

## Research Article

# IBP': A New Index to Estimate Biogeographical Peculiarity

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The biogeographical peculiarity of a given geographical area is directly linked to the number of its endemic species. This paper aims to formulate an index directly linked to the biogeographical peculiarity of an area. A graphical model and an index of the biogeographical peculiarity are proposed, based on a cumulative sum (i.e., including all the amounts that were added previously). An example of the computations is proposed, based on the number of different types of geographical ranges (i.e., chorotypes) characterizing two different ecosystems; their biogeographical peculiarity of was evaluated on the basis of presence versus absence of carabid species. Both the graphical model and the index mirrored the different faunistic compositions of the ecosystems, because the index reached a higher value where more endemic species have been found. Our investigation has found a new method for evaluating the biogeographical peculiarity of a given area or biota in a simple way. The index could be used for either conservation biogeography (e.g., monitoring of biotic homogenization) or for theoretical studies integrating ecology and biogeography.

## 1. Introduction

The geographical distribution of living organisms is the result of cladogenesis combined with palaeogeographic events (e.g., continental drift) and palaeoclimatic events (e.g., ice ages) [1–3]. For a discussion on cladistic versus evolutionist see [4]. Furthermore, living organisms, whether or not they are undergoing the process of speciation, have to deal with changeable environmental factors (e.g., biotic interactions, human factors, realized ecological niche, and dispersal ability), where their power of adaptation is a decisive factor in determining their present distribution range [5].

The types of geographical range in a given area characterize the natural resources of that area not only taxonomically but also ecologically, because the geographical range of a species is directly linked to several morphofunctional traits of that species, which allow it to survive in a particular environment for sufficient time to cope with the constraints of evolution [6–9]. This is why the species distribution range is not simply a matter of squared kilometers, while it is reasonable to regard it as a biological characteristic of

a species [10, 11]. This way it is an important parameter to be taken into account, for example, in the evaluation of conservation protocols [12–15].

Similarities among geographical ranges make it possible to classify them into types called chorotypes, the sum of which gives the chorological spectrum of a given biota [16, 17]. Each chorological spectrum is a sort of picture of the peculiarity of the taxa in that biota. It is usual to make comparisons among biota, or other geographical units, either from a quantitative point of view on the basis of the number of species belonging to each chorotype, or by a visual comparison of the chorological spectrum histograms [18–21]. Generally, more attention appears to have been paid to endemic species [22] on the basis of either a subjective [21, 23] or an objective criterion [24].

The aim of this paper is to propose a new method for comparing different biota, or ecogeographical units, based on the formulation of an index directly linked to the biogeographical peculiarity of the chorological spectrum in a given unit. Since a high biogeographical peculiarity is a property of a given biota when many species live only within that

biota, for example, when there are many endemic species [4, 25], our aim is to find an index that integrates in a simple measure the weight of the endemic species compared against the weight of the other chorotypes.

From a biogeographical point of view, this index might be a valuable help in cases where, for example, two regions sheltering the same number of endemic species differ in species richness; furthermore it could aid in determining biogeographical peculiarities for conservation policies, for example, the preservation of endemism centres (see [26]) or the habitat conservation for avoiding species range contraction [27].

## 2. Method

The family of carabid beetles was used just as an example of how the index performs. In particular, attention was focused on Italian species. Carabids have been thoroughly studied from the taxonomical and biogeographical point of view, at least in Europe (see <http://www.faunaeur.org/>).

The Italian carabid fauna has several geographical ranges, which can be classified into chorotypes following [28]; see also [29].

The index presently proposed is based on that of [30], applied by [31–38]. In the present paper the index proposed by [30] has been implemented for avoiding the possibility of getting inaccurate results.

**2.1. Data Organization Prerequisites.** For the index computation it is necessary to first classify the biological distinctiveness of an area. This is why we have grouped the chorotypes into chorological categories based on their degree of peculiarity, where a high biogeographical peculiarity is a property of a given biota when many species live only within that biota, for example, when there are many endemic species [4, 25]. In the following the categories (i.e., peculiarity degrees), in roman numeral, are ordered according to decreasing peculiarity—I: regional endemic species; II: Italian species; III<sub>m</sub>, Mediterranean and Euro-Mediterranean species; III: European species; IV: Euro-Asiatic, Euro-Siberian species; and V: Palaearctic, Holarctic species. Such a classification was used with the exclusive intent of testing how the index performs. It is likely that it has no general value outside the Mediterranean basin, but it has the advantage that it is possible to outline the carabid chorological spectrum for any territorial unit (administrative, biogeographical, ecological, and geomorphological).

