Global 'hotspots' of biodiversity

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Biodiversity, which refers to a variety in living organisms, is not equally distributed across the globe. It is well known that some habitats, particularly tropical forests among terrestrial systems, harbour a greater diversity of species. Although these habitats cover only 7% of the Earth's land surface, they contain more than half the species of the entire world[1]. Despite this richness, tropical forests are one of the most fragile systems of the whole world. This diversity of species is under severe pressure of extinction and if Wilson's[1] conservative estimate of a total of 5 million species is considered then, with the current rate of deforestation and other anthropogenic factors, 7500 species are becoming extinct every year. Given the budgetary constraints on conservation and competing demands of other forms of land use, some system thus becomes necessary for identifying the areas in which certain allocation of effort will maximize species survival. Through different methodologies, areas of conservation priorities – the 'hotspots' rich in biodiversity but under constant threat of destruction – have been determined. Eighteen global hotspots have been identified so far out of which two lie in India, namely the Western Ghats and the Eastern Himalaya. The subsequent paragraphs highlight the culmination of the efforts made by scientists all over the world to prioritize these hotspots so inimical to human survival.

Overall species richness

The first approach was to identify countries with the highest number of species. Studying the overall species richness of different countries, Mittermeier[2] and Mittermeier and Werner[3] concluded that tropical countries possess 70% of the world's species diversity and introduced the concept of 'megadiversity countries'. Subsequently, Mc Neely *et al.*[4] used country-specific species list of vertebrates, swallow tail butterflies, and higher plants to identify 12 such megadiversity countries. These are: Mexico, Columbia, Ecuador, Peru, Brazil, Zaire, Madagascar, China, India, Malaysia, Indonesia and Australia.

Although this approach looks relatively simple in that it involves species inventory within a geopolitical boundary, it suffers from serious drawbacks. Firstly, it takes into account only the species richness but not the uniqueness of the flora and fauna of a country or a region. Secondly, there may be considerable overlap in the species composition between different regions with high species numbers, particularly if they are situated close to each other geographically. Taking mammal species in two megadiversity countries as an example: 271 species of mammals (excluding Cetaceae) have been recorded from Ecuador and 344 from neighbouring Peru, but 208 of these are common to both the countries. Finally, high-diversity regions may contain large numbers of very widely distributed species which are currently neither threatened nor otherwise of special conservation concern.

Endemic species diversity

An alternative approach is to identify areas with greatest numbers of

Table 1. The global 'hotspots' and the number of endemic species[7]

Region	Higher plants	Mammals	Reptiles	Amphibians	Swallow tail butterflies
Cape Region (South Africa)	6000	15	43	23	0
Upland Western Amazonia	5000	NA	NA	70	NA
Atlantic coastal Brazil	5000	40	92	168	7
Madagascar	4900	86	234	142	11
Philippines	3700	98	120	41	23
Borneo (North)	3500	42	69	47	4
Eastern Himalaya ((India)	3500	NA	20	25	NA
SW Australia	2830	10	25	22	0
Western Ecuador	2500	9	NA	NA	2
Colombian Choco	2500	8	137	111	0
Peninsular Malaysia	2400	4	25	7	0
Californian Floristic province	2140	15	15	16	0
Western Ghats (India)	1600	7	91	84	5
Central Chile	1450	NA	NA	NA	NA
New Caledonia	1400	2	21	0	2
Eastern Arc Mts (Tanzania)	535	20	NA	49	3
SW Sri Lanka	500	4	NA	NA	2
SW Cote d'Ivorie	200	3	NA	2	0
Total	**49,955**	**375**	**892**	**737**	**59**

Table 2. Biodiversity scores for Afrotropical antelopes[7,10–12]

Step no.	Cumulative diversity (%)	Conservation area name	Country
1	23.95	Serengeti National Park (NP)	Tanzania
2	37.65	Kafue (NP)	Zambia
3	47.64	Haut Dodo Faunal Reserve (FR)	Cote d'Ivorie
4	56.96	O. Rime–O. Achim	Chad
5	61.81	Yangudi Rassa NP	Ethiopia
6	66.52	Odzala NP	Congo
7	71.79	W. Pretorius GR	S. Africa
8	75.29	Manovo G St Floris NP	Central African Republic
9	78.10	De Hoop National Reserve	S. Africa
10	80.91	Gorongosa NP	Mozambique

'endemic' or 'restricted range' species. Focusing on the tropical forests, Myers[5] identified 10 regions or 'hotspots' that are characterized by high concentrations of endemic species and are experiencing unusually rapid rates of extinction or loss. These 10 areas cover only 292,000 km^2 or 0.2% of the Earth's surface. Together, however, they harbour 34,400 endemic species (27% of all the tropical forest species, 13% of all the plants worldwide).

