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Global patterns of tiger beetle species richness (Coleoptera: Cicindelidae): their use in conservation planning

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Abstract

The total numbers of tiger beetles species known in 157 countries or subregions in the world are reported and updated, based on both published and unpublished information. Also reported are the numbers and rate of species endemic to each country and the species richness patterns (total surface in km^2/number of species) of the individual countries considered. The most current publications providing new data or detailing the tiger beetles of a country or political region are provided as references. A comparison is made between the present rank order of the 30 countries with the highest number of recorded tiger beetle species and their rank order in 1992, as well as between currently known species numbers in each of the major biogeographical regions of the world and the numbers registered in 1992. These comparisons show considerable constancy in spatial patterns and reinforce the claim for taxonomic stability of tiger beetles and for their reliability for use, especially by non-scientific decision-makers in conservation policy and management plans.

Keywords: Tiger beetles; Cicindelidae; Species numbers; Taxonomic stability; Conservation

1. Introduction

Species numbers can be used as one of several factors to quantitatively assess conservation priorities (Heywood, 1995). Species numbers data, especially at relatively small spatial scales, can be accurately analyzed and modelled to make predictive assessments and incorporate robust comparisons (Carroll and Pearson, 1998; Pearson and Carroll, 1998). However, conservation decisions are often made by politicians and non-scientists, many of whom lack the experience and training to fully appreciate or incorporate the accuracy of these complex statistics and models in their decisions. As a supplement to these sophisticated quantitative approaches, total species numbers and endemic species numbers are a readily understood concept that decision makers without statistical or modelling backgrounds can comprehend (Collins and Morris, 1985; Mittermeier and Mittermeier, 1997). If these species numbers are available for many countries and regions, the impact of the comparisons can be significant, even if the biological significance is more limited. Thus the total number of species and that of species restricted or endemic to each country can represent powerful tools for assessing the biodiversity of the given country, for emphasizing its relative importance for the preservation of global biodiversity, and for gaining political support of conservation issues.

One of the taxa for which these world wide species numbers are available is the family of tiger beetles (Cicindelidae). Over 2300 species of tiger beetles have been described to date, and they are found around the world except Antarctica, the Arctic above 65° latitude, Tasmania and some isolated oceanic islands like Hawaii and the Maldives. In altitude, their distribution ranges from about 3500 m above sea level to −220 m below sea level. The last compendium of tiger beetle species numbers found in countries of the world (Pearson and Cassola, 1992) has been used widely in conservation

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publications (Samways, 1994; Mittermeier and Mittermeier, 1997; McGeoch, 1998; New, 1998). In the eight intervening years, however, over 300 species have been newly described or recognized, others have been synonymized or downgraded to subspecific rank, and information from many new countries has been obtained. Therefore, this paper has two goals. First, by including these new species and recent political boundaries, we present an update of species totals and species richness patterns of individual countries of the world. Second, by comparing these current numbers of tiger beetle species to those known in the early 1990s, we test the stability of tiger beetle taxonomy and their reliability for use as biodiversity indicators in conservation policy decisions and management planning.

2. Methods

We determined the number of tiger beetle species and the number of endemic species presently known for each of 157 countries and subregions (Table 1). We based these numbers on the latest world catalogue of species (Wiesner, 1992) and on current literature that details tiger beetles of individual countries and political regions. As far as possible, all published and unpublished data presently known to us have been included.

While giving the surface area (in km^2) and the total number of tiger beetle species for all countries of the world examined, we chose the 30 most diverse countries in terms of tiger beetle species richness and ranked them. We then calculated the number of km^2 per species for each country, a value which provides a rough comparison of their respective species richness that helps control for differences in the size of countries: low numbers obviously indicate high biodiversity (which may reflect a wide range of habitats and biogeographic influences), while high numbers indicate low species richness (which reflects few or unfavourable habitats, and sometimes insufficient field work).

