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Physico-chemical characteristics of habitats colonized by the pond snail *Radix labiata* (Gastropoda, Basommatophora, Lymnaeidae): a model approach

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Abstract: Optimum habitat conditions of the pond snail *Radix labiata* were theoretically modelled by application of the logistic regression concept. As derived from the computations the gastropod exhibits enhanced tolerance for most of the studied environmental variables, whereby geographic altitude of the habitat, water temperature, electric conductivity, and nitrate concentration in the water have to be particularly emphasized in this context. The theoretical study once more underlines the circumstance that *R. labiata* is a generalist and, thus, has the potential to act as an important pioneer species concerning the colonization of alpine waters.

Key words: Logistic regression, environmental variable, tolerance, habitat, *Radix labiata*, Lymnaeidae.

Introduction

Numerous malacological studies carried out in the past decades have yielded evidence that freshwater mollucs represent essential bioindicators for the evaluation of aquatic ecosystems (e.g. STURM 2005, 2006, 2007, 2012). Basically, aquatic gastropods and bivalves may be subdivided into two main categories: Whilst so-called generalists show an enhanced tolerance for diverse biotic and abiotic factors being life-controlling determinants in their habitats, so-called specialists, on the other hand, exhibit a quick reaction to any changes of their environment which enhances their value as indicators for diverse environmental variables (GLÖER & MEIER-BROOK 2003). Although comprehensive knowledge of habitat requirements of specialized and, not less important, generalistic mollusc species represents a tremendous contribution to water quality management in cities and restoration projects (STATZNER & SPERLING 1993, OSBORNE et al. 1993), optimum habitat ranges of very few Central European freshwater gastropods have been explored in detail hitherto (STURM 2005, 2006).

The evaluation of habitat requirements being necessary for optimum living conditions of single mollusc species may be conducted with the help of various regression models (HOSMER & LEMESHOW 1989). Among these approaches logistic regression, where the probability of occurrence of an organism is commonly predicted as function of one or more independent environmental variables (AUSTIN 1987, JONGMAN et al 1987, HASTIE & TIBSHIRANII 1990, PEETERS & GARDENIERS 1998), has found a wide acceptance in ecological sciences. Application of this mathematical concept to freshwater animal ecology has been realized successfully for about 20 years (e.g. EYRE et al. 1993, PEETERS & GARDENIERS 1998, GROGER 2000, FIELD et al. 2002, YSEBAERT et al. 2002).

In the contribution presented here habitat requirements of a widely distributed gastropod species, *Radix labiata* (ROSSMAESSLER 1835), were subjected to a detailed modelling approach using the logistic regression concept. This should help to give a precise characterization of those ecosystems that are preferably colonized by the snail.

Materials and Methods

Brief ecological characterization of *Radix labiata* and available malacological data