The categories I and II are the most peculiar biogeographical features of their territorial unit, because they represent a unique faunistic resource of that unit (i.e., endemic species) or of that geographical area (Italian species). Therefore, for achieving the aim of this paper these categories have been ranked at the highest degree of peculiarity.

The category III<sub>m</sub> includes the chorotypes linked to the Mediterranean basin (Euro-Mediterranean, circum-Mediterranean, Sicily-Magreb, and so on). They were grouped in

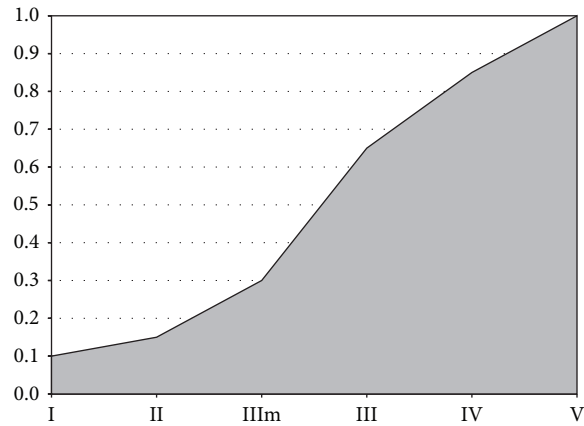


FIGURE 1: Graphical model of the biogeographical peculiarity (GMBP) based on a cumulative sum where the relative abundance of each chorological category has been summed starting from the most peculiar one and including all the amounts that have been added previously ( $IBP' = 0.92$ ).

a separate category for reasons of peculiarity, because the main part of the Italian territory is in the middle of the Mediterranean basin, which is characterized by a particular biogeographical history [39–44]; hence just for the purpose of this example the III<sub>m</sub> category has been considered a little more peculiar to the Italian fauna than category III.

As a second step to compute the index, it is necessary to outline an operational ecological unit (OEU), where it will be possible to analyse the biogeographical spectrum. Administrative, hydrological (catchment), or ecological (CORINE habitats and ecosystems) criteria may be followed for drawing the boundaries of the unit.

These steps are similar to those described in [30, 35] in studies of environmental evaluation for conservation.

**2.2. The Index of the Biogeographical Peculiarity (IBP).** The relative abundance of each chorological category inside any OEU is given by the ratio of species belonging to that category to the number of species living in the OEU. A finite number of species live in any OEU, and there could be some chorological category that is not represented by that species. This means that, for example, if the fauna of a given OEU has been populated by the IV and V categories over time, then that fauna is not peculiar to that OEU. Conversely, if that OEU was a speciation site or a confinement site for geographical relicts, then its fauna may be marked by many endemic species; hence that fauna has high degree of peculiarity to that OEU.

In Figure 1 the chorological diversity of a hypothetical OEU is depicted by drawing a graphical model of the biogeographical peculiarity (GMBP) where the relative abundance of each chorological category was summed, starting from the most peculiar one and including all the amounts that were added previously (see Table 1 for the detailed computation steps). From a mathematical point of view, it is possible to evaluate such a graphical model, by a cumulative sum ( $A$ ),

TABLE 1: Rank ord.: rank order of the categories; chor.cat.: chorological categories; rel.ab.: relative abundance of each category; GMBP: step by step cumulative sum (left) for getting the numbers (right) used to draw the Graphical Model of Biogeographical Peculiarity (Figure 1); IBP': sum (first six cells) and computation (bottom separate cells) of the Index of Biogeographical Peculiarity (in bold).

