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SPECIES RICHNESS AND ABUNDANCE OF SOCIAL VESPIDS AT FOREST FRINGE AND FORESTED AREA OF THE KUALA LOMPAT WILDLIFE FOREST RESERVE, PENINSULAR MALAYSIA

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ABSTRACT

A study on species richness and abundance of social vespids at the forest fringe and forested area of the Kuala Lompat Wildlife Forest Reserve was conducted for 15 months period beginning from September 2009 to May 2011. The vespids were collected by using 'Malaise trap', sweep netting and light trapping. A total of 695 individuals of social vespids belonging to 25 species and nine genera from three subfamilies were successfully collected. Species richness was found to be not significantly different ($P > 0.05$) between the forest fringe and forested area, however, the species abundance among samples between the two sites was significantly different as confirmed by 'Blocked multiresponse permutation procedures' (MRBP, $T = -9324$, $A = 0.2938$, $P < 0.05$). *Mao Tau* species accumulation curves indicated that almost ample sampling effort in retrieving species at both sites. Although prolong

sampling should be done to get all the possible species from these areas, other aspect of ecological and behavioral studies of this wasps also need to be conducted to better understand and gain important information to be used for their conservation purposes.

Key words: Hymenoptera, Vespidae, Species Richness, Abundance, Peninsular Malaysia.

ABSTRAK

Satu kajian mengenai kekayaan dan kelimpahan spesies vespids sosial di pinggir hutan dan kawasan hutan Hutan Simpan Hidupan Liar Kuala Lompat telah dijalankan selama tempoh 15 bulan bermula dari September 2009 hingga Mei 2011. Vespid ini telah dikumpulkan dengan menggunakan'perangkap Malaise', jaring sapuan dan perangkap cahaya. Sejumlah 695 individu vespid sosial yang dipunyai oleh 25 spesies dan sembilan genus daripada tiga subfamili telah berjaya dikumpulkan. Kekayaan spesies didapati tidak berbeza secara bererti ($P > 0.05$) di antara pinggir hutan dan dalam hutan, akan tetapi, kelimpahan spesies di antara dua kawasan ini adalah berbeza secara bererti seperti yang disahkan melalui 'prosedur permutasi multirespon berblok' (MRBP, $T = -9.324$, $A = 0.2938$, $P < 0.05$). Lengkuk pengumpulan spesies *Mao Tau* menunjukkan usaha persampelan yang hampir mencukupi dalam mengumpulkan spesies dari setiap kawasan kajian. Walaupun memanjangkan waktu persampelan perlu dilakukan untuk mendapatkan semua spesies yang mungkin dari kawasan-kawasan ini, aspek-aspek lain kajian ekologi dan tingkah laku tebuan ini juga perlu dilakukan untuk memahami dan mendapatkan maklumat penting untuk digunakan bagi tujuan pemuliharaannya.

Kata kunci: Hymenoptera, Vespidae, Kekayaan Spesies, Kelimpahan, Semenanjung Malaysia.

INTRODUCTION

As dominant in many terrestrial habitats (Edwin 1982; Wilson 1990), the ecological importance of social vespids is not only being at the top of terrestrial insect food web but also as effective pollinators of various plants (Kojima 1993; Carpenter & Wenzel 1999) as well as valuable bio-indicators for habitat disturbances and environmental changes.As such, many of them can be classified as the key stone species in that particular ecosystem. Their ecological information including their diversity and abundance, however, was limited (Jeanne 1991), but there were several studies have been recently conducted especially in Brazil (i.e. by Santos et al. 2007; Silveira et al. 2008; Gomes & Noll 2009; Lima et al. 2010; etc.). In Malaysia, unfortunately is yet very poorly available even it is one of the special places for social vespids (Carpenter & Nguyen 2003). Although there were several studies have been conducted by Bequaert (1936, 1939), Vecht (1957), Turillazzi (1999), Kojima et al. (2006, 2009) and Nicholas et al. (2011), but, their study was focusing more on taxonomic and systematic.

