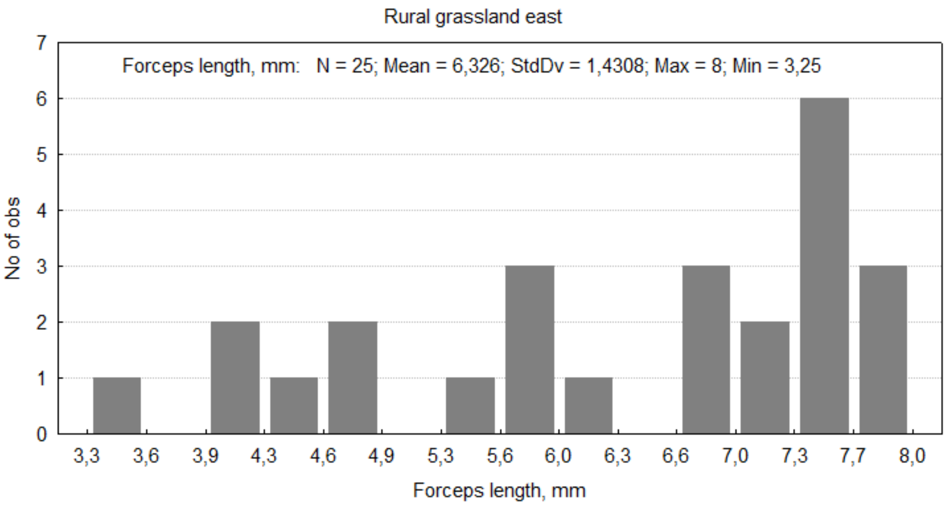

Fig 12: Forceps length distribution in Rural grassland in east from Kaluga

Mean forceps length and proportion of macrolabic males did not correlate with total abundance of earwigs, with abundance of males or with operational sex ratio (Table 2, Figures 13, 14). But extremely high total abundance of earwigs was presented only in case of high forceps length.

There were significant differences in the mean forceps length between three types of habitats (Table 3). Males from grasslands had the longest forceps, and males from woodlands had the shortest forceps (Figure 13). Males from a bulk of gardens had intermediate mean forceps length, although some gardens supplied earwigs with as long forceps as from grasslands, and some those supplied earwigs with as short forceps as from woodlands. In grasslands macrolabic males prevailed. Brachylabic males prevailed in ever woodland. In gardens the proportion of macrolabic specimens varied, but in the most of samples it consisted from a quarter to a half of males (Figure 14). Urban gardens did not differ from suburban gardens in mean forceps length or in proportion of macrolabic males. The role of habitat features is proved by samples from adjacent habitats (Figures 9, 10), where forceps length in birch woodland was significantly lower than those in grassland adjacent to it.

Table 2: Spearman's correlation between some characteristics of samples of earwigs.

Variables	Valid N	Spearman R	P-value
Mean forceps lengths & Total abundance	26	0.007	0.972
Mean forceps length & Proportion of males	26	0.125	0.541
Proportion of macrolabic & Total abundance	26	-0.037	0.859
Proportion of macrolabic & Proportion of males	26	0.180	0.378

Table 3: Influence of some features of habitats on mean forceps length and proportion of macrolabic males in the earwigs: Kruskal – Wallis tests (N=27 samples).

Factor	Number of gradations	Forceps length		Proportion of macrolabic	
		H	P-value	H	P-value
Type	3	10.831	0.004	11.204	0.004
Tree cover	3	8.522	0.014	9.027	0.011
Herb layer	3	10.958	0.004	11.054	0.004
Cultivation	2	0.197	0.657	0.156	0.693

Mean forceps length and proportion of macrolabic males significantly increased with increasing of herbal cover and decreasing of crown cover (Table 3, Figures 5-13). There were no significant differences between cultivated and non-cultivated sites.

Earwigs sampled in different times of year in the same habitat did not significantly differ from each other in forceps length (in KSU Kruskal-Wallis test H (8, N=338) =5.646, *p*=0.687). Samples of earwigs collected by shelters in different times did not significantly differ from each other in forceps length (in suburban garden 1 Kruskal-Wallis test H (3, N=111) =1.637, *p*=0.651).

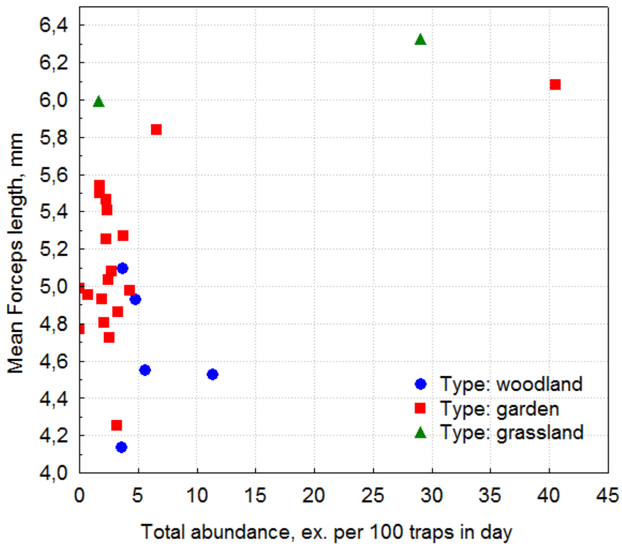

Fig 13: Relation of the mean forceps length to a total abundance of earwigs and to three types of habitats

Statistically significant differences between earwigs collected with pitfall traps and with shelters occurred in both suburban gardens (Table 4). However these differences were not equal in both sites: males from crowns had longer forceps than from pitfall in garden 1, but males from crowns had shorter forceps in garden 2.

Table 4: Forceps length of earwigs collected in suburban gardens with pitfall traps and with shelters in crowns.