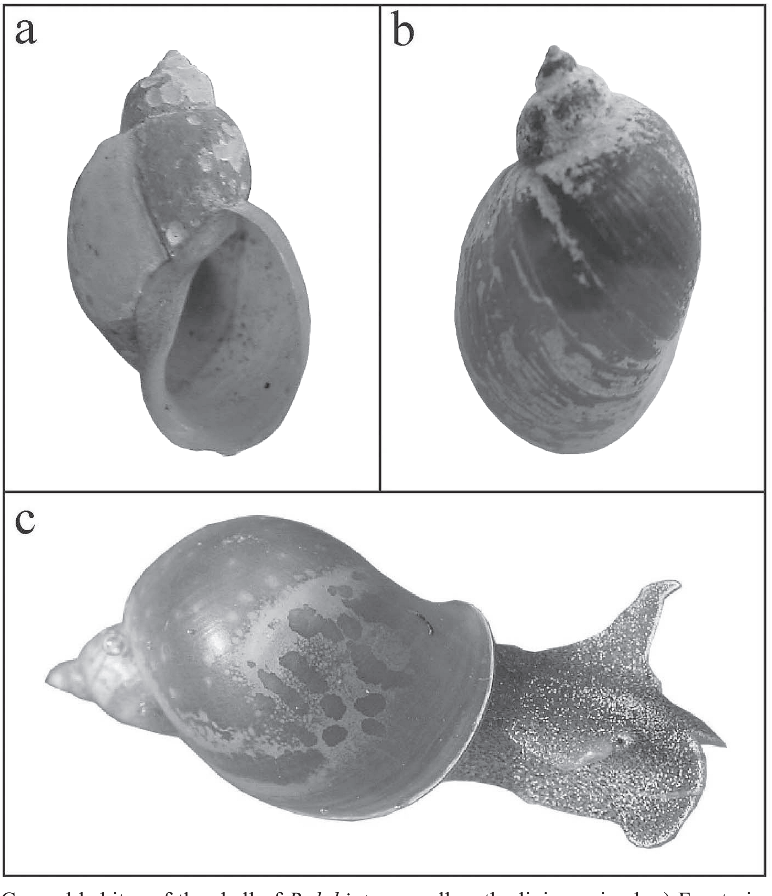

Fig. 1: General habitus of the shell of *R. labiata* as well as the living animal: a) Front view of the shell (height: 1.4 cm, width: 0.75 cm), b) back view of the shell, c) living animal with its typical triangular tentacles.

According to the overview of GLÖER & MEIER-BROOK (2003) *R. labiata* generally belongs to the family of the mud snails (Lymnaeidae) which is characterized by rather big animals (shell height up to 5 cm) with typical triangular tentacles. The bodies of the snails have a yellow to greenish grey colour with small black dots. Due to the fact that the Lymnaeidae are pulmonate gastropods (order Pulmonata) they come to the water surface for breathing within regular time intervals. *R. labiata* represents an intermediately sized gastropod species (shell height: 0.8 – 1.5 cm, shell width: 0.3 – 1 cm; Fig. 1) with very frequent occurrence in the alpine foreland as well as the northern alps of Austria (STURM 2004, 2007).

In Austria *R. labiata* was recorded at over 1,500 of the 2872 sample points published in the malacological literature hitherto. All sample points with determined occurrence of the pond snail were included into the model approach presented in this contribution. Concerning essential environmental determinants influencing the distribution of the gastropod ten factors measured at most of the selected sample locations were used for theoretical computations: 1) water temperature, 2) pH, 3) electric conductivity, 4) oxygen content in the water, 5) nitrate concentration in the water, 6) water depth at the sample point, 7) biological oxygen demand within five days, 8) ammonium nitrogen content of the water, 9) altitude of the sample location, and 10) current velocity in the case of running water habitats.

Logistic regression analysis

For the sake of completeness the main characteristics of the logistic regression concept used in this study are described briefly. More detailed information on this mathematical topic may be obtained from e.g. TERBRAAK & LOOMAN (1986), HOSMER & LEMESHOW (1989), HASTIE & TIBSHIRANII (1990), PEETERS & GARDENIERS (1998), or STURM (2005, 2006). In general, logistic regression represents an appropriate analysis of the relationship between a binary response variable and one or more independent parameters. Regarding the solution of ecological problems like that introduced in this contribution the so-called 'presence/absence curve' (TERBRAAK & LOOMAN 1986) is applied, by which the probability of a species occurring at a given sample point, p(x), is expressed as function of an analyzed environmental factor, x. This essential relationship may be written as follows:

$$p(x) = \frac{e^{(\beta_0 + \beta_1 x + \beta_2 x^2)}}{1 + e^{(\beta_0 + \beta_1 x + \beta_2 x^2)}} \tag{1}$$

In Eq. (1) β_0, β_1, and β_2 represent the coefficients of regression with β_0 denoting the constant term. If $\beta_2 \neq 0$, a symmetrical and bell-shaped function is derived from the formula noted above ('Gaussian logit curve'). If, on the other hand, $\beta_2 = 0$, p(x) follows a sigmoidal increase or decrease. Based upon the contribution of JONGMAN et al. (1987) the optimal range of an environmental factor may be determined by the two mathematical parameters u and t that are obtained from the following equations:

$$u = \frac{-\beta_1}{2\beta_2} \tag{2}$$

$$t = \frac{1}{-2\sqrt{\beta_2}} \tag{3}$$

Whilst the first parameter expressed by Eq. (2) indicates the position of the maximum of the probability curve, x_{max}, the second parameter expressed by Eq. (2) describes the range of a given independent variable x between the turning points of p(x) (p(x)'' = 0). Statistical significance of the regression coefficients β_1 and β_2 was computed by using a so-called likelihood ratio test (HOSMER & LEMESHOW 1989, TREXLER & TRAVIS 1993) which compares the predictive power between normal logistic regression and its associated null model ($\beta_1 = 0$ and $\beta_2 = 0$). Regression coefficients are excluded, if no differences between both models are noticeable.