Social vespids build nests and are foragers (Spradbery 1973). For these reasons, they can be considered as semi- sessile organisms with some fidelity to their environments, which makes them appropriate for richness and abundance studies (Heithaus1979). Therefore, as the beginning, this study was conducted in Kuala Lompat Wildlife Forest Reserve (KLWFR). KLWFR located in Krau Wildlife Reserve which is one of the largest tropical rainforest in Peninsular Malaysia that covering an area of about 60,338 hectares. Diversity of flora and fauna in KLWFR has been recognized by scientists and researchers, prompting the use of KLWFR as a natural laboratory to study the ecology mostly of mammals, particularly bats and primates. Information on insect including social vespids however is still under-reported, but high diversity of them is expected.

The aim of our study was to compare the species richness and abundance of social vespids between the two different forest habitats (forest fringe and forested area) of the well known Kuala Lompat Wildlife Forest Reserve, in Pahang, Peninsular Malaysia.

Result of this study is expected to provide base line information for future study on socials vespids in Malaysia.

METHODS

Study Site. This study was conducted within approximately 1.5 km^2 area, viz., along roads and forest trails in both opened (forest fringe) and forested portions of the Kuala Lompat Wildlife Reserve Forest Reserve. Forest fringe where is near to the stream cover an area of open vegetation which is consists of shrubs, grass, trees (<5 meters height), flowering plants, orchards and oil palm plantations. Whereas, the forested portions cover areas of dense vegetation; closed-canopy with trees mostly taller than 5 m height which dominated by dipterocarp tree such as *Dipterocarpus comutus*, *Dipterocarpus baudii*, *Hopea sangal*, *Shorea accuminata* and *Shorea ovalis*. There are many trails, but the field collection was carried out only in the three selected trails.

Field Collection. The field collection at both sites was carried out once a month in six consecutive days per week per month over 15 months from September 2009 to May 2011 using three collection methods namely the malaise trapping, sweep netting and light trapping. Sweep netting was carried out randomly in both sites of the forests over six days, from 0800 to 1700 h. A light trap used consisted of a piece of vertically-hung white cloth and a mercury vapor bulb hung in front of the white cloth. Light trapping was carried out from 1800 h to 2200 h. Malaise traps with a collecting bottle half filled with 70% ethyl alcohol were set in both study sites (six and eight units for forest fringe and forested area, respectively). The traps were left untended throughout the research period, but insects were collected once a month after which the collecting bottle of each malaise trap was replaced with new ones. All vespids collected were brought to the Centre for Insect Systematic in the UKM for identification and those specimens are housed in the center as voucher specimens. The numbers of individual vespid collected per site per month from all the collection methods were pooled to constitute as one ‘sample’. As such, a total of 30 set of samples were available to us which is consist of 15 set of samples (15 months) for each site.

Species Identification and Data Analysis. The specimens were identified following Kojima et al. (2009). The species richness between the two sites was compared using 'unpaired T-test' (which was manually performed) while the species abundance (number of individuals per species) among the samples between the two sites was compared using 'blocked multi-response permutation procedure (MRBP)'. The MRBP analysis was performed using PC-ORD for Windows version 6 (McCune & Mefford 2011). Number of singletons and unique species were also calculated. Species accumulation curves (*Mao Tau* function) were calculated and constructed to predict the asymptote, which identify sampling effort as well as estimate species richness by two non-parametric estimators, the Jackknife 1st order and Abundance Based-Coverage (ACE) which is known to perform well with most data set (Walther & Moore 2005). Because the social vespids density was uneven among the sites, the Mao Tau, Jackniffe1 and ACE curves were constructed based on the individuals-based assessment protocol (Gotelli& Colwell, 2001). All the calculation (Mao Tau, Jackniffe1 and ACE) were computed using EstimateSWin version 8.20 (Colwell 2009) with 100 times randomization without replacement.

