Volume 26, Number 4 July-August 1995
ISSN: 1067-4136 CODEN: RJOEEW

RUSSIAN JOURNAL OF ECOLOGY

Official English Translation of *Ekologiya*

Editor-in-Chief
Vladimir N. Bolshakov

Member of the Russian Academy of Sciences
Director of the Institute of Plant and Animal Ecology,
Ural Division of the Russian Academy of Sciences

A Journal of Original Papers and Reviews on Theoretical and Applied Ecology

Translated and Published by
MAИK HAУKA/INTERPERIODICA PUBLISHING

Distributed worldwide by PLENUM/CONSULTANTS BUREAU

Russian Journal of Ecology, Vol. 26, No. 4, 1995, pp. 281 - 284. Translated from Ecologiya, Vol. 26, No. 4, 1995, pp. 307 - 310.
Original Russian Text Copyright © 1995 by Seifert, Khokhutkin.
English Translation Copyright © 1995 by МАИК Наука/Interperiodica Publishing (Russia).

Application of Terrestrial Mollusks for Assessing Environmental Quality

D. V. Seifert* and I. M. Khokhutkin**

* *Sterlitamak Branch of the Bashkir Research Ecological Center, Bashkortostan, Russia*

** *Institute of Plant and Animal Ecology, Ural Division, Russian Academy of Sciences, ul. Vos'mogo Marta 202, Ekaterinburg, 620144 Russia*

Received October 26, 1994

Abstract – With consideration of original and published data the life cycles of four species of mollusks are analyzed, these mollusks being suggested as convenient objects for bioindication of anthropogenic impact in the territory of the European part of Russia and of the Urals. They may be easily identified, and such investigations are facilitated by low mobility of individuals in populations and by the possibility of regularly collecting of material.

Over the last 20 years numerous data have been published that confirm the possibility of applying terrestrial mollusks for indication of pollution with heavy metals (Williamson, 1979; Popham, D'Auria, 1980; Beeby, Eaves, 1983; Kalinovska, 1984) and with pesticides (Dmitrienko, 1975; Forsyth *et al.*, 1982; Haque, Ebing, 1983). Large terrestrial mollusks of the temperate zone are, as a rule, polyphages and have a wide range of food items. The tendency for diversification of food composition increases with an increase in animal size. The bulk of the diet of terrestrial mollusks in natural habitats consists of dead or moribund parts of plants (Seifert, Shutov, 1981). During the period of animal activity the accessibility of different feed significantly varies (Striganova, 1980). In addition, in widely distributed species of soil organisms, including terrestrial mollusks as well, the composition of the diet in different parts of a geographical area and under various landscape-zonal conditions may be diverse (Striganova, Chernov, 1980). The efficiency of food assimilation is high in comparison with other groups of soil organisms (Striganova, 1980), on average comprising 60% (Seifert, 1990). Organic and inorganic food components are assimilated similarly (Moser and Wieser, 1979).

Analysis of our own data and published data on quantitative regularities of feeding of mollusks from various ecological groups made it possible to determine the reference value of their diets. The maximum level of feeding activity is recorded for slugs. The relationship between the living weight of individuals (g) and the value of their daily diet (mg of air-dry weight) is described by the equation $C = 81.4W^{0.37}$. In tropical snails this function is in the form $C = 52.5W^{0.46}$. In snails of the temperate zone the relationship between the weight and the daily diet is described by the equation $C = 25.2W^{0.82}$.

Within the temperature range at which the animals feed normally, these values are slightly dependent on temperature. Differences in the value of diets in tropical snails and snails of the temperate zone depend on the different rate of the transmission of food through the alimentary canal. The aforementioned relationships may be used for quantitative assessment of the intake of pollutants with food. At present there are no data on the energy balance of terrestrial mollusks under conditions of intact and polluted biotopes.

The impact of anthropogenic factors on terrestrial mollusks is investigated at three levels: (1) organismal, (2) populational, and (3) by changes in the composition of the malacofauna on the territory under study during a certain period. Most investigations are made at the organismal level.

The differences in concentration of particular microelements depending on age and season are revealed. The total quantity of cadmium accumulated in *Cepaea hortensis* is described by an equation of the type $\log Y = a + b_1 \log X_1 + b_2 \log X_2$, where Y – the quantity of cadmium, μg; X_1 – dry weight of soft tissues, g; X_2 – age, years (Williamson, 1979).

