Conservation Prioritization Based on Distribution of Land Snails in Hungary

PÉTER SÓLYMOS*‡ AND ZOLTÁN FEHÉR†

*Evolutionary Genetics and Conservation Biology Research Group of the Hungarian Academy of Sciences, Debrecen University, P.O. Box 3, 4010 Debrecen, Hungary
†Hungarian Natural History Museum, Baross Str. 13., 1088 Budapest, Hungary

Abstract: *The preservation of biodiversity requires high-quality data and efficient methods for prioritizing species and sites for conservation. We examined the distribution data of 121 Hungarian land snail species in a 10 × 10 km resolution grid system. The spatial consistency of the data set varied significantly among regions, so we excluded cells with <5 species. Thus we used data from 512 out of 1052 grid cells. We prioritized Hungarian land snail species based on an additive scoring index ranging from 2 to 10 in which higher scores indicate rarer species. The index included global range size, local frequency, and a correction factor because of the biased frequency estimate or special importance of some species. We analyzed the relationship between protection status and rarity scores for each species. There were 15 unprotected species of land snails out of 30 considered rare, according to the quartile definition of rarity, and 16 protected species fell out of the score range of rare species. Four of these protected species are threatened by other than their restricted ranges (e.g., habitat loss and overexploitation). We prioritized areas by simple-ranking and complementary-areas methods based on species richness (SR), sum of rarity scores (RS), 25% rarest species richness (SQ), and a multiple-criteria index (SSQ = SR × [SQ + 1]). In the area-selection procedures the indices based on the quartile definition of rarity (SQ and SSQ) were slightly more efficient in representing species than species richness and sum of rarity scores. We also made regional comparisons, identified hotspots at the national scale, and investigated the overlap between hotspots and existing reserve areas. The distribution of species richness and rarity among the main geographical regions of Hungary revealed differences between lowland and highland areas. Most of the hotspots were located in the mountain areas and isolated hotspots were identified in lowland areas. All species of Hungarian land snails occurred within current protected areas, but selected hotspots did not overlap with current protected areas in all cases. The location of protected areas in Hungary is adequate to preserve land snails, although we recommend that unprotected hotspots be considered for protection.*

Key Words: area selection, biodiversity, Gastropoda, hotspots, Hungary, Mollusca, rarity, species richness

Priorización de la Conservación con Base en la Distribución de Caracoles Terrestres en Hungría

Resumen: *La preservación de la biodiversidad requiere de datos de alta calidad y métodos eficientes para la priorización de especies y sitios para la conservación. Examinamos los datos de distribución de 121 especies de caracoles terrestres húngaros en un sistema cuadriculado de resolución de 10 × 10 km. La consistencia espacial del conjunto de datos varió significativamente entre regiones, por lo que excluimos celdas con <5 especies. Así, utilizamos datos de 512 de 1052 celdas. Priorizamos a las especies de caracoles terrestres con base en un índice aditivo entre 2 y 10 en el que valores altos indica especies más raras. El índice incluyó el rango de tamaño global, la frecuencia local y un factor de corrección debido a sesgos en la estimación de frecuencia o la importancia especial de algunas especies. Analizamos la relación entre estado de protección y valores de rareza para cada especie. Hubo 15 especies de caracoles terrestres no protegidas en las 30 consideradas*

‡*Current address: Department of Ecology, Faculty of Veterinary Science, Szent István University, Rottenbiller Street 50, 1077 Budapest, Hungary, email solymos.peter@aotk.szie.hu*
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raras, de acuerdo con la definición de rareza, y 16 especies protegidas quedaron fuera del valor de especies raras. Cuatro de esas especies protegidas están amenazadas por causas distintas a su distribución restringida (e.g. pérdida de hábitat y sobreexplotación). Priorizamos áreas con métodos de clasificación simple y áreas complementarias basados en la riqueza de especies (RE), suma de valores de rareza (SR) 25% de la riqueza de especies más rara (SQ) y un índice de criterio múltiple (SSQ = RE × [SQ + 1]). En los procedimientos de selección de áreas, los índices basados en la definición de rareza (SQ y SSQ) fueron ligeramente más eficientes en la representación de especies que la riqueza de especies y la suma de valores de rareza. También hicimos comparaciones regionales e identificamos sitios de importancia a escala nacional e investigamos el traslape entre sitios de importancia y áreas de reserva existentes. La distribución de riqueza de especies y rareza en las principales regiones geográficas de Hungría reveló diferencias entre áreas bajas y elevadas. La mayoría de los sitios de importancia se localizaron en las áreas montañosas y se identificaron sitios de importancia aislados en las áreas bajas. Todas las especies de caracoles terrestres húngaros ocurrieron dentro de áreas protegidas, pero no hubo traslape entre los sitios de importancia seleccionados y áreas protegidas en todos los casos. La localización de áreas protegidas en Hungría es adecuada para proteger a los caracoles terrestres, aunque recomendamos que se considere la protección de los sitios de importancia no protegidos.