In a subsequent publication, Myers[6] added further eight terrestrial hotspots, four in the tropical forest areas and four in the Mediterranean-type regions, thus making a total of 18 hotspots. Together these contain 454,955 endemic plant species, or 20% of the world's plant species, in just 746,400 km^2 or 0.5% of the Earth's land surface. Table 1 shows the number of endemic species present in the 18 hotspots.

Despite its limitations, like difficulty in quantifying threats to the existing habitat, and the paucity of distributional information available for many of the world's plant species, Myers' work signified an important step toward determining areas where conservation requirements are greatest and where the potential benefits from conservation measures could be maximized. As seen in Table 1, Western Ghats and Eastern Himalaya, in India, surfaced out to be two important global hotspots rich in endemic species.

Interestingly, there exists, though not always, a very strong correlation between the endemism in one taxonomic group with that of the others in a region. Bibby *et al.*[8] examining the available data showed that the countries with high number of endemics in one vertebrate group often had high number of endemics in other vertebrate groups too. These correlations are, however, generalizations, and interpretations should be made only after a detailed statistical analysis. Myers' hotspots are also rich in endemism and hence are ideal sites for conservation priority as conservation of these sites might result in protection of a large number of endemic species in different taxonomic groups.

Critical faunal analysis

Ackery and Vane Wright[9] introduced the concept of critical faunal analysis, which is now increasingly being used to determine the conservation priorities. In this approach the entire set of taxa within the group under consideration, e.g. single-country endemic amphibians, reptiles or mammals, constitutes the 'complement'. The site at which the greatest proportion of this complement is represented is given the first priority. The portion of the complement not included is called the residual complement. The priority for the second site selection can be determined by identifying the site that adds the greatest proportion of the residual complement to the initial choice. The process can be continued in a stepwise sequence until all the sites have been considered and allocated a priority. Critical faunal analysis was applied for conservation of antelopes in the African protected areas (Table 2).

Serengeti National Park in Tanzania is the richest single site for antelopes and accounts for 23.95% of the complement (antelopes). The second important site in terms of priority for conservation measure is the Kaufe National Park, Zambia. These two parks together hold 38% of the African antelope population. When the third and fourth sites of priority are added to the list, i.e. Haut Dodo Faunal Reserve, Cote d'Ivorie and Achim Faunal Reserve, Chad, 56.96% of the antelope diversity is covered.

Conclusion

Newer methods are constantly being evolved to evaluate the areas of conservation interest. This evaluation is not being restricted to species level only but higher levels in taxonomic hierarchy like the 'genus' and the family are taken into consideration. This enables conservation sites harbouring a monotypic genera like that of giant panda *Ailuropoda melanoleuca* to get a precedence over the other sites. Vane Wright *et al.*[13] suggest using a diversity measure based on information content of the branching pattern of evolution (cladestic diversity).

The approaches highlighted above have thus enabled the policy makers and planners to prioritize sites and target the limited resources available for conservation practices optimally. On the basis of Myers' 18 hotspots World Wide Fund for Nature India (WWF-India) has launched a Biodiversity 'Hotspots' Conservation Programme in 1992 which directs special focus on two of the Indian hotspots, the Western Ghats and the Eastern Himalaya. The author is presently coordinating projects at these two sites from the WWF-India Secretariat at New Delhi.

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RESEARCH NEWS

Can animals count?

