Baltic J. Coleopterol. 11(1) 2011
ISSN 1407 - 8619

Standard deviation of carabid size in Western German forest succession – a complex picture

Armin Schreiner, Axel Schwerk

Schreiner A., Schwerk A. 2011. Standard deviation of carabid size in Western German forest succession – a complex picture. *Baltic J. Coleopterol., 11(1): 25 - 31.*

The large size range of carabids (Coleoptera: Carabidae) in, e.g., Western German beech and Douglas fir forests depends on the colonization of various habitats and microhabitats. These may change in the run of forest succession. Therefore, we hypothesized an increase of different microhabitats in ageing forests that is reflected by a corresponding rise in size variability within each of, e.g., two carabid species (*Carabus violaceus*, n = 2,853; *Carabus problematicus*, n = 428) in comparable forest stands of increasing age. Beetles were trapped according to Barber on 18 separate forest stands (beech: 14 sites, 1 – 165 years; Douglas fir: 4 sites, 1 – 30 years) over the vegetation period 2009. Subsequent to determining the species their elytrae were longitudinally measured. The mean values as well as standard deviations (SD) of elytrae length were calculated for the males and females in order to analyze correlations between SD of male and female beetle sizes and age of the stands by Spearman rank test statistics. In our most abundant species (*C. violaceus*) there was no significant correlation between elytrae-length SD of males (beech: 18.24 ± 0.70 mm, n = 1,560; Douglas fir: 18.23 ± 0.65 mm, n = 104) and females (beech: 19.71 ± 0.77, n = 1,120; Douglas fir: 19.57 ± 0.85 mm, n = 69). Except for a non-significant trend indicating a positive correlation between size SD of male *C. violaceus* and forest age (combined beech and Douglas fir, p = 0.051) our initial hypothesis could not be confirmed, neither for *C. violaceus* nor for *C. problematicus*. In conclusion, more field-ecological data on the variety of microhabitats in forest succession should be generated in order to elucidate the complex picture of differences in carabid size.

Key words: Carabidae, Carabus violaceus, Carabus problematicus, size, standard deviation, forest, succession

Full Address for Correspondence: Armin Schreiner. Warsaw University of Life Sciences, Laboratory of Evaluation and Assessment of Natural Resources, Nowoursynowska Street 166, 02-787 Warsaw, Poland; E-mail: tapferes.schreinerlein@yahoo.de

Communication No. 374 of the Laboratory of Evaluation and Assessment of Natural Resources, Warsaw University of Life Sciences - SGGW.

INTRODUCTION

Ground beetles or carabids (Coleoptera: Carabidae) are excellent bioindicators for the state of succession of a forest ecosystem (Szyszko 1990, Koivula & Niemelä 2002, Rainio & Niemelä 2003, Schwerk 2008). In the run of succession, e.g., their species composition changes markedly (e.g. Neumann 1971, Schwerk & Szyszko 2006). Since most carabids are nocturnal predators they hunt for epigaeic arthropods that match their body size. Carabid size in Central Europe may vary from ca. 2 mm (e.g. genus *Bembidion*) to more than 4 cm of large individuals of genus *Carabus*. This large range is due to the fact that carabids colonize various habitats and microhabitats (Müller-Motzfeld 2004, Schwerk et al. 2006). Also, there may be a difference in size within one species and even within the same habitat (Skłodowski 2005, Garbalińska & Skłodowski 2008). This difference is probably related to the nutrient-availability pattern of the respective habitat (Szyszko et al. 1996, Garbalińska & Skłodowski 2008).

In an earlier paper on the same study sites in Western Germany the relationship between the mean elytrae length of *Carabus violaceus* and age of the study sites was analyzed (Schreiner et al. 2011). Since, while forests grew older, the length of elytrae increased in both male and female animals only slightly our stands seemed to offer rather constant feeding conditions for large carabids. However, the distribution of body-length data is not only characterized by its mean values but also by other parameters. E.g., the standard deviation (SD) may provide additional information on beetle populations and their responsiveness to environmental changes (Skłodowski 2005).