In the contribution presented here presence (p(x) = 1) or absence (p(x) = 0) of *R. labiata* at the sample points noted above was plotted against each of the considered environmental variables, respectively. Related regression models were computed on specific spread sheets programmed in MS-EXCEL©. The parameters u and t were calculated automatically to determine optimum habitat ranges of a given independent variable.

Results

Main computational results of the logistic regression procedure applied to *R. labiata* are summarized in Figs. 2 and 3. As underlined by the bell-shaped curves exhibited in Fig. 2, the regresion coefficient β_2 was significantly different from zero ($p < 0.01$) for all investigated environmental variables. Concerning water temperature, highest probability of occurrence of the pond snail is predicted for 13.54°C, whereas optimal water temperatures of habitats colonized by the gastropod range from 10.91°C to 16.17°C. Generally, the species tolerates water temperatures ranging from 5.02°C to 22.06°C (Fig. 2a). The pH value with highest occurrence of *R. labiata* amounts to 7.47 (optimum range: 6.81 – 8.19; Fig. 2b), whereas electric conductivity adopting values between 132 µS cm^{-1} and 574.8 µS cm^{-1} (x_{max} = 353.4 µS cm^{-1}) provides best environmental conditions for the gastropod (Fig. 2c). According to the model computations *R. labiata* exhibits a preference for oxygen concentrations in the water ranging from 9.04 mg L^{-1} to 11.79 mg L^{-1} (x_{max} = 10.42 mg L^{-1}; Fig. 3d), whilst nitrate content in the water should plot within the interval ranging from 0.51 mg L^{-1} to 5.74 mg L^{-1} (x_{max} = 3.12 mg L^{-1}; Fig. 3e). With regards to water depth the pulmonate gastropod prefers habitats that are positioned 4.4 cm to 40.9 cm under the water surface (x_{max} = 22.7 cm; Fig. 3f). On the other hand, variations of the BOD between 1.05 mg L^{-1} and 2.35 mg L^{-1} (x_{max} = 1.70 mg L^{-1}) are well tolerated by the pond snail (Fig. 3g). Concerning the tolerance for ammonium nitrogen in the water of the colonized habitat *R. labiata* exhibits a strongly defensive behaviour which is reflected by an interval of optimal living conditions ranging from 0 mg L^{-1} to 0.179 mg L^{-1} (x_{max} = 0.077 mg L^{-1}; Fig. 3h). An important environmental variable controlling the dispersal of the gastropod is the geographic altitude, whose optimal range starts at 143 msm (metres supra mare) and ends at 1,214 msm (x_{max} = 627 msm). In addition, it has to be noted that *R. labiata* may climb to geographic altitudes of 2,350 msm in optional cases which underlines its role as an essential pioneer species (see Discussion; Fig. 3i). The last environmental variable of enhanced relevance is the current

