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Original Paper

Arthropod functional feeding groups as indicators of small-scale disturbance: a first approach in Mt. Manunggal, Cebu Island, Philippines

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Abstract

The growing pressure placed by human disturbances on natural resources creates a need for quick and precise answers about the state of conservation of different ecosystems worldwide. Hence, identifying and making use of ecological indicators becomes an essential task in the conservation of tropical ecosystems. This study assessed the effects of small-scale disturbances on terrestrial arthropods and select functional feeding groups (FFGs) that could be used as ecological indicators in one of the protected areas of Central Cebu Protected Landscape. Arthropods were sampled within Mt. Manunggal, Cebu Island, Philippines, both in highly-disturbed (S1) and less-disturbed sites (S2) of CCPL from October 2017 to March 2018. Arthropods were collected using a combined transect-quadrat method, where 24 quadrats were established within six transects (20 × 20 m) in S1 and S2. All data were analyzed using Odum and Barrett's formulae for abundance and richness, Shannon Wiener index for diversity and Pielou's index for evenness. A total of 12 403 arthropods under ten distinct FFGs were recorded, whose abundance contrasted across S1 and S2, with scavenger feeders showing the highest abundance (S1: $n = 2363$; 19.05%) while seed feeders with the lowest abundance (S1: $n = 9$; 0.13%; S2: $n = 38$; 0.67%). In S1, there were $n = 6759$ under 48 arthropod families while $n = 5644$ under 45 arthropod families were recorded in S2. The diversity index of arthropod assemblages in both sites (S1: $H' = 1.94$; S2: $H' = 1.93$) was classified in the medium category, indicated by $H' > 3.87$. The evenness value in range $0.40 < e < 0.60$ also indicated a medium number of arthropods in both sites. The abundance of arthropods was higher in the highly-disturbed site, and this pattern seems to be an adequate indicator of anthropogenic disturbance. This novel approach in categorizing arthropods based on FFGs provides an important complement to link contrasting patterns of composition to differences in forest functioning and habitat disturbances across geographical and environmental gradients. This study underlines that habitat disturbances are the main driver of the variation in arthropod diversity. Potential applications for FFGs as indicators include the choice and evaluation of sites for the establishment of protected areas, elaboration of management plans, and the assessment of ecological impacts due to human disturbances, either for the purpose of licensing or legal compensation.

Key words: abundance, arthropod assemblage, Cebu Island, diversity, richness.
Abbreviations: *%N*, percentage abundance; CCPL, Central Cebu Protected Landscape; *D*, Simpson diversity index; DENR, Department of Environment and Natural Resources; FFGs, functional feeding groups; *H'*, Shannon-Weiner diversity index; masl, meters above sea level; Mt., mountain; N, abundance; *PE*, Pielou's evenness; *R*, taxa (family) richness; S1, Site 1; S2, Site 2.

Introduction

Arthropods are one of the most diverse group of animals in the Philippines. These are most numerous in tropical forests and serve as excellent indicator species because they are specious, diverse, abundance, widespread, easy to sample and often predictably responsive to environmental alterations (Aukema et al. 2017; Wong et al. 2019). These organisms may act as indices of environmental conditions or biological phenomena that are difficult, inconvenient or expensive to be directly measured, comprising an attempt to synthesize information and recognize key aspects that at length should guide reliable conservation decisions (Litt, Steidl 2010). Biological indication may involve assessment of changes in species richness and abundance, shifts in biological attributes or, in a more general way, by some change in species composition from an undisturbed state (Garces 2019). Habitat destruction brought by the conversion of forests to agricultural lands and by infrastructure development is considered as one of the significant threats to the survival of arthropods in their natural environment (McKee et al. 2004). Large areas of forests have been lost in the last 50 years due to habitat fragmentation, introduction of non-native species, pollution, climate change and overexploitation of resources (Tilman et al. 2017). Besides the universal need for developing ways to assess status and trends in environmental state and for the effects of human disturbance on arthropod assemblages to help making conservation decisions is still a challenge in the most biodiverse countries, where taxonomic and natural history knowledge is greatly deficient (Standish et al. 2004). This task is especially urgent in the megadiverse countries, since their natural systems are being continually destroyed by human disturbances.

Mt. Manunggal, Cebu Island, Philippines, one of the protected areas of the Central Cebu Protected Landscape (CCPL), is considered a 'hotspot' due to its high species diversity associated with high rates of endemism and elevated level of disturbance, and has highest conservation priority (Paguntalan, Jakosalem 2008). Besides habitat loss, Mt. Manunggal suffers from wood harvesting, plant collecting, hunting, invasion by alien species among anthropogenic pressures (Garces, Genterolizo 2017; Garces, Flores 2018; Garces 2019). Due to its altered state, the development and testing of indicators to assess and monitor the condition of Mt. Manunggal remnants in CCPL should be a priority. Terrestrial arthropod assemblages share a number of qualities that make them highly adequate as biological indicators. These include their sensitivity to habitat change, rapid responses to various disturbances, and easy and cost-effective sampling (Aukema et al. 2017; Tilman et al. 2017; Wong et al. 2019). However, their usefulness has been systematically neglected in conservation planning in the Philippines, where most attention is focused on more "charismatic", but sometimes less informative groups. Even when in cases where arthropods were used in the assessment of anthropogenic disturbances in the island of Cebu, multi-taxonomic approaches have rarely been applied for this purpose, making it difficult to extrapolate the results from one taxon to another.

The main goal of this study was to select a set of specific arthropod FFGs that can serve as an excellent small-scale ecological indicator of anthropogenic disturbance in one of the protected areas of Central Cebu Protected Landscape, Mt. Manunggal, Cebu Island, Philippines. The specific objectives were (i) to determine how anthropogenic disturbances affect species composition (i.e., arthropod abundance, richness and diversity) based on FFGs in S1 and S2 of Mt. Manunggal, Cebu Island, Philippines, and (ii) to determine the efficacy of arthropod FFGs as surrogates for others. Responses of each arthropod group can be employed as excellent indicators of small-scale anthropogenic disturbances, and this information can be used to guidestrategies designed to protect and preserve faunal species. especially those which are threatened or endangered in the Philippine setting.

Materials and methods

Study area and site descriptions

This study was carried out on Mt. Manunggal, Cebu Island, Philippines (10°27'39.41"N and 123°46'50.72"E), which is 53 km Northwest of Cebu in Balamban, Cebu Island, Philippines (Fig. 1). The region is located on mountainous relief, with altitudes ranging from 400 to 1003 m. The regional climate is humid, with an average annual temperature of 32 ˚C and average annual precipitation of 210 mm. The region is part of the Central Cebu Protected Landscape (CCPL), classified as dipterocarp forest (DENR-VII 2017). About 70% of the forest is represented by different lauan family: 'white lauan' (*Pentacme contorta*), 'red lauan' (*Shorea negrosensis*), 'tangile' (*Shorea polysperma*), 'apitong'