When applying terrestrial mollusks as bioindicators of environmental condition, it is desirable to use distribution maps of particular species with squares on scales of 100, 50, 10, and 1 km (Inanez *et al.*, 1976). On the basis of such maps it is possible to relate the distribution of particular species to physical, climatic, and other factors (Kerbey, 1982). Further analysis implies the screening of taxa that tend to decrease in the area or to disappear (Reischutz, Seidl, 1982). These species are not suitable for long-term ecological monitoring.

The fauna of Russia and adjacent countries includes not less than 550 species of terrestrial mollusks belonging to 30 families. Twenty species of them are widely distributed, some being represented by small forms,

1067-4136/95/2604-0281$12.50 © 1995 МАИК Наука / Interperiodica Publishing

which complicates their collection in the quantity adequate for analyses. An abundant large slug *Deroceras reticulatum* cannot serve as a monitoring object due to its clearly expressed synanthropic habits. For the European part of Russia and the Urals we suggest three species of the order Geophila as bioindication objects. Morphology and systematics of species of this order are considered in detail by A.A. Shileyko (1979).

(1) *Bradybaena fruticum* (Müller, 1774). A large long-lived snail. Shell height is 14 - 19 mm, and width is 14 - 23 mm. It populates mainly floodplain meadows with tall herbs, humid forests, and shrub thickets over most of Europe. The western boundary of distribution of this species is indicated by Kerney and Cameron (1979). In the East this species reaches the Ob' River. A few finds have been recorded in the Yenisei basin. In the South of Russia it spreads to the North Caucasus inclusively. Under optimum climatic conditions the mollusks can exist in a wider range of habitats than are found at the boundary of the species area.

The ecology of *B. fruticum* at the eastern boundary of its geographical area is described by D.V. Seifert (1985). Most of its young emerge in the middle of May, the actual term being related to weather conditions. The lower peak of the emergence of young is noted in the middle of August in years when the sum of positive average daily temperatures over 10°C comprised not less than 2015. Snails of the spring generation reach maturity (the lip is formed on the shell) in the fourth year, they are a reproductive group during the fifth year, and in spring of the sixth year they perish. In May of different years the population density of *B. fruticum* varied from 0.9 to 6.1 ind/m^2 on different plots. The maximum growth rate is noted in May and June. Beginning in August the snails continue actively feeding but do not grow any more; in this period their shells gain in thickness. Under better climatic conditions their growth rate increases, they reach maturity sooner, and the total life span decreases. A difference in the food composition in specimens of different ages is noted (Seifert and Shutov, 1981). The emerged young stay for some time in the nest chamber feeding on undeveloped eggs, remains of egg membranes, and soil particles. Snails seem to consume soil microorganisms. Having left the nest chamber the snails travel regularly up to the herbaceous layer, and their diets then contain green parts of plants. In adults the amount of green mass in the diet decreases. The maximum quantity of green mass in the diet of snails of all ages is noted during a seasonal peak of phytomass increment.

(2) *Deroceras agreste* (L., 1785). The abundant slug reaches 40 mm in length. It inhabits meadows, swamps, and roadside ditches and is found less often in kitchen gardens and orchards. It occurs at forest margins and in alder groves, but never penetrates into the depths of the forest, and hides under pieces of wood, stones, and soil lumps and in cracks of soil. It is more common on plainlands and lowlands and rarer in the mountains. In floodplains of big rivers on the Valdai Hills the distribution of *D. agreste* is determined by windrose (Shikov, 1978). This slug prefers the most windy and dry areas of river valleys. It is common in Middle Europe, and in Russia it is distributed almost everywhere – from the Kola Peninsula and Bol'shezemel'skaya Tundra in the North to the Caucasus, the Crimea, and Central Asia in the South, and also in the Altai, the Sayan Mountains, the Amur region, the Primor'e Territory, in the southern part of Kamchatka, and on Sakhalin and the Kuril Islands.

In the Northwest of the European part of Russia and in the Transurals eggs are commonly laid in autumn, and it is only eggs that winter. To the south of these areas the eggs and semiadult slugs winter and begin reproduction in late spring - early summer.

Thus, 2 - 3 generations may be observed in autumn. In the Transurals the peak of biomass increment is noted in August. The growth rate is considerably different in varying habitats. Adults consume more coarse food than young slugs do (Likharev and Victor, 1980).