Site	Method	N	Mean, mm	Median, mm	Mann – Whitney Z	P-value
Garden 1	Pitfall	30	4.65	4.2	-2.21	0.027
	Shelter	111	5.17	4.6		
Garden 2	Pitfall	36	5.27	4.9	-2.19	0.029
	Shelter	98	4.61	4.2		

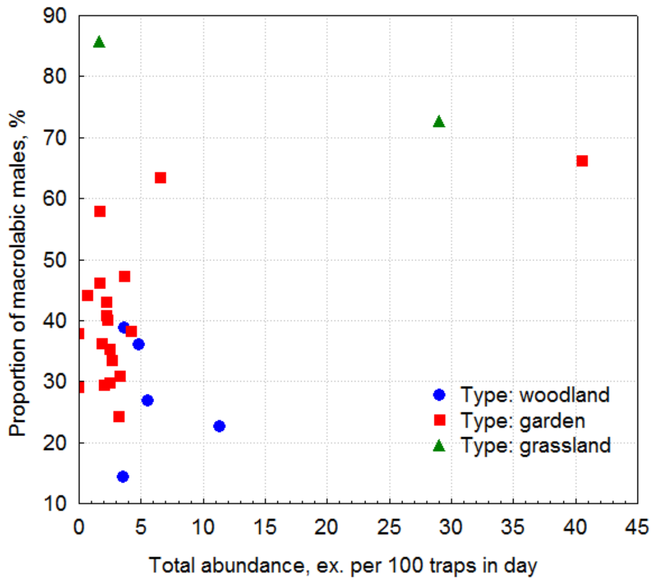

Fig 14: Relation of the proportion of macrolabic specimens to a total abundance of earwigs and to three types of habitats

Earwigs collected with pitfall traps in different patches of a one habitat (in different microhabitats) do not differ in forceps length from each other (Table 5). Only in suburban garden 1 there was significant difference – earwigs collected in regularly tilling patch under periphery of apple crown had a shorter forceps (median =4.0 mm) than earwigs collected in other patches (median =4.6 mm). Crowns of apple trees, plums and currants do not differ in forceps length of earwigs from each other.

Table 5: Results of Kruskal-Wallis tests of microhabitats on forceps length of the earwigs

Habitat	Method	Number of groups	N	H	P-value
Suburban garden 1	shelter	2	111	0.907	0.341
Suburban garden 2	shelter	3	98	1.852	0.396
Suburban garden 1	pitfall	3	63	8.244	0.016
Suburban garden 2	pitfall	2	36	0.816	0.367

Year to year variations of the forceps length were revealed in Eco-biological center. In the yard macrolabic males were less abundant at 2007 than 2003 (Kruskal-Wallis test H (3, N= 146) =12.590, p =0.006). In tree-cover sites there were less brachylabic males in 2011 than in 2007, but this difference was not significant. In other gardens annual variation of forceps length was not shown (Table 6).

Table 6: Results of Kruskal-Wallis tests of annual variation on forceps length of the earwigs

Habitat	Groups (years)	N	H	P-value
Podgornaya garden	3	62	2.807	0.246
Suburban garden 1	5	144	1.610	0.807
Eco-biological center, yard	4	146	12.590	0.006
Eco-biological center, tree-cover	4	134	4.783	0.188

Discussion

Quantitative characteristics of the forceps length – range, delimiter of morphs, modes of brachylabic and macrolabic morphs – in Kaluga are similar to those in Great Britain (Bateson & Brindley, 1892, Tomkins 1999, Tomkins & Brown, 2004) [1, 9, 10], in North America (Walker & Fell, 2001) [15], and in north of Russian Plain (Diakonov, 1925, Huxley, 1927) [2, 4]. Macrolabic males in Kaluga occur more frequently than those in Great Britain. Proportion of macrolabic males in Kaluga is similar to Swedish population of earwigs (Forslund, 2003) [3] and is slightly less than this proportion in Djakonov's collections from Perm region (Diakonov, 1925, Huxley, 1927) [2, 4]. A high proportion of macrolabic males in north and east populations of *Forficula auricularia* may correspond to their belonging to monocyclic taxon while west-European populations belong to recyclic taxon (Wirth *et al*., 1998) [16].

An absence of correlation between abundance and forceps length contradicts to the results of Tomkins and Brown (2004) [10] about mainland and island British earwigs. But contrary to the islands urban habitats of Kaluga are not true isolated. And we cannot consider our samples as different populations of earwigs. So this fact confirms to results of Tomkins (1999) [9] which found no influence of density on the male dimorphism in samples from one locality.

The results showed that male dimorphism is quite stable in the time. Differences between earwigs from shelter and from pitfall traps may be accidental and caused to non-equal sample sizes. So no ecological differences between two morphs according to its microhabitat and layer distribution were recognized. Noticeable differences in forceps length and proportion of macrolabic males were shown only between different habitats.

It is obvious that proportion of macrolabic males in every habitat is influenced by their vegetation. Woodlands with dense tree cover may be less favorable habitats than gardens because these are colder and give less nutrition. But one cannot say that all grasslands are more suitable habitats for earwigs than woodlands. Grasslands have more simple structure of vegetation than woodlands and gardens. So grasslands have more chances that males of earwigs would get together and fight in competition for female than woodlands have. Long forceps are considered as adaptation for mate guarding, so long forceps can be advantage to compete for females where challenges occur regularly, and dependence between density of earwigs and male dimorphism is connected to this fact (Tomkins & Brown, 2004) [10]. Consequentially, long forceps have more advantage in grasslands than in woodlands. This supposition corresponds to a manipulative experiment on mite completed by Tomkins with coauthors (2011) [11] where habitat complexity reduced fitness of fighters.

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