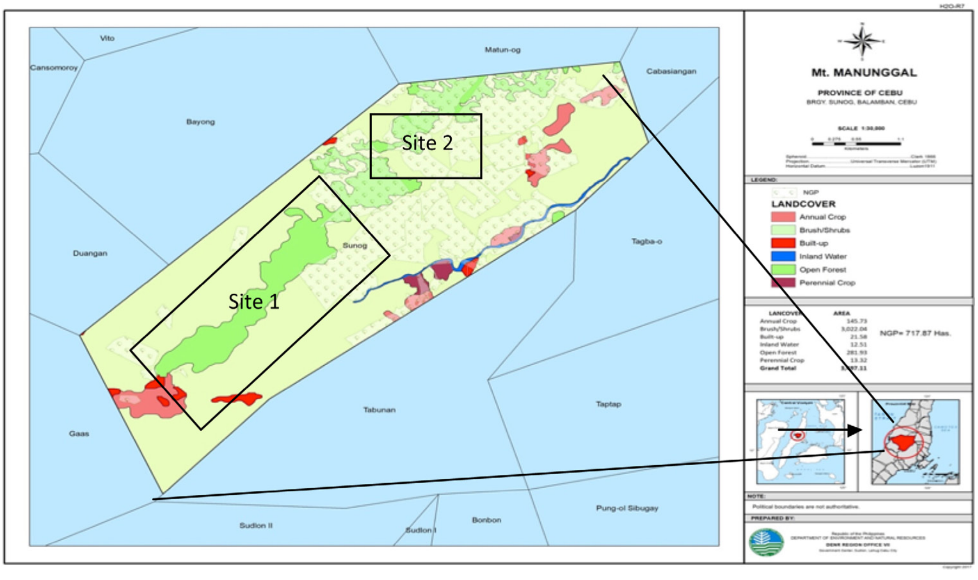

Fig. 1. Geographic location and plot establishment of the study sites, Mt. Manunggal, Cebu Island, Philippines (DENR-VII, 2017).

(*Dipterocarpus grandifloras*), 'yakal' (*Hopea* sp.) and 'guijo' (*Shorea guiso*). The study area was ca. 717.87 ha (DENR-VII, 2017), and was located inside the CCPL. The Department of Environment and Natural Resources (DENR) Region VII considers CCPL where Mt. Manunggal is located as an "area of extreme biological importance", alongside with its neighboring forest (Mt. Tabunan), of priority toward conservation of CCPL (Paguntalan, Jakosalem 2008).

In the 1970s, part of the forest that currently belongs to Mt. Manunggal suffered slash-and-burn management and was subsequently replaced by pasture (Garces 2019; DENR-VII 2017). Nowadays, this part of the forest is a mosaic composed of old-growth forest, abandoned pasture occupied by woody vegetation, abandoned 'abaca' plantations, and secondary forest at different regeneration stages. Another section of the forest was severely logged for hardwood before the establishment of the CCPL in 1970 (Tura, personal communication), and now is a fairly well-preserved old growth forest, with some nearby remnants of forest. Hereafter, these sites with different disturbance degree will be referred to as S1 – "highly-disturbed" and S2 – "less-disturbed", respectively. It is worth emphasizing that both sites are embedded within a continuous, well-preserved forest context in the CCPL region (Paguntalan, Jakosalem 2008). By comparing sites within a vegetation continuum, noise due to fragmentation effects can be minimized.

Sampling design and procedures

Two sampling stations (S1: highly-disturbed site and S2: less-disturbed site) were set in Mt. Manunggal, Cebu Island, Philippines. At each station three transects with a total of 12 quadrats were established for arthropod sampling (Fig. 1). Sampling stations were set within structurally similar vegetation in both sites but within locations with different abundances. The sampling of arthropods was conducted using the combined explorative survey method and transect-quadrat method. For each transect, quadrats were laid alternately left and right with a 20 m distance from each other. Sampling of arthropods was made using a quadrat measuring at 20 × 20 m (400 m^2); there were twelve (12) quadrats in total in each site. The quadrats were scrutinized to collect arthropod sample. Techniques utilized in the sampling of arthropods included: (i) pitfall trap sampling (Greenslade 1964) and (ii) bait sampling (Sathe 2009).

The pitfall traps consisted in 500 mL clear plastic cups, 85 mm wide at the opening and 120 mm in depth, flush with ground level, with a polystyrene cover suspended above the cup by wooden sticks. Each trap contained ca. 60 mL of a mixture of 70% water, 29% propylene, and 1% formaldehyde, and a few drops of detergent. Pitfall traps were placed in lines parallel to the bait traps lines, inside the forest understory, at 2 m intervals, and at least 20 m from the trails. For pitfall trap sampling and bait trap sampling, five traps were established per sampling unit and were at least 100 m apart from each other. Bait traps were made of cylinders of netting, with an internal funnel, baited with a mixture of mashed banana and sugar cane juice, fermented for at least 48 h. Bait traps were located along pre-exiting trails in the understory of each site, suspended at a height of 1.5 to 2.0 m above the ground with a distance of at least 23 m between adjacent traps. The traps were checked every 48 h, and the bait was replaced at each visit (see Greensdale 1964 for details on the sampling scheme). The collected samples were released to its habitat immediately once data on abundance, richness and species were recorded. Both pitfall and bait traps were kept simultaneously in the field for 7 days per month, respectively. Sampling was done monthly from October 2016 to May 2017, including the most favorable season for the capture of arthropods in the This choice of time period was based upon the peak and subsequent end of arthropod activity. Philippines. Only a few samples samples required identification in the laboratory, using Blondel et al. (2003), Moran and Southwood (1982) and Bambaradeniya et al. (2008) for different functional feeding groups (FFGs). Some arthropod species captured in the pitfall and bait traps were identified in the field and were released after marking. Although defining FFGs in such a way is not a perfect approach, this is an efficient and useful step forward to relate diversity and ecosystem function (Bengtsson 1998; Pearson 2009). All individuals were taxonomically identified to the family level only. For individuals that could not be classified, their feeding habits were based on the morphology and mechanism of the arthropod's mouthparts at the family level (Sathe 2009).

Data analysis

The null hypothesis of no difference in abundance within arthropod groups between disturbed and undisturbed sites was assessed by the test on $\log_{10}$ (x + 1) transformed abundance data. Fisher's logarithmic series parameter (*a*) was compared between sites by the bootstrapping procedure (see Marguran 2004) using Minitab Version 16.0. Overall similarity between sites was calculated by Pielou's evenness index. Species richness of arthropod groups with 10 or more species (see Table 1) was compared between sites by individual-based rarefaction analysis. The statistical significance (at $p < 0.05$) of differences in species richness was evaluated by comparing 95% confidence limits in the point of the rarefaction curves with same abundance. Rarefaction analyses were performed using the Analytic Rarefaction 1.3 software (available from htt://www.u-ga.edu/strata/software/anRareReadme.html) (Tipper 1979).

