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Seasonal Variation of Carabid Beetle (Coleoptera: Carabidae) Abundance and Diversity in Ranomafana National Park, Madagascar

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ABSTRACT

Seasonal variation in arthropod abundances is observed in many tropical forests all over the world. This study examines seasonal occurrence of carabid beetles in Ranomafana National Park, Madagascar, where little research has been done concerning seasonality of arthropods. Carabid beetles were collected from secondary and primary montane rainforests throughout a one year. In total, 1205 individuals of 50 species were collected. During the year there was a considerable variation in the abundances of carabids. The highest number of individuals was collected in February, which is a warm and rainy month while the lowest numbers were obtained in May, which is in the beginning of drier months. Species composition varied considerably during the year, 28% of the species were found only in one month, and only one species was collected in every sampling month. For total species inventory at least one year of collecting is then recommended.

Keywords: Ground Beetles, Madagascar, Phenology, Seasonality, Tropical Forests

1. Introduction

Seasonal fluctuation in arthropod abundances and biomass is observed in many tropical and subtropical regions [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]. In general, abundances and biomass are highest during the wet season and lowest during the dry season. However, there is a high variation in species composition during a year [5, 11] and considerable short-term (day-to-day, week-to-week) [8] and year-to-year variation in species abundances [7, 12].

Different insect groups have their highest abundance in different times of the year [13, 14], species might have one or several peaks in abundance or have relatively stable abundance. Seasonality of carabid beetles is reflected in variation of abundances, breeding time(s), dormancy period and larval development [15, 16, 17, 18]. However, many species show flexibility in their seasonal rhythms. Especially in disturbed habitats, species may have flexible lifecycles enabling breeding at different times of the year [19].

In Madagascar, seasonal cycles have been observed in small mammals0 [20] and primates [21, 22], but very little is known about arthropods. Most of the Malagasy carabid beetles are known only from a few localities, and very little is known about their ecology and seasonal patterns. The aim of this study is to document seasonal patterns of carabid beetle occurrence in Ranomafana National Park. Specific study questions are: (1) How do species abundances and numbers of individuals vary during the year, (2) Are species richness or number of individuals related to rainfall and/or temperature, and (3) are there differences in seasonality between primary and secondary forests.

2. Materials and Methods

2.1. Study Areas

Madagascar is the fourth largest island of the world located ca 400 km from the southeastern African coast. Because of its large size (ca 587 000 km^2) and topographical variation (from sea level up to ca 2800 meters), climate varies in different parts of the island. Ranomafana National Park (RNP), where this study was conducted, is located in Fianarantsoa Province on the southeastern escarpment of Madagascar (21°02'–21°25´S, 47°18´–47°37' E).

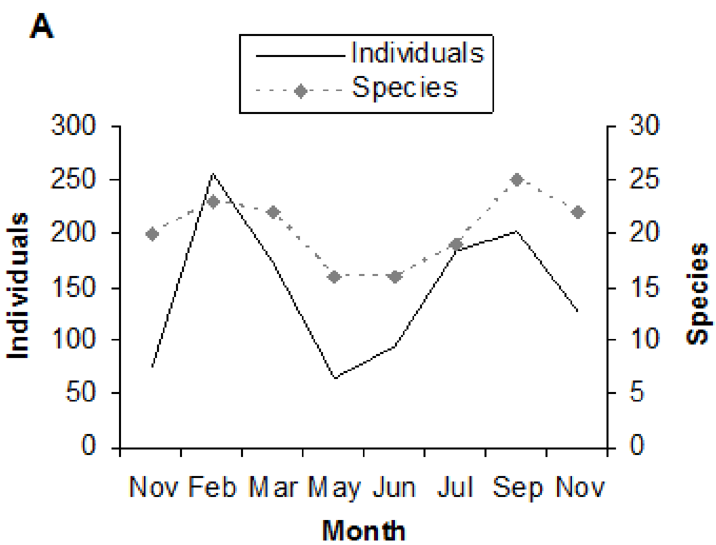
Climate in RNP is subtropical with average monthly temperature 14-20 °C during the year. Annual rainfall varies between 1500 and 4000 mm, and is highly variable from year to year depending on tropical depressions and cyclones, which occur mostly in January - March. Monthly rainfall is highest from December to March (~ 400 mm/month) and lowest from May to October (~ 90 mm/month). However, there are no months (or weeks) that are completely without rain and relative humidity is over 90% throughout the year.
The core area (41 600 ha) of RNP is mountainous and contains relatively undisturbed lowland rain forests, cloud forests and high plateau forests. This study was conducted in three study areas: (1) intact montane primary forest (Valohoaka), (2) slightly selectively logged montane primary forest (Vatoharanana), and (3) 18 year prior the study partly selectively logged secondary forest (Talatakely). Vatoharanana and Valohoaka are four and eight km south from Talatakely, respectively. In each study area there were six sites (10 x 10 m) for a total of 18 sites.