Palabras Clave: biodiversidad, Gastropoda, Hungría, Mollusca, rareza, riqueza de especies, selección de áreas, sitios de importancia

Introduction

Resources for the conservation of species diversity are always limited, thus, to maximize the benefits of any actions it is advisable to focus on the highest conservation priorities (Margules & Pressey 2000; Sutherland 2001). Conservation planning often omits invertebrates (Myers et al. 2000), which are largely undocumented but make up a large proportion of species compared with well-documented vertebrate taxa. Land snails are facing an unprecedented survival crisis (Wells 1995; Bouchet et al. 1999) resulting from loss of habitats, overexploitation (Bouchet et al. 1999; Pokryszko 2003), and their poor dispersal capability and small ranges (Solem 1984; Cameron 1999). Rarity relates to vulnerability because rarity makes extinction more probable if other determinants are equal, and it is important in establishing species-based conservation priorities (Heller & Safriel 1995; Mace & Kershaw 1997).

An alternative way to maximize the conservation benefit is to identify hotspots (Reid 1998)—areas with exceptional concentrations of species richness and narrow range endemics that face exceptional degrees of threat. Area-selection methods have gained increasing popularity as part of systematic conservation planning (Margules & Pressey 2000; Pressey & Cowling 2001). Recently, algorithms for site prioritization have been used to identify indicative sets of potential conservation areas (Thiollay 2002; Lei et al. 2003) or to review and strengthen existing reserves (Sarakinos et al. 2001; Benayas & Montana 2003).

We sought to establish conservation priorities among Hungarian land snails, identify rare species and hotspots, and determine whether current conservation actions are adequate to preserve land snails. We used a rarity-related scoring method based on land snail range size and local distribution. Relatively extensive data on the occurrence of land snail species are available for Hungary (Pintér et al. 1979; Pintér & Szigethy 1979, 1980; Fehér & Gubányi 2001). Such data, however, have not been used to set conservation priorities for Hungarian land snails. Based on this scoring method, we investigated whether the protection of land snail species is well founded. We also compared the species richness and the rarity of land snails among regions and identified hotspots at the national scale with different area-selection methods based on species richness and rarity scores. Additionally, we compared the localization of the hotspots in relation to existing protected areas.

Methods

Data Set

We examined the distribution of 121 species of Hungarian land snails in 10 × 10 km resolution Universal Transverse Mercatore (UTM) grid cells (Pintér et al. 1979; Pintér & Szigethy 1979, 1980; Fehér & Gubányi 2001). The modal cell size was 100 km^2. Grid cells adjacent to the country border or to borders between different UTM coordinate zones were slightly different in size.

We clustered the UTM grid cells into main geographical units based on the geographical classification of Hungary (Dévai & Miskolczi 1987). Seven regions were distinguished (Fig. 1): (1) Tisza Plain, (2) Danube Plain, (3) Small Plain, (4) Western Marginal Area, (5) Transdanubian Hills, (6) Transdanubian Mountains, and (7) Northern Mountains.

We did not consider freshwater molluscs because their distribution and dispersing ability are not comparable to those of terrestrial species. We excluded introduced