Therefore, the focus of this work was laid on the analysis of elytrae-length SD of both genders of our most abundant *Carabus* species, *C. violaceus*, with increasing age of forest stands (beech and Douglas fir). Where appropriate, these investigations were supplemented by analyzing the elytrae lengths of another *Carabus* species (*C. problematicus*). We assumed that an impact of changes in environmental conditions would affect both male and female animals in the same way. Hence, with ageing habitats that may offer an expanding variety of microhabitats we expected positive correlations between (1) size SD of males and females and (2) size SD of both males and females and age of the forest stands.

MATERIAL AND METHODS

Western German beech and Douglas-fir forests of the Ruhr valley, North Rhine-Westphalia, were studied at different ages (Tab. 1 a and b) by ground-trapping carabids (Coleoptera: Carabidae) over the complete vegetation period 2009 (Barber 1931). Subsequently, their elytrae (as accurately representing beetle size) were subjected to longitudinal measurement. Three traps were used in each site while keeping a distance of 5 – 10 m between them. Due to placing the traps at least 20 m away from the site's edges boundary effects were widely avoided (den Boer 1977).

Collected carabids were stored in commercial EtOH 70 % v/v before determining the species and checking for the elytrae length development over the run of succession. The mean values as well as standard deviations (SD) of elytrae length on the respective study sites were calculated for both male and female animals. SD was used for further statistical analyses if the data source was 6 or more individuals.

Correlations between SD of male and female beetle sizes and age of the stands were tested using the Spearman rank correlation coefficient (r_s, Sachs 1984) as calculated using the SPSS 9.0 software package.

Due to vandalism or loss of traps, regarding areas B9, D1, and D2 only limited data were available for analyses.

RESULTS

In 2,853 individuals of *C. violaceus* the elytrae lengths over the run of succession were rather uniform within each gender (Schreiner et al. 2011) while showing a clear difference of mean values between male and female animals (Tab. 1 a and b, Fig. 1). A similar situation was observed for *C. problematicus* (n = 428, Tab. 1 a and b).

As is depicted in Fig. 2 no significant correlation between elytrae-length SD of male and female *C. violaceus* resulted when applying the Spearman rank test. The same holds true for aligning the size SD of male or female beetles with age of the forest stands (Figs. 3 and 4, respectively). All resulting r_s and p values are listed in Tab. 2. There was also no effect of the forest type (beech or

Table 1. Study sites and elytrae lengths of *C. violaceus* (mean ± SD) and *C. problematicus* (mean ± SD) over the vegetation period 2009 – a) Beech and b) Douglas fir

a) Beech

Site	Age (years)	Size (ha)	Byplants	Ordinance Survey Map	*C. violaceus* males mm (n)	*C. violaceus* females mm (n)	*C. problematicus* males mm (n)	*C. problematicus* females mm (n)
B1	1	0.5	Few larch & cherry	4609/1	18.10 ± 0.60 (33)	19.43 ± 0.82 (18)	14.87 (1)	15.94 ± 0.74 (7)
B2	1	0.9	5% cherry	4609/1	18.07 ± 0.61 (45)	19.40 ± 0.65 (28)	15.22 ± 0.61 (8)	16.75 ± 1.14 (5)
B3	3	0.5	None	4510/3	18.58 ± 0.54 (19)	19.88 ± 0.67 (18)	15.26 ± 0.51 (3)	16.09 ± 0.36 (8)
B4	4	0.4	None	4609/1	18.20 ± 0.59 (23)	19.68 ± 0.88 (23)	-	16.47 (1)
B5	13	1.6	None	4510/3	18.36 ± 0.70 (18)	19.88 ± 0.63 (18)	15.25 (1)	-
B6	20	0.8	None	4609/1	18.32 ± 0.80 (106)	20.09 ± 0.73 (64)	14.61 (1)	16.30 ± 0.62 (7)
B7	26	1.8	10% larch	4609/1	18.18 ± 0.54 (103)	19.62 ± 0.70 (84)	14.95 ± 0.70 (33)	15.97 ± 0.81 (45)
B8	28	0.6	Few larch & cherry	4609/1	18.23 ± 0.65 (282)	19.77 ± 0.67 (238)	15.13 ± 1.13 (14)	16.61 ± 1.24 (15)
B9*	52	2.2	10% larch	4609/1	18.21 ± 0.62 (102)	19.62 ± 0.74 (127)	14.59 ± 0.80 (6)	15.86 ± 0.29 (7)
B10	78	2.5	10% oak	4609/1	18.44 ± 0.82 (202)	19.82 ± 0.74 (113)	14.50 ± 1.03 (4)	16.42 ± 0.98 (2)
B11	146	1.0	10-year-old beech	4609/1	18.12 ± 0.67 (224)	19.62 ± 0.85 (133)	14.59 ± 0.56 (49)	15.97 ± 0.80 (69)
B12	146	4.0	None	4609/1	18.23 ± 0.69 (229)	19.52 ± 0.79 (119)	14.34 ± 0.88 (4)	16.72 ± 0.99 (5)
B13	152	3.5	10% oak	4609/1	18.30 ± 0.66 (68)	19.87 ± 0.67 (51)	15.10 ± 0.53 (3)	16.70 (1)
B14	165	3.1	None	4609/1	18.17 ± 0.76 (106)	19.75 ± 0.91 (86)	15.57 (1)	15.64 ± 0.56 (5)
Total	-	-	-	-	**18.24 ± 0.70 (1,560)**	**19.71 ± 0.77 (1,120)**	**14.82 ± 0.74 (128)**	**16.08 ± 0.84 (177)**