To evaluate if disturbance affected the species composition of the selected arthropod groups, a non-metric multidimensional scaling (NMDS) on the resemblance matrix of Bray-Curtis disturbances for arthropod groups with $S > 12$ (Table 1), with 1000 random restarts (Kruskal 1964) was conducted. This ordination method has been frequently used in ecological studies, and presents several

Table 1. Functional feeding groups (FFGs) for arthropods described. Adapted from the papers of Moran, Southwood 1982 and Bambaradeniya et al. 2008

Functional feeding groups (FFGs)	Description
Predator	This broad group comprises arthropods which feed on other arthropods, irrespective of the mode of feeding.
Phytophagous	This group includes arthropods which feed on plant matter and possess biting/ chewing mouth parts
Parasitoid	Includes arthropods which feed in or on another living animal for a relatively long time during one or all of their life stages
Nectar Feeder	Arthropods feeding on nectar in some way or form during any of their life stages
Weevil	Coleoptera which feed on plant material by making holes into plant parts for feeding on the internal plant tissues and oviposition
Saprophagous	Arthropods feeding on dead and decaying plant or animal matter by using enzymes to first liquefy the material, w/c is subsequently ingested
Fungus Feeder	Arthropods feeding on fungi
Sap-sucking	Includes organisms w/c feed on plant matter and possess piercing/ sucking mouth parts
Seed Feeder	Arthropods feeding primarily/ exclusively on the seeds of plants
Scavenger	Arthropods which feed on dead plants or animals, or any other form of animal waste
Tourist	Arthropods which are only present in the habitat for reasons other feeding
Rasper	Arthropods where the mandible is used to rupture plant tissues from which plant liquids are sucked up and ingested.

advantages (i.e., minimizing the arch effect, releasing linearity constraints, and not requiring multivariate normality of data. Moreover, as in other indirect gradient analyses, NMDS depicts the environment in the organism's point of view. To test the null hypothesis of equal species composition between highly-disturbed and less-disturbed forest sites, an analysis of similarities (ANOSIM) on the matrix of Bray-Curtis similarity with 999 permutations was applied. Before running these multivariate techniques, dispersion weighting was applied to the original dataset in order to downweight species of highly variable abundance, clumped into replicates. These analyses were done using PRIMER software and Minitab Version 16.0 (Brown et al. 2001).

To test the species richness surrogacy, two approaches: (i) pairwise correlation of species richness among taxa; and (ii) correlation of species richness of one taxon with the pooled richness of the remaining taxa were employed. Pearson's correlation coefficient was determined for $\log_{10}$ (x + 1) transformed data. A procedure to control for false discovery rate was applied, due to the large number of correlations tested. To test surrogacy on species composition, RELATE tests (PRIMER software by Clarke and Gorley 2006) with Spearman's correlation coefficient were used to correlate Bray-Curtis similarity matrices based on species composition. This function calculates the Spearman rank correlations between two similarity matrices and calculates the significance of this correlation by a permutation test. When comparisons were done between hierarchically related taxa (e.g. family vs. order), the lower taxon was removed from the higher taxon dataset.

Table 2. The evenness criteria

E value	Condition of community structures	Category
> 0.81	Very equally	Very good
0.61 – 0.80	More equally	Good
0.41 – 0.60	Equally	Medium
0.21 – 0.40	Fairly equally	Poor
< 0.20	Not equally	Very poor

The following was used to calculate the abundance of each arthropod species using Odum, Barret (2008) formula:

K = the amount of the taxa (family) / the number of individuals of all taxa (families) × 100%;

Family (taxa) richness = no. of families found in each quadrat.

Shannon Wiener Index (*H'*) was calculated as:

$$H' = -\sum_{i=1}^{S} \frac{ni}{N} \ln \frac{ni}{N}$$

where *ni* is number of individuals, *N* is total number of families.

To calculate evenness, Pielou's evenness was used:

$$Pi = ni / N;$$

where *ni* is comparison of the number of families; *N* is total of individuals.

$$E = H' / H'max = H' / \ln S;$$

where *E* is evenness index, *H'* is diversity index, *H' max* is maximum diversity, *S* is the number of taxa (family). Criteria for characterization of condition of community structures as based on evenness are given in Table 2.

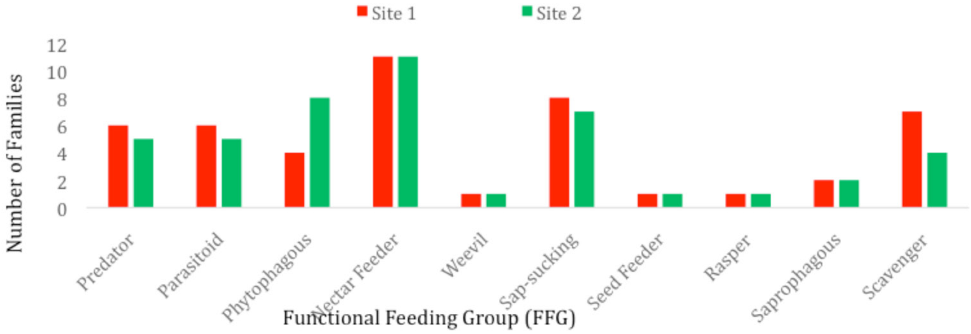

Fig. 2. Number of taxonomic families per FFG in S1 and S2, Mt. Manunggal, Cebu Island, Philippines.

Table 3. Mean abundance, species richness, similarity and diversity of arthropods in disturbed (S1) and undisturbed (S2) sites use in Mt. Manunggal, Cebu Island, Philippines. See methods for details on the disturbance history of each site. [a]differences in abundance evaluated by *t*-test on $\log_{10}$ (x+1) transformed abundance data; [b]differences in species richness evaluated by visual comparison of rarefaction curves and their 95% confidence intervals; [c]differences in Shannon Weiner Diversity for each site; [d]forty-eight families. *, significant at $p < 0.05$; **, significant at $p < 0.01$; ns, $p > 0.05$

Arthropod FFGs	**Taxon (family)**	**Mean abundance (± SD) [a]**		**Species richness [b]**				**Shannon-Wiener Diversity**	
		S1	**S2**	**S1**	**S2**	**Total**	**Pielous evenness**	**S1**	**S2**
Predator	Coccinellidae, Reduviidae, Elmidae, Dictyophoridae, Tettigoniidae, Salticidae, Centipede, Carabidae, Vespidae	734 (720) **	1101 (1051) **	6	5	5	0.10	0.24	0.32 **
Parasitoid	Nepidae, Reduviidae, Myrmelionidae, Mantidae, Pentatomatidae	695 (688)	317 (304) **	6	5	4	0.05	0.23	0.16
Phytophagous	Coreidae, Acrididae, Lampyridae, Buprestidae, Culicidae, Apidae	1161 (1123) **	566 (543) **	4	8	7	0.14	0.30 **	0.23 *
Nectar feeder	Vespidae, Formicidae, Nymphalidae, Pieridae, Erebidae, Saturniidae, Sphingidae	981 (970) **	1050 (1031) **	11	11	10	0.15	0.28 *	0.31 *
Weevil	Curculionidae, Calliphoridae, Muscidae, Cicadellidae	51 (45)	41 (29)	1	1	1	0.01	0.04	0.04
Sap-sucking	Aphrophoridae, Cicadidae, Ricannidae, Fulgoridae	919 (906) **	1444 (1440) **	8	7	7	0.08	0.27 *	0.35 **
Seed feeder	Chrysomelidae	9 (6) ns	38 (30)	1	1	1	0.005	0.01	0.03
Rasper	Pyrrhocoridae	284 (271) **	223 (241) *	1	1	1	0.035	0.13	0.13
Saprophagous	Scarabaeidae, Termitidae, Anthicidae, Cerambycidae	140 (135)	172 (173) *	2	2	1	0.025	0.08	0.11
Scavenger	Tipulidae, Formicidae, Blattidae, Gryllidae	1785 (1779) **	692 (679) **	7	4	7	0.08	0.35 *	0.26 *