RESULTS

Overall Vespids Collection. A total of 695 individuals of social vespids belonging to 25 species and nine genera from three subfamilies were successfully collected in 30 set of samples (Table 1). Of this, the most abundant species recorded was *Provespa anomala* with 207 individuals, followed by *Provespa nocturna* with 60 individuals and *Parischnogaster mellyi* with 58 individuals. Two species were singletons (each with only one individual collected throughout the study period) namely the *Eustenogaster fraterna* and *Vespa multimaculata* which were collected at the forest fringe and in the forested area, respectively. Besides that, both species were also treated as unique as they were encountered only in one sample occasion. In addition to these two singletons, there were two others species which we considered as unique. They are the *Polistes stigma* and *Parapolybia indica* which were found in forested area (Table 1).

Table 1. Cumulative number of individuals of social vespids in 15 samples from forest fringe and forested area (Total samples = 30 samples), respectively, at Kuala Lompat Wildlife Forest Reserve.

	Cumulative number of individuals		
SPECIES/GENERA	**FORESTED**	**FRINGE**	**TOTAL**
STENOGASTRINAE			
Eustenogaster gibbosa	11	10	21
Eustenogaster micans	3	2	5
Eustenogaster hauxwellii		2	2
Eustenogaster fraterna		1*(+)	1
Liostenogaster varipicta	5	3	8
Liostenogaster vechti	6	9	15
Parischnogaster mellyi		58	58
Parischnoagaster striatula		17	17
Parischnoagaster unicuspata		18	18
POLISTINAE			
Polistes stigma	2+		2
Parapolybia indica	2+		2
Parapolybia varia	16	28	44
Polybiodes raphigastra	21	26	47
Ropalidia fasciata	6	43	49
Ropalidia flavopicta	3	13	16
Ropalidia latebalteata		14	14
Ropalidia malayana	3	1	4
Ropalidia stigma		16	16

Table 1continue…

...Table 1 continued

Ropalidia sumatrae	8	9	17
Vespa multimaculata	75	132	207
Provespa anomala	23	37	60
Provespa nocturna	10	3	13
Vespa affinis	24	2	26
Vespa mocsaryana	12	20	32
Vespa tropica	1 *(+)		1
TOTAL	**231**	**463**	**695**
Number of species	**18**	**22**	**25**

Note: *: Singleton species (found only with one individual)
+: Unique species (found only in one sample)
*(+): Both singleton and unique species

Species Richness and Abundance Between Sites. The highest species richness was recorded in forest fringe with 22 species while the forested area recorded only 18 species (Table 1). However, the species richness between the two sites was not significantly different ($t= 1.749$, $df= 456$, $P> 0.05$). Apart from being richness, the forest fringe was also has higher species abundance compared to forested area. MRBP confirmed that species abundance differed significantly between the two sites (MRBP, $T= -9.324$, $A= 0.2938$, $P < 0.05$).

Estimated Species Richness. The *Mao Tau* species accumulation curves for both sites did not plateau but continued to increase, indicated that not all the social vespid species from the two sites were collected during sampling (Fig.1a-b). However, *Mao Tau* species accumulation curves showed that almost ample sampling effort in retrieving species at both sites. In forest fringe, Jackniffe1 and ACE predicted a species richness of 23.86 and 23.92 species, respectively (Fig. 2 a-b), while in forested area, Jackniffe1 and ACE predicted a species richness of 20.8 and 18.41 species, respectively (Fig. 3 c-d). This means that only a few more species was expected to be collected in forest fringe (1.86 – 1.92

species) and forested area (0.41 – 2.80 species). Therefore, it can be concluded that the sampling effort in forest fringe represents approximately 92.2% (22 out of 23.86 species) and 91.8% (22 out of 23.92 species) of its estimated total species richness which are based on Jackniffe1 and ACE, respectively, whereas, in the forested area, sampling effort represents approximately 86.5% (18 out of 20.8 species) of its estimated total species richness based on Jackniffe1 and 97.8% (18 out of 18.41 species) based on ACE.