b) Douglas fir

Site	Age (years)	Size (ha)	Byplants	Ordinance Survey Map	*C. violaceus* males mm (n)	*C. violaceus* females mm (n)	*C. problematicus* males mm (n)	*C. problematicus* females mm (n)
D1**	1	0.2	None	4510/3	18.07 ± 0.61 (31)	19.33 ± 0.92 (31)	14.69 ± 0.37 (9)	16.34 ± 0.63 (12)
D2**	3	0.2	None	4510/3	18.25 ± 0.48 (9)	20.18 ± 0.78 (7)	15.23 ± 0.22 (5)	16.21 ± 0.60 (8)
D3	10	0.4	None	4510/3	18.10 ± 0.68 (12)	19.52 ± 0.47 (6)	15.31 ± 0.52 (18)	16.13 ± 0.64 (18)
D4	30	0.5	None	4510/3	18.34 ± 0.66 (52)	19.71 ± 0.74 (25)	14.50 ± 0.61 (24)	16.05 ± 1.05 (29)
Total	-	-	-	-	**18.23 ± 0.65 (104)**	**19.57 ± 0.85 (69)**	**14.86 ± 0.63 (56)**	**16.14 ± 0.83 (67)**

* Vandalism
** 1 of 3 traps lost

Douglas fir) on beetle-size SD correlations. However, when combining both beech and Douglas fir data for male beetles, thus creating a relatively large group of individuals for statistical analyses, a clear trend was detected pointing to a positive correlation between beetle-size SD and forest age ($r_s = 0.467$, $p = 0.051$).

With regard to *C. problematicus* not all data were subjected to test statistical analyses due to

Table 2. Spearman rank correlation coefficients (r_s) and corresponding p-values when comparing size SD of *C. violaceus* – males vs. females and males/females vs. age of the stands for beech and Douglas fir combined (n = 18 sites), beech alone (n = 14 sites), and Douglas fir alone (n = 4 sites)

C. violaceus	Beech + Douglas fir n = 18 sites	Beech n = 14 sites	Douglas fir n = 4 sites
SD – males vs. SD – females	$r_s = -0.102$ p = 0.687	$r_s = 0.284$ p = 0.326	$r_s = -0.400$ p = 0.600
SD – males vs. Age of the stands	$r_s = 0.467$ p = 0.051	$r_s = 0.515$ p = 0.059	$r_s = 0.000$ p = 1.000
SD – females vs. Age of the stands	$r_s = 0.176$ p = 0.485	$r_s = 0.480$ p = 0.082	$r_s = 0.800$ p = 0.200

Table 3. Spearman rank correlation coefficients (r_s) and corresponding p-values when comparing size SD of *C. problematicus* – males vs. females and males/females vs. age of the stands for beech and Douglas fir combined (n = 8 sites (males), 11 sites (females)) and beech alone (n = 5 sites (males), 7 sites (females))

C. problematicus	**Beech + Douglas fir n = 8 sites (males), 11 sites (females)**	**Beech n = 5 sites (males), 7 sites (females)**
SD – males vs. SD – females	$r_s = 0.429$ p = 0.337	$r_s = 0.400$ p = 0.600
SD – males vs. Age of the stands	$r_s = 0.443$ p = 0.272	$r_s = -0.100$ p = 0.873
SD – females vs. Age of the stands	$r_s = 0.297$ p = 0.375	$r_s = 0.179$ p = 0.702