Pearson and Cassola (1992) considered that among the important criteria of an appropriate bioindicator taxon was a stable and reliable taxonomy, and claimed that tiger beetles met this criterion. To test whether there is even taxonomic coverage of tiger beetle species globally, we compared the relative numbers in the current list with that in the early 1990s. If the proportions of species across the world's surface in the two periods are similar, despite the addition of so many newly described species resulting from the uncoordinated effort of collectors and taxonomists (these surpass the total number of species we predicted would eventually be described for some of these regions: Pearson and Cassola, 1992), we would consider the claim for taxonomic stability reinforced. Likewise, we determined the current number of species known from the major biogeographical areas of the world, and compared them with the numbers registered in 1992. Subspecies have not been considered in these reckonings.

3. Results

The total number of species presently known for the world tiger beetle fauna is 2328. The total number of species and endemic species within each country are given in Table 1. A comparison (Table 2) of the 30 highest ranked countries (30 was an arbitrary cut off point) by number of tiger beetle species to their rank in 1992 (see Pearson and Cassola, 1992) shows they are correlated ($r = 0.87$; no probabilities are given because of spatial autocorrelations). A similar comparison (Table 3) of the current rank by number of tiger beetle species in each of 11 major biogeographical regions of the world to that of these regions in 1992 (world catalogue: Wiesner 1992) shows they are also correlated ($r = 0.98$). Of the ca. 300 additional species added to the world's total since 1992 (see Pearson and Cassola, 1992), most of them are known to be endemic to individual countries. Nine countries each added 15 or more endemic species in this time period (Laos 48, the Philippines 36, Australia 35, Vietnam 21, Indonesia 20, Brazil 19, India, Ecuador and Mexico 15) and account for a great part of the total number of species discovered or recognized worldwide since 1992. All these countries except Ecuador are in the top 13 ranked countries for total tiger beetle species, and this pattern of new species discovery apparently reflects actual species richness patterns and not just collector bias or differential national effort. These results thus confirm our hypothesis that tiger beetles provide a stable and reliable taxonomic group for global use as a bioindicator.

Consequently, a careful analysis of Tables 1 and 2 can help identify countries with particularly rich and endemic tiger beetle faunas, characteristics that can be used to help determine priorities for any international conservation effort. For example, the Philippines appear to be, despite their small land surface, the fifth richest country of the world in absolute number of tiger beetle species (km^2/species ratio: 2294) and very high in percentage and absolute number of endemic species (fourth highest). Also, apart from New Zealand and New Caledonia (which have fully endemic but small tiger beetle faunas), Madagascar is immediately evident as a country with a rich, almost completely endemic, tiger beetle fauna. This comparison clearly emphasizes the biotic significance of such a country relative to the three only other countries (Indonesia, India and Brazil) that have richer total numbers but lesser endemic faunas.

Thus, data on tiger beetles as biodiversity indicators could prove to be useful for helping identify areas of maximum collective diversity (Humphreys et al., 1995),

Table 1
Total number of tiger beetle species known from within the political boundaries of the world's countries, the number of species endemic to each country, the surface area of each country and literature references from which species numbers are calculated