Rank ord.	Chor.cat.	Rel.ab.	GMBP	IBP'
6	I	.1	.1	.1 +
5	II	.05	.1 + .05 = .15	.15 +
4	III <sub>m</sub>	.15	.1 + .05 + .15 = .3	.3 +
3	III	.35	.1 + .05 + .15 + .35 = .65	.65 +
2	IV	.2	.1 + .05 + .15 + .35 + .2 = .85	.85 +
1	V	.15	.1 + .05 + .15 + .35 + .2 + .15 = 1	1.0 =
				3.05
				(3.05 - 1)/(6 - 1) = .41
				(.41 + 6)/(1 + 6) = <b>.92</b>

TABLE 2: Hypothesized scenario for the IBP. Several cases have been hypothesized in the OEUs from 1a to 6, that is, from the highest to the lowest number of endemic species. To get consistent values of peculiarity the IBP must be weighed, so that the value of each chorological spectrum is gradually decreasing from 1a to 6. If the IBP is computed following [3] it fluctuates from 1a to 6 with inconsistent values (e.g., 2a versus 2b), while the IBP' gradually decreases from 1a to 6 following the gradient of decreasing peculiarity.

Rank ord.	Cases chor.cat.	1a		1b		2a		2b		3a		3b		4a		4b		5a		5b		6	
		%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ
6	I	1	1	0.10	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	II	0	1	0	0.1	1	1	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	III <sub>m</sub>	0	1	0	0.1	0	1	0	0.01	1	1	0.01	0.01	0	0	0	0	0	0	0	0	0	0
3	III	0	1	0	0.1	0	1	0	0.01	0	1	0	0.01	1	1	0.01	0.01	0	0	0	0	0	0
2	IV	0	1	0	0.1	0	1	0	0.01	0	1	0	0.01	0	1	0	0.01	1	1	0.01	0.01	0	0
1	V	0	1	0.9	1	0	1	0.99	1	0	1	0.99	1	0	1	0.99	1	0	1	0.99	1	1	1
	IBP	1		0.100		0.800		0.008		0.600		0.006		0.4		0.004		0.200		0.002		0.000	
	wIBP	7		6.1		5.8		5.01		4.6		4.0		3.4		3.0		2.2		2.0		1.0	
	IBP'	1		0.87		0.83		0.72		0.66		0.57		0.49		0.43		0.31		0.29		0.14	

which is in direct relation to the number of endemic species (i.e., peculiarity) as follows:

$$A = \left( \sum_{j=1}^{nc} \sum_{i=1}^j X_i \right) - 1, \tag{1}$$

where “ $X_i$ ” is the relative abundance of each chorological category (i.e., ratio of species belonging to that category to the total number of species) and “ $nc$ ” is the number of chorological categories (the last category will always add up to over 1, and it is not depicted by an area in the graph, which is why 1 is subtracted).

It is easy to link the grey area of Figure 1 to an index of the biogeographical peculiarity (IBP), ranging between 0 and 1 and directly related to the categories most characterizing the OEU fauna (i.e., endemic species in our example).

The maximum value of  $A$  is reached when all the species belong to the most peculiar category

$$A_{\max} = nc - 1; \tag{2}$$

therefore the IBP is

$$IBP = \left( \frac{A}{A_{\max}} \right). \tag{3}$$

In this way the IBP is directly linked to the chorotype that enhances the biogeographical peculiarity. Furthermore, by simply multiplying the IBP by 100 we would get the percentage of peculiarity. The steps for drawing Figure 1 and its related IBP have been summarized in Table 1.

Worth of attention is the fact that as a consequence of the properties of numerical series IBP gives comparable values when different OEUs are made by the same categories, while it is possible to get biogeographically inconsistent values when the maximum peculiarity category is not the same in the different OEUs, as clearly shown in Table 2.

To get comparable values from any chorological spectrum the IBP must be weighed, so that, for example, a chorological spectrum with at least one endemic species is ranked higher than a chorological spectrum made with all category II species, while the latter gets an intermediate rank between the first spectrum and a spectrum made with all category III<sub>m</sub> species, and so on for as much as the number of categories.

An effective weighing rule is to add the rank order of the most peculiar category to IBP. Several cases have been hypothesized in Table 2, where, for example, in case 2b there are species belonging to categories II and V, thus II being the most peculiar and in 5th position (V is in the 1st position and I is in the 6th position); 5 will be added to the computed IBP

TABLE 3: Carabid species in eight sample sites of the Mediterranean bioclimatic region. Column headings with Le: holm oak, while Su: cork oak. Ci: Mediterranean short bushes. Choro.: chorological category. Mean: mean percentage value of each category. *I*: information value of each category and Evenness value (*E*, bottom cell).