2.2. Collecting Methods, Species Identification and Analyses

Carabids were collected by hand using several methods, including beating trees and bushes, gathering dead leaves from bushes, and turning stones and decaying logs. One hour was spent in each collecting site and the sites were visited once during the year 2005 in February, March, May, June, July, September and November (sites were visited in November 2004 and in 2005).
Species identification was based on several morphological characteristics, including male and female genitalia, using the keys of Jeannel [23, 24, 25] and Basilewsky [26, 27]. Approximately 30 specimens could not be reliably identified, and they are not included to any of the analyses.
Most of the species were identified in collaboration with Dr. David Kavanaugh (California Academy of Sciences, USA). In addition, part of the material was identified by the following taxonomic specialist: Prof. Achille Casale, University of Sassari, Italy (*Callidiola*), Dr. Thierry Deuve, Museum of Natural History of Paris, France (*Eucamptognathus* and *Tshitscherinellus*), and Jiří Moravec (*Pogonostoma*).
Monthly temperatures (minimum, maximum and average) and amount of rainfall (total and average) were measured in ValBio research station in RNP. Distances between ValBio and study sites ranged from a few hundred meters up to eight kilometers. Relationship between number of species and individuals and the following factors: monthly rainfall, previous month's rainfall, monthly average temperature and previous month's average temperature were tested by regression analysis and Pearson's correlation coefficient. The software package used was SPSS.

3. Results

In total, 1205 individuals of 50 species were collected. Because of the identification problems 30 individuals were omitted from analysis. Numbers of individuals were highly variable during the year. The lowest number of individuals (65) was collected in May, which is in the "dry season" and the highest number (255) in February, which is in the warm rainy season (Fig. 1A). Variation in numbers of species roughly followed the same pattern. Number of species (16) was lowest in May and June and highest in September (25 species). However, in February, March and November species richness was only slightly lower (Fig 1A). Most (60%) of the species occurred in the rainy season during February and March.
Annual rainfall (3033 mm) was spread very irregularly over the year (Fig. 1B). Total rainfall was lowest in June and highest in March. However, there were high variations in rainfall between months *e.g.* in June and August there were less than 100 mm/month but in July almost 400 mm/month. Average temperatures were highest in the summer months from November through February.



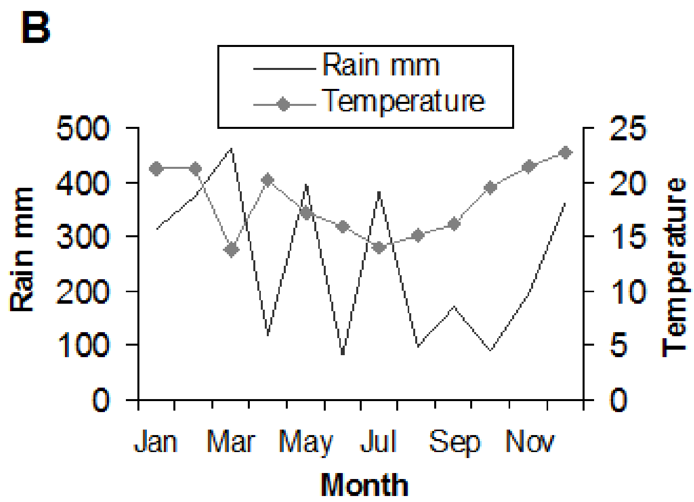


Fig. 1: Seasonal variation of A.) Numbers of individuals and species and B.) Rain and temperature during a year.