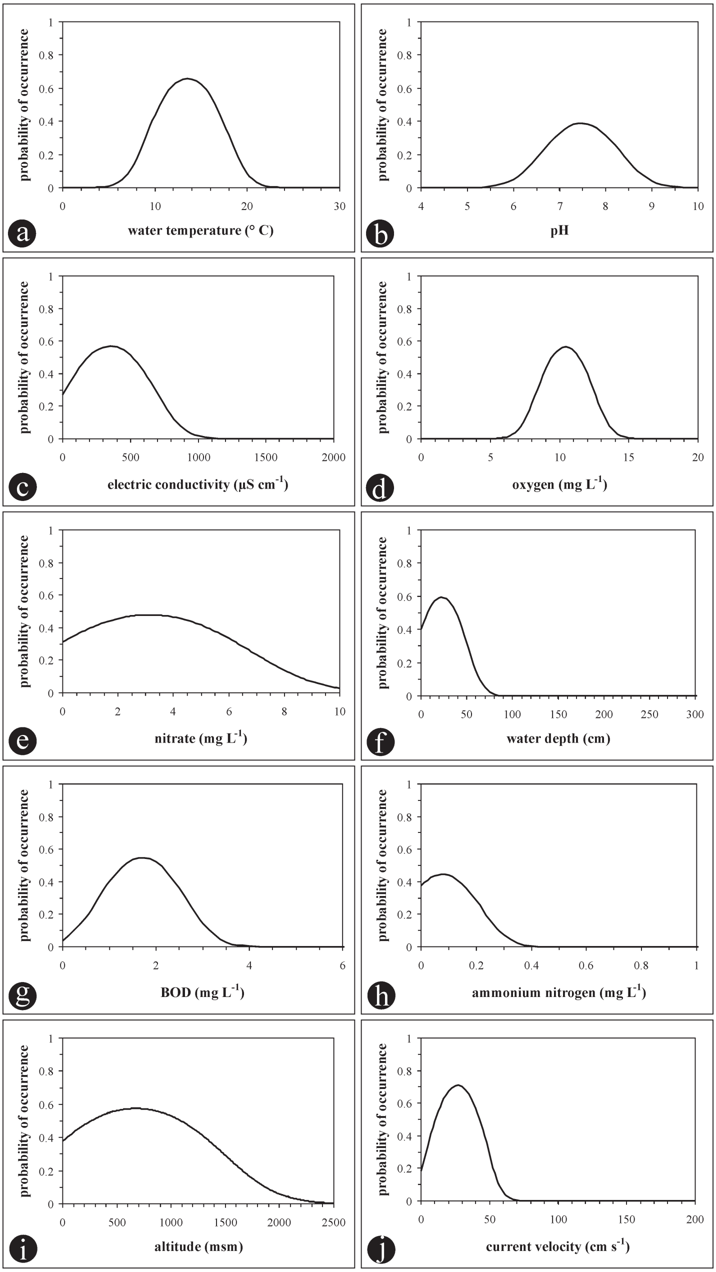

Fig. 2a-j: Results of the logistic regression procedure carried out for ten environmental variables: **a**) water temperature, **b**) pH, **c**) electric conductivity, **d**) oxygen content in the water, **e**) nitrate concentration in the water, **f**) water depth, **g**) biological oxygen demand within five days, **h**) content of ammonium nitrogen, **i**) geographic altitude, **j**) current velocity.