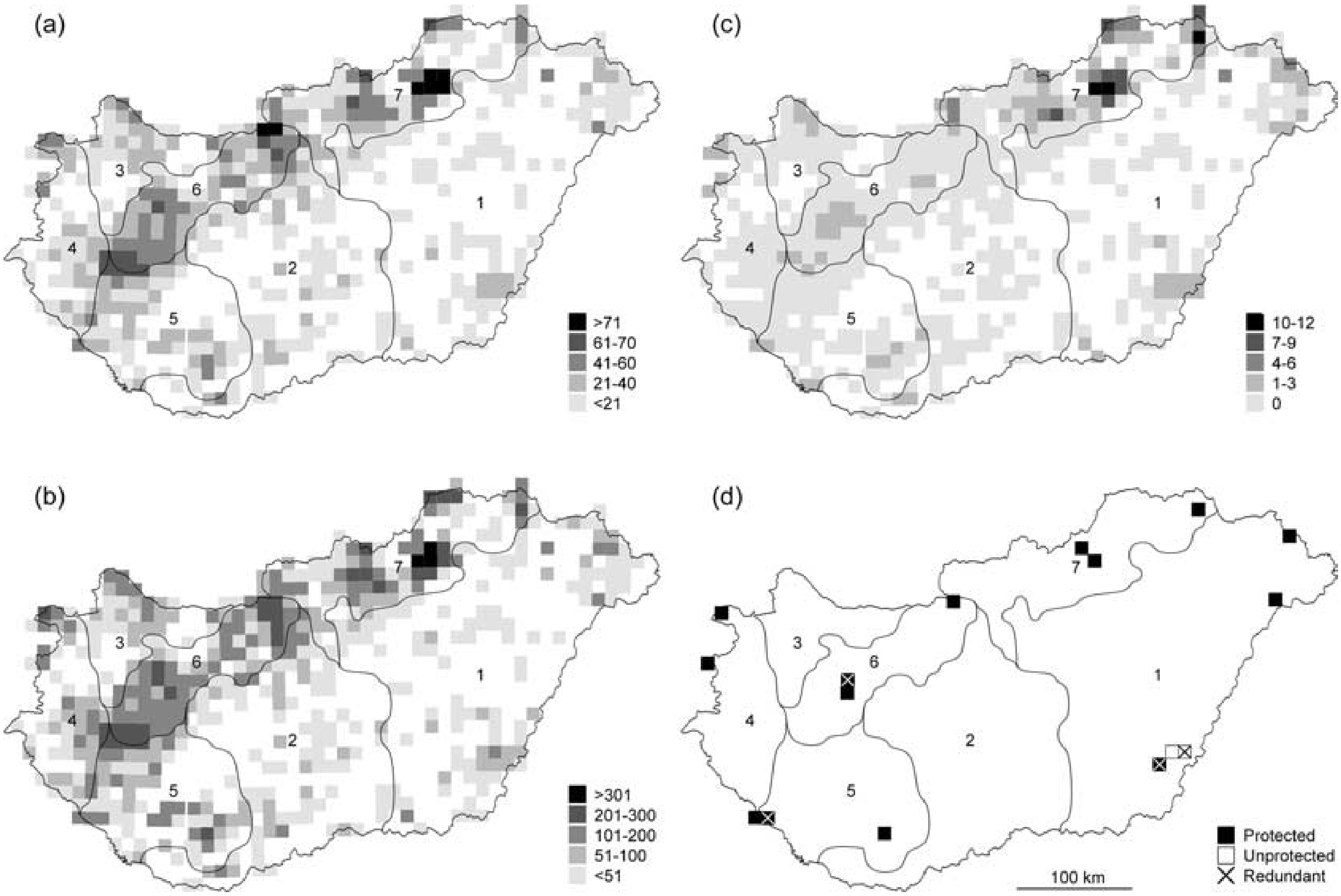

Figure 1. Patterns of snail species richness and rarity among 10 × 10 km grid cells in Hungary (a-c) and the results of area selection (d): (a) species richness (SR), (b) sum of rarity scores (RS), (c) 25% rarest species richness (SQ), different shades of grey correspond to the value of the variables, see legends in each map, (d) complementary grid cells based on the multiple criteria index (SSQ = SR × [SQ + 1]) with protection status indicated (see legend). Numbers represent main geographical regions of Hungary: 1, Tisza Plain; 2, Danube Plain; 3, Small Plain; 4, Western Marginal Area; 5, Transdanubian Hills; 6, Transdanubian Mountains; 7, Northern Mountains. Borders between regions are approximate, cells are clustered into regions according to Dévai and Miskolczi (1987). Original distribution data on land snails from Pintér et al. (1979), Pintér and Szigethy (1979, 1980), and Fehér and Gubányi (2001).

species from the analyses because their conservation value is doubtful (Patten & Erickson 2001). Slugs were also excluded because of scarce data resulting from difficulties with collection and identification (Wiktor & Szigethy 1983).

The published data on occurrence of snail species are far from complete (Pintér 1981, 1985), and such large-scale data have inherent shortcomings (Ponder et al. 2001; Reddy & Dávalos 2003). The geographical coverage of our data set varied considerably among regions (Table 1). The spatial consistency of existing data sets can be improved by spatial modeling techniques, but problems may arise when organisms are dispersal limited (Williams et al. 2002). The variation in spatial coverage may indicate differences in sampling intensity. Methods to correct species richness to account for variation in sampling intensity (Prendergast et al. 1993; Soberón & Llorente 1993; Colwell & Coddington 1994; Keating et al. 1998) are not applicable to coarse-scale presence-only data. Thus, when prioritizing the snails in the UTM grid cells, we excluded cells with <5 species. We used data from 512 out of 1052 grid cells. We assumed that by eliminating grid cells with <5 species, sampling intensity would be even in all analyzed grid cells. This assumption may have biased our results.

We determined the proportion of agricultural areas in all regions based on the CORINE land-cover map of Hungary (Ángyán et al. 2001). Maps in Fig. 1 were made by the DMAP for Windows 7.2c software (Morton 2004).

Species Prioritization

The rarity of each species of Hungarian land snail was evaluated based on an additive scoring index ranging from

Table 1. Statistics of the scoring indices used to prioritize species of land snails and characteristics of the main geographical regions of Hungary.

Index[a] and characteristic	*Total*	*Region[b]*						
		1	*2*	*3*	*4*	*5*	*6*	*7*
SR								
mean	22.8	13.1a	15.2a	21.5ac	23.4bc	22.5b	39.8bd	30.9bc
SD	16.96	9.15	10.21	12.26	15.83	13.29	16.98	21.42
RS								
mean	74.6	37.9a	44.1ab	66.4ab	77.2b	72.2b	135.4c	112.3c
SD	65.27	31.27	33.11	42.04	58.26	46.99	66.05	91.36
SQ								
mean	0.5	0.4a	0.01a	0.1a	0.2a	0.2a	0.2a	2.2b
SD	1.52	0.84	0.11	0.30	0.63	0.40	0.48	3.10
Total number of grid cells in the region	1052	353	222	70	91	123	77	116
Total number of grid cells analyzed (%)	512 (48.7)	117 (33.1)	88 (39.6)	40 (57.1)	54 (59.3)	62 (50.4)	71 (92.2)	80 (69.0)
Proportion of agricultural areas (%)[c]	55.3	70.3	56.3	68.4	43.7	47.3	32.1	31.3