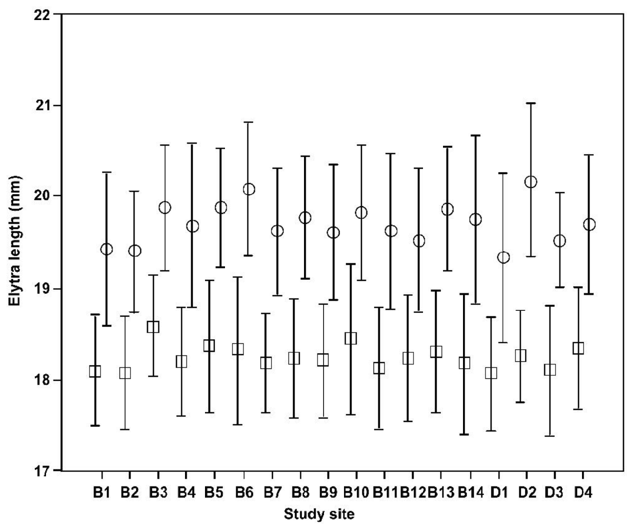

Fig. 1. Male (squares) and female (circles) elytrae lengths of *C. violaceus* (mean ± SD).

insufficient catching results. No trend regarding correlations between beetle-size SD of male and female animals or between beetle-size SD and age of the forest stands was observed (Tab. 3).

DISCUSSION

Our study shows considerable size differences within *C. violaceus* as well as *C. problematicus* only between male and female animals. Gender dimorphism with respect to body size is a common phenomenon among arthropods. However, when calculating male-to-female ratios of elytrae-length means of *C. violaceus* of 0.925:1 (beech) and 0.932:1 (Douglas fir) on the base of our results, also of *C. problematicus* of 0.922:1 (beech) and 0.921:1 (Douglas fir), these may be assumed to be rather low, thus representing a relatively large gender-related size difference, in comparison to

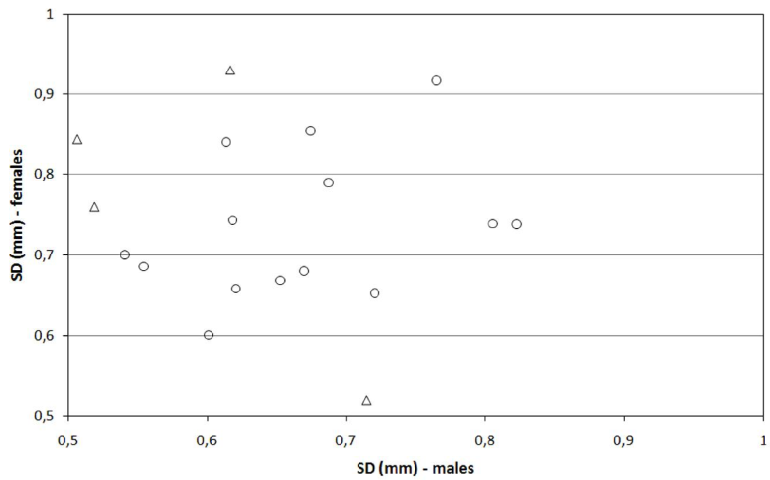

Fig. 2. Relationship between SD of elytrae length of male and female *C. violaceus* (circles – beech, triangles – Douglas fir).