Region/country	Total number of species	Number of endemic species	% Endemic species	Surface area (km^2)	References
Nearctic					
Canada	29	0	0	9,976,140	9, 99, 140, 184, 192, 213
Mexico	122	60	49	1,972,550	9, 38, 52, 131, 178, 192, 194, 213
USA	120	50	42	9,372,610	7, 9, 65, 97, 140, 192, 194, 213
Neotropical					
Argentina	65	13	20	2,780,090	38, 131, 171, 175, 176, 183, 213, 222
Belize	10	0	0	22,965	88, 131, 213
Bolivia	103	23	22	1,098,580	34, 38, 42, 74, 80, 131, 144, 222, 224
Brazil	203	122	60	8,511,970	64, 131, 176, 213, 222, 227
Chile	6	1	17	756,630	146, 213
Colombia	78	10	13	1,138,910	34, 38, 56, 57, 88, 92, 131, 213, 222
Costa Rica	41	4	10	51,100	34, 87, 88, 90, 92, 131, 176, 213, 222
Cuba	12	4	33	110,920	63, 213
Ecuador	89	27	30	283,560	34, 40, 54, 92, 131, 135, 141, 222
El Salvador	16	1	6	21,041	86, 88, 90, 131, 213
Guatemala	25	1	4	108,890	86, 88, 89, 90, 131, 213, 222
Guayanas	36	7	19	448,793	131, 176, 213
Hispaniola	10	3	30	76,190	63, 213
Honduras	19	2	11	112,088	86, 88, 89, 90, 131, 213, 222
Jamaica	4	0	0	10,990	63, 213
Nicaragua	25	0	0	139,000	86, 88, 90, 131, 176, 213
Panama	50	11	22	75,650	34, 86, 88, 90, 92, 131, 176, 213, 222
Paraguay	54	3	6	406,750	131, 157, 176, 213, 222, 224
Peru	96	20	21	1,285,215	34, 38, 92, 131, 139, 145, 174, 176, 213, 222
Trinidad and Tobago	4	1	25	5128	63, 213
Uruguay	18	0	0	177,510	5, 58, 213, 222
Venezuela	58	11	19	912,050	34, 38, 79, 131, 152, 176, 213, 222
Palaearctic					
Afghanistan	18	0	0	649,970	68, 101, 102, 213
Albania	4	0	0	28,750	38, 70, 213
Algeria	14	1	7	2,381,740	213
Armenia	14	0	0	28,400	70, 98, 213
Austria	10	0	0	83,850	70, 103, 213
Azerbaijan	19	0	0	86,600	70, 98, 213
Baltic (Lithuania, Latvia and Estonia)	5	0	0	174,000	6, 70, 98, 213
Belarus	5	0	0	207,600	70, 98, 213
Bulgaria	11	0	0	110,910	70, 73, 77, 213
Cyprus	8	0	0	9250	66, 83, 213
Denmark	4	0	0	43,070	75, 213
Egypt	10	0	0	1,002,000	3, 105, 163, 213
Finland	4	0	0	337,030	70, 100, 213
France	16	0	0	543,990	8, 70, 213
Georgia	15	0	0	69,700	70, 98, 213
Germany	9	0	0	356,130	70, 143, 180, 213
Great Britain	5	0	0	244,030	70, 213
Greece	14	0	0	131,940	20, 70, 213
Holland	6	0	0	36, 150	70, 182, 213
Hungary	8	0	0	93,030	70, 213
Iran	36	2	6	1,648,000	70, 119, 213
Iraq	13	0	0	438,446	213
Israel	8	0	0	20,770	66, 105, 136, 213
Italy	17	1	6	301,250	18, 70, 213
Kazakhstan	28	1	4	2,669,800	68, 70, 98, 151, 213
Kyrgyzstan	12	0	0	198,500	68, 70, 98, 213
Kuwait	6	0	0	17,818	4, 45, 46, 213
Luxembourg	5	0	0	2586	10, 11, 213
Lybia	10	1	10	1,759,540	72, 164, 213
Malta	4	0	0	315	16, 213
Moldova	10	0	0	33,700	70, 98

(continued on next page)

Table 1 (*continued*)