[a]*Abbreviations: SR, species richness; RS, sum of rarity scores; and SQ, 25% rarest species richness.*
[b]*Regions: 1, Tisza Plain; 2, Danube Plain; 3, Small Plain; 4, Western Marginal Area; 5, Transdanubian Hills; 6, Transdanubian Mountains; 7, Northern Mountains. Different letters indicate significant (p < 0.05) differences by Tukey test. Original distribution data on land snails from Pintér et al. (1979), Pintér and Szigethy (1979, 1980), and Fehér and Gubányi (2001).*
[c]*Proportion of agricultural areas was determined after Ángyán et al. (2001).*

2 to 10, in which higher scores indicate rarer species (Sólymos 2004 modified from Heller & Safriel 1995). The index included the following factors: global size of the geographical range (1–4 scale from wide to narrow range), local frequency of occurrence (1–5 scale from common to rare) according to the Hungarian UTM grid data, and a correction factor (0–1 scale).

The geographic range size scores were as follows: 1, beyond Europe (e.g., Eurosiberian, western Palearctic, Palearctic, Holarctic species); 2, large within Europe (in more biogeographical regions, e.g., central European, boreo-montane, Alpine-Carpathian species); 3, restricted to one well-defined biogeographical region (e.g., Carpathian endemic species); and 4, narrow within one biogeographical region (e.g., endemic to northern Carpathians). We based geographic range size on Pusanow (1928), Soós (1943), Ehrmann (1956), Jaeckel et al. (1957), and Kerney et al. (1983). Local frequency scores were indicated as the percentage of UTM grid cells occupied by the species: 1, >25%; 2, 15–25%; 3, 5–15%; 4, 1–5%; and 5, <1% of the total number of grid cells containing data on land snail distribution ($n = 704$). The local frequency was based on Pintér et al. (1979), Pintér and Szigethy (1979, 1980), and Fehér and Gubányi (2001). We used the correction factor to add one point to the index value when Hungarian conservation is essential for the global conservation of a species (e.g., *Kovacsia kovacsi*) or a widespread species has few relictual occurrences in Hungary (e.g., *Oligolimax annularis*, *Discus ruderatus*, *Vertigo moulinsiana*). We also used the correction factor to adjust biased frequency estimates of some species (e.g., *Vallonia enniensis*, *Daudebardia brevipes*). Otherwise, the value of the correction factor was zero. A complete list of the species studied here and their rarity scores and scoring components is available from P.S. upon request.

The local frequency of a species does not necessarily reflect its conservation relevance on the global scale, and this is especially true in geopolitically complex regions (Rodrigues & Gaston 2002). Our additive scoring method for assessing the rarity of land snail species considers the global and local rarity of the species at the same time. Although relative weighting of the components is subjective and may be crucial (Cameron 1998), weighting alters the rank order of the species only in extreme cases (P.S., unpublished).

We tested the difference between the rarity scores of legally protected and unprotected Hungarian land snails with the Mann-Whitney *U* test. Protection status of the land snail species was based on the current protection list of the Hungarian Ministry of Environment (2001), which includes all the Hungarian species listed in the Bern Convention (Council of Europe 1979) and the European Habitats and Species Directive (Council of Europe 1992). Nomenclature of the species is based on the CLECOM (Check List of European Continental Mollusca) classification (Falkner et al. 2001). We used synonyms as well when the names mentioned in the protection list differed from the CLECOM nomenclature.

Area Prioritization and Gap Analysis

Our approach to data organization and analysis followed Williams et al. (1996) with some modifications. We determined local species richness (SR) as the number of species of land snails recorded in each 10 × 10 km UTM grid cell. For assessing the rarity of the fauna in each UTM cell, we calculated the sum of rarity scores (RS) from the rarity index values of the species in each UTM cell as a continuous measure of rarity (Gaston 1994). As a discontinuous measure of rarity, we determined the 25% rarest species richness (SQ) (Gaston 1994; Williams et al. 1996) for the UTM cells by counting the number of species in the upper quartile of all species (score 7–10). Differences among the regions were tested by Kruskal-Wallis nonparametric analysis of variance (ANOVA) and Tukey-type multiple comparisons based on these characteristics of the grid cells.

The above variables showed considerable positive correlations (Spearman rank correlations with Bonferroni correction for levels of significance; SR—RS: $r = 0.987$, $p < 0.001$; SR—SQ: $r = 0.390$, $p < 0.001$; RS—SQ: $r = 0.451$, $p < 0.001$). Based on this, the 25% rarest species richness provides most additional information to species richness; thus, we calculated $SSQ = SR \times (SQ + 1)$ for the multiple-criteria index.

National hotspots were determined in two ways. First, we ranked the grid cells according to local species richness, sum of rarity scores, 25% rarest species richness, and multiple-criteria index. The highest scoring 5% of the grid cells was used as a cut-off value for selecting hotspots in a simple-ranking analysis of the grid cells (Williams et al. 1996).