No statistically significant correlations were found between monthly total rainfall, previous month's rainfall, monthly average temperature and previous month's average temperature and numbers of species/individuals using either regression analysis or Pearson correlation coefficient (Table 1). The only significant correlation found was between number of individuals and number of species collected over the year (Table 1)

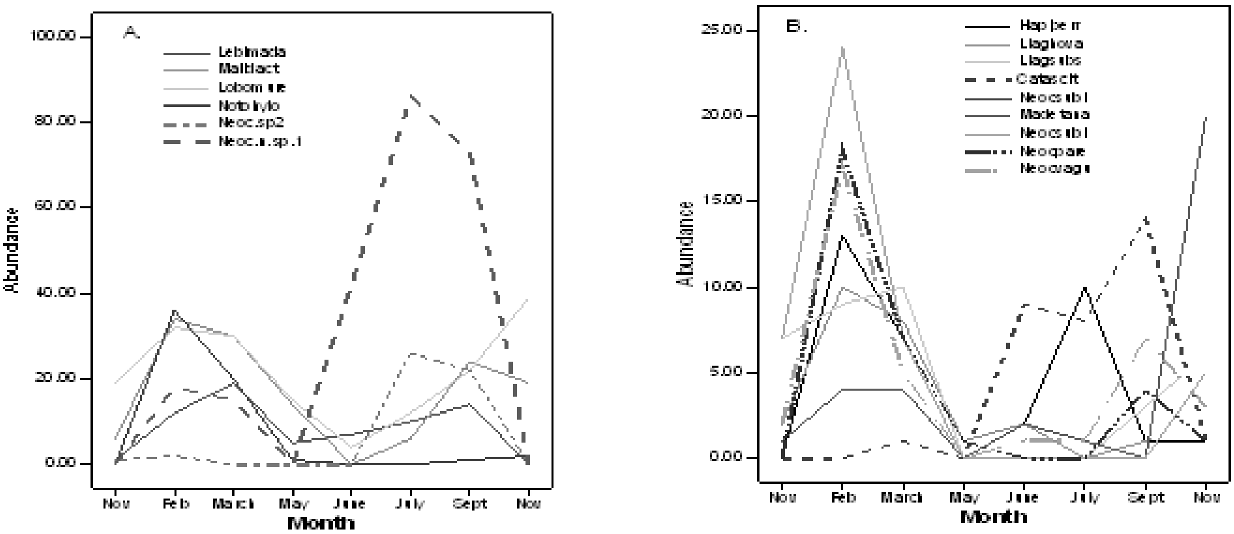


Fig 2: A and B. Seasonal variation of the 15 most common carabid species.

Table 1: Correlations between individuals, species, rain (monthly total rainfall), temperature (monthly average), previous month rainfall and previous month temperature.
*Correlation is significant at the 0.05 level.

Correlations	Individuals	Species	Rain	Temperature	Prev. rain	Prev. temp.
Individuals	1	0.784*	0.247	0.128	0.082	-0.086
Species	0.784*	1	0.036	0.251	-0.200	0.200
Rain	0.247	0.036	1	-0.199	0.023	0.297
Temp.	0.128	0.251	-0.199	1	-0.250	-0.128
Prev. rain	0.082	-0.200	0.023	-0.250	1	0.099
Prev. temp.	-0.086	0.200	0.297	-0.128	0.099	1

There was considerable monthly variation among abundances of species (Fig 2A and 2B). Many of the species had their lowest abundance in May and highest in February, but some had maximum abundance during cooler winter months (June-September). Some of the species had one clear peak, while some other species had more than one peak. Only one species (*Lobocolpodes murex*) was found in every sampling time while 28% of species were found only during one month (Appendix 1.).
Abundances of some of the species were related to amount of rainfall, previous month rainfall, previous month's temperature and/or temperature as shown by Pearson correlation coefficients, but most of the species did not show significant correlation to any of these environmental variables (Appendix 1.).
The highest number of individuals was collected from the secondary forest area of Talatakely and the lowest number from the intact primary forest of Valohoaka (Table 2). However, differences were small: 416 individuals in secondary forest, 398 in logged primary forest and 361 in intact primary forest. Total numbers of species varied from 30, 29 and 32, respectively. Although species numbers were almost the same, there were differences in species compositions between areas.