(3) *Arion subfuscum* (Draparnaud, 1805). Abundant large slugs, 35 - 80 mm in length. They live in broadleaf, mixed, and coniferous forests, in forest tundra, and in mountain tundra of the Kola Peninsula. They are very common on forest margins and in bushes. In mountains they occur much higher above the forest zone. Sometimes they are found on peat bogs. In the daytime they hide under fallen trees, in rotting stumps, under stones, and in litter. In anthropogenic biotopes they are comparatively rare, mainly occurring in old parks and cemeteries. They are common almost all over Europe, and have been introduced to North America and New Zealand. In Russia they are distributed very widely over forest and forest steppe regions of the European part of the country and penetrate in the adjacent forest tundra. They are common in the Carpathians and in their forest and forest steppe foothills, on western and eastern slopes of the Middle and Southern Urals, and in the Transurals. In the steppe zone they live in ravines and floodplains in forests of the Ukraine and the North Caucasus.

Most often, and always in the European part of Russia, the young in autumn emerge from eggs. After one and a half years the grown up slugs begin reproduction again. Under optimum conditions the slugs may complete their life cycle in 12 months (Likharev, Victor, 1980). In the Transural region we observed wintering young slugs with an average weight of 400 mg, and in August we observed the young emerge from eggs. The principal food items of *A. subfuscus* are dead parts of plants, and fruit bodies of mushrooms are also intensively consumed. The slug consumes only the green parts of plants, dead animals, and feces of vertebrates. A one-moment sample reveals considerable individual variation in the food composition (Bless, 1977). Twenty-eight of the 58 investigated specimens of *A. subfuscus* contained only plant remains, 24 contained only fungi, and 4 contained mainly fresh and dead plant material. In addition, in 10 slugs the quantity of insects found in the stomachs was so great that it was obvious they were not just eaten occasionally.

Of representatives of the order Succineida, the biology and distribution of *Succinea putris* (L., 1758) is studied best of all, and this species should be preferred for bioindication. This is a snail with a thin transparent shell. Shell height is 16 - 22 mm, and width is 8 - 11 mm. It inhabits damp ravines, humid low forests, humid tall herb meadows, shrub thickets in floodplains, and coasts of water bodies. In mountain regions it occurs in the upper zone of the forest belt. This is a Palearctic species. The geographic area includes Europe, North Asia, the Transcaucasus, and Northern Iran.

On the basis of an analysis of the size structure of a population of *S. putris* in different periods of the vegetative season, its total life duration in England has been determined as 15 months (Rigby, 1965). The genital system is developed at a shell length of 12 mm, and reproducing individuals have a size of 14 - 16.5 mm. In the opinion of this author, the life span is longer in some specimens occurring in the early summer and reaching a length of 18.5 mm. For *S. putris* living in the Transurals the peak of emergence of the young takes place in the middle of July. In the investigated area the populations of this snail are represented by semelparous individuals that perish after laying eggs. The total life span of *S. putris* in the Transurals is 3 years. No qualitative differences in the food composition of *S. putris* and *B. fruticum* living together have been revealed.

The aforementioned data on biotopical variation and geographical distribution of these species demonstrate that they meet the requirements for organisms used for bioindication. In addition, their populational biomass comprises a significant part of the biomass of jointly living species of terrestrial mollusks, thus making it possible to take samples regularly even in the periods of lower numbers. The biomass of *B. fruticum* in the investigated habitats in the Transurals varies from 0.082 to 0.787 g of dry weight/m^2. In *S. putris* in the region of Zarnowieckie Lake (Poland) this parameter is 0.220 - 0.684 g of dry weight/m^2 (Kallinowska, Grzybowska, 1983).

Mollusks earmarked for analysis of the microelement composition and the content of polychlorinated biphenyls and other pollutants are picked by hand and placed in plastic vessels, where they are kept for two days so that the alimentary canal is freed from remains of food. Coughtrey and Martin (1976) killed the animals by placing them in a tightly closed vessel with boiled deionized water that contained several drops of chloral hydrate. The analyzed objects (mollusks, their soft tissues or particular organs) are placed in a drying oven and dried at 65 - 70°C for 24 hours. For analysis of the mercury content, it is necessary that the temperature not exceed 40°C. If the proper equipment is available the desiccation of samples may be made by lyophilization of tissues. The water content in slugs kept under laboratory conditions is, on average, 85.7%; the relative water content decreases as animal size increases. Under natural conditions the water content in slugs varies from 81.2 to 90.0% (Lyth, 1982). The relative water content in snails is strongly dependent on size and weight of the shell, being on average 58%. The dried samples are placed in packages of parchment paper or plastic weighing bottles. In this state the samples may be kept until analysis by atomic absorption spectrophotometry, gas liquid chromatography, and radiography. Prior to analyses the samples are dissolved. The reagents and their actual dosages depend on the particular methods employed.