Second, we used complementarity analysis as an alternative selection technique. The analysis identifies how the greatest species diversity can be conserved at a minimum number of sites (Church et al. 1996; Justus & Sarkar 2002). We analyzed our data through a series of manual complementarity analyses. Each analysis used an iterative selection technique to identify the minimum number of sites necessary to conserve all the species in the data set. These analyses were performed with the same single and multiple-criteria indices listed above. When the first area with the highest score was selected, all the species contained therein were removed from the data set. The selection criteria scores were then recalculated, and this process was repeated until all the species were accounted for.

The algorithm based on species richness is often referred to as the simple-greedy algorithm (Csuti et al. 1997), and it does not take the distributions of rare species into particular account (Moore et al. 2003). The algorithm based on sum of rarity scores gives weight to sites with rare species (Williams et al. 1996; Memstas 2003). The use of 25% rarest species richness in the iteration procedure differs from the conventional definition of progressive-rarity algorithm, which identifies first those areas that contain the rarest species (Moore et al. 2003). The algorithm based on 25% rarest species richness identifies first those areas that contain the highest number of rare species. The algorithm based on multiple-criteria index combines the properties of species richness and 25% rarest species richness.

To improve the performance of heuristic algorithms we performed a redundancy check (Csuti et al. 1997). We determined that all grid cells contained at least one species that was not represented elsewhere (Moore et al. 2003). Ties among complementary grid cells were broken according to 25% species richness, maximum rarity score, and species richness, and we chose the highest-ranking grid cell.

Step-wise heuristic algorithms are considered suboptimal, although there is very little difference in the performance of the heuristics with redundancy checking compared with the optimal solution (Moore et al. 2003). Thus, heuristic algorithms are reliable comparative tools compared with optimality algorithms (Pressey et al. 1996; Csuti et al. 1997).

We decided that species needed to be represented only once for each site selection because land snails have one magnitude higher number of populations in a unit area compared with other taxa of land animals (Hughes et al. 1997).

The result was a set of hotspots for each of the area-selection methods. Then we performed a gap analysis (Burley 1988; Caicco et al. 1995; Kiester et al. 1996) to examine the coincidence of existing reserves and selected hotspots. We investigated the relationship between the grid cells chosen by either method of area selection and the grid cells that contained protected areas at 10×10 km resolution.

Results

Species Prioritization

Fifteen of the 31 protected species had rarity scores ranging from 7 to 10 (25% rarest species), and 16 protected species scored below 7. The rarity scores of the protected species ($n = 31$) were significantly higher (Mann-Whitney $U = 618$, $p < 0.001$) than the scores of the unprotected species ($n = 90$). Unprotected species with rarity scores ranging from 7 to 10 should be considered for protection (e.g., *Platyla banatica*, *Cochlodina fimbriata*, *Macrogastra densestriata*, *Balea stabilis*, *Faustina illyrica*, *Vertigo substriata*, *Macrogastra borealis*, *Aegopinella nitens*, and *Faustina faustina*).

Regional Comparisons

The geographical coverage (proportion of grid cells analyzed) differed considerably among regions. Coverage was lowest in the Great Hungarian Plain (regions 1 and 2) and increased toward the mountain areas (regions 6 and 7) (Table 1). The spatial coverage in the regions showed significant negative correlation with the proportion of agricultural areas (Spearman $r = -0.833$, $p < 0.05$; Table 1).

Species richness varied significantly among the regions (nonparametric ANOVA, $H = 135.2$, df $= 6$, $n = 512$, $p < 0.001$; Table 1, cf. Fig. 1a). The species richness in the UTM grid cells was significantly lower in the lowlands (regions 1–3) and highest in the Transdanubian Mountains (region 6) (Tukey-test, $p < 0.01$; Table 1). Differences in the sum of rarity scores were also significant (nonparametric ANOVA, $H = 148.0$, df $= 6$, $n = 512$, $p < 0.001$; Table 1, cf. Fig. 1b). The sum of rarity scores was significantly lower in the lowlands (regions 1–3) and highest in the Transdanubian and Northern Mountains (regions 6–7) (Tukey test, $p < 0.05$; Table 1). The 25% rarest species richness also varied significantly among the regions (nonparametric ANOVA, $H = 95.8$, df $= 6$, $n = 512$, $p < 0.001$; Table 1, cf. Fig. 1c). The 25% rarest species richness was significantly higher in the Northern Mountains (region 7) than in other regions (Tukey test, $p < 0.001$; Table 1).