Ten years ago Tetsuro Matsuzawa of the Primate Research Institute at Kyoto University in Japan put a 5-year-old female chimpanzee named Ai through a severe test and she came out with flying colours. Matsuzawa taught Ai to distinguish between 14 different objects, namely, padlock, glove, shoe, glass, bowl, brick, rope, paper, ball, box, spoon, brush, key and pencil. Ai was shown one of these objects on a computer screen and she had to press a key that she had been taught to associate with that object. Similarly, Ai was taught to identify 11 colours, namely, red, orange, yellow, green, blue, purple, pink, brown, white, grey and black. Finally, Ai was also taught to identify numbers from 1 to 6 by pressing the appropriate key when she was shown a certain number of objects on the computer screen. In the final exam she was shown any one of the five objects, pencil, paper, brick, spoon and toothbrush. The objects could be red, blue, yellow, green or black and there could be anywhere from 1 to 5 of these objects. This makes 125 possible combinations. Ai was given 830 tests in each of which she was required to identify correctly the object, its colour and the number of objects Her accuracy score exceeded 98 5%, enough to gain her entrance to any IIT of her choice! And it is not as if Ai had not worked hard. In 95 separate sessions, she had spent a total of 68 hours and 21 minutes at the computer and had gone through 28,799 trials before taking the final exam. But the bottom line is that chimps can count[1]. It is a bold step from this to ask if honey bees can also count, but that is exactly what Chittka and Geiger at the Institute for Neurobiology at Berlin have done[2].

Chittka and Geiger worked with honey bees in a large meadow of about 2 km^2 which was practically devoid of any natural landmarks that could be used by the bees. This made it convenient for them to set up their own landmarks, which consisted of tetrahedral-shaped yellow tents, 3.46 m in height. As in almost all such training experiments, the bees were trained to accept sugar solution from a feeder kept at some distance from the hive. In the training period there were four tents in the flight path of the bees at distances of 75, 150, 225 and 300 m from the hive (Figure 1). The feeder was at 262.5 m from the hive and thus exactly midway between the third and the fourth tents. The bees, therefore, had to cross three tents on their way to the feeder

In the first experiment, they put a second feeder midway between the second and the third tents at a distance of 187.5 m from the hive, retaining the original feeder midway between the third and the fourth tents at a distance of 262.5 m from the hive (Figure 1). Out of the 39 bees tested, only one went to the new feeder between the second and the third tents while all the remaining 37 went promptly to the feeder between the third and the fourth tents. This shows that the bees had actually learned to go to the original feeder at a distance of 262 5 m between the third and the fourth tents and that (with one exception) they were not merely going to the first feeder they encountered What rules might the bees have employed to reach the feeder of training and ignore another feeder that came even earlier in their flight path, with such accuracy? Since there were no other natural landmarks, there are really only two possibilities. One is that the bees had some independent method of estimating that they had flown 262.5 m and the other is that they learned to cross three tents before searching for the feeder.

In the second experiment five tents were placed in the flight path of the bees at regular intervals of 60 m. One feeder was placed midway between the fourth and the fifth tents (Figure 1). This amounted to a distance of 270 m from the hive and thus very close to the location of the feeder during the training The second feeder was placed between the third and the fourth tents and this amounted to a distance of 210 m from the hive. Feeder one, between the fourth and the fifth tents at 270 m, would be very nearly the correct choice by the criterion of distance from the hive but the wrong choice by the criterion of the number of tents to cross Conversely, feeder two, between the third and the fourth tents at 210 m from the hive, would be the wrong choice by the criterion of distance from the hive but the correct choice by the criterion of the number of tents to be crossed. Of the 65 bees tested, 48 (74%) landed on feeder one – correct by distance but wrong by number. It is important, however, that the remaining 17 (26%) landed on feeder two – wrong by distance but correct by number. This proportion of bees landing on feeder two is significantly greater than the proportion of bees (1/38) that landed on feeder two in the first experiment, where feeder two was wrong even by the criterion of the number of tents crossed.

In the third experiment six tents were placed at regular intervals of 50 m from the hive (Figure 1). Now there were three feeders. Feeder one was between the fifth and the sixth tents and thus at a distance of 275 m from the hive, feeder two was placed between tents four and five and thus at a distance of 225 m from the hive and feeder three was placed between tents three and four and thus at a distance of 175 m from the hive. Feeder three would be the correct