Appendix 1

List of species collected in each month from November 2004 to November 2005. Total = total number of individuals, Corr =Correlations between number of individuals and: R=amount of rainfall, pR=previous month rainfall, T=temperature, pT=previous month temperature, **significant at the 0.01 level (2-tailed), *significant at the 0.05 level (2-tailed).

Species	Total	Corr.	Dec 2004	Feb	Mar	May	June	July	Sep	Dec
Antimerina elegans (Alluad, 1897)	2		0	0	0	0	0	0	2	0
Caelostomus (Alocothorax) ambiguus (Tshitschérine, 1900)	12		4	0	1	1	0	1	0	5
Caelostomus (Alocothorax) anthracinus (Klug, 1833)	1		0	0	0	0	0	0	0	1

Caelostomus (Alocothorax) cribratus (Jeannel, 1948)	7		2	1	2	0	0	0	2	0
Caelostomus (n.sp 3.)	1		0	0	0	0	0	0	1	0
Calleida (Callidiola) marginalis (Jeannel, 1949)	1		0	0	0	1	0	0	0	0
Calleida (Callidiola) olsoufieffi (Jeannel, 1949)	3		0	0	1	1	1	0	0	0
Calleida (Callidiola) n.sp.	1		0	0	0	1	0	0	0	0
Catacolpodes scitus (Jeannel, 1948)	33	-pT**, -R**, -T*	0	0	1	0	9	8	14	1
Catacolpodes (n.sp. 1.)	5		0	0	0	0	0	4	1	0
Dactalyleurys (n.sp.1.)	2		1	1	0	0	0	0	0	0
Drypta (Nesiodrypta) waterhousei (Oberthur, 1881)	37		1	0	3	13	14	5	0	1
Eurydera armata (Castelnau, 1831)	1		1	0	0	0	0	0	0	0
Haplocolpodes perrieri (Alluaud, 1899)	34		13	7	0	0	2	10	1	1
Lebia (Metalebia) madagascariensis (Chaudoir, 1850)	68		1	12	19	5	7	10	14	0
Lebia [sp. 3.]	9		1	5	1	0	0	0	1	1
Liagonum hova (Alluaud, 1897)	26	pT*, pR*	2	10	8	1	2	0	1	2
Liagonum subsolanum (Jeannel, 1948)	35	pT*	7	9	10	0	0	0	3	6
Lobocolpodes murex (Alluaud, 1909)	173	T**	19	32	30	15	4	12	22	39
Madecassina [nr. *Tanala* (Alluaud, 1935)]	32	T**	1	4	4	0	2	1	0	20
Madecassina picta (Alluaud, 1897)	3		0	0	0	0	0	1	0	2
Microcheila denticollis (Jeannel, 1949)	2		0	2	0	0	0	0	0	0
Neocolpodes bessoni (Alluaud, 1909)	8		0	0	0	2	1	0	2	3
Neocolpodes gemmula (Alluaud, 1897)	8	R**, pT*	0	0	0	0	5	1	2	0
Neocolpodes imerinae (Alluaud, 1897)	3		0	0	2	0	0	0	0	1
Neocolpodes isakae (Jeannel, 1948)	1		0	1	0	0	0	0	0	0
Neocolpodes leptoterus (Alluaud, 1935)	9	T*	0	7	1	0	0	0	0	1
Neocolpodes micaauri (Alluaud, 1897)	7		0	1	0	0	1	4	1	0
Neocolpodes parenthesis (Alluaud, 1897)	31		0	18	7	1	0	0	4	1
Neocolpodes sublaevis (Alluaud, 1909)	43	T*, pT**	7	24	7	0	0	0	0	5
Neocolpodes tanalensis (Jeannel, 1948)	6		1	1	1	1	0	0	0	2
Neocolpodes vagus (Alluaud, 1899)	36		2	17	5	1	1	0	7	3
Neocolpodes (n. sp. 1.)	234	-pT**, -T**	0	18	15	0	42	86	73	0
Neocolpodes (n.sp.2.)	1		0	0	1	0	0	0	0	0
Neocolpodes (n.sp.3.)	2		0	0	0	0	1	0	1	0
Neocolpodes (n. sp. 5.)	1		0	0	0	0	0	0	1	0
Neocolpodes (n.sp.7.)	1		0	0	0	0	0	0	1	0
Neocolpodes [sp. 1.]	16	T**, pT**	0	11	0	4	0	0	0	1
Neocolpodes [sp. 2.]	51	-pT**	1	2	0	0	0	26	22	0