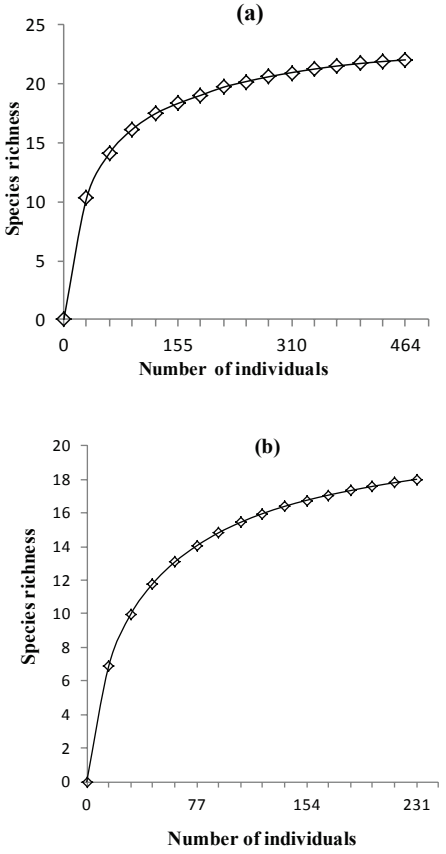

Figure 1. Species accumulation curve (*Mao Tau* functions) for (a) forest fringe and (b) forested area. The *Mao Tau* species accumulation curves were constructed based on the Gotelli and Colwell (2001) terminology (individuals based-assesment protocol).

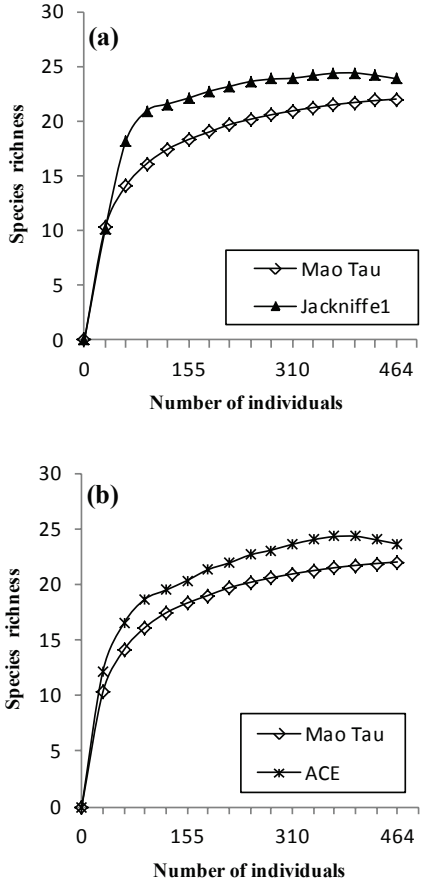

Figure 2. *Mao Tau* species accumulation curve and estimated species richness by two non-parametric estimators for forest fringe (a-b) which were constructed based on the Gotelli and Colwell (2001) terminology (individuals based-assesment protocol).