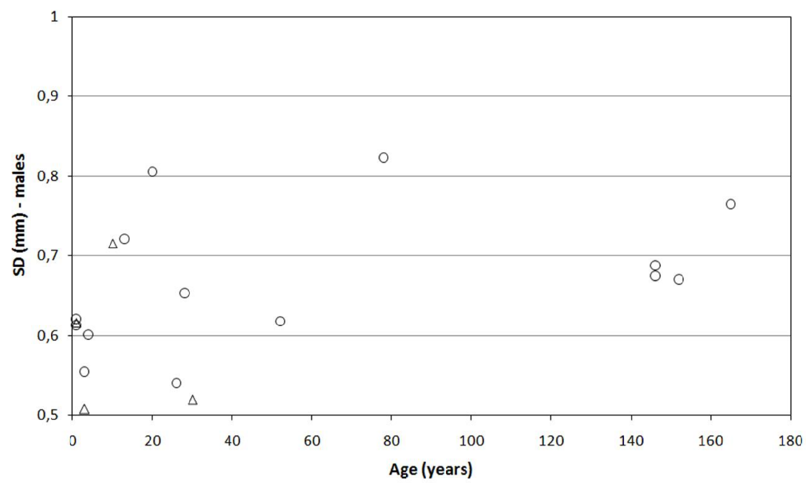

Fig. 3. Relationship between SD of elytrae length of male *C. violaceus* and age of the stands (circles – beech, triangles – Douglas fir).

literature data. E.g., by measuring head width of *C. violaceus* from heathy birch forests in Norway, 830 m a.s.l., Refseth (1984) detected ratios of 0.967:1 for *C. violaceus* and 0.976:1 for *C. glabratus*. This may indicate that size differences between male and female *C. violaceus* or other carabid species may differ regionally.

Our research hypotheses as to positive correlations between beetle-size SD of male and female animals and between beetle-size SD and age of the forest stands could not be confirmed by our data. There is only a non-significant trend suggesting a rise in the body-size SD of male *C. violaceus* with increasing forest age. This trend seems to be independent of the forest type (beech or Douglas fir) but to need a broad data source. It may point to an ongoing process of diversification at least within some forest stands over time, possibly relating to a rising

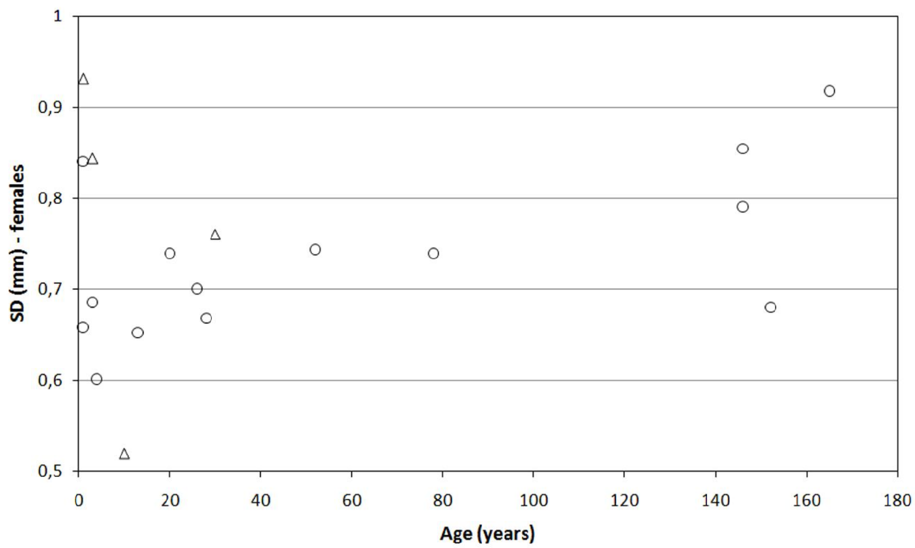

Fig. 4. Relationship between SD of elytrae length of female *C. violaceus* and age of the stands (circles – beech, triangles – Douglas fir).

imbalance of the distribution of carbon or other substances essential for beetle growth. E.g., Szyszko et al (1996) demonstrated clear relations between body size and consumption and respiration in populations of *Pterostichus oblongopunctatus*. However, the possibility exists that beetle-size SD is only marginally congruent with any ecological condition underlying the individual habitat. Thus, we may have studied statistical fluctuation.

Interestingly, previous data on this subject can also be considered equivocal. Skłodowski (2005) observed smaller body sizes of *C. violaceus* in fertile deciduous habitats than in relatively poor coniferous forests. In contrast, Garbalińska & Skłodowski (2008) describe reduced body sizes of *C. violaceus* in hurricane-disturbed and therefore degraded forest areas. A lot more field-ecological aspects that determine beetle growth should be studied in order to elucidate the complex picture of differences in beetle size over the run of succession.

CONCLUSIONS

There is a tendency towards a positive correlation between the standard deviation of elytrae length of male *C. violaceus* with age of the forest habitat. However, since this tendency may reflect a statistical artefact more research is needed to explore the concept of a wider variety of different microhabitats in old vs. young forests.