Since slugs are very mobile and pollutants are taken in not only with food, analysis of representatives of this life form requires larger samples than that of snails. In addition, at the same concentration in soil or vegetation the pollutants weakly toxic for terrestrial mollusks are accumulated in their organism in much higher quantities than the highly toxic pollutants (Edwards, 1976). Some data on the chemical composition of species suggested as objects of bioindication are listed in the review by A.D. Pokarzhevskii (1985).

The first stage of investigation of these species of terrestrial mollusks includes determinating their chemical composition in different geographical areas. At the second stage it is already possible to discern the pollution zones by comparing the data on chemical composition of animals with the background parameters. Only such an approach makes it possible to apply the obtained data to practical aims. The approach based on the analysis of the impact of pollution on the populational structure and numbers of terrestrial mollusks is not yet advisable, since only a few investigations have been made on the influence of natural factors on the population dynamics of terrestrial mollusks. When such data accumulates, it may be possible to estimate the impact of pollution at this level. Composition of distribution maps on the territory of Russia and adjacent countries would also make possible analysis of the impact of pollution based on the data on changes in the malacofauna's composition.

REFERENCES

Dmitrienko, V.K., Change in the Numbers of Large Invertebrates in Taiga Sites Treated with MME DDT, *Problemy Pochvennoi Zoologii* (Problems of Soil Zoology), Vilnius, 1975, pp. 146 - 148.

Beeby, A.N. and Eaves, S.L., Short-Term Changes in Ca, Pb, Zn, and Cd Concentrations of the Garden Snail, *Helix aspersa* Müller, from a Central London Car-Park, *Environ. Pollut.*, 1983, vol. A30, no. 516, pp. 233 - 244.

Bless, R., Beitrag zur Ernahrungsweise ausgewahlter Nackschneckenarten des Naturparks Kottenforst-Ville, *Anz. Schadlingskd. Pflanzenschutz.*, 1977, vol. 50, no. 5, pp. 73 - 74.

Coughtrey, P.J. and Martin, M.H., The Distribution of Pb, Zn, Cd, and Cu within the Terrestrial Mollusks *Helix aspera* Müller, *Oecologia*, 1976, vol. 23, no. 4, pp. 315 - 322.

Edwards, C.A., The Uptake of Two Organophosphorus Insecticides by Slugs, *Bull. Environ. Contam. Toxicol.*, 1976, vol. 16, no. 4, pp. 406 - 410.

Forsyth, D., Peterle, T., and Goodwin, M.K., Uptake of 36 Cl-DDT Residues by Slugs and Isiolids in the Laboratory and Field, *Environ. Pollut.*, 1982, vol. A29, no. 2, pp. 135 - 143.

Haque, A. and Ebing, W., Uptake, Accumulation, and Elimination of HCB and 2,4-D by the Terrestrial Slug, *Deroceras reticulatum* (Müller), *Bull. Environ. Contam. Toxicol.*, 1983, vol. 31, no. 6, pp. 727 - 733.

Ibanez, M., Alonso, M.R., and Alvarez, I., El Cartografiado de los Seres Vivos en Espana, *Trab. y Monogr. Dep. Zool. Univ. Granada*, 1976, no. 2, pp. 1 - 10.

Kalinowska, A., Lead Concentrations in the Slug *Arion rufus* from Sites at Different Distances from a Tourist Road, *Ecol. Bull.*, 1984, vol. 36, pp. 46 - 49.

Kalinowska, A. and Grzybowska, D., Concentration of ^{90}Sr and ^{137}Cs in Plants and Population Phytophagous Snail *Succinea putris* L. in Meadow Biocenosis around the Zarnowieckie Lake, *Ecol.*, 1983, vol. 31, no. 1, pp. 201 - 216.