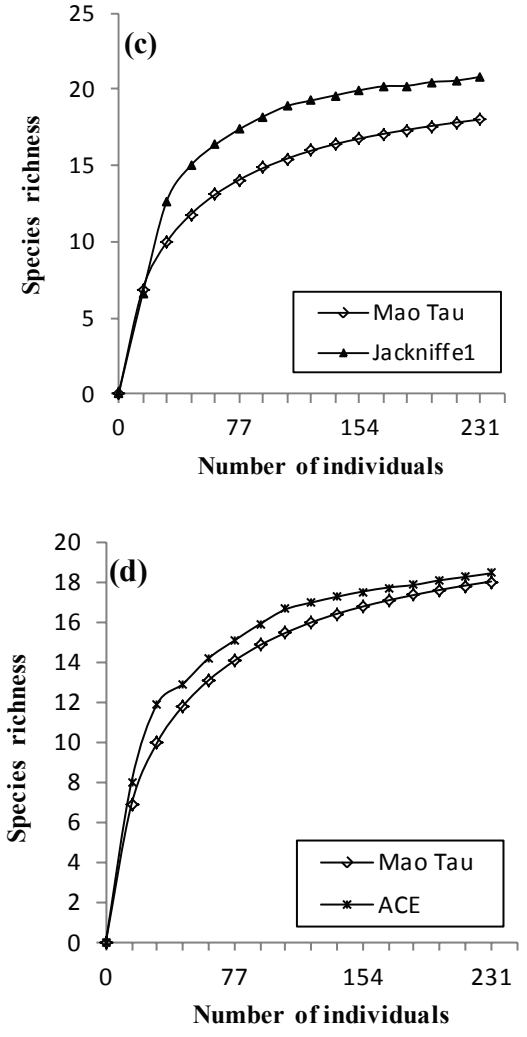

Figure 3. *Mao Tau* species accumulation curve and estimated species richness by two non-parametric estimators for forested area (c-d) which were constructed based onthe Gotelli and Colwell (2001) terminology (individuals based-assesment protocol).

DISCUSSION

Overall Social Vespid Collection. In this study, all the social vespid subfamilies were present in both forest fringe and forested area with Polistinae had the highest species richness (10 species), followed by Stenogastrinae (9 species) and Vespinae (6 species). This study was conducted along together with Nicholas et al. (2011). For a six months study, they successfully recorded a total of 21 species of social vespids of KLWFR. As we continued for another 10 months sampling, we managed to collect another four species, viz., *Euestenogaster hauxwellii*, *Euestenogaster fraterna*, *Polistes stigma* and *Parapolybia indica* as additional list for KLWFR, bringing the overall total of 25 species. Interestingly, one of these species, *P. indica* is not only an additional record for KLWFR, but it was also new record for Peninsular Malaysia since it was previously reported to occur only in India, Myanmar, Borneo, China, Taiwan, Korea and Japan (Kojima & Carpenter 1997). This study was also successfully collected one previously recorded species that was unable recorded in Nicholas et al. (2011), namely, *Vespa multimaculata*. Unfortunately, this study was still unable to collect the only one previously recorded species, viz., *Liostenogaster campanulae*. This is a bad indication and as such further study need to be conducted to investigate the possible reason that these species seemed to be missing. Each site in this study was dominated by one or more species of foraging social vespids. Forest fringe was dominated by *Parischnogaster mellyi, Ropalidia fasciata, Parapolybia varia, Polybiodes raphigastra, Provespa anomala, Provespa nocturna*, and *Vespa tropica*, whereas, forested area dominated by *Parapolybia varia, Polybiodes raphigastra, Provespa anomala, Provespa nocturna*, and *Vespa mocsaryana*. Occurrences of singletons and unique species were noticed within samples with two species were singletons and four species (including singletons) were unique (Table 1). As well as the ecological study of social vespids is yet very poorly available, not much could be deduced from the occurrences of species (except *V. multimaculata*), either being rare or exclusively unique species for any sites, especially *P. indica* who had just recently reported to occur in Peninsular

Malaysia. Meanwhile, *V. multimaculata* have been previously reported by Martin (1995) as an occasional species in Peninsular Malaysia, thus, no wonder why this species is present as singletons in KLWFR. Interestingly, an unexpected result, the *Vespa mocsaryana* who have been previously reported as rare in Peninsular Malaysia by Martin (1995) was collected with relatively large number of individuals (26 individuals) in KLWFR.

Richness and Abundance. Result showed that the forest fringe has higher species richness and abundance than in the forested area. However, the social vespids collected are actually did not represent their real richness and abundance in each environment, but reflect the richness and abundance of foraging wasps and their species-specific preferences of foraging habitats. According to Spradbery (1973), the social wasps are foragers. They can set their nests in one environment and forage in others (Diniz & Kitayama 1998). Foraging in social wasps is important in the development of the colony (Richter 2000; Jeanne & Taylor 2009) and reflects an important ecological interaction between the colony and the environment since the colony needs water, plant fibers, protein, and carbohydrates (Edwards 1980). The water is required for temperature control (Akre 1982; Greene 1991), nest construction (Jeanne 1996) and metabolic processes (Richter 2000). Plant fibers are essential for construction and repair of cells, peduncle and envelope (Wenzel 1991). For these reason, high richness and abundance of social vespids at forest fringe may reflect heterogeneity of its environment (vegetation consists of shrubs, grass, trees, flowering plants, orchards, rubber, water and oil palm plantations) which offers more resources than that of forested area. Santos et al. (2007) observed a greater social wasps species in environments that were more heterogeneous and that offer more resources such as nectar, prey, and water. Besides that, species richness and abundance may also relate to the environmental condition. Ito (1993) and Lima et al. (2010) reported that the social wasps are much more abundance and diverse in opened area (fringe) compared to dense area. The conditions that establish the limits where and when foraging is feasible are mainly physical, such as light and temperature intensity (Spradbery 1973). Temperature and relative humidity