Table 4. Arthropod abundance, richness, and diversity indices, S1 and S2, Mt. Manunggal, Cebu Island. *N*, abundance; *R*, taxa (family) richness; *%N*, percentage abundance; *H'*, Shannon-Weiner diversity index; *D*, Simpson diversity index; *PE*, Pielou's evenness

FFG	S1						S2					
	N	*R*	*% N*	*H'*	*D*	*PE*	*N*	*R*	*%N*	*H'*	*D*	*PE*
Predator	734	6	10.86	0.241	0.01	0.06	1101	5	19.51	0.32	0.04	0.08
Parasitoid	695	6	10.28	0.234	0.01	0.06	317	5	5.62	0.16	0.00	0.04
Phytophagous	1161	4	17.18	0.303	0.03	0.08	566	8	10.03	0.23	0.01	0.06
Nectar Feeder	981	11	14.51	0.28	0.02	0.07	1050	11	18.60	0.31	0.03	0.08
Weevil	51	1	0.75	0.037	0.00	0.01	41	1	0.73	0.04	0.00	0.01
Sap-sucking	919	8	13.60	0.271	0.02	0.07	1444	7	25.58	0.35	0.07	0.09
Seed feeder	9	1	0.13	0.009	0.00	0.00	38	1	0.67	0.03	0.00	0.01
Rasper	284	1	4.20	0.133	0.00	0.04	223	1	3.95	0.13	0.00	0.03
Saprophagous	140	2	2.07	0.08	0.00	0.02	172	2	3.05	0.11	0.00	0.03
Scavenger	1785	7	26.41	0.352	0.07	0.09	692	4	12.26	0.26	0.02	0.07
TOTAL	6759	48	100	1.94	0.16	0.50	5644	45	100	1.93	0.17	0.51

Results

A total of 12 403 arthropods were collected across three sampling transects in S1 and S2 (Fig. 2). Arthropods observed in S1 and S2 were categorized into diverse functional feeding groups (FFGs) based on feeding style and taxonomic order of different insect families (Table 2) (Buschke, Seaman 2011). The novel approach of assigning arthropods based on FFGs is an essential feature in predicting impacts of arthropods to ecosystem structures and processes, and vice versa. The proportion of individual arthropods in both sites varied widely from group to group (Table 2). The total number of trapped individuals of arthropods in S1 was higher compared to S2 (Table 3). The arthropod FFGs were scavenger, sap-sucking, nectar feeder, predator, phytophagous, parasitoid, rasper, saprophagous, weevil and seed feeder (Table 3). In S1, there were 6759 individuals, under 48 arthropod families, while 5644 individuals under 45 arthropod families were recorded in S2. S1 was characterized by much higher arthropod abundance than S2. Of the recorded families in S1 and S2 (Table 4), the most abundant FFG in the sample was scavengers, with 1785 individuals, 26.40% of which were found in the disturbed site (Table 4). Sap-sucking arthropods were also abundant with 2363 individuals (19.05%).

Centipedes, Centipedes, under Order Chilopoda and common spiders of Order Araneae (Salticidae) were also recorded but were identified up to the subclass level only. Several arthropod species could serve as natural enemies of pests in both S1 and S2. Abundance, family richness and diversity were higher in S1 than in S2. The most abundant of the FFGs in S1 were the scavengers with 1785 individuals (26.41%), most of which were ants of the family Formicidae (Table 4). This was followed by the phytophagous feeders with 1161 individuals (17.18%), most of which were grasshoppers of the family Acrididae. The least abundant were seed feeders with only nine individuals or 0.13% of the total abundance for Site 1 (Table 4). In S2, sapsuckers dominated in number at 1444 individuals (25.58%), most of which belonged to the Order Diptera (true flies). Similar to

Table 5. NMDS and ANOSIM results for arthropod data groups sampled in disturbed and undisturbed sites in Mt. Manunggal, Cebu Island, Philippines. [a]Araneae and epigaeic Coleoptera ground into families; all remaining groups were grouped into subfamilies; [b]visual inspection or ordination diagrams; *, significant at $p < 0.05$; **, significant at $p < 0.01$

Arthropod family	ANOSIM R	NMDS stress		Ordination quality at higher taxon level [b]
		Species	Higher taxonomic level [a]	
Predator	0.701*	0.19	0.18	Same
Parasitoid	0.655*	0.17	0.17	Same
Phytophagous	0.725**	0.18	0.18	Same
Nectar feeder	0.640*	0.10	0.09	Worse
Weevil	−0.043ns	0.04	0.04	Worse
Sap-sucking	0.563*	0.12	0.13	Same
Seed feeder	−0.020ns	0.05	0.05	Worse
Rasper	0.500*	0.11	0.12	Same
Saprophagous	0.211ns	0.03	0.04	Worse
Scavenger	0.606*	0.17	0.16	Same

Table 6. Correlations among groups in species richness (above diagonal) and species composition (below diagonal). *, significant at p < 0.05, **, significant at p < 0.01

	Predator	Parasitoid	Phytophagous	Nectar Feeder	Weevil	Sap-sucking	Seed feeder	Rasper	Saprophagous	Scavenger
Predator		−0.655	0.664	0.246	0.221ns	−0.413	0.661**	−0.466ns	0.440*	0.439
Parasitoid	0.678**		0.777	0.441*	0.768	0.433*	0.152	0.349	−0.788**	−0.233
Phytophagous	0.233	0.567*		0.409	−0.811*	0.511	0.577*	0.519**	0.474	−0.329
Nectar feeder	0.434*	0.450	−0.378		0.411	−0.221	0.500	0.623	0.455*	0.559**
Weevil	0.600	0.313	0.891*	0.150ns		0.504ns	−0.611	0.766*	0.489	−0.244
Sap-sucking	0.701	0.740**	0.900*	0.322	0.333		0.522ns	−0.433	0.133	0.322
Seed feeder	0.812**	0.888	0.679	0.455*	0.417	−0.622		0.573*	−0.663**	0.455
Rasper	−0.210	−0.211	−0.811	0.771	0.555**	0.406*	−0.335		0.451	0.561*
Saprophagous	0.467*	0.910**	0.945*	0.600**	0.616*	−0.123	0.500**	0.517*		0.663**
Scavenger	0.566*	0.677**	0.566*	0.661**	−0.344	0.500**	0.771*	0.451	0.131ns	

S1, the least abundant were seed feeders with 38 individuals (0.67%). There were slightly more families in S1 than in S2 (Fig. 2) with scavengers and phytophagous arthropods dominating (Table 4). Sap-sucking, nectar-feeding, and predatory arthropods dominated in S2 (Table 7). Seed feeders and weevils had the lowest abundance in both S1 and S2 (Table 4). Along with differences in abundance between study sites (Table 4), scavengers (26.40%, *n* = 1785) and sap-sucking arthropods (19.05%, *n* = 2363) were more abundant at the site where anthropogenic intervention was more intense in the past (Table 4). For example, Formicidae had the highest abundance in S1 (Table 3), compared to S2. Higher abundance of ants in S1 might be attributed to greater anthropogenic activity, which created an open, warmer habitat, providing more suitable habitat for ants. There was a greater abundance of phytophagous FFG in highly disturbed sites, compared to that in less-disturbed sites (Table 4).