Neocolpodes [sp. 4.]	1		0	0	0	0	0	0	1	0
Notocolpodes hylonomus (Alluaud, 1935)	60	pT*	0	36	20	1	0	0	1	2
Nycteis (Belonognatha) signatipennis (Chaudoir, 1869)	4		0	0	0	0	1	3	0	0
Nycteis (Belonognatha) stellulata (Fairmaire, 1897)	1		1	0	0	0	0	0	0	0
Peliocypas insularis (Fairmaire, 1897)	13		3	0	2	0	0	0	0	8
Perigona (Ripogena) (n.sp.1.)	1		0	0	0	0	0	1	0	0
Perigona (Ripogena) (n.sp.2.)	1		0	0	0	0	0	0	1	0
Thysanotus [sp.1.]	9		1	2	0	0	1	1	0	4
Thysanotus (n.sp.1.)	4		0	0	0	3	0	1	0	0
Thysanotus (n.sp.2.)	2		0	0	0	0	0	2	0	0
Trichillinus (Mallopelmus) dactyleuryoides (Alluaud, 1936)	133		6	34	30	14	0	6	24	19
In total number of individuals	1175		75	255	171	65	94	183	203	129
In total number of species	50		20	23	22	16	16	19	25	23

Table 2: Numbers of individuals and species collected from each study area.

	Individuals	**Species**
Talatakely (secondary)	416	30
Vatoharanana (selectively logged)	398	29
Valohoaka (intact)	361	32

Variation in numbers of individuals during the year was very similar in two of the logged areas (Talatakely and Vatoharanana) (Fig 2), and they were also significantly correlated (at 0.01 level by Pearson correlation coefficient: 0.974). However, compared to the intact forest (Valohoaka), there were some differences in peaks and slopes (Fig 3), and no significant correlation was detected between the logged and the intact forest.

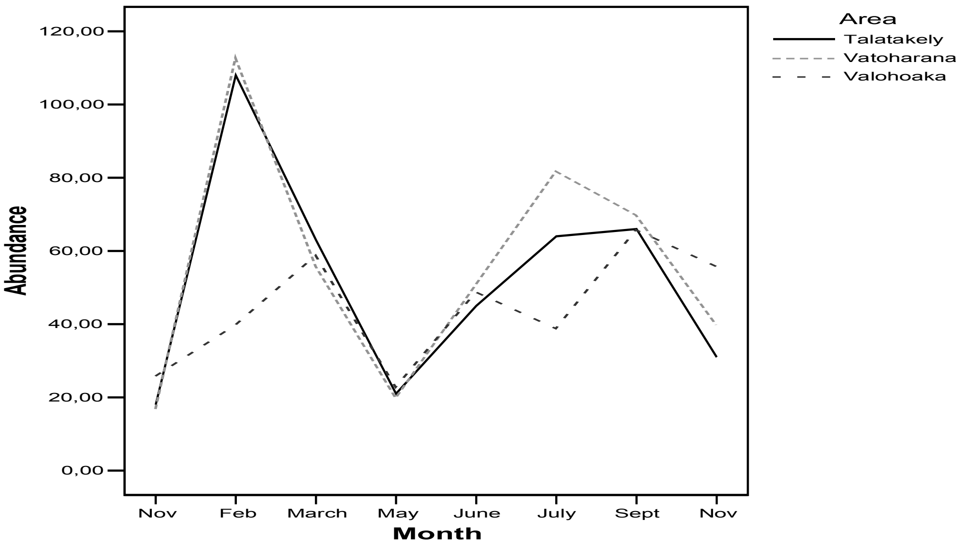


Fig 3: Seasonal variation of carabid beetle abundances in the three study areas.