Sclerophyllous forests	Le	Su1	Su2	TLe2	TCi	TLe3	TLe4	TLeQ	Choro.	
<i>Abax ater curtulus</i> Fairmaire, 1856	1								III	
<i>Amara fusca</i> Dejean, 1828					1				IV	
<i>Brachinus brevicollis</i> Motschulsky, 1844		1							IV	
<i>Brachinus crepitans</i> (Linné, 1758)		1							V	
<i>Calathus cinctus</i> Motschulsky, 1850	1				1				V	
<i>Calathus fuscipes latus</i> Serville, 1821			1		1			1	IIIIm	
<i>Calathus montivagus</i> Dejean 1831	1	1	1	1	1	1	1	1	II	
<i>Calosoma sycophanta</i> (Linné, 1758)					1		1	1	V	
<i>Carabus convexus convexus</i> Fabricius, 1775							1		IV	
<i>Carabus coriaceus mediterraneus</i> Born, 1906				1	1				III	
<i>Carabus lefebvrei lefebvrei</i> Dejean, 1826		1	1						II	
<i>Cychrus italicus</i> Bonelli, 1809	1								II	
<i>Cymindis axillaris</i> (Fabricius, 1794)					1				V	
<i>Harpalus attenuatus</i> Stephens, 1828		1							IIIIm	
<i>Harpalus rubripes</i> (Duftschmid, 1812)		1	1						IV	
<i>Harpalus sulphuripes sulphuripes</i> Germar, 1824		1			1				IIIIm	
<i>Laemostenus cimmerius cimmerius</i> (Fischer-Waldheim, 1823)					1				IIIIm	
<i>Masoreus wetterhallii wetterhallii</i> (Gyllenhal, 1813)		1	1						V	
<i>Microderes scaritides</i> Sturm, 1818					1				IV	
<i>Microlestes luctuosus</i> Holdhaus, 1904					1				IV	
<i>Nebria brevicollis</i> (Fabricius, 1792)		1							IV	
<i>Nebria kratteri</i> Dejean, 1831				1				1	III	
<i>Notiophilus rufipes</i> Curtis, 1829		1				1	1	1	III	
<i>Ophonus pumilio</i> (Dejean, 1829)					1				IIIIm	
<i>Percus bilineatus</i> (Dejean, 1828)	1	1							II	
<i>Platyderus neapolitanus jannonei</i> Binaghi in Magistretti, 1955		1	1		1		1	1	II	
<i>Pseudomasoreus canigoulensis</i> (Fairmaire & Laboulbène, 1854)		1	1	1			1		IIIIm	
<i>Pseudoophonus rufipes</i> (Degeer, 1774)						1			V	
<i>Steropus melas italicus</i> (Dejean, 1828)		1	1	1	1			1	III	
<i>Trechus quadristriatus</i> (Schränk, 1781)				1	1			1	IV	
Species number	5	14	8	6	15	3	6	8		
									Mean	<i>I</i>
V	0,20	0,14	0,13	0	0,2	0,33	0,17	0,13	0,16	0,29
IV	0	0,21	0,13	0,17	0,27	0	0,17	0,13	0,13	0,27
III	0,20	0,14	0,13	0,50	0,13	0,33	0,17	0,38	0,25	0,35
IIIIm	0	0,21	0,25	0,17	0,27	0	0,17	0,13	0,15	0,28
II	0,6	0,29	0,38	0,17	0,13	0,33	0,33	0,25	0,31	0,36
I	0	0	0	0	0	0	0	0	0	0
										<i>E</i> = 0,87

of 0.008, giving a weighed  $wIBP = 5.008$ . Consequently, the new weighed maximum value will be

$$wA_{\max} = IBP_{\max} + nc = 1 + nc; \quad (4)$$

therefore the new  $IBP'$  will be

$$IBP' = \frac{wIBP}{wA_{\max}}, \quad (5)$$

and in our example  $IBP' = 5.008/7 = 0.72$ .

An application example of the IBP is given using real data from 16 sample sites located in two different types of ecosystems (i.e., two OEUs) in the Calabria region of southern Italy [45]. In this case, the boundaries between OEUs are ecological and not geographical. Carabid beetles were sampled with pitfall traps. Eight samples were collected in Mediterranean sclerophyllous forests (holm and cork oak), while the others were collected in oro-Mediterranean beech forests (Tables 3 and 4). The mean relative abundance in

TABLE 4: Carabid species in eight beech forests. Column headings: different localities and same vegetation. Choro.: chorological category. Mean: mean percentage value of each category. *I*: information value of each category and Evenness value (*E*, bottom cell).