Based on the abundance of different arthropod groups in the samples, some widespread, abundant species had potential to be good indicators of anthropogenic disturbance in Mt. Manunggal. For example, ground beetles in the family Scarabaeidae and sap-sucking Cicadidae were at least two times more abundant in the highly disturbed site than in the less disturbed site (Table 6 and 7). In comparison to other FFGs, the above species are larger, easily identifiable, and more is known about their natural history. Therefore, they could be focal species for further studies with anthropogenic disturbance effects on arthropods. The great majority of individuals in the predator (*n* = 1101) and nectar feeder (*n* = 1050) groups were at the undisturbed site and should be considered for future studies as well. However, in contrast with the above examples, basic aspects of the biology of most predators and nectar feeder FFGs remain to be unexplored. In this study, indicator-related interpretations based on a particular taxon might be limited, but set of species might provide more effective representation of ecological change. The applicability of single taxa as disturbance indicator will need to be validated by additional studies in other areas of Mt. Manunggal.

The increase in species richness with disturbance observed for most arthropod FFGs corresponds to the literature. This result was obtained despite the use of unbaited traps, which is a less efficient method for most arthropod FFGs. Patterns of response of the other groups (parasitoids, phytophagous, weevil, seed feeder, rasper and scavengers) to disturbance are either unknown or poorly studied in tropical forests. The observed higher species richness for scavengers, sap-sucking and nectar feeder FFGs in the disturbed site was opposite to that found in other studies at a similar scale. Fig. 2 shows that family richness slightly differed within FFG in S1 and S2. Nectar feeders had the greatest number of families (11) in both sites. On the other hand, the least number of families were found for saprophagous feeders (2), weevils, seed feeders, and raspers, with 1 family each in both S1 and S2 (Table 4). Arthropod diversity and abundance measured at the family level were higher in S1 than in S2. Anthropogenic activities alter certain environmental conditions, which affect arthropod assemblage and floral composition in different forest ecosystems.

Non-metric multidimensional scaling results for predator, parasitoid, phytophagous, nectar feeder, sap-sucking, rasper and scavenger groups clearly showed different species composition between disturbed and undisturbed sites (Table 5). These differences were confirmed by ANOSIM (Table 5). Several arthropod FFGs showed significant correlation (Table 5). In particular, saprophagous FFG had the greatest number of significant relationships with other FFGs. It showed a positive relationship with parasitoid FFG (r = 0.910; p = 0.01) and phytophagous FFG (r = 0.945; p = 0.01). Weevil FFG parameters had a positive relationship (Table 6) with phytophagous FFG (r = 0.891; p = 0.05), while seed feeder FFG had positive correlation with predator FFG (r = 0.812; p = 0.01). Among all arthropod FFGs (Table 6), scavengers had the largest number of positive correlations among other FFGs: predator FFG (r = 0.566; p = 0.05), parasitoid FFG (r = 0.677; p = 0.01), phytophagous FFG (r = 0.566; p = 0.05), nectar feeder (r = 0.661; p = 0.01), sap-sucking (r = 0.500; p = 0.01), and seed feeder FFG (r = 0.771; p = 0.05). The index of diversity of arthropods in S1 and S2 was high with H' > 3.87; S1 (H' = 1.94) had higher arthropod diversity compared to S2 (H' = 1.93; Fig. 3, Tables 6 and 7). Likewise, taxa (family) richness was higher in S1 (R = 48) compared to S2 (R = 45) (Table 7). Higher diversity of arthropods can be attributed to the nature of S1, as arthropod diversity was higher in the disturbed site (Table 7).

Discussion

Anthropogenic disturbance may affect species richness and diversity in several ways and responses may vary within studies among taxonomic or functional groups or among studies within the same group (Hill, Hamer 2004; Pardini et al. 2009). This variation may be attributed to several factors, such as the sensitivity of species richness to sampling effort, the spatial and temporal scale of the study and disturbance frequency, type and intensity. Also, differences in species richness between highly disturbed and less disturbed sites may be not observed due to low species richness of some taxa (Mason et al. 2005). As reported in several previous studies, correlations of species richness may vary depending on certain circumstances (e.g., Barlow et al. 2007; Fiedler et al. 2007). Most the species richness correlations may be attributed to high variability in ecological requirements inherent to the sampling of a number of different taxa. In this study, perhaps the sampling method was not as specific as would be desirable for some arthropod groups, and perhaps existing variability was not captured resulting in the insufficient data for examining species richness correlations. However, as the methods and sampling effort were similar in disturbed and undisturbed sites, it is expected that comparability would be maintained. Additionally, the sampling protocol was designed in such a way that it could be conducted by one or two people in the field, minimizing operational costs and increasing the chance of replication in future studies (Gardner et al. 2008). Adding several specific methods would certainly reduce the cost-effectiveness of sampling in the sites. It is expected that the methods are applicable per se and should be improved in later studies with additional methods.

Arthropod FFGs in both sites are dependent on environmental conditions and biological adaptation (Triplehorn, Johnson 2005; Burghardt et al. 2009). In particular, larvae of phytophagous FFG prefer to live in animal waste which is suitable for their growth and development. Moreover, greater plant biomass also favored the densities and diversity of Acrididae (grasshoppers) in Mt. Manunggal. Adult scarabs are usually attracted to fresh dung pads of carabao to feed on its liquids and construct burrows in the soil beneath the pads (Larsen et al. 2006). Animal domestication and grazing of animals such as cow, carabao, and goats are rampant in S1 which could have resulted in the high species abundance of this arthropod group (Garces, Flores 2018; Garces 2019). According to Litt and Steidl (2010), plants are considered to be suitable food source and shelter by Acrididae, where most of the species exhibit higher densities in greater biomass of plants. Sap-

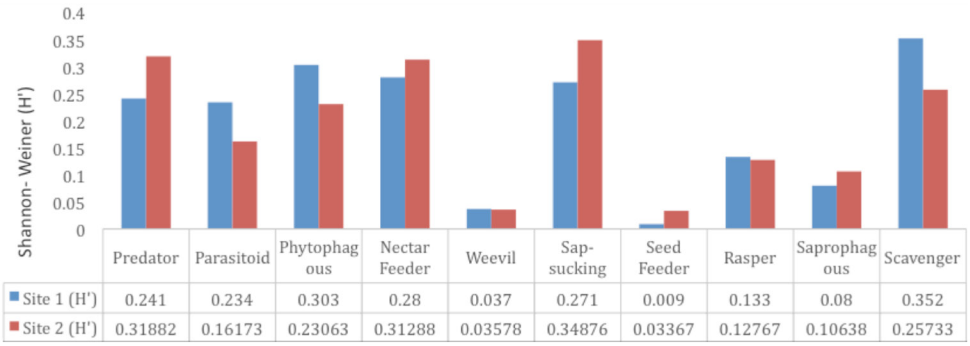

Fig. 3. Arthropod diversity (H') in Mt. Manunggal, Cebu Island, Philippines, from October 2016 to March 2017.