Region/country	Total number of species	Number of endemic species	% Endemic species	Surface area (km^2)	References
Mongolia	20	2	10	1,565,000	68, 70, 213
Morocco	14	3	21	458,730	19, 213
Norway	4	0	0	324,220	70, 100, 213
Oman	12	1	8	300,000	45, 137
Poland	7	0	0	311,730	13, 14, 70, 213
Portugal	10	0	0	92,020	70, 84, 213, 226
Romania	10	0	0	237,500	70, 213
Russia	42	0	0	17,100,000	68, 70, 98, 213
Saudi Arabia	11	0	0	2,153,170	46
Spain	17	1	6	504,750	70, 84, 213, 226
Syria	19	1	5	185,180	60, 213
Sweden	4	0	0	442,750	70, 100, 213
Switzerland	8	0	0	41,290	70, 109, 213
Tadjikistan	20	0	0	143,500	68, 98, 213
Tunisia	14	1	7	163,610	96, 213
Turkey	26	2	8	779,450	38, 59, 61, 70, 94, 95, 187, 188, 213
Turkmenistan	24	1	4	448,100	68, 98, 213
Ukraine	18	0	0	603,700	70, 98, 213
United Arab Emirates	8	0	0	250	214, 216, 221
Uzbekistan	20	0	0	447,400	68, 98, 213
Yemen	12	2	17	482,680	51, 225
Yugoslavia (former)	8	0	0	255,800	38, 70, 213
Ethiopian					
Angola	73	23	32	1,246,700	30, 31, 38, 107, 186, 213
Benin	17	0	0	112,620	38, 203, 213
Botswana	30	1	3	600,370	31, 38, 107, 213
Burkina Faso	12	0	0	274,200	38, 203, 213
Burundi	9	0	0	27,830	38, 205, 213
Cameroon	47	3	6	470,200	38, 203, 213
Central African Republic	49	1	2	622,980	38, 203, 213
Chad	16	0	0	1,284,000	38, 213
Congo-Brazzaville	29	0	0	342,000	38, 213
Congo (ex-Zaire)	128	30	23	2,344,880	15, 22, 31, 38, 107, 213
Eritrea	18	0	0	125,000	21, 191, 213
Ethiopia	54	12	22	1,096,900	21, 191, 193, 199, 200, 203, 205
Gabon	12	0	0	267,670	38, 213
Gambia	13	0	0	11,290	38, 213
Ghana	16	0	0	238,540	38, 213
Guinea	33	0	0	245,860	36, 196, 198
Guinea-Bissau	35	0	0	36,120	167, 168, 169
Guinea (Equatorial)	12	0	0	28,050	38, 213
Ivory Coast	26	2	8	322,460	38, 195, 203, 213
Kenya	54	6	11	582,640	31, 38, 190, 203, 205
Liberia	12	0	0	111,370	38, 213
Malawi	50	0	0	118,480	31, 38, 107, 204, 213
Mali	19	0	0	1,240,140	36, 38, 169, 203, 213
Mauritania	13	0	0	1,030,700	38, 213
Mozambique	58	11	19	799,380	29, 31, 38, 107, 213
Namibia	41	5	12	824,280	29, 30, 107, 108, 206, 207
Niger	13	0	0	1,267,000	38, 213
Nigeria	27	0	0	923,770	38, 203, 213
Rwanda	8	0	0	26,337	38, 213
Senegal	37	0	0	196,190	197
Sierra Leone	22	0	0	71,740	23, 27, 213
Somalia	33	9	27	637,660	41, 67, 200, 205, 213
South Africa	98	34	35	1,221,040	29, 30, 38, 107, 108, 166, 203, 213+
Sudan	38	0	0	2,505,810	38, 69, 93, 203, 213
Tanzania	86	23	27	939,470	38, 107, 115, 201, 202, 203, 205
Togo	24	1	4	56,600	38, 213
Uganda	36	0	0	235,880	31, 38, 203, 213
Zambia	63	1	2	746,250	31, 38, 107, 203, 213
Zimbabwe	68	4	6	389,300	29, 31, 38, 107, 213

(*continued on next page*)

Table 1 (*continued*)