Area Prioritization

The simple ranking method with the 5% limit of the grid cells resulted in grid-cell combinations that failed to represent all Hungarian land snail species involved in our analysis, regardless of the index used (Table 2). Simple ranking based on species richness and sum of rarity scores showed very similar results as to high number of species-in-grid-cell records (sum of species representations in the selected grid-cells) (Table 2). Both results contained multiple representation of the most widespread species (Figs. 2a & 2b) and failed to represent seven rare species (*Pomatias rivularis* [= *Pomatias rivulare*], *Pseudofusulus varians*, *B. stabilis*, *Mediterranea hydatina*, *K. kovacsi* [= *Hygromia kovacsi*], *Drobacia banatica* [= *Chilostoma banatica*], *F. illyrica*; Table 2). Simple ranking based on 25% rarest species richness and multiple-criteria index captured fewer species-in-grid-cell records (Table 2), particularly for the most widespread species (Figs. 2c & 2d). Simple-ranking based on 25% rarest species richness and multiple-criteria index failed to represent two species (*Pomatias elegans*, *F. illyrica*; and *Pseudofusulus varians*, *F. illyrica*, respectively).

In contrast, the iterative complementary-areas method captured all the snail species in 1.1–1.3% of the total area of Hungary (Table 2). With redundancy check, all four algorithms showed similar results with few grid cells chosen (Table 2). The algorithm based on 25% rarest species richness performed worse with the highest number of redundant grid cells (Table 2). The redundancy check shifted the distribution of species representation toward the lower numbers of representations (Figs. 2e–2h).

The simple-ranking method identified hotspots mainly in the mountain areas with few hotspots in the lowlands. The complementary areas method revealed hotspots more evenly distributed among the lowland and the highland areas.

Gap Analysis

The UTM grid-cells containing protected areas represented all the Hungarian land snail species. However, the locations of the protected areas and the hotspots identified by different area-selection methods did not necessarily overlap. The proportion of unprotected areas in the selected hotspots varied between 7.1% and 17.3% (Table 2).

The representation of some species reached 25% or more of the Hungarian distribution in unprotected hotspots based on simple ranking (e.g., *Discus ruderatus* in cell DU11, *Drobacia banatica* in cells EU96 and ES27, and *K. kovacsi* in cells ES17 and ES27). Based on the complementary areas method unprotected hotspots in the Small Plain (Szigetköz area, cells XP71 and XP80) and in the Tisza Plain (Békés County, cells ES17 and ES27; Fig. 1d) should be considered for protection based on the

Table 2. Results of the area-selection methods based on different scoring indices in representing land snails among 10 × 10 km grid cells in Hungary and the relation of the selected areas to the distribution of existing protected areas.[a]

Area-selection method and scoring index[b]	*Grid cells chosen (n = 1,052)*	*Number of redundant grid cells*	*Total species represented (n = 121)*	*Total 25% rarest species represented (n = 30)*	*Total species in grid-cell records represented (n = 11,695)*	*Number of selected but unprotected grid cells*
Simple-ranking						
SR	5.0 (53)	—	94.2 (114)	76.7 (23)	26.8 (3136)	11.3 (6)
RS	4.9 (52)	—	94.2 (114)	76.7 (23)	26.3 (3072)	11.5 (6)
SQ	4.6 (48)	—	98.3 (119)	96.7 (29)	18.1 (2122)	16.7 (8)
SSQ	4.9 (52)	—	98.3 (119)	93.3 (28)	23.5 (2744)	17.3 (9)
Complementary areas, with redundancy check						
SR	1.3 (14)	41.7 (10)	100.0 (121)	100.0 (30)	6.3 (734)	7.1 (1)
RS	1.3 (14)	22.2 (4)	100.0 (121)	100.0 (30)	5.9 (695)	14.3 (2)
SQ	1.1 (12)	63.6 (21)	100.0 (121)	100.0 (30)	5.0 (579)	8.3 (1)
SSQ	1.1 (12)	25.0 (4)	100.0 (121)	100.0 (30)	4.9 (568)	8.3 (1)

[a] *Representation results are shown as percentages of the total. Original distribution data on land snails from Pintér et al. (1979), Pintér and Szigethy (1979, 1980), and Fehér and Gubányi (2001).*

[b] *Indices: SR, species richness; RS, sum of rarity scores; SQ, 25% rarest species richness; SSQ = SR × [SQ + 1], multiple-criteria index.*

