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RODENTS OF ITALY SPECIES RICHNESS MAPS AND *FORMA ITALIAE*

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ABSTRACT - The most effective way of mapping species diversity, is to choose an abundant, sedentary, small and widespread taxon, such as rodents are.
At present, thanks to a recent improvement of karyology and genetics, knowledge is growing faster at the macro - regional level than at the local level. This is due to a delay in assessing the whole territory. In fact new findings often come from one or very few and small localities.
This implies new problems in mapping species richness. Indeed today, even less than in the past, Richness can be evaluated directly by the crude species number, without any kind of standardisation of data do weighing.
A study of maps of Italian rodents has shown that the more up to date the maps are, the more they coincide with theoretical calculations based on consolidated ecological and biogeographical rules. Richness maps (i.e., weighted and standardised species number) show an even more satisfactory representation of the general geo-ecological outline of the Italian peninsula and its subpeninsulae.

Key words: biodiversity, species richness maps, rodents, taxonomy, Italy.

INTRODUCTION

The need for an extensive mapping of biodiversity, species diversity in particular, is growing more urgent (see I.C.B.P., 1992). It would be especially useful in environmental conservation.
The most appropriate taxa to evaluate taxonomic diversity in an eco-geographical perspective should be: fairly abundant (to reduce sampling efforts and stochastic local disappearance of isolated populations); not too vagrant (to minimise the “noise” linked to individual, stochastic or deterministic displacements); small (to prevent problems of scale when individual territories pertain to the same order of magnitude as the used geographic units or “pixels”); widespread (to prevent bio-geographical effects).
In general, at least among vertebrates, small mammals seem to fulfil such requirements. However, throughout most of the territory, the data required to carry out an exhaustive evaluation of species diversity and all its components, are still lacking. Consequently, there is a need for many more taxonomists and ecologists.
Today, in present conditions, many argue that the study of species diversity must be limited to its richness component, this being the easiest to evaluate. The number of species recorded in a given territory should be a reliable estimate of richness, representing therefore an estimate of species diversity. In fact there has been an increase in knowledge due to improvements in karyology and genetics. However this improvement has occurred at macro-regional rather than at a local level. This is due to a delay in assessing the whole country. In fact new findings often come from one or very few small localities.
So, caution is needed when using non-critical and/or un-weighed data, taken from different years and authors, to compile a territorial synthesis at local level. This is especially so with small mammals, as can be seen by the following, brief analysis.

Recent advances in Italian fauna

Our current knowledge of Italian rodents by no means exhaustive. Since 1965 (Toschi), the number of taxa recorded in Italy has changed noticeably. Furthermore, there are some situations of particular interest and complexity. *Microtus (Terricola) savii* (De Sélys Longchamps, 1838), for example, seems to be a polytypic taxon (see Contoli, 1998 and in press), with clearly recognisable subspecies, such as, *Microtus (Terricola) savii niethammeri* from the Gargano area (with an acrocentric **X** chromosome, NF= 60, M^3 "simplex" to "typica" and, normally, 6 teats); *Microtus (Terricola) savii tolfetanus* from Roman Tuscia (dark and large, normally with C.B.> 24 mm, U.Dia> **7** mm, Jaw> 15 mm and M^3 "typica" not less frequent than "simplex"). *Microtus (Terricola) savii brachycercus* (Von Lehmann, 1961) is now considered to be a true, distinct species, according to Galleni *et al.* (1994).
The above kind of problems are thought to be quite widespread among Italian rodents (*i.e.* the problems concerning *Microtus multiplex* (Fatio, 1905) *v.s M. liechtensteini* (Wettstein, 1927), and concerning the genus *Arvicola*). The need for an immediate reliable estimation of true species richness throughout the Italian peninsula, fully justifies the present methodological effort in our opinion.