Table 7. Abundance per arthropod family in different FFGs in S1 and S2, Mt. Manunggal, Cebu Island, Philippines

FFG	Order	Family	S1		S2	
			Abundance	% abundance	Abundance	% abundance
PREDATOR	Coleoptera	Coccinellidae	304	4.52	325	5.76
	Hemiptera	Reduviidae	13	0.19	363	6.43
		Elmidae	77	1.14	0	0
		Dictyophoridae	145	2.16	275	4.87
	Orthoptera	Tettigoniidae	38	0.56	35	0.62
	Araneae	Salticidae	157	2.33	65	1.15
		Centipede	0	0	38	0.67
PARASITOID	Coleoptera	Carabidae	371	5.52	278	4.93
	Hymenoptera	Vespidae	31	0.46	19	0.34
		Evaniidae	37	0.55	19	0.34
	Hemiptera	Nepidae	8	0.12	1	0.02
		Reduviidae	14	0.21	0	0
	Neuroptera	Myrmelionidae	234	3.48	0	0
PHYTOPHAGOUS	Mantodea	Mantidae	291	4.33	158	2.8
	Hemiptera	Pentatomatidae	13	0.19	106	1.88
		Coreidae	249	3.7	1	0.02
	Orthoptera	Acrididae	608	9.04	301	5.33
NECTAR FEEDER	Coleoptera	Lampyridae	68	1.01	0	0
		Buprestidae	323	4.8	136	2.41
	Diptera	Culicidae	8	0.12	5	0.09
	Hymenoptera	Apidae	84	1.25	28	0.5
		Vespidae	43	0.64	21	0.37
		Formicidae	315	4.68	549	9.73
	Lepidoptera	Nymphalidae	26	0.39	197	3.49
		Pieridae	3	0.04	63	1.12
		Erebidae	32	0.48	35	0.62
		Saturniidae	37	0.55	16	0.28
		Sphingidae	9	0.13	0	0
WEEVIL	Coleoptera	Curculionidae	51	0.76	41	0.73
SAP-SUCKING	Diptera	Calliphoridae	24	0.36	494	8.75
		Muscidae	117	1.74	456	8.07
	Hemiptera	Membracidae	295	4.39	3	0.05
		Cicadellidae	168	2.5	438	7.76
		Aphrophoridae	5	0.07	3	0.05
		Cicadidae	171	2.54	22	0.39
		Ricaniidae	70	1.04	28	0.5
		Fulgoridae	69	1.04	0	0
SEED FEEDER	Coleoptera	Chrysomelidae	9	0.13	38	0.67
RASPER	Hemiptera	Pyrrhocoridae	284	4.22	223	3.95
SAPROPHAGOUS	Coleoptera	Scarabaeidae	126	1.87	172	3.05
	Isoptera	Termitidae	14	0.21	0	0
SCAVENGER	Coleoptera	Scarabaeidae	486	7.23	76	1.35
		Anthicidae	35	0.52	49	0.87
		Cerambycidae	29	0.43	64	1.13
	Diptera	Tipulidae	82	1.22	38	0.67
	Hymenoptera	Formicidae	839	12.47	382	6.77
	Orthoptera	Blattidae	52	0.77	40	0.71
		Gryllidae	262	3.9	43	0.76
Family richness	48	45				
Total abundance	6759	5644				

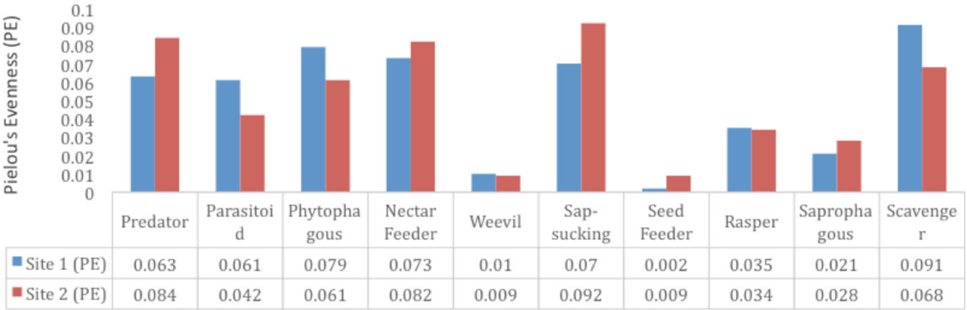

Fig. 4. Arthropod evenness (*PE*) in Mt. Manunggal, Cebu Island, Philippines, from October 2016 to March 2017.

sucking arthropods such as species under Cicadellidae (true bugs) are natural plant feeders. They suck on plant sap from grasses, shrubs and trees (Wolkovich 2009). As a generalist group, plant surfaces also serves for their breeding, where their eggs stay for the days necessary for growth and development (Sax et al. 2005). Also, sap sucking Calliphoridae (blow files) were also dominant in both sites, where S1 was not only a camp site but was also dominated by grazing animals such as cow and goat. The wastes (i.e., dung) excreted by these animals and carrion could serve as medium for blow flies to live on. These wastes and decaying flesh serve as their breeding ground, where their eggs will hatch into larvae or maggots (Triplehorn, Johnson 2005; Burghardt et al. 2009).

For other FFGs, the dominance of Formicidae (ants) is explained by the fact that this group can benefit from invasive plants through food source availability and changes in microclimatic conditions (Tallamy 2004). This is also supported by the Thermal Limitation hypothesis, where cool temperatures limit the ability of ants to harvest resources (Kaspari et al. 2000). This group does not only belong to a single group but can also be considered as herbivore, carnivore, or detritivore and are best employed as indicator of trophic cascades at the community level (Fork 2010). For some FFGs, such as Scarabaeidae under saprophagous FFG, showed the second highest abundance in S1 (Table 2). Families under phytophagous FFGs are considered to be generalist species that uses plant litter as their habitat. They are more likely to incorporate a variety of plants in their diet easily and effectively (Tallamy, 2004). Generalists have high environmental adaptation, which allows greater survival (Haddad et al. 2001; Pearson 2006). Several previous papers pointed out that disturbances cause significant changes in community structure, species richness and abundance of this phytophagous group (Litt et al. 2014). Responses of Acrididae have been better documented, but they differ. Orthoptera abundance decrease in areas dominated by alien plants (Standish, 2004), but researchers have also reported increases (Tallamy 2004). Such different responses could be a result of different life forms of plants and degree of diet specificity. For example, some Orthoptera species feed on dead plant material and live on prey (Triplehorn, Johnson 2005) and may benefit from structural changes associated with floral composition. Biological indices revealed a slight variation in taxonomic richness, abundance, and diversity of arthropods between S1 and S2 (Tables 2 and 3).

Studies have documented that anthropogenic activities assist in the introduction and persistence of arthropods in disturbed ecosystems (e.g., Spafford et al. 2013). However, the characterization of general diversity patterns of response to disturbance at the continental and local scale may be a very difficult task because of functional and structural differences among biomes and history of disturbance of different regional communities. General patterns may emerge from studies focused on specific biomes within regions, thereby validating the use of ecological indicators, within specific geographical limits (Kim, Byrne 2006). It is therefore suggested that further studies about diversity patterns of potential ecological indicators be conducted in Mt. Manunggal, and to focus on increasing the geographical sampling coverage of this biome, in search of well-defined patterns of response to disturbance. As found in studies with more comprehensive taxonomic coverage (Barlow et al. 2007; Geraldes et al. 2008), responses to anthropogenic disturbance based on species composition are more informative than those based on species richness or diversity. In the present study, significant correlations among species diversity indices of most arthropod FFGs also indicate that they respond similarly and can effectively be used as surrogates of anthropogenic disturbance. This could be promising for future application of ecological indicators in the island of Cebu, as one could use only one of the arthropod FFGs, reducing sampling and sorting-related time and costs in situations with financial and time constraints.