seem to have a great influence on the foraging activity social vespids (Rocha & Gianotti 2007; Ribeiro et al. 2006; Santos et al. 2009) and even luminosity is also recognized as an important factor (Rocha et al. 2009). Moreover, other factors such as atmospheric pressure and winds may affect foraging rhythm of wasps (Gianotti et al. 1995). However, besides the heterogeneity of the vegetation type and resources availability or differences in environmental condition, differences in sampling effort (number of individuals) can explain this fact. Quantifying species richness or abundance at a designated area by sampling alone without reference to "sampling curve" is problematic at best. Denslow (1995) reported that communities may differ in measured of species richness because of differences in the shaped of relative abundance distribution or differences in the number of individuals collected. Based on Figure 1, one can conclude that high species richness at the forest fringe might be related to the high number of individuals collected. In contrast, low species richness in the forested area might be correlated to the small number of individuals collected. Bunge and Fitzpatrick (1993) noted that as more individuals are sampled, more species will be recorded.

Estimated Species Richness. Although the 15 month collection period were not enough to sample all the social vespids species in both sites, but, nearly all the social vespids at both sites was successfully collected. The small different between *Mao Tau* and true species richness (as predicted by Jackniffe1 and ACE) at both sites is may due to the reduction in the number of rare species (i.e. singleton, unique) as sampling effort (number of individuals) increased. The larger the number of rare species within a sample, the greater will be difference between observed species (Mao Tau value) and true species richness, and vice versa (see Chazdon et. al 1998).

CONCLUSION

As a conclusion, this study had successfully collected a total of 25 species and nine genera of social vespids from three subfamilies with four species as additional list to KLWFR and one species as new to Peninsular Malaysia. All the social vespids species

collected in both sampling sites were foragers with higher number of species collected at the forest fringe compared to in the forested area. The collections in both sites were high as nearly all the social vespids species were collected throughout the period of study. Of all, no new species was currently recorded for Peninsular Malaysia, but it is expected some new species will be obtained with further study. As no previous study on social vespids richness and abundance in Peninsular Malaysia, this result can be made as a special reference for the next study.

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REFERENCES

Akre, R.D. 1982. "Social wasps," in *Social Insects*, H. R. Hermann, Ed., vol. 4, (pp. 1–105), Academic Press, New York, NY, USA.

Bequaert, J. 1936. The common oriental hornets, Vespa tropica and Vespa affinis, and their colour forms.*Treubia*, 15: 329-351.

Bequaert, J. 1939. The oriental Vespa analis and its colour forms, etc. *Transactions of the American Entomological Society*, 65: 37-42.

Bunge, J. & Fitzpatrick, M. 1993.Estimating the number of species; a review. J. *Am. Statist. Assoc*., 88, 364-373.

Carpenter, J.M. & Nguyen, L.T.P. 2003. Key to the genera of social wasps of South-East Asia (Hymenoptera: Vespidae). *Entomological Science*. 6: 183-192.

Carpenter, J.M. &Wenzel, J.M. 1999. The relative abundance of swarm-founding social wasps in the Congo Basin (Insecta:

Hymenoptera; Vespidae, Polistinae). *Natural History Bulletin of Ibaraki University* (**3**): 9-14.