Methodological problems with species richness maps

The traditional approach to devising a diversity map is to use distribution maps. These are characterised by presence/absence spots, based on the knowledge of each individual author. However, the reliability of the absences (Contoli, 1986) is clearly subjective, thus making such an approach for comparing different authors and/or taxa unreliable.
The "Atlas of distribution" approach aims to overcome this problem by using standardised recording procedures. The advantage is that it allows for the minimum number of species to be known. Nonetheless, despite being an invaluable approach, this method is heavily affected by the inevitable lack of uniformity in the research and information gathered in different sections of studied territory. So, for example, in the different 1:100,000 map units of Italian territory, the number of recorded individuals of wild rodents ranges up to **3** orders of magnitude. The number of published papers on the same subject ranges up to *2* orders of magnitude. This is even less desirable in a country like Italy, where there is a big and fine-grained environmental heterogeneity. Consequently the number of recorded species can change due to differences in methodology.
The G.I.S. (Geographic Information System) approach tries to overcome such problems; the habitat of each species is characterised on the basis of certain environmental parameters and available records, so as to infer the presumptive geographical range of the given taxon. This important approach enables us to discover another limit, namely the maximum number of species. However, there are some problems with this approach, namely the finite number of studied parameters and their "resolution" power. Especially in large geographical ranges, it is difficult to correctly quantify the bio-geographic ("historical") factors of the real area occupied by the species. A very good example of the use of such methods is in "Mammals of Switzerland", edited by J. Hausser (1995). It shows a striking territorial difference between the results obtained through the different approaches mentioned above.
Clearly, it is difficult to identify the correct level average, because it strongly depends on the taxon under consideration. Very vagrant species are probably influenced by ecological factors. Therefore their actual distribution should be better represented by a G.I.S. approach. On the contrary, less mobile species should be more affected by bio-geographic factors,

and therefore be better represented by an atlas derived map.
However, through a suitable weighting index:

R_t = (N di specie osservate)/[(a · 1 · e)$^{1/3}$]

it is possible to obtain a species richness estimate free from some degrees of freedom, namely those linked to actual land surface of the given geographical unity, sampling effort and the intensity of local research. See Contoli and Penko, 1996, noting that, due to a misprint, the weighting expression reported there should be corrected as follow:

R_t= (N di specie osservate)/(a · 1 . e)$^{1/3}$.

Then, values can be brought back to the frame of the actually known faunistic numbers (Contoli and Penko, 1996) through a suitable adjustment-of data. But, how can one evaluate *a posteriori,* if the adopted weighting approach has actually improved the reliability of results? **A** direct evaluation, implying the knowledge of the exact number of species present in each geographical unity of the studied territory, is practically impossible. However, two kinds of indirect evaluation seem possible.

a) By comparing weighed and unweighed species number with a theoretical prevision of richness, based on some empirical laws, which are already consolidated in ecology, such as insular or peninsular effect, absolute and relative environmental heterogeneity, latitudinal effect (Rapoport, 1982), etc. Especially with peninsulae, this allows for the implementation of some "expected richness" indices such as the Relevant Expected Richness (R.E.R.) index:

R.E.R. = [Σ of relevant ranks of territorial non - isolation (i.e., peninsular width), absolute environmental heterogeneity, relevant environmental heterogeneity] - [Σ of relevant ranks of territorial isolation (i.e., maximum distance "peninsular bottom/top"), relevant latitude].

Caeteris paribus, each disagreement of observed species number with the above expectations can be explained, either via particular factors such as anthropization, or by improper use of methodology.

b) By comparing the weighted species number using two or more distinct sets of observed number of species that differ in their reliability. By reliability we intend improvements in information, linked to updating, optimum use of methodology, etc. If this concords with the most exhaustive set of observed number of species, then the reliability of the weighting procedure should be confirmed. This same criterion also applies, in a sense, to the R.E.R. index. The different level of agreement can be evaluated at first, by direct inspection of the relevant maps and/or of the derived diagrams "or species number v.s main geographic vector", then tested through statistical methods.

The above approaches were applied to the rodents of the Italian peninsula in a large sense. For this purpose, here as in Contoli and Penko (1996), the Italian territory was divided into topographical units (1:100,000 of I.G.M.) and their grid lines were mainly oriented from north-east to south-west, in order to produce transects which were perpendicular to the main peninsular axis. The R.E.R. index was applied to the above transects of non-insular Italy by using:

- the number of topographical units (1:100,000 of I.G.M.) as an estimator of geographical distances;
- the difference between maximum and minimum altitude a.s.l. as an estimator of absolute environmental heterogeneity;
- the above, divided by the respective transect width, as an estimator of relative environmental heterogeneity;
- the ratio: "transect mean latitude/(mean latitude of the northernmost transect - mean latitude of the southernmost one)" as an estimator of relative latitude.

RESULTS AND DISCUSSION

Tables 1 and 2 report the considered rodent species and the average values of the transects examined.