In terms of overall diversity and evenness of both sites, Figure 4 shows that arthropod evenness in the sampling sites was similar, with S2 having a slightly higher value (*PE* = 0.51) compared to S1 (*PE* = 0.50). An evenness value closer to 1 indicates high evenness while values closer to 0 indicate low species evenness in an ecosystem (Studeny et al. 2010). The evenness index in S1 and S2 had an average value of 0.51 that corresponds to a "medium" levels of $0.4 < e < 0.6$ (see evenness criteria Table 2). This indicates no competition among Arthropod families in terms of limiting factors (i.e. space and food availability).

Odum, Barrett (2008) claimed that domination of a specific arthropod family would result to high individual count of a particular arthropod. High evenness would also result to higher community diversity. Also, the presence of dominant arthropod families in both sites (i.e., Formicidae for both sites; Acrididae for S1; Calliphoridae and Muscidae in S2) could be responsible for the observed values. The dominance of these families could also be related to the presence of dominant species of vegetation (Garces, Genterolizo 2018). Therefore, the evenness index is an excellent indicator to describe community stability, especially in forest ecosystems. Refarding species diversity, increasing plant cover usually results in higher diversity of arthropods in highly disturbed sites (Sax et al. 2005; Bartomeus, Santamaria 2008). Shannon Wiener Diversity comparisons between sites followed the same pattern of species richness, with the only exception of predator, parasitoid, nectar feeder, seed feeder FFGs, while scavenger FFG showed no significance difference between sites (Table 6; Fig. 4).

As a whole, there are still problems in terms of identifying arthropods to species level. Fortunately, for the arthropods sampled, there was the same quality of discrimination between disturbed and undisturbed sites, even when species were grouped into arthropod FFGs. Discovering disturbance related response patterns at higher taxonomic levels may be important in a practical sense, since it is a manner of overcoming the difficulty of identifying arthropod species, particularly from poorly studied, species rich systems. Sometimes, the time lag from sampling to identifying a taxon may be decisive for its inclusion in assessment and monitoring studies with financial and time constraints (Pawar 2003; Gardner et al. 2008). Though it may not be simple to sort these arthropod FFGs into families without previous taxonomic training, it is obviously much easier than sorting them into specific families or orders. The lack of taxonomists available to sort specimens into species hindered the selection and inclusion in our analyses of several taxa in the sample. Even in the majority of the selected taxa, most specimens had unnamed taxonomic species due to a lack of taxonomic studies on the sampled groups. Therefore, there is an urgent need for support for taxonomy and natural history research in Mt. Manunggal and in the island of Cebu as well as other tropical ecosystems. Despite the clear advantage of using species composition in studies, the other approaches used in this study aimed at ecological indication (abundance and species richness) have their merits and drawbacks (Basset et al. 2008). Choosing among them in practical situations may ultimately depend upon the availability of financial support and taxonomic expertise in the selected groups.

Conclusions

In this study, arthropods that were sampled and sorted showed potential as local ecological indicators of forest disturbance in a reserve forming a large continuum of Mt. Manunggal, Cebu Island, Philippines, a condition not often found in this highly fragmented ecosystem. A total of 48 families of arthropods were recorded in Mt. Manunggal, Cebu Island, Philippines. Arthropod richness, abundance and diversity significantly differed among various FFGs. In S1, there were n = 6759, under 48 arthropod families, while n = 5644 under 45 arthropod families in S2. S1 was characterized by much higher arthropod abundance than in S2. In terms of abundance, scavengers and phytophagous arthropods dominated in S1, while sap-suckers, nectar feeders, and predators dominated S2. Seed feeders and weevils were found to have the lowest abundance in both sites. In terms of family richness, however, nectar feeders had the highest richness, while saprophagous feeders, weevils, seed feeders, and raspers had the lowest in both sites. The difference in abundance, richness and diversity of the different arthropod FFGs seemed to be influenced by the presence of plants, anthropogenic disturbances and by the interactions between the different arthropod FFGs. Finding responses in this apparently low-contrast situation may provide good information about the sensitivity of the selected indicators. Additional local-scale studies with different anthropogenic disturbances should enhance the generalization power of this study. The use of metrics based on species identity in biological assessment (as opposed to richness alone) indicated a high sensitivity of arthropod assemblages to disturbance. Surrogacy in species composition of different arthropod groups was shown in the response to disturbance, while this was not observed for species richness. It is recommended therefore that future studies on ecological indication in Mt. Manunggal (and other ecosystems) do not limit their analyses to richness-related patterns.

Future studies should assess the relationship of various environmental factors, arthropod biodiversity at various FFGs and anthropogenic activities in forests ecosystems in order to understand the effects of widespread forest management practices on floral and faunal diversity. Some of the potential applications of terrestrial arthropods as ecological indicators in Mt. Manunggal, Cebu Island, Philippines (and elsewhere) are for the evaluation of sites for the establishment of reserves, the implementation of management plans in already established reserves, and the evaluation of ecological impacts due to human activities, either for licensing or legal compensation purposes. The absence of robust, tested ecological indicators for terrestrial ecosystems makes it unfeasible to conduct quick, objective, and precise evaluation about the conservation status of target sites. The overwhelming pressure imposed by human activities on natural systems puts at risk not only species and their interactions and dynamics, but also limits conservation and management options, reducing the number of ways in which humans can interact with natural remnants. Identifying the effects that such disturbances have on the biota of a locality or region is only the first step in a long journey toward the conservation of the vanishing forests of Cebu, Island, Philippines.

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References

Aukema J.E., Pricope N.G., Husak G.J., Lopez-Carr D. 2017. Biodiversity areas under threat: overlap of climate change and population pressures on the world's biodiversity priorities. *PloS One* 12: e0170615.

Bambaradeniya C.N.B., Ediringhe J.P. 2008. Composition, structure and dynamics of arthropod communities in a rice agro-ecosystem. *Ceylon J. Sci. Biol. Sci.* 37: 23–48.

Barlow J., Gardner T.A., Araujo I.S., Ávila-Pires T.C., Bonaldo A.B., Costa J.E., Esposito M.C., Ferreira L.V., Hawes J., M. Hernandez I.M., Hoogmoed M.S., Leite R.N., Lo-Man-Hung N.F., Malcolm J.R., Martins M.B., Mestre L.A.M., Miranda-Santos R., Nunes-Gutjahr A.L., Overal W.L., Parry L., Peters S.L., Ribeiro-Junior M.A., da Silva M.N.F., da Silva Motta C., Peres C.A. 2007. Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. *Proc. Natl. Acad. Sci. USA* 104: 18555–18560.

Bartomeus I., Vilà M., Santamaría L. 2008. Contrasting effects of invasive plants in plant–pollinator networks. *Oecologia* 155: 761–770.

Bengtsson J. 1998. Which species? What kind of diversity? Which ecosystem function? Some problems in studies of relations between biodiversity and ecosystem function. *Appl. Soil Ecol.* 10: 191–199.

Blondel J. 2003. Guilds or functional groups: does it matter? *Oikos* 100: 223–231.

Brown M., Hankerson D., López J., Menezes A. 2001. Software implementation of the NIST elliptic curves over prime fields. In: Cryptographers' Track at the RSA Conference. Springer, pp. 250–265.