Chazdon, R.L., Colwell, R.K., Denslow, J.S. & Guariguata, M.R. 1998.Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of NE Costa Rica. Pp. 285-309 in F. Dallmeier and J. A. Comiskey, eds. *Forest biodiversity research, monitoring and modeling: Conceptual background and Old World case studies.* Parthenon Publishing, \Colwell, R.K. 2009.EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.20.User's guide and application published at http://purl.oclc.org/estimates.

Denslow, J.S. 1995. Disturbance and diversity in tropical rain forest: the density effect. *Ecological Applications*, 5, 962-968.

Diniz, I.R. & Kitayama, K. 1998. Seasonality of vespid species (Hymenoptera: Vespidae) in Central Brazilian Cerrado. *Revista de Biologica Tropical.Vol* 46 (1): 109-114.

Edwards, R. 1980. Social wasps: Their biology and control. East Grinstead: *Rentokill Limited.*

Edwin, T.L. 1982. Tropical forest: Their richness in Coleoptera and other arthropod species. *Coleopterists Bull*. 36:74-75.

Giannotti, E., Prezoto, F. & Machado, V.L.L. 1995.Foraging activity of *Polistes lanio laniov* (Fabr.) (Hymenoptera, Vespidae). *Anais da Sociedade Entomol´ogica do Brasil*, vol. 24, no. 3, pp.455–463.

Gomes, B. & Noll, F.B. 2009**.** Diversity of social wasps (Hymenoptera, Vespidae, Polistinae) in three fragments of semideciduous seasonal forest in the northwest of Sa˜oPaulo State, Brazil. Rev. Bras. *Entomol*. 53: 428-431

Gotelli, N.J. & Colwell, R.K. 2001.Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. *Ecol. Lett.* 4: 379-391.

Greene, A. 1991. *Dolichovespula* and *Vespula*. In *The social biology of wasps* (pp. 263–305), edited by K. G. Ross and R. W. Matthews. Ithaca, NY: Cornell University

Heithaus, E.R. 1979. Community structure of neotropical flowervisiting bees and wasps: Diversity and phenology. Ecology 60: 190-202.

Ito, Y. 1993. Behaviour and social evolution of wasps. New York: Oxford University Press Inc.Hlm. 34-42

Jeanne, R.L. 1991. The swarm-founding polistinae in The social biology of wasps. Cornell University press.pp 191-231.

Jeanne, R.L. 1996.Regulation of nest construction behaviour in *Polybia occidentalis*. *Animal Behaviour*, vol. 52, no. 3, pp. 473–488.

Jeanne, R.L. & Taylor, B.J. 2009. Individual and social foraging in social wasps in *Food Exploitation by Social Insects: Ecological, Behavioral, and Theoretical Approaches*, S. Jarau and M. Hrncir, Eds., pp. 53–79, CRC Press, Boca Raton, Fla, USA.

Kojima, J. 1993. Relative abundance of swarm-founding *Ropaidia* in the euso-cial wasps (Hymenoptera: Vespidae) in tropical Australia. *New Entomologist,* 42: 4-7

Kojima, J. & Carpenter, J.M. 1997. Catalog of species in the polistine tribe Ropalidiini (Hymenoptera: Vespidae). *American Museum Novitates* 3199: 1-96.

Kojima, J., Saito, F., Ubaidillah, R., & Nguyen, L.T.P 2006. Distributional summary, taxonomic notes and putative

scenario of dispersal of social wasp (Hymenoptera: Vespidae) in the Sunda Island. *Serangga*.11 (1-2): 1-43

Kojima J., Ng, Y.F, Ruslan, M.Y., Saito, F., Norliyana, H.A., Tamalia, T.P.O. & Idris, A.B. 2009. Key to The Social Wasp Species (Hymenoptera: Vespidae) Known from Peninsular Malaysia. *Serangga*. 14 (1-2) : 1-51

Lima, A.C.O., Castilho-Noll., M.S.M., Gomes, B., & Noll, F.B. 2010. Social wasps diversity (Vespidae, Polistinae) in forest fragment in the norteast of Sao Paulo State sampled with different methodologies. *Sociobiology., Vol* 56 (1): 121-131.