The mean ± σ of the R.E.R. index applied to the transects of each main geo-ecological

Table 1 - Rodent species considered (recently introduced taxa vere not included); from the list due to Amori *et al.* (1993), modified.

Sciurus vulgaris	L., 1758	North to South
Marmota marmota	(L., 1758)	North
Eliomys quercinus	(L., 1758)	North to South
Myoxus glis	(L., 1766)	North to South
Muscardinus avellanarius	(L., 1758)	North to South
Dryomys nitedula	(Pallas, 1778)	North to South
Clethrionomys glareolus	(Schreber, 1780)	North to South
Arvicola terrestris	(L., 1758)	North to South
Microtus agrestis	(L., 1761)	North
M. arvalis	(Pallas, 1779)	North
M. liechtensteini	(Wettstein, 1927)	North
M. multiplex	(Fatio, 1905)	North to South
M. savii	(De Sélys Longchamp, 1838)	North to South
M. subterraneus	(De Sélys Longchamp, 1836)	North
Chionomys nivalis	(Martins, 1842)	North to South
Apodemus agrarius	(Pallas, 1771)	North
A. alpicola	(Heinrich, 1952)	North
A. flavicollis	(Melchior, 1834)	North to South
A. sylvaticus	(L., 1758)	North to South
Micromys minutus	(Pallas, 1771)	North
Rattus norvegicus	(Berkenhout, 1769)	North to South
R. rattus	(L., 1758)	North to South
Mus domesticus	Schwarz and Schwarz, 1943	North to South
Hystrix cristata	L., 1758	North to South

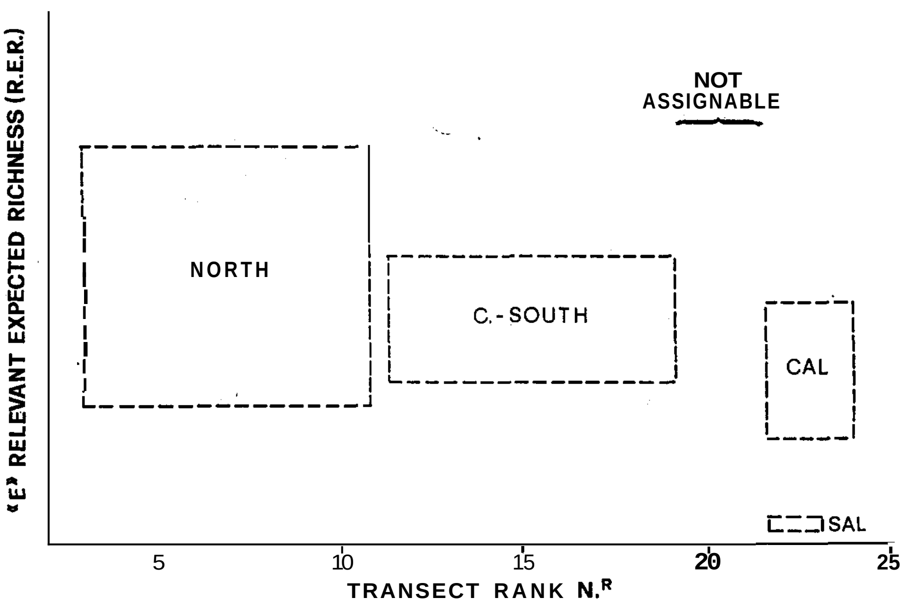

Figure 1 – Mean ± σ values of relevant expected richness (R.E.R. index) in 4 transects blocks along Italy ("E" approach). Note that some transects were not assignables to only one of the above blocks and, so, not utilized. North (NORTH): 132.5±39.6; Middle-South (C.-SOUTH): 118.4±19.1; Salento **(SAL):** 55.8±1.6; Calabria (CAL7): 103.4±20.0.

Table 2 - Average values of each transect (≡"Tr. n.r"), from South to North, according to: "E (RER)"≡ R.E.R. index (expected species richness); "B"≡ observed species n.r, before the "Atlas" data; "W"≡ weighted species n.r, from the same sources of "B"; "A"≡ observed species n.r, after the "Atlas" data.