Region/country	Total number of species	Number of endemic species	% Endemic species	Surface area (km^2)	References
Madagascar					
Comore Islands	2	0	0	2,170	85, 213
Madagascar	176	174	99	587,040	38, 39, 85, 106, 114, 116, 213
Mauritius Island	3	2	67	1,860	85, 213
Réunion Island (with Juan de Nova and Glorieuses Islands)	6	5	83	2,520	85, 213
Seychelles Islands	1	0	0	410	85, 213
Oriental					
Bangladesh	47	1	2	133,910	2, 38, 125, 213
Bhutan	23	0	0	47,000	92, 104, 125, 213
Burma (Myanmar)	103	19	18	657,740	2, 38, 125, 132, 143, 158, 160, 203, 212, 213, 224
Cambodja	42	0	0	176,520	38, 125, 159, 213, 224
China, PR	101	21	21	9,326,410	38, 68, 70, 78, 98, 125, 150, 179, 212, 213
India (with Nicobar and Andaman Island)	208	108	52	3,287,590	2, 38, 68, 125, 156, 161, 212, 213, 218
Indonesia	237	125	53	1,904,560	210
Irian Jaya	59	23	39	414,800	24, 26, 38, 48, 49, 50, 111, 165, 210, 212, 213, 223
Java	41	9	22	138,204	124, 129, 210, 212, 213
Kalimantan	49	3	6	535,834	38, 125, 129, 170, 210, 212, 213
Sulawesi	92	71	77	186,145	28, 33, 35, 110, 125, 154, 189, 208, 209, 210, 212, 213
Sumatra	71	16	23	473,616	38, 125, 210, 211, 212, 213, 219
Lesser Sundas	18	5	28	195,219	38, 125, 213
Maluku	19	0	0	74,705	24, 38, 125, 210, 212, 213
Japan	24	6	25	372,540	118, 125, 213
Korea (N and S)	15	0	0	219,360	70, 91, 213
Laos	107	22	21	230,800	38, 117, 125, 155, 159, 161, 162, 212, 213, 224
Malaysia	115	39	34	331,800	138
Peninsular	58	6	10	131,235	38, 125, 128, 138, 212, 213, 215
Borneo (incl. Brunei and Sabah)	88	32	36	200,565	32, 38, 43, 125, 138, 170, 212, 213, 217, 220
Nepal	64	2	3	140,800	2, 121, 125, 147, 148
Pakistan	33	1	3	796,100	2, 68, 213
Philippines	130	111	85	298,170	37, 38, 125, 133, 185, 212, 213
Sri Lanka	56	35	62	64,740	2, 120, 122, 126, 128, 213
Taiwan	28	10	36	36,180	1, 38, 125, 212, 213
Thailand	123	29	24	511,770	2, 38, 124, 125, 129, 130, 149, 159, 212, 213, 224
Vietnam	114	40	35	325,360	38, 44, 47, 125, 127, 130, 159, 181, 189, 212, 213, 218, 224
Australia and Oceania					
Australia	116	104	90	7,617,930	62, 81, 111, 172, 173, 177, 178, 213
Fiji	2	2	100	18,270	213
New Caledonia	16	15	94	17,400	38, 55, 213
New Zealand	14	14	100	269,060	12, 213
Papua New Guinea	79	46	58	451,710	24, 25, 26, 38, 48, 50, 203, 213
Solomon Islands	20	11	55	27,540	25, 213
Vanuatu	3	0	0	12,190	213
Western Samoa	2	1	50	2840	213

as they should be indicative of total biological diversity (McGeoch, 1998). In fact, if faunistic or floristic analyses of other taxonomic groups confirm the species richness patterns and the rankings of countries in biodiversity that have been found here for the tiger beetles, efforts should be better focused on these countries and their habitats, in order to help maintain their part of the global biodiversity.

Table 2
Rank order of the 30 countries with the highest number of recorded tiger beetle species and a comparison to the rank order of each by number of species in Pearson and Cassola (1992)