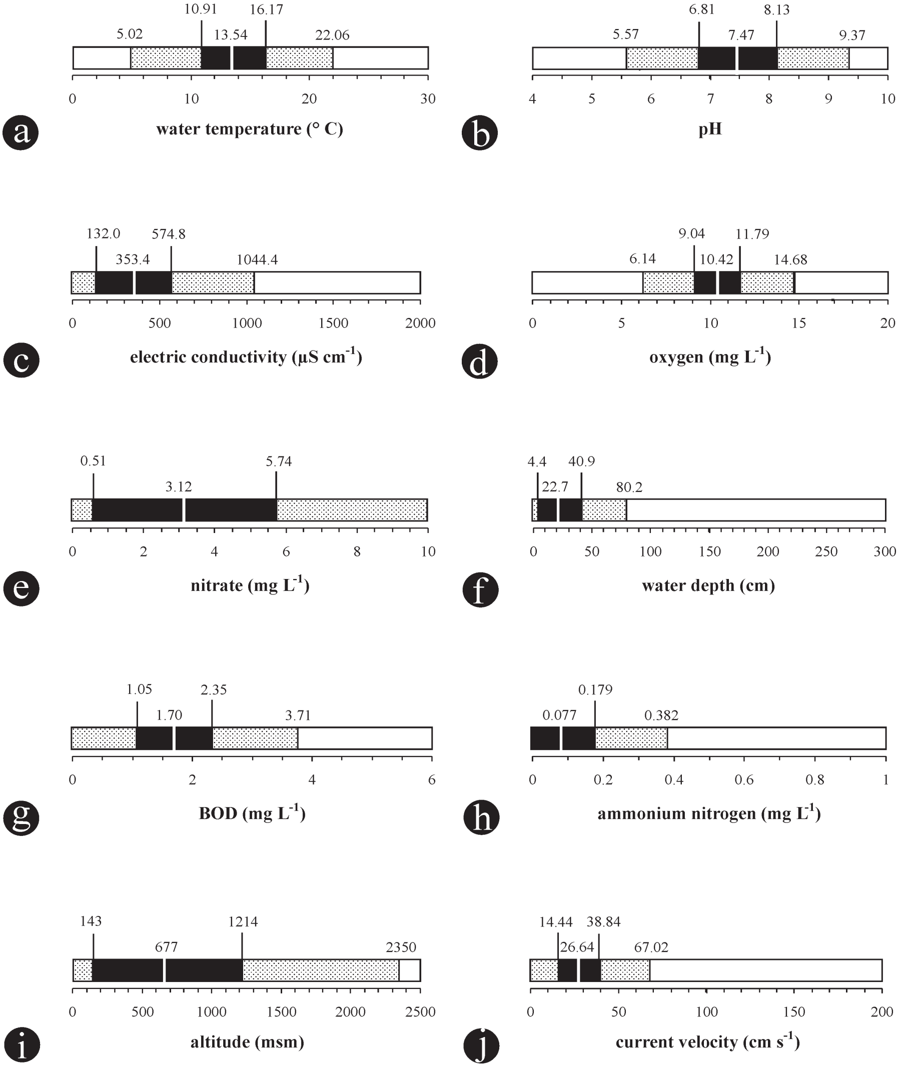

Fig. 3a-j: Graphical presentation of essential parameters associated with logistic regression: white vertical line: position of the maximum probability of occurrence (x_{max}), black bar: optimum range of the given variable, grey-shaded area: range of the given variable that is still tolerated by the species; **a**) water temperature, **b**) pH, **c**) electric conductivity, **d**) oxygen content in the water, **e**) nitrate concentration in the water, **f**) water depth, **g**) biological oxygen demand within five days, **h**) content of ammonium nitrogen, **i**) geographic altitude, **j**) current velocity.

velocity which should range from 14.44 cm s^{-1} to 38.84 cm s^{-1} to guarantee a 75%-occurrence (related to the maximum probability of occurrence) of the pond snail and should adopt a value of 26.64 cm s^{-1} to obtain the highest possible probability of occurrence (p_{max}; Fig. 3j).

Discussion

In the present contribution logistic regression was used as the state-of-the-art method for the determination of optimum ranges of environmental variables that play an essential role in those habitats colonized by the pond snail *R. labiata*. Although the basic linear model crystallized out as an efficient tool regarding the solution of common ecological problems, it has been successively substituted by more complex mathematical approaches such as general additive models (STURM 2005), or canonical correspondence analysis (STURM 2007, 2012) in the meantime. However, with the help of the logistic regression model it could be demonstrated that *R. labiata* is characterized by a somewhat generalistic behaviour with regards to the tolerance for fluctuations of specific environmental variables. This phenomenon is chiefly reflected by rather wide tolerance levels of the pond snail with respect to most variables (Fig. 2, 3). Thereby, highest tolerance may be attested for the geographic altitude of the colonized habitat, water temperature, electric conductivity, and the content of nitrate ions in the water. These observations are to a high extent covered by descriptions outlined in the recent literature (TURNER et al. 1998, GLÖER & MEIER-BROOK 2003, STURM 2007, 2012) and lead to the conclusion that *R. labiata* has an enhanced potential to act as one of very few pioneer species concerning a successive colonization of high mountain lakes in the Eastern and Western Alps. According to very current studies this characteristic may be also attributed to the lymneid *Galba truncatula* (MÜLLER 1774) and the sphaeriid *Pisidium casertanum* (POLI 1791) (STURM 2012).

Although *R. labiata* behaves as a perfect generalist over wide ranges it is also marked by increased sensitiveness and intolerance with regards to some environmental variables. Most strongly emphasized in this context have to be water depth on the one hand and current velocity on the other hand (Fig. 2, 3). According to the available data the occurrence of the pond snail is limited to habitats with very shallow water which can have several reasons: First, *R. labiata* belongs to the pulmonate aquatic snails and thus has to come to the water surface for breathing (BAUR 1998, GLÖER & MEIER-BROOK 2003). This is made impossible, if the snail colonizes deeper waters; second, most sampling points including the record of *R. labiata* are situated along the shores of the investigated waters, so that information on deeper habitats is rather sparse and, as a consequence of this, water depth of habitats colonized by the pond snail is systematically underestimated by the model. The intolerance of *R. labiata* for high current velocities is mainly confirmed by the scientific literature (GLÖER & MEIER-BROOK 2003, STURM 2007, 2012), where the species is described as a colonizer of lakes, moores, and very slowly running waters.

Finally it may be concluded that mathematical models provide partly excellent tools for the clarification of scientific problems arising in all fields of ecology.