TR	E (RER)	B	W	A
1	74.50	2.00	14.00	3.00
2	82.00	5.33	14.33	3.00
3	126.00	7.50	14.00	13.13
4	57.50	3.00	7.50	3.00
5	119.00	7.33	15.00	11.50
6	53.50	3.50	7.00	3.00
7	123.50	12.00	15.00	14.50
8	55.00	3.00	6.50	2.50
9	97.50	6.50	14.50	13.00
10	57.00	5.00	8.00	3.00
11	144.00	5.20	10.00	9.10
12	121.50	2.75	9.00	8.50
13	124.50	3.33	9.67	6.25
14	116.50	4.00	11.25	5.25
15	106.50	6.67	13.33	8.33
16	112.00	4.33	12.67	7.00
17	116.50	6.00	12.60	7.40
18	89.00	8.75	14.00	8.75
19	113.00	5.00	12.00	9.67
20	88.00	6.33	14.00	10.67
21	132.00	8.00	12.50	11.25
22	144.50	11.00	14.67	14.33
23	140.00	8.50	13.25	12.38
24	154.50	8.50	12.25	11.50
25	143.50	10.50	13.50	11.00
26	145.00	8.00	11.75	12.13
27	109.50	8.00	12.20	11.20
28	99.00	6.75	12.50	11.38
29	112.50	8.25	13.75	11.25
30	94.00	7.25	11.25	11.25
31	105.50	9.00	15.33	11.80
32	105.00	7.25	13.00	14.13
33	84.00	9.00	17.20	11.60
34	97.50	7.71	16.43	11.50
35	130.50	6.75	17.00	12.94
36	143.50	7.75	17.25	12.88
37	147.50	7.88	18.63	14.00
38	150.50	8.00	19.13	13.00
39	163.50	4.60	18.40	11.60
40	169.50	7.20	19.30	10.80
41	168.00	7.40	19.00	11.45
42	175.00	8.10	19.90	11.90
43	174.00	6.50	18.63	12.19
44	180.00	6.25	19.25	12.75
45	174.50	5.33	18.83	10.67
46	169.50	5.25	18.50	9.00
47	142.00	5.00	19.00	10.50
48	146.50	3.00	19.00	7.00

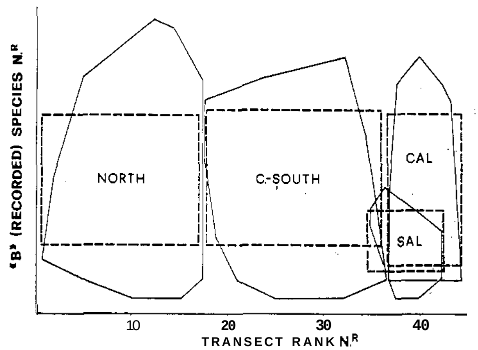

Figure 2 – Mean ± σ values and minimum convex perimeter of distribution "clouds" of recorded before the "Atlas", unweighted species n.r, in the same blocks as in Fig. 1 ("B" approach). North: 6.94±3.51; Middle-South: 7.40k3.50; Salento: 3.69±1.54; Calabria: 6.65±4.19.

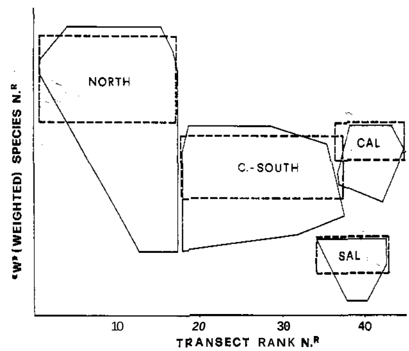

Figure 3 – Mean ± σ values and minimum convex perimeter of distribution "clouds" of weighted data of the "B" approach, in the same blocks as in Fig. 1 ("W' approach). North: 18.31±2.65; Middle-South: 12.61±1.92; Salento: 7.17±1.14; Calabria: 14.26±1.12.

zone of the Italian territory shows the expected pattern clearly (graph "E", Fig. 1), differentiating the North, the centre-South and the two large subpeninsulae of Calabria (as a geomorphologic continuation of the Apennine range) and Salento (much poorer in species, and with almost insular features). On the other hand, the unweighted number of species from data available before the "Atlas of European Mammals" (graph "B", Fig. 2), shows a large dispersion of values in the territorial zones mentioned above.