Beech	Fa3	Fa2	Fa	AsF	AF3	AF1	AbF	AF2	Choro.	
<i>Abax ater curtulus</i> Fairmaire, 1856	1	1	1	1	1	1			III	
<i>Paranchus albipes</i> (Fabricius, 1796)					1				V	
<i>Bothriopterus quadrifoveolatus</i> (Letzner, 1852)						1			III	
<i>Metallina lampros</i> (Herbst, 1784)							1		V	
<i>Ocydromus latinus</i> (Netolitzky, 1911)								1	III	
<i>Calathus fracassii fracassii</i> Heyden, 1908						1	1		II	
<i>Calathus fuscipes latus</i> Serville, 1821		1		1	1			1	IIIIm	
<i>Calathus montivagus</i> Dejean 1831	1	1	1	1	1	1	1	1	II	
<i>Calathus piceus</i> (Marsham, 1802)	1		1	1	1	1	1	1	III	
<i>Carabus convexus convexus</i> Fabricius, 1775	1	1	1		1			1	IV	
<i>Carabus lefebvrei lefebvrei</i> Dejean, 1826	1	1	1	1		1	1	1	II	
<i>Carabus preslii neumeyeri</i> Schaum, 1856	1	1	1		1	1	1	1	III	
<i>Cychrus italicus</i> Bonelli, 1809	1	1	1		1	1	1		II	
<i>Leistus fulvibarbis fulvibarbis</i> Dejean, 1826						1			IIIIm	
<i>Leistus spinibarbis fiorii</i> Lutshnik, 1913	1	1						1	III	
<i>Nebria kratteri</i> Dejean, 1831	1	1	1	1	1	1	1	1	III	
<i>Notiophilus biguttatus</i> (Fabricius, 1779)								1	V	
<i>Notiophilus rufipes</i> Curtis, 1829						1			III	
<i>Ophonus jeanneli</i> Sciaky, 1987	1								III	
<i>Platyderus neapolitanus jannonei</i> Binaghi in Magistretti, 1955	1	1	1		1	1	1		II	
<i>Haptoderus apenninus</i> (Dejean, 1831)					1	1	1	1	II	
<i>Platysma nigrita</i> (Paykull, 1790)			1						V	
<i>Steropus melas italicus</i> (Dejean, 1828)			1	1					III	
<i>Pterostichus micans</i> Heer, 1841		1							II	
<i>Pterostichus ruffoi</i> Sciaky, 1986						1	1	1	I	
<i>Synuchus vivalis</i> (Illiger, 1798)	1								IV	
<i>Trechus quadristriatus</i> (Schrank, 1781)	1								IV	
<i>Trichotichnus nitens</i> (Heer, 1838)			1						III	
Species number	13	11	12	7	11	14	11	12		
									Mean	<i>I</i>
V	0	0	0,08	0	0,09	0	0,09	0,08	0,04	0,14
IV	0,23	0,09	0,08	0	0,09	0	0	0,08	0,07	0,19
III	0,46	0,36	0,50	0,57	0,36	0,43	0,27	0,42	0,42	0,36
IIIIm	0	0,09	0	0,14	0,09	0,07	0	0,08	0,06	0,17
II	0,31	0,45	0,33	0,29	0,36	0,43	0,55	0,25	0,37	0,37
I	0	0	0	0	0	0,07	0,09	0,08	0,03	0,11
										<i>E</i> = 0,74

the sites was evaluated for each chorological category and used to compute the Evenness Index (i.e., the ratio between the information content and the maximum possible information; see Tables 3 and 4) and the IBP.

### 3. Results

Table 2 shows a possible scenario of the index variation from complete peculiarity (case 1a) to lack of peculiarity (case 6). In the examples of Table 2 there are six chorological categories, with rank order ranging from 6 for the most peculiar (I) to 1 for the least peculiar (V), so that the chorological spectra

including category I will be weighed by adding the value of 6, while spectra including at most category II will be weighed by adding the value of 5, and so on ending with spectra made with category V that will be weighed by adding the value of 1. In Table 2 it is possible to see that the values of IBP fluctuate from left to right, while  $IBP^I$  gradually decreases consistently with decreasing peculiarity from case 1a to case 6.