Buschke F.T., Seaman M.T. 2011. Functional feeding groups as a taxonomic surrogate for a grassland arthropod assemblage. *African Invertebr.* 52: 217–228.

Burghardt K.T., Tallamy D.W., Gregory-Shriver W. 2009. Impact of native plants on bird and butterfly biodiversity in suburban landscapes. *Conserv. Biol.* 23: 219–224.

Clarke K.R., Gorley R.N. 2006. User Manual/ Tutorial. PRIMER-E Ltd., Plymouth, 93.

Department of Environment and Natural Resources (DENR) Region VII. FMB Technical Bulletin No. 19- Guidelines in the Establishment of an Arboretum of Native/Endemic Trees. Forest Management Bureau, pp. 1-9.

Elton C.S. 1958. *The Ecology of Invasions by Plants and Animals*. Methuen, London.

Fiedler K., Hilt N., Brehm G., Schulze C.H. 2007. Moths at tropical forest margins—how mega-diverse insect assemblages respond to forest disturbance and recovery. In: Tscharntke T. et al. (eds) *Stability of Tropical Rainforest Margins. Environmental Science and Engineering*. Environmental Science. Springer, Berlin, Heidelberg, pp. 37–58.

Fork S.K. 2010. Arthropod assemblages on native and nonnative plant species of a coastal reserve in California. *Environ. Entomol.* 39: 753–762.

Garces J.J.C. 2019. Native and alien plant species inventory and diversity in disturbed forests and its economic value. *Global J. Environ. Sci. Manage.* 5: 249–264.

Garces J.J.C., Flores M.J.L. 2018. Effects of environmental factors and alien plant invasion on native floral diversity in Mt. Manunggal, Cebu Island, Philippines. *Curr. World Environ.* 13: 390–402.

Garces J.J.C., Genterolizo J.M.B. 2018. Impacts of anthropogenic activities on invasive alien plants in Mt. Manunggal, Cebu Island, Philippines. J. Biodiv. Environ. Sci. 13: 337–346.

Gardner A., Foster K.R. 2008. The evolution and ecology of cooperation–history and concepts. In: Korb J., Heinze J. (eds) *Ecology of Social Evolution*. Springer, Berlin, Heidelberg, pp. 1–36.

Geraldes A., Basset P., Gibson B., Smith K.L., Harr B., YU H.T., Bulatova N., Ziv Y., Nachman, M.W. 2008. Inferring the history of speciation in house mice from autosomal, X-linked, Y-linked and mitochondrial genes. *Mol. Ecol.* 17: 5349–5363.

Greenslade P.J.M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). *J. Anim. Ecol.* 33: 301–310.

Hill J.K., Hamer, K.C. 2004. Determining impacts of habitat modification on diversity of tropical forest fauna: the importance of spatial scale. *J. Appl. Ecol.* 41: 744–754.

Haddad N.M., Tilman D., Haardstad J., Ritchie M., Knops J.M.H. 2001. Contrasting effects of plant richness and composition on insect communities: a field experiment. *Am. Nat.* 158: 17–35.

Kaspari M., Alonso L., O'Donnellkwd S. 2000. Three energy variables predict ant abundance at a geographical scale. *Proc. Royal Soc. London B Biol. Sci.* 267: 485–489.

Kim K.C., Byrne, LB. 2006. Biodiversity loss and the taxonomic bottleneck: emerging biodiversity science. *Ecol. Res.* 21: 794–810.

Kruskal J.B. 1964. Nonmetric multidimensional scaling: a numerical method. *Psychometrika* 29: 115–129.

Larsen T.H., Lopera A., Forsyth A. 2006. Extreme trophic and habitat specialization by Peruvian dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae). *Coleopt. Bull.* 60: 315–324.

Litt A.R., Steidl R.J. 2010. Insect assemblages change along a gradient of invasion by a nonnative grass. *Biol. Invas.* 12: 3449–3463.

Litt A.R., Cord E.E., Fulbright T.E., Schuster G.L. 2014. Effects of invasive plants on arthropods. *Conserv. Biol.* 28: 1532–1549.

Mason N.W.H., Mouillot D., Lee W.G., Wilson J.B. 2005. Functional richness, functional evenness and functional divergence: the primary components of functional diversity. *Oikos* 111: 112–118.

McKee J.K., Sciulli P.W., Fooce, C.D., Waite T.A. 2004. Forecasting global biodiversity threats associated with human population growth. *Biol. Conserv.* 115: 161–164.

Moran V.C., Southwood T.R.E. 1982. The guild composition of arthropod communities in trees. *J. Anim. Ecol.* 51: 289–306.

Odum E., Barret G.W. 2008. *Fundamentos de Ecologia.* Cengage Learning, Sao Paulo, Brazil.

Pardini R., Faria D., Accacio G. M., Laps R.R., Mariano-Neto E., Paciencia, M.L., Baumgarten J. 2009. The challenge of maintaining Atlantic forest biodiversity: a multi-taxa conservation assessment of specialist and generalist species in an agro-forestry mosaic in southern Bahia. *Biol. Conserv.* 142: 1178–1190.

Paguntalan L.M.J., Jakosalem P.G. 2008. Significant records of birds in forests on Cebu island, central Philippines. *Forktail* 24: 48–56.

Pawar S., Koo M.S., Kelley C., Ahmed M.F., Chaudhuri S., Sarkar S. 2007. Conservation assessment and prioritization of areas in Northeast India: priorities for amphibians and reptiles. *Biol. Conserv.* 136: 346–361.

Pearson D.E. 2006. Invasive plant architecture alters trophic interactions by changing predator abundance and behaviour. *Oecologia* 159: 549–558.

Sathe T.V. 2009. *A Textbook of Forest Entomology*. Daya Publishing House, New Delhi.

Sax D.F., Kinlan B.P., Smith K.F. 2005. A conceptual framework for comparing species assemblages in native and exotic habitats. *Oikos* 108: 457–464.

Spafford R., Lortie C., Butterfield B. 2013. A systematic review of arthropod community diversity in association with invasive plants. *NeoBiota* 16: 81–95.

Standish R.J., Williams P.A., Robertson A.W., Scott N.A., Hedderley D.I. 2004. Invasion by a perennial herb increase decomposition rate and alters nutrient availability in warm temperate lowland forest remnants. *Biol. Invas.* 6: 71–81.

Studeny G.G. 2010. Pielou's evenness, a measure of biological index in restoration ecology. *Ecology* 76: 231–246.

Tallamy D.W. 2004. Do alien plants reduce insect biomass? *Conserv. Biol.* 18: 1689–1692.

Tilman D., Clark M., Williams D.R., Kimmel K., Polasky S., Packer C. 2017. Future threats to biodiversity and pathways to their prevention. *Nature* 546: 73.

Tipper J.C. 1979. Rarefaction and rarefiction- the use and abuse of a method in paleontology. *Paleobiology* 5: 423–434.

Triplehorn C.A., Johnson N.F. 2005. *Borror and DeLong's Introduction to the Study of Insects*. 7th Ed. Brooks/Cole, Belmont, California.

Wolkovich E.M. 2010. Nonnative grass litter enhances grazing arthropod assemblages by increasing native shrub growth. *Ecology* 91: 756–766.

Wong M.K., Guénard B., Lewis O.T. 2019. Trait-based ecology of terrestrial arthropods. *Biol. Rev.* 94: 999–1022.

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