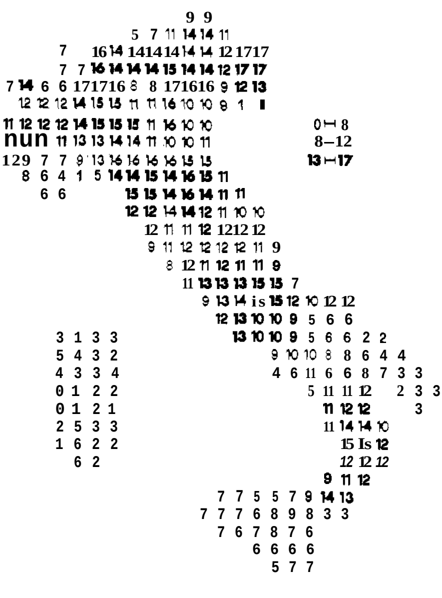

Figure 4 – Map of unweighted species n.r, after the "Atlas".

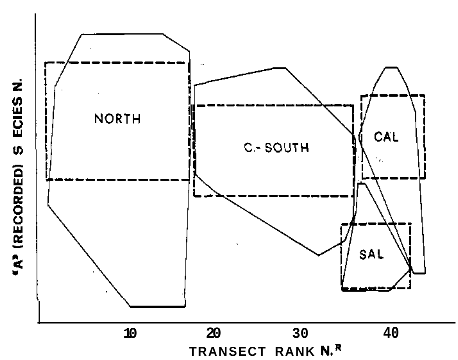

Figure 5 – Mean ± σ values and minimum convex perimeter of distribution "clouds" of recorded after the "Atlas", unweighted species n.r, in the same blocks as in Fig. 1 ("A" approach). North: 11.98±3.71; Middle-South: 10.30±2.66; Salento: 3.67±1.84; Calabria: 11.30±3.01.

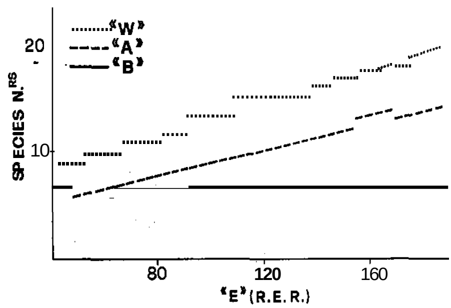

Figure 6 - "B/E", "W/E", and "A/E" regression lines.

This does not allow any discrimination such as that observed through "E". On the contrary, after the weighing procedure of the data in "B" (graph "W", Fig. 3), the grouping of value "clouds" shrinks and eco-geographical zones become more clearly differentiated from one another, similarly to "E'.

Furthermore, another map of the unweighed number of species was derived from provisionally available data after the compiling of the "Atlas" mentioned above (Fig. 4). This data (Mitchell-Jones *et al.*, 1999) has increased from about 50-100%, in respect to the sources in "B". It should be noted that, owing to the necessary transfer of the data from a UTM to an IGM system, the information from the more inclusive UTM map was attributed to each IGM map. The resulting pattern (graph "A", Fig. 5) is now quite similar to both "E' and "B". However, distinction between eco-geographical zones is still somewhat weak. In all the graphs of "B", "W" and "A", one can see the "higher" position, towards the ordinatae axis of Calabria, than that predicted in "E'. This could be due to the well known scarcity of human disturbance in the area, which can enhance richness.

In general, with respect to the improvement of the adopted approach, one can obtain diagrammatic reconstruction of a *forma Italiae* which is quite similar to the expectations based on geography, geomorphology and ecology. This confirms the prevailing rule of the above factors. At least as far as the distributions of rodent species in Italy are concerned.

The average values of transects according to the different procedures mentioned above ("E", "B", "W" and "A"), were tested against each other for correlation (Kendall, Pearson, Spearman indices). All indices gave the same answer: "E" was not significantly ($P > 0.05$, 2 t), albeit positively, correlated with "B", while it was significantly correlated ($P << 0.01$, **2** t) with "A" and, even more, with "W'. Furthermore, "W" was much more correlated with "A" than with "B", despite the fact it derived directly from the last approach.

Finally, the regression lines "W/E" and "B/E" are significantly ($P < 0.05$) not parallel, while "A/E" lies in an intermediate position, also if it appears to be more similar to the first one (Fig. 6).

CONCLUSIONS

The above results seems to confirm both the proposed weighing procedure and the R.E.R. index. On the whole, taking into account the present lack and especially non uniformity of data, biodiversity and in particular its richness components cannot be reliably ascertained directly from any of the methodologies presently being used. Each of which must nevertheless still be considered useful and often necessary approaches. Especially for applied purposes, **a** richness analysis seems to be the most practical device to fulfil a reliable evaluation of the, perhaps unrecognisable, "objective reality".

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