REFERENCES

Barber H.S. 1931. Traps for cave inhabiting insects. J. Mitchel. Soc. 46: 259-266.

den Boer P.J. 1977. Dispersal power and survival. Carabids in a cultivated countryside. Misc. Papers Landbouwhogeschool Wageningen 14, Veenmann H. & Zonen B. V. (Wageningen): 1-190.

Garbalińska P., Skłodowski J. 2008. Body size differentiation in selected carabid species inhabiting Puszcza Piska forest stands disturbed by the hurricane. Baltic J. Coleopterol. 8: 101-114.

Koivula M., Niemelä J. 2002. Boreal carabid beetles (Coleoptera, Carabidae) in managed spruce forests - a summary of Finnish case studies. Silva Fennica 36: 423-436.

Müller-Motzfeld G. 2004. Xerotherme Laufkäfer in Deutschland. Verbreitung und Gefährdung. Angewandte Carabidologie Supple. III: 27-44. (In German).

Neumann U. 1971. Die Sukzession der Bodenfauna (Carabidae (Coleoptera), Diplopoda und Isopoda) in den forstlich rekultivierten Gebieten des Rheinischen Braunkohlenreviers. Pedobiologia 11: 193-226. (In German).

Rainio J., Niemelä J. 2003. Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodiversity and Conservation 12: 487-506.

Refseth D. 1984. The life cycles and growth of Carabus glabratus and C. violaceus in Budalen, central Norway. Ecol. Entomol. 9: 449-455.

Sachs L. 1984. Angewandte Statistik: Anwendung statistischer Methoden (6th ed.). Springer, Berlin / Heidelberg / New York / Tokyo: 552 p. (In German).

Schreiner A., Schreiner W., Schwerk A. 2011. Western German beech and Douglas fir stands in forest succession research: Focus on *Carabus violaceus*. In: Szyszko J., Bodzenta M., Dymitryszyn I., Jojczyk A. (eds.): Opportunity for economic growth and biodiversity protection in rural areas – spatial management and forestry. WULS-SGGW Press, Warsaw: 63-68.

Schwerk A. 2008: Model of the rate of succession of epigeic carabid beetles (Coleoptera: Carabidae) on degraded areas. Instytut Badawczy Leśnictwa, Sękocin Stary: 71 p.

Schwerk A., Sałek P., Duszczyk M., Abs M., Szyszko J. 2006. Variability of Carabidae in time and space in open areas. Entomol. Fennica 17: 258-268.

Schwerk A., Szyszko J. 2006. Succession of carabid fauna (Coleoptera: Carabidae) on post-industrial areas near Bełchatów (Central Poland). Wiad. Entomol. 25, Supple. 1: 71-85.

Skłodowski J.J.W. 2005. Interspecific body size differentiation in Carabus assemblages in the Białowieża primeval forest, Poland. DIAS Report 114: 291-303.

Szyszko J. 1990. Planning of prophylaxis in threatened pine forest biocoenoses based on an analysis of the fauna of epigeic Carabidae. Warsaw Agricultural University Press, Warsaw.

Szyszko J., Vermeulen H.J.W., den Boer P. 1996. Survival and reproduction in relation to habitat quality and food availability for Pterostichus oblongopunctatus F. (Carabidae, Col.). In: Booij C.J.H., den Nijs L.J.M.F. (eds.): Arthropod natural enemies in arable land. II. Survival, reproduction and enhancement. Acta Jutlandica 71: 25-40.

Received: 29.05.2011.
Accepted: 15.07.2011.

15th European Carabidologists' Meeting
Daugavpils University, Daugavpils, Latvia
23rd to 27th of August 2011.

The Meeting will provide an opportunity to bring together colleagues and friends, students and researchers and give inspiration for new researches and investigations. It will offer a unique platform for presenting work results in oral or poster form and encouragement of discussions on the latest research results, ideas and concepts in the field of carabidology. The Meeting will seek to develop new strategies, theories and contributions. It will address various theoretical and practical topics, which should be gripping and relevant for a wide range of specialists.

The motto of the meeting:

"21st century challenges in Carabidology: new knowledge and approaches"

We are looking forward to meeting you and exchanging knowledge, results and ideas.

http://15thmeeting.biology.lv/

Organising Committee