Martin, S.J. 1995. Hornets (Hymenoptera: Vespinae) of Malaysia. *Malayan Nature Journal*, 49, 71-82.

McCune, B. & Mefford, M.J. 2011.PC-ORD- Multivariate analysis of ecological data, version 6.0. MjM software. Gleneden Beach, Oregon, USA

Nicholas, A.S., Kojima, J., Ruslan, M.Y., Fauzi, M. & Idris, A.B. 2011. A list of social vespid wasps (Hymenoptera: Vespidae) from Kuala Lompat, Krau Wildlife Reserve, Pahang, Peninsular Malaysia. *Serangga*. 16(1): 59-74.

Ribeiro Jr., C., Guimar˜aes, D.L., Elisei, T. &Prezoto, F. 2006. Foraging activity rhythm of the neotropical swarm-founding wasp *Protopolybia exigua*(Hymenoptera, Vespidae, Epiponini) in different seasons of the year. *Sociobiology*, vol. 47, no. 1, pp.115–123

Richter, M.R. 2000. Social wasp (Hymenoptera: Vespidae) foraging behaviour. *Annual Review of Entomology*, vol. 45, pp. 121–150.

Rocha, A.A. & Giannotti, E. 2007. Foraging activity of *Protopolybia exigua* (Hymenoptera, Vespidae) in different phases of the colony cycle, at an area in the region of the

M´edioS˜ao Francisco River, Bahia, Brazil. *Sociobiology*, vol. 50, no. 3, pp. 813–831.

Rocha, A.A., Giannotti, E. & Filho, A.C.B. 2009. Resources taken to the nest by *Protopolybia exigua*(Hymenoptera, Vespidae) in different phases of the colony cycle, in a region of the m´edios˜aofrancisco river, Bahia, Brazil. *Sociobiology*, vol. 54, no. 2, pp. 439–456.

Santos, G.M.M., Bichara, C.C., Resende, J.J., Cruz, J.D. & Marques, O.M. 2007. Diversity and community structure of social wasps (Hymenoptera: Vespidae) in three ecosystem in Itaparica Island, Bahia State, Brazil. *Neotropical Entomology.,*Vol 36 (2): 180-185.

Santos, G.P., Cola Zanuncio, J., Pires, E.M., Prezoto, F., Milagres Pereira, J.M. & Serr˜ao, J.E. 2009. Foraging of *Parachartergus fraternus* (Hymenoptera: Vespidae: Epiponini) on cloudy and sunny days. *Sociobiology*, vol. 53, no. 2B, pp. 431–441.

Silveira, O.T., Costa Neto, S.V. & Silveira, O.F.M. 2008. Social wasps of two wetland ecosystems in brazilian Amazonia (Hymenoptera, Vespidae, Polistinae). *Acta Amazonica*, vol. 38, no. 2, pp. 333–344.

Spradbery, J.P. 1973. Wasps. An account of the biology and natural history of social and solitary wasps. *Seatle, University Washington Press*, 408p.

Turillazzi, S. 1999. New species of *Liostenogaster* van der Vecht 1969, with keys to adults and nests (Hymenoptera VespidaeStenogastrinae). *Tropical Zoology* 12, 335 358.

Vecht, J. van der. 1957. The Vespinae of the Indo-Malayan and Papuan areas (Hymenoptera, Vespidae). *Zoologische Verhandelingen 34, 1–83.*

Walther, B.A., & Moore, J.L. 2005. The concepts of bias, precision and accuracy, and their use in testing the performance of species richness estimators, with a literature review of estimator performance, *Ecography*, 28. 815–829.

Wenzel, J.W. 1991. Evolution of nest architecture.In *The social biology of wasps* (pp. 480–519), edited by K. G. Ross and R. W. Matthews. Ithaca, NY: Cornell University Press

Wilson, E.O. 1990. Success and dominance in ecosystems: The case of the social insects. Ecology Institute, Oldenfdorf/Luhe, Germany.