Zusammenfassung

Optimale Habitatbedingungen für die Schlammschnecke *Radix labiata* wurden unter Anwendung des logistischen Regressionsmodells theoretisch ermittelt. Wie sich anhand der Berechnungen feststellen ließ, zeigt die Schnecke eine erhöhte Toleranz gegenüber den meisten der im Rahmen dieser Studie untersuchten Umweltvariablen, wobei die geographische Höhe des Habitats, Wassertemperatur, elektrische Leitfähigkeit und Nitratkonzentration im Wasser in diesem Zusammenhang zu besonderer Hervorhebung Anlass geben. Die theoretische Untersuchung unterstreicht einmal mehr die Tatsache, dass es sich bei *R. labiata* um einen Generalisten handelt, welcher das Potential besitzt, als Pionierspezies in Bezug auf die Besiedlung alpiner Gewässer aufzutreten.

References

AUSTIN M.P. (1987): Models for the analysis of species' response to environmental gradients. — Vegetatio **69**: 35-45.

BAUR W.H. (1998): Gewässergüte bestimmen und beurteilen. — Berlin (Parey Verl.), 1-218.

EYRE M.D., FOSTER G.N. & A. G. YOUNG (1993): Relationships between water-beetle distributions and climatic variables: A possible index for monitoring global climatic change. —Archiv für Hydrobiologie **127**: 437-450.

FIELD L.J., MACDONALD D.D., NORTON S.B., INGERSOLL C.G., SEVERN C.G., SMORONG D. & R. LINDSKOOG (2002): Predicting amphipod toxicity from sediment chemistry using logistic regression models. — Environmental Toxicology and Chemistry **21**: 1993-2005.

GLÖER P. & C. MEIER-BROOK (2003): Süsswassermollusken. — Hamburg (Deutscher Jugendbund für Naturbeobachtungen), 1-137.

GROGER J. (2000): Separation of two herring stocks in the transition zone between Baltic and North Sea, based on logistic regression and meristic characters. — Archive of Fishery and Marine Research **48**: 161-174.

HOSMER D.W. & S. LEMESHOW (1989): Applied Logistic Regression. — New York (John Wiley & Sons), 1-418.

JONGMAN R.H.G., TERBRAAK C.J.F. & O.F.R. VANTONGEREN (1987): Data Analysis in Community and Landscape Ecology. — Wageningen (Pudoc), 1-209.

OSBORNE L.L., BAYLEY P.B., HIGLER L.W.G., STATZNER B., TRISKA F. & T.M. IVERSEN (1993): Restoration of lowland streams: an introduction. — Freshwater Biology **29**: 187-194.

PEETERS E.T.H.M. & J.J.P. GARDENIERS (1998): Logistic regression as a tool for defining habitat requirements of two common gammarids. — Freshwater Biology **39**: 605-615.

STATZNER B. & F. SPERLING (1993): Potential contribution of system-specific knowledge (SSK) to stream-management decisions: ecological and economic aspects. — Freshwater Biology **29**: 313-342.

STURM R. (2005): Modelling optimum ranges of selected environmental variables for habitats colonized by the spring snail *Bythinella austriaca* (V. FRAUENFELD, 1857) (Gastropoda: Prosobranchia). — MalakologischeAbhandlungen **23**: 67-76.

STURM R. (2006): Habitatansprüche der Süßwasserschnecke *Viviparus contectus* (MILLET, 1813) (Gastropoda: Prosobranchia): theoretische Modellbildung und experimentelle Ergebnisse. — Malakologische Abhandlungen **24**: 19-27.

STURM R. (2007): Freshwater molluscs in mountain lakes of the Eastern Alps (Austria): relationship between environmental variables and lake colonization. — Journal of Limnology **66**: 160-169.

STURM R. (2012): Aquatic molluscs in high mountain lakes of the Eastern Alps (Austria): Species-environment relationships and specific colonization behaviour. — Chinese Journal of Oceanology and Limnology **30**: 59-70.

TERBRAAK C.J.F. & C.W.N. LOOMAN (1986): Weighted averaging, logistic regression, and the Gaussian response model. — Vegetatio **65**: 3-11.

TREXLER J.C. & J. TRAVIS (1993): Nontraditional regression analyses. — Ecology **74**: 1629-1637.

TURNER H., KUIPER J.G.J., THEW N., BERNASCONI R., RUETSCHI J., WÜTHRICH M. & M. GOSTELI (1998): Fauna Helvetica II: Atlas der Mollusken der Schweiz und Liechtensteins. — Neuchatel (Schweizer Entomologische Gesellschaft), 1-527.

YSEBAERT T., MEIRE P., HERMAN P.M.J. & H. VERBREEK (2002): Macrobenthic species response surfaces along estuarine gradients: prediction by logistic regression. — Marine Ecology Progress Series **225**: 79-95.

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