A cumulative sum and a chart were linked to each sampled OEU, as in Figures 2 and 3. In sclerophyllous forests the weight of the categories ranges between 0.13 and 0.31, while in beech forests the range is between 0.04 and 0.42 (see Tables 3 and 4). Weights are more evenly

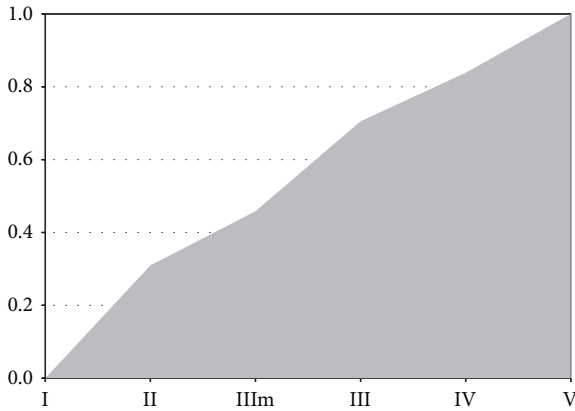


FIGURE 2: Graphical model of the biogeographical peculiarity in the sclerophyllous forests of Table 3 ( $IBP' = 0.78$ ).

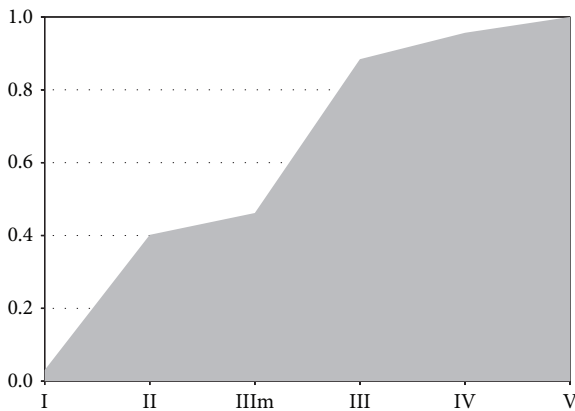


FIGURE 3: Graphical model of the biogeographical peculiarity in the beech forests of Table 4 ( $IBP' = 0.94$ ).

distributed among categories in the sclerophyllous forests than in the beech forests, as confirmed by the Evenness Index, which is 0.87 for the former, while it is 0.74 for the latter. The Evenness is mirrored also by the graphical model of the biogeographical peculiarity, as the sclerophyllous chart (Figure 2) rises gradually to 1, while the beech chart (Figure 3) is broken into two steps with increasing steepness among the breaks.

Figures 2 and 3 show that the Italian endemic species, together with European species, are more abundant in beech forests than in sclerophyllous ones, while Mediterranean species are more abundant in sclerophyllous forests. Only a few species with a wide distribution range (categories IV and V) colonized mountain environments, while they are as abundant as Mediterranean species in sclerophyllous forests.

The species composition is mirrored by the IBP of each ecosystem. The  $IBP'$  is higher where the fauna was populated by more peculiar species, that is, beech forests ( $IBP' = 0.94$ ), where the index is 16% points higher than in sclerophyllous forests ( $IBP' = 0.78$ ).

The index has also been calculated for each sampled site; two series of eight values have been obtained and then

statistically compared by the  $U$  test. The  $IBP'$  is significantly different for the two ecosystems ( $U = 9$ ,  $n_1 = n_2 = 8$ , and  $P = 0.02$ ).

To get a very high degree of peculiarity in beech forests there should have been fewer European species (category III) and a significant number of endemic species (category I).

#### 4. Discussion

The index of biogeographical peculiarity gives a new method for integrating in a single measure of peculiarity the chorological spectrum characterizing the present species composition of a given OEU. This means that the IBP takes into account the relative weight of every chorological category, that under a biological point of view means to give a value to the whole biogeographical history of a given OEU and not only to the endemism phenomenon alone. As a consequence, total species richness of the OEUs will have an influence on the IBP, because if, for example, two OEUs sheltering the same number of endemic species differ in species richness, then the OEU with the higher species richness will probably have smaller IBP. This is a property the index was intended for.

Another property lies in the possibility to compare the peculiarity of different OEUs belonging to similar biogeographical areas. The application of the index at the local scale is needed because the characterization of the species is based on chorological categories that should be common. Furthermore this index is adaptable, because different operational units can be chosen, either administrative boundaries or biogeographical units or surfaces.