Kerney, M., The Mapping of Nonmarine Mollusca, *Malacologia*, 1982, vol. 22, no. 112, pp. 403 - 407.

Kerney, M.P. and Cameron, R.A.D., *A Field Guide to the Land Snails of Britain and Northwest Europe*, London: Colline, 1979.

Likharev, I.M. and Viktor, A.I., *Slizni Fauny SSSR i Sopredel'nykh Stran (Gastropoda terrestria nuda)* [Slugs of the Fauna of the USSR and Adjacent Countries (*Gastropoda terrestria nuda*)], Leningrad: Nauka, 1980 (*Fauna SSSR: Molluski, Akad. Nauk SSSR Zool. Inst., Novaya Ser.*, vol. 3, no. 122, issue 5).

Lyth, M., Water Contents of Slugs (Gastropoda: Pulmonata) in Natural Habitats, and the Influence of Culture Conditions on Water Content Stability in *Arion ater* (Linne), *J. Moll. Stud.*, 1982, vol. 49, no. 3, pp. 179 - 184.

Moser, H. and Wasser, W., Copper and Nutrition in *Helix pomatia* (L.), *Oecologia*, 1979, vol. 42, no. 2, pp. 241 - 251.

Pokarzhevskii, A.D., *Geokhimicheskaya Ekologiya Nazemnykh Zhivotnykh* (Geochemical Ecology of Terrestrial Animals), Moscow: Nauka, 1985.

Popham, J.D. and D'Auria, J.M., *Arion ater* (Mollusca: Pulmonata) as an Indicator of Terrestrial Environmental Pollution, *Water, Air, Soil Pollut.*, 1980, no. 14, pp. 115 - 124.

Reinschutz, P.L. and Seidl, F., jun. Gefahrdungsstufen der Mollusken Ostrreichs, *Mitt. Zool. Ges. Braunau*, 1982, vol. 4, nos. 4 - 6, SS. 117 - 128.

Righby, J.E., *Succinea putris*: A Terrestrial Opistobranch Mollusk, *Proc. Zool. Soc. Lon.*, 1965, vol. 144, no. 4, pp. 445 - 486.

Seifert, D.V., Some Aspects of Bioenergetics of Terrestrial Mollusks, *Energetika Rosta i Razvitiya Zhivotnykh* (Energetics of the Growth and Development of Animals), Sverdlovsk: Ural. Nauchn. Tsentr Akad. Nauk SSSR, 1985, pp. 76 - 88.

Seifert, D.V., Quantitative Aspects of Feeding of Terrestrial Mollusks, *Energetika Pitaniya i Rosta Zhivotnykh* (Energetics of Feeding and Growth of Animals), Sverdlovsk: Ural. Nauchn. Tsentr Akad. Nauk SSSR, 1990, pp. 105 - 130.

Seifert, D.V. and Shutov, S.V., Consumption of Leaf Litter by Land Mollusks, *Pedobiologia*, 1981, vol. 21, no. 3, pp. 159 - 165.

Shikov, E.V., Dependence of Distribution of Slugs of the Genus *Deroceras* Rafinesque 1820 in Floodplains of Big Rivers of the Valdai Hills on the Direction of Dominant Winds, *Ekologiya*, 1978, no. 5, pp. 97 - 99.

Shileiko, A.A., The System of the Order Geophila (=Helicida) (Gastropoda: Pulmonata), *Morfologiya, Sistematika, i Filogeniya Molluskov*: *Tr. Zool. Inst. Akad. Nauk SSSR* (Morphology, Systematics, and Philogeny of Mollusca: Proc. Zool. Inst. of the Acad. Sci. of USSR), Leningrad, 1979, vol. 80, pp. 44 - 69.

Striganova, B.R., *Pitanie Pochvennykh Saprofagov* (Feeding of Soil Saprophages), Moscow: Nauka, 1980.

Striganova, B.R. and Chernov, Yu.I., Trophic Relations of Animals and Their Zonal-Landscape Features, *Strukturno-Funktsional'naya Organizatsiya Biogeotsenozov* (Structural and Functional Organization of Biogeocenoses), Moscow: Nauka, 1980, pp. 269 - 288.

Williamson, P., Opposite Effects of Age and Weight on Cadmium Concentration of a Gastropod Mollusk, *Ambio*, 1979, vol. 8, no. 1, pp. 30 - 31.