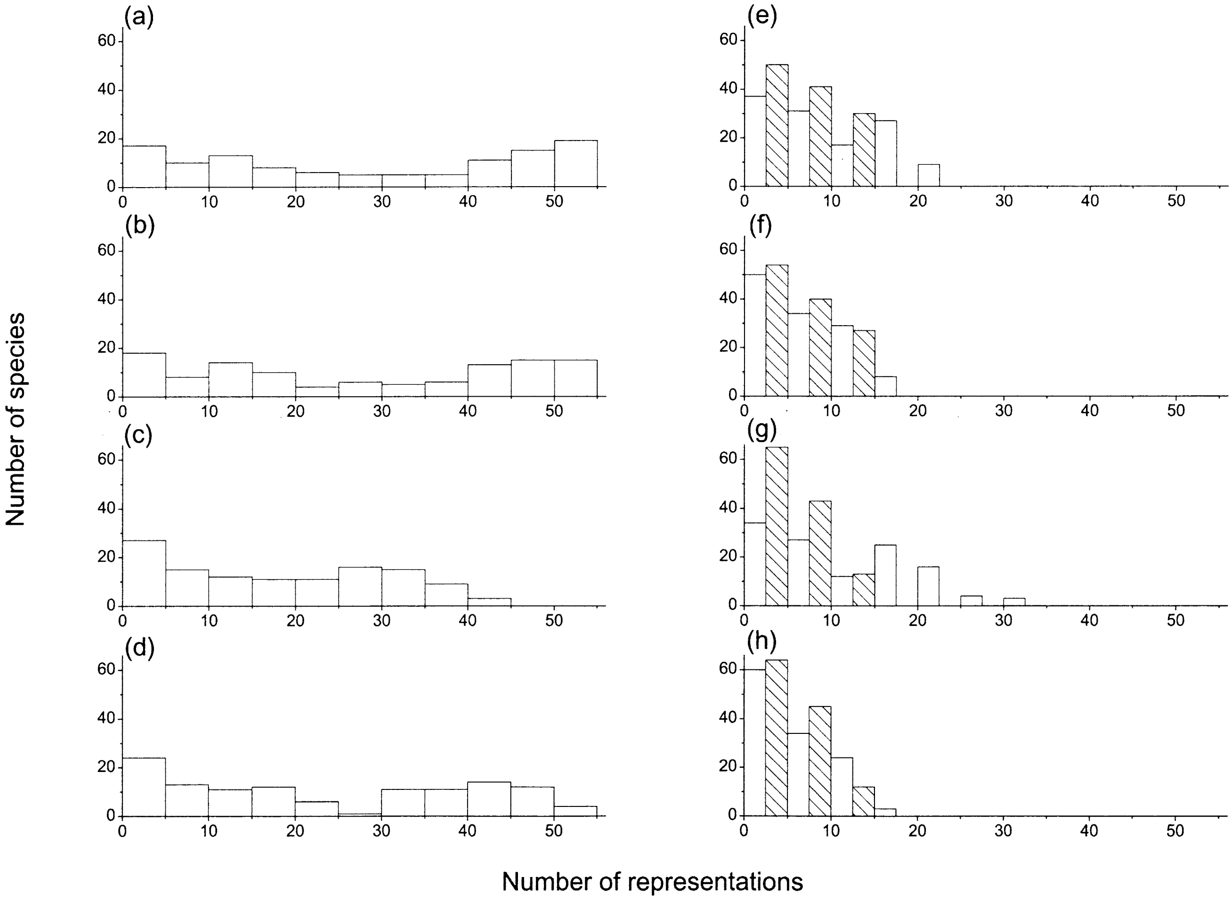

Figure 2. Frequency of species representation in the results by each of the area-selection methods: (a-d) simple ranking based on (a) species richness, (b) sum of rarity scores, (c) 25% rarest species richness, (d) multiple-criteria index, (e-h) complementary areas based on (e) species richness, (f) sum of rarity scores, (g) 25% rarest species richness, (h) multiple-criteria index. Columns with diagonal lines represent results with redundancy check. Original distribution data on land snails from Pintér et al. (1979), Pintér and Szigethy (1979, 1980), and Fehér and Gubányi (2001).

occurrence of rare species (*Aegopinella nitens*, *Drobacia banatica*, *K. kovacsi*). A list of the species representation in the results by each of the area-selection methods is available from P.S. upon request.

Discussion

Species Prioritization

Large-scale biological data sets inevitably incorporate some degree of bias (Ponder et al. 2001; Williams et al. 2002), so the local frequency estimates of the species, and thus the rarity scores, are biased (pseudorarity, sensu Gaston 1994). Another problem is the occurrence of subfossil and fossil pieces appearing as recent specimens in museum collections, as in the case of *Vallonia enniensis* (nonapparent rarity, sensu Gaston 1994). Although we corrected for these biases with a correction factor in the scoring method, only the presence and not the extent of the biases was taken into consideration.

Some species listed in the European Habitats and Species Directive (Council of Europe 1992) and in the World Conservation Union (IUCN) Red List (IUCN 2002) have low rarity scores (e.g., *Vertigo moulinsiana* and *Vallonia enniensis*, rarity score 5; *Vertigo angustior*, rarity score 4). The vulnerability of these species is not related to the size of their geographical range but to the decline of their habitats (Bouchet et al. 1999; Hornung et al. 2003; Pokryszko 2003). The status of the edible snail *Helix pomatia* (rarity score 3) is also remarkable. This species is threatened by seasonal overexploitation in western Europe (Bouchet et al. 1999) and is protected by the Bern Convention (Council of Europe 1979) and the European Habitats and Species Directive (Council of Europe 1992). The low rarity score of the species in Hungary does not seem to support its protection status, although the protection is preemptive to overexploitation and future decline of Hungarian populations (Halmágyi et al. 1997).

Fifteen species were unprotected out of 30 that were among the 25% of rarest species. There were 16 protected species that were not rare according to the quartile (25%) definition of rarity. The legal status of these species needs reconsideration.

Area Selection and Gap Analysis

The distribution data of land snails are well documented compared with other invertebrate taxa in Hungary. Although relatively poor data can be highly effective in the representation of the species (Gaston & Rodrigues 2003), the quality of our data set might have had an effect on the results of area-selection methods. Further occurrences of rare species can be expected in areas of low geographical coverage; consequently, the results of area selection will need reconsideration in the light of new data.