4. Discussion and Conclusion

Overall the highest abundances of carabids were found when temperatures and rainfalls were highest. During the cooler (and drier) winter months species abundances were lower. These are in accordance with other studies of seasonal variation of arthropods in tropical region [6, 7, 14]. However, no statistically significant correlations between particular environmental variables (rainfall, temperature) were detected. This might be due to the unusually high amount of rain in May and July, which are typically relatively dry months. In addition, short-term weather variations may have influenced results, especially because of the relatively small amount of data available.

Most of the species had their highest abundance during the time when temperature and rainfall were both high. However, there were also species that had their highest abundance in some other time of year or had more than one abundance peak during the year. Only one species was found in all collecting months and 28% of the species were found only during one month. Erwin and Scott [5] reported that, in a Panamanian tropical rainforest, 40% of the annual beetle fauna was found only in early rainy season and less than 5% was found throughout the entire year. Phenological (*i.e.*, diapause, adult longevity, breeding times, larval development and movements during lifecycles) adaptations to different times of year might increase number of species. Variation between species abundances during the year and between years have been observed in other carabid studies [28, 29]. Thus, for total species inventory a whole year (at least) is recommended.

Although the total numbers of species and individuals did not show correlation with amount of rainfall/temperature, there were some species, abundances of which were correlated with these factors (Appendix 1.). It seems that some of the species are more dependent on these factors than others. This species level difference to drought/moisture also has been observed in other study [30].

Results presented here are based on only one year of collecting, so it is impossible to say with confidence that observed variations are truly seasonal. Only studies covering several years can confirm the seasonality of fluctuations. Furthermore, nothing is known about the movements of species or their preferred habitats at different times of a year, either of which may account for fluctuations in abundance at particular sites at particular times of the year. One possibility for monitoring species movements between habitats is by radio-telemetrically [31, 32].

In conclusion, rainfall and temperature are the basic factors influencing abundances of most of the species. However, there appear to be species level differences in the response to these factors such that some species are more closely dependent on these factors than other species. At present, there is nothing known breeding times, migration, and larval development of carabid species in Ranomafana National Park. Much more specific information is needed before the causes of seasonal variation can be better understood.