Rank/country		Total number of species	km^3/species	Number of endemic species	% Endemic species	Rank in 1992
1.	Indonesia	237	8,036	125	52.7	1
2.	India (with Andaman and Nicobar Islands)	208	15,805	108	51.9	2
3.	Brazil	203	41,931	122	60.1	3
4.	Madagascar	176	3335	174	98.9	4
5.	Philippines	130	2294	111	85.4	10
6.	Congo (ex-Zaire)	128	18,319	30	23.4	5
7.	Thailand	123	4161	29	23.6	8
8.	Mexico	122	16,168	60	49.2	6
9.	USA	120	78,105	50	41.7	7
10.	Australia	116	65,672	104	89.7	16
11.	Malaysia	115	4574	39	33.9	9
12.	Vietnam	114	2854	40	35.1	13
13.	Laos	107	2157	22	20.6	24
14.	Bolivia	103	10,666	23	22.3	15
15.	Burma (Myanmar)	103	6386	19	18.4	14
16.	China, PR	101	93,341	21	20.8	12
17.	South Africa	98	12,460	34	34.7	11
18.	Peru	96	13,388	20	20.8	17
19.	Ecuador	89	3186	27	30.3	18
20.	Tanzania	85	11,055	24	28.2	21
21.	Papua New Guinea	79	5718	46	58.2	19
22.	Colombia	78	14,601	10	12.8	36
23.	Angola	73	17,078	23	31.5	20
24.	Zimbabwe	68	5725	4	5.9	26
25.	Argentina	65	42,771	13	20.0	22
26.	Nepal	64	2200	2	3.1	23
27.	Zambia	63	11,845	1	1.6	27
28.	Venezuela	58	15,725	11	19.0	30
29.	Mozambique	58	13,782	11	19.0	33
30.	Sri Lanka	56	1156	35	62.5	25

Table 3
A comparison of the number of tiger beetle species currently known from each of the major biogeographical regions of the world and the number registered in Wiesner's Catalogue (1992)

Biogeographical region	Present number of spp	Number of spp. in Wiesner's (1992) World catalogue
Nearctic	184	171
Neotropical	467	340
Palaearctic	110	102
Ethiopian	395	351
Madagascar	186	177
Indian subcontinent	260	231
China and Japan	115	105
South East Asia	530	400
New Guinea and Pacifica	138	132
Australia	104	70
New Zealand	14	13
World fauna	*2328*	*1923*

4. Discussion

Our point here is that simple analyses of insect groups, provided they are well-known worldwide (as tiger beetles certainly are), can provide useful information for conservation planners and administrators. Because most final conservation decisions are made by non-professional conservation biologists, we emphasize the importance of simple but reliable species numbers within political boundaries and easily recognized biogeographic areas. These "political" data can then be used in concert with advice from scientists and formal analysis of more sophisticated spatial data to make final decisions of conservation import. In a previous paper (Pearson and Cassola, 1992) we had already offered a preliminary analysis of critical tiger beetle faunas, essentially an assessment of the distribution of endemic species throughout the world, based just on political boundaries. Instead of giving here an updated version of such a list, our present Table 1 offers the total number of tiger beetle species for all the countries considered, as well as the number and the rate of endemic species, thus giving the basic data for directing national and international attention to biologically important countries, states and provinces.

It is obvious that much more detailed work would be needed to identify centres of species richness and

importance within a country, and to plan a system of protected areas around these centres, as all countries should do in accordance with the Convention on Biological Diversity (Glowka et al., 1994). However, like swallowtail butterflies (Papilionidae) (Collins and Morris, 1985), tiger beetles are useful either "as pointers for delimitation of biogeographical boundaries for planning the conservation of whole biotopes" or, because of their strict ecological requirements, as useful bioindicators of general threats. In other words, tiger beetles seem to fit the main procedural steps suggested by McGeoch (1998) for considering them as both ecological and biodiversity indicators. In a broader sense, tiger beetles have several characteristics that help make them appropriate tools for conservation biology approaches: worldwide occurrence in a rich range of habitat types, high habitat specificity of species, conspicuousness in the field, and, last but not least, availability of specialist taxonomists able to identify them worldwide up to the species level. Thus they can be considered to be one of the few invertebrate groups which are "sufficiently well-known ecologically and taxonomically, sufficiently visible and obtainable, to be of great value both for conservation planning from biogeographical analyses and for environmental monitoring on a more local scale" (Collins and Morris, 1985).

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