Some rare species (e.g., *C. fimbriata*, *Pseudofusulus varians*, *Macrogastra densestriata*, and *B. stabilis*) were from incomplete UTM cells located along the country border. In these grid cells the data were less extensive because of the smaller surface area, and these species will appear to be more range restricted than they actually are. Restricting the analysis to the political boundaries of Hungary also produced a source of bias. Complementary hotspots tend to represent areas near the periphery of species' ranges more often than expected by chance (Araújo & Williams 2001).

The scoring indices we used were significantly correlated with one another. The species richness and the sum of rarity scores were essentially identical with respect to the correlation between them and the results of the area selection. The correlation was lowest between species richness and 25% rarest species richness. Thus, it was reasonable to incorporate them into one multiple-criteria index. This index performed well in both simple-ranking and complementarity analyses. Lowest correlation between species richness and 25% rarest species richness also indicated that the number of rare species is not necessarily a good predictor of species richness.

The difference in the spatial arrangement of the selected areas based on simple-ranking and complementarity analysis refers to the opposing integration model and the segregation model of nature conservation, respectively (Mader 1991). Highland hotspots selected by simple ranking contained multiple representations of rare and common species, and some of these hotspots were redundant in terms of the principle of complementarity.

The 10×10 km scale of our study is relatively coarse, but the utility of a hotspot approach in setting conservation priorities is greatest at a relatively coarse spatial scale (Curnutt et al. 1994; Bunnell & Huggard 1999). On a finer scale, rare species may play an indicator role in habitat management (Ponder 1995) because land snails are often dispersal limited and face high mortality risks in trying to move from patch to patch (Cameron 1999; Noss 1999). This poor active dispersal ability promotes mosaic diversity (Solem 1984), and characteristic species are associated with definite habitats (Sólymos & Nagy 1997; Sólymos 2001; Deli et al. 2002). Thus, further studies are needed to incorporate small-scale data into geographic information systems.

All Hungarian species of land snails occurred within current protected areas, although the selected hotspots did not overlap with current protected areas in all cases. The coincidence between protected areas and hotspots increased with decreasing number of selected sites, which indicates that a minimum set of sites necessary to protect all the land snail species in Hungary can be found within existing reserves. Additionally, unprotected hotspots (UTM cells DU11, ES17, ES27, EU96, XP71, and XP80) should be considered for protection based on occurrence of rare species (*A. nitens*, *Discus ruderatus*, *Drobacia banatica*, *K. kovacsi*), which are often accompanied by common species and low species numbers in their natural habitats. Prioritization must be part of conservation efforts (Kiester et al. 1996), and it helps in identification of localities where more detailed work must be undertaken.

The Importance of Hotspots

Our study reconfirms that Hungarian hills and mountains maintain high species richness compared with the plains. Higher species richness in the mountains at a coarse scale could be due to higher habitat diversity (Shmida & Wilson 1985), whereas in the plains intensive agriculture has removed the mosaic of varied habitats in many places and mollusc diversity has declined in such areas (Wells & Chatfield 1995). Lower species richness can be explained only partly by the lower collecting effort in lowland areas.

Narrow-range endemics with mainly alpine and Carpathian distribution were restricted to mountain areas (Bába 1982; Hausdorf & Hennig 2003). The Northern Mountains, which are the southernmost part of the Northern Carpathians, were the richest in rare species whereas wide-ranging species were distributed evenly among the regions (Soós 1934, 1943). This pattern is explained by the geographical situation of Hungary (Varga 1995; Sümegi & Krolopp 2002), where regions possess different environmental histories from the Pleistocene up to the present (Fűköh et al. 1995; Krolopp & Sümegi 1995; Rudner & Sümegi 2001). Such areas are called biogeographic crossroads, and representativeness can be achieved with relative efficiency in such areas (Spector 2002).

Saving the biota requires greater efforts to preserve not only the pattern of biodiversity but also the processes and mechanisms that generate and maintain it (Noss 1990; Smith et al. 2001). The alluvial plains along the rivers originating from high-diversity areas were also characterized by rare species of land snails. These areas function as "green corridors" and promote the transfer of different faunal elements (Deli et al. 1995; Obrdlík et al. 1995; Deli & Sümegi 1999). Some areas in the northeastern part of the Tisza Plain served as Quaternary refugia (Willis et al. 1995; Sümegi & Hertelendi 1998).

To enhance the conservation of the land snails in Hungary we established conservation priorities among species, and identified rare species and hotspots with simple-ranking and complementarity analysis based on different scoring indices. In the area-selection procedures the indices based on the quartile definition of rarity (SQ and SSQ) were slightly more efficient in representing species than species richness and sum of rarity scores. Based on the results of species prioritization, the legal status of some land snail species in Hungary needs reconsideration. The results of the area-selection methods revealed that the location of protected areas in Hungary is basically adequate to preserve land snails. In addition to existing reserves, we identified unprotected hotspots that should be considered for protection based on the occurrence of rare species.

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