From a mathematical point of view, the most important factor influencing the index variability is the order of the chorological category weights, because if the highest weights are found at the beginning of the numerical series then the  $IBP'$  will have high values, while the opposite case will lead to low  $IBP'$  values. The IBP is a value linked with a numerical series, but complex mathematical operations are needed to link numerical series with a single value; this is why the mathematical simplicity of the IBP is limited by the fact that any IBP is linked to a set of graphs slightly different from each other (i.e., the curves smooth in slightly different ways), while the GMBP is unique for each chorological spectrum. As a general rule, the higher the  $IBP'$ , the higher the contribution of the categories leftward of the ordinal sequence ( $x$ -axis). The highest  $IBP'$  is reached when all the species belong to the leftmost category.

This method can be accurately applied to areas with a complete knowledge of the biota in question, since a unique new record of an endemic species can change the score; moreover the significance among small differences of the index must be interpreted under a biogeographical rather than numerical perspective.

As outlined by [23] an index should not be used as an *a priori* tool in biogeographical studies, because living organisms are characterised by different bioevolutionary features. We think that the chorological spectrum of a given region is strongly affected by the biogeographical history of that region, whose understanding should be framed into the

processes of speciation, extinction, and population dynamic [10]. The comparison of different  $IBP'$  values may be an aid in such understanding, as for the above example where carabid species belonging to category II have been found to be very abundant in beech forests. It is possible that this is a consequence of the glacial ages, which exerted a strong influence on the dispersal of living organisms by pushing species southward along the Italian peninsula [46, 47]. Then, during interglacial periods, the cold-preferring fauna was forced to find shelter upward either latitudinally or altitudinally on the mountains, where some species evolved to endemic status. In the coastal part of the Calabria, the new (in the sense that it appeared during the Pleistocenic era) biome of the Mediterranean sclerophyllous forest was colonized by widely tolerant species with a wide geographical range. Palaeoclimatic circumstances gave rise to a more peculiar fauna in temperate montane environments than in the Mediterranean belt. This greater peculiarity is clearly mirrored by the  $IBP'$  values.

Spatiotemporal features of chorotypes are the result of evolutionary events as well as of proximate causes [48], and focusing on the typology of the chorotype (e.g., local, regional, and national endemism) should give more insight into the global nature of spatial variation in geographic range sizes and a better understanding of how these relate to ecosystems [49, 50]. This means that it is possible to adapt or to improve the index with chorotypes tailored to the particular features (if any) of the studied territory.

The index is useful not only to outline the faunistic or floristic history of a region but also to highlight the concentration of endemic species for addressing conservation priorities [51]. This is why it can be used to evaluate biotic homogenization [52], because it is sensitive to the incoming of allochthonous species, which change the chorological spectrum. Allochthonous species are clearly the less peculiar ones, so that they must be placed near the end of  $x$ -axis, even by adding a new category if necessary. Furthermore, the graphical model linked to the  $IBP'$  may be used to monitor temporal changes towards homogenization or differentiation or for hypothesizing future scenarios to optimize broad-scale surveillance of invasive species [17], either in the case of the spreading of individual species [53] or when native versus nonnative species interaction has to be evaluated [54].

From a general point of view, evaluation for conservation should be based not simply on species richness but also on species life strategies. The chorotype of a species either mirrors its adaptive pathway, because it is the manifestation of complex interactions between species' niche and environmental pressures [55], or is a short-term response at the population level [56]. This is why it is indirectly related to species life strategies. The  $IBP'$  which synthesizes the set of chorotypes of a given region could be used for studies integrating ecology and biogeography [57] or for paralleling analysis from a hotspots approach [58] or for monitoring conservation efficiency in priority areas for conservation [59].

In the light of some global change monitoring approaches based on species range study (e.g., global coherence approach [60]; global versus local diversity variation [61]; projecting models of current species range [62]), policies focusing on

multispecies management could be helped by applying one evaluation index (i.e., the  $IBP'$ ) for comparing plants and animals responses to climate variation.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

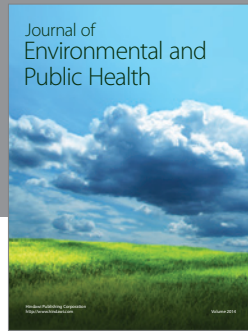
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