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6. Reference

1. Janzen DH. Sweep samples of tropical foliage insects: Effects of seasons, vegetation types, elevation, time of day, and insularity. Ecology 1973; 54:687-708.
2. Wolda H. Fluctuations in Abundances of Tropical Insects. Am Nat 1978; 112:1017-1045.
3. Wolda H. Seasonality of Homoptera on Barro Colorado Island. In: Leigh jr. EG, Rand AS, Windsor DM. (Eds.). The Ecology of a Tropical Forest. Seasonal Rhythms and Long-term Changes, Smithsonian Institution Press 1983; 319-330.
4. Wolda H. Insect Seasonality: Why? Annu Rev Ecol Syst 1988; 19:1-18.
5. Erwin TL, Scott JC. Seasonal and Size Patterns, Trophic Structure, and Richness of Coleoptera in the Tropical Arboreal Ecosystem: The Fauna of the Tree Luehea seemannii Triana and Planch in the Canal Zone of Panama. The Coleopterists Bulletin 1980; 34:305-322.
6. Tanaka LK, Tanaka SK. Rainfall and Seasonal Changes in Arthropod Abundances on a Tropical Oceanic Island. Biotropica 1982; 14:114-123.
7. Pearson DL, Derr JA. Seasonal Patterns of Lowland Forest Floor Arthropod Abundance in Southeastern Peru. Biotropica 1986; 18:244-256.
8. Hammond P. Insect abundances and diversity in the Dumoga-Bone National Park, N. Sulawesi, with special reference to the beetle fauna of lowland rain forest in the Toraut region. In: Knight WJ, Holloway JD. (Eds.) Insects and the Rain Forests of South East Asia (Wallacea), 1990; 197-254. Royal Entomological Society of London, London.
9. Nummelin M. The Community structure of arthropods in virgin and managed sites in the Kibale Forest, Western Uganda. Trop Ecol 1996; 37:203-213.
10. Akutse K, Khen CV, Toda MJ. Assessment of higher insect taxa as bioindicators for different logging-disturbance regimes in lowland tropical rain forest in Sabah, Malaysia. Ecol Res 2007; 22:542-550.
11. Wolda H. Trends in abundance of tropical forest insects. Oecologia 1992; 89:47-52.
12. Nummelin M, Fürsch H. Coccinellids of the Kibale Forest, Western Uganda: a comparison between virgin and managed sites. Trop Zool 1992; 5:155-166.
13. Smythe N. The Seasonal Abundance of Night-flying Insects in a Neotropical Forest. In: Leigh jr ER, Rand AS, Windsor DM (Eds.). The Ecology of a Tropical Forest. Seasonal Rhythms and Long-term Changes, Smithsonian Institution Press, 1983; 309-318.
14. Nummelin M, Nshubemuki L. Seasonality and structure of the arthropod community in a forested valley in the Uluguru Mountains, Eastern Tanzania. Journal of East African Natural History 1998; 87: 205-212.
15. Thiele H-U. Carabid beetles in their environments. Springer-Verlag. 1977.
16. Paarman W, Stork NE. Seasonality of ground beetles (Coleoptera: Carabidae) in the rain forests on N. Sulawesi (Indonesia). Insect Science and Its Application1987; 8:483-487.
17. Lövei GL, Sunderland KD. Ecology and Behavior of Ground Beetles (Coleoptera: Ground beetleae). Annu Rev Entomol 1996; 41:231-256.
18. Vennila S, Rajagopal D. Phenology of tropical carabids (Coleoptera: Carabidae). J Entomol Res 2003; 27:1-7.
19. Fadl A, Purvis G. Field observations on the lifecycles and seasonal activity patterns of temperate carabid beetles (Coleoptera: Carabidae) inhabiting arable land. Pedobiologia 1998; 42:171-183.
20. Stephenson PJ. Seasonality Effects on Small Mammal Trap Success in Madagascar. Journal of Tropical Ecology 1994; 10:439-444.
21. Tan CL. Group Composition, Home Range Size, and Diet of Three Sympatric Bamboo Lemur Species (Genus Hapalemur) in Ranomafana National Park, Madagascar. Int J Primatol 1999; 20:547-566.
22. Randrianambinina B, Rakotondravony D, Radespiel U, Zimmermann E. Seasonal changes in general activity, body mass and reproduction of two small nocturnal primates: a comparison of the golden brown mouse lemur (*Microcebus ravelobensis)* in Northwestern Madagascar and the brown mouse lemur (*Microcebus rufus*) in Eastern Madagascar. Primates 2003; 44:321-331.
23. Jeannel R. Coléoptères carabiques de la région Malgache (première partie). Faune de L'Empire Français 1946; 5:1-372.

24. Jeannel R. Coléoptères carabiques de la région Malgache (deuxième partie). Faune de L'Empire Français 1948; 10:373-765.
25. Jeannel R. Coléoptères carabiques de la région Malgache (troisième partie). Faune de L'Empire Français 1949; 11:766-1146.
26. Basilewsky P. Insectes Coléoptères: Carabidae Scaritinae. Faune de Madagascar 1973; 37:1-322.
27. Basilewsky P. Insectes Coléoptères: Carabidae Platyninae. Faune de Madagascar 1985; 64:1-543.
28. Boivin G, Hance T. Ground beetle assemblages in cultivated organic soil and adjacent habitats: temporal dynamics of microspatial changes. Pedobiologia 2003; 47:193-202.
29. Werner SM, Raffa KF. Seasonal Activity of Adult, Ground-occurring Beetles (Coleoptera) in Forests of Northeastern Wisconsin and the Upper Peninsula of Michigan. Am Midl Nat 2003; 149:121-133.
30. Kadar F, Szentkiralyi F. Effects of Climatic Variations on Long-term Fluctuation Patterns of Ground Beetles (Coleoptera, Carabidae) Collected by Light Trapping in Hungary. Acta Phytopathol Entomol Hung 1997; 32:185-203.
31. Rink M, Sinsch U. Radio-telemetric monitoring of dispersing stag beetles: implications for conservation. J Zool 2007; 272:235-243.
32. Negro M, Casale A, Migliore L, Palestrini C, Rolando A. Habitat use and movements in the endangered ground beetle species, *Carabus olympiae* (Coleoptera: Carabidae). Eur J Entomol 2008; 105:105-112.