

Trophic spectrum of Turdidae birds in a *Pinus cembroides* forest with two canopy openings

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Abstract

During January to October 2014, variables of insectivorous birds Turdidae were recorded in order to determine patterns of their trophic spectrum considering their feeding techniques and diets in a *Pinus cembroides* forest under two conditions of apparent disturbance in their canopy opening: semi-preserved (BPS) and disturbed (BPP) in the high protected natural area (ANPPA). It is used Canfield line methods, quadrants with central point and embedded frames, cut and shake of branches, count in points of 25 m with intensive search, capture with fog nets by constant effort; as well as indices of relative abundance (IAR), frequency of observation (Fo); Kruskal-Wallis, multiple correspondences (ACM); indexes of Jackknife1, Shannon-Wiener, Jaccard; χ^2 tests, Cluster, Poisson regression (ARP). The IAR was similar, Fo show analogy; Kruskal-Wallis there are no differences, ACM formed defined groups; the average richness, diversity and similarity of the entomological orders were relatively low; χ^2 the proportion of registered individuals are different, cluster graphically there are different groups, ARP there is effect of some plant variables on the abundances of insects and birds. Some patterns of the trophic amplitude of this type of birds were understood; finding that they contribute to the biological control of certain entomological components that could become harmful and forest pests of this type of forest; generating basic knowledge about the role played by the opening of the canopy in the presence of prey; however, it seems not to have it on avifaunal abundances in this particular region of Mexico.

Keywords: insectivore avifauna, trophic coexistence, determination of diets, hunting techniques.

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Introduction

The Turdidae family, belonging to the Passeriform order, is made up of more than 300 species of birds, of homogeneous, omnivorous characteristics, predominantly diurnal between residents and migrants, with quasi-cosmopolitan distribution, being Africa and Eurasia the sites with the greatest diversity followed by the South America (Meller, 2013). Trophic resources, as well as their capture and consumption, normalize the coexistence of organisms (Bo *et al.*, 2007). In birds, the morphology seems to be evolutionarily associated with the selection of habitat, allowing in some cases to know the mechanisms of segregation between different guilds (Hernandez *et al.*, 2017).

In some species of insectivorous birds, the variations in the availability of food seem to be related to the migration phenological patterns they make towards the tropics, so the structure, conformation, distribution and trophic ecology of bird communities fluctuate seasonally (Michalski *et al.*, 2011). The vertical and horizontal distribution of some entomological communities are influenced by the existing plant physiognomy (Wen *et al.*, 2016).

Insects are the food of multiple predators, including birds, which have acquired hunting techniques ranging from flight, to excavation using the beak (Norris and Martin, 2012) to optimize their feeding, some species have used the partition of resources to be able to coexist (Lovette and Hochachka, 2006). Studies related to trophic aspects and diets in birds such as Quilarque *et al.* (2010); however, they did not relate hunting techniques with morphological patterns to explain the consumption of prey.

Mexico is home to seven genera and 26 species of birds of the Turdidae Family (Navarro and Gordillo, 2006) distributed from forests to arid and semi-arid ecosystems, particularly temperate forests; nevertheless, their forests present diverse processes of ecological degradation, which alter the patterns in the distribution, abundance and composition of species (Almazán-Núñez *et al.*, 2009).

An important forest remnant of *Pinus cembroides* (Zucc.) is distributed in the high natural protected peña alta area (ANPPA), which is not free of disturbances of various kinds that influence the dynamics and physiognomy of their forest stands, eliminating natural enemies of some insects causing their proliferation, even turning them into harmful species and pests, altering with it, patterns at various levels trophic system (Badii and Abreu, 2006).

The ANPPA supports 134 bird species (IEEG, 2002) of which the Turdidae family is represented by four species: *Catharus guttatus*, *Sialia mexicana*, *Sialia sialis* and *Turdus migratorius*, which are of vital importance as they directly and indirectly influence the maintenance of the ecological balance, incorporating and regulating various energy flows of the system; however, these species acquire relevance because they are frugivorous-insectivorous food habits (Flores and Galindo-González, 2004), since they help the dispersal of seeds and vegetative propagation, as well as the biological control of insects.

Despite its commercial, recreational, ethical, aesthetic, scientific value, contribution to the structure of ecosystems, efficiency as biological indicators and specifically the ecological role they play in the study area associated with its potential trophic amplitude, it is still unknown in forests that exhibit different canopy opening conditions as a result of various disturbance events. The objective of the research was to determine patterns of the trophic spectrum of Turdidae insectivorous birds considering feeding techniques and entomological components registered in the diets associated with their morphological characteristics (body fat, structure, skull and peak) in a *P. cembroides* forest under two conditions of apparent disturbance in its canopy opening: semi-preserved (BPS, in 85%) and disturbed (BPP, with 55%) of the ANPPA.

Materials and methods

The forest of *P. cembroides* (Zucc; Rzedowski, 2006) under study is located in the southern part of the ANPPA, at coordinates 21° 27' 30.6" North latitude and 100° 59' 6.5" West latitude, between the elevations of 2 147 at 2 332 masl (IEEG, 2002) where two apparent disturbance conditions were chosen in its canopy opening: BPS with 35.48 and BPP with 82.01 ha.

The sampling design implemented was the Systematic with random election of the units of choice (UEI's); Cochran (1977), establishing 11 (BPS) and 14 (BPP) UEL's of 0.5 ha each, in order to obtain the average number of birds and insects' prey in each of them (Figure 1).

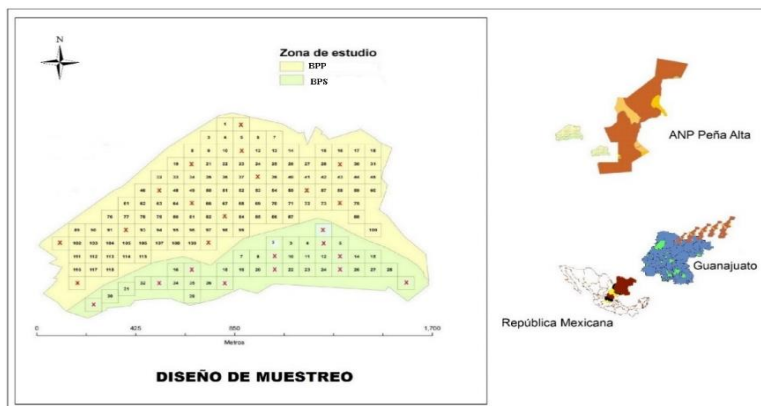


Figure 1. Location of the study area and sampling design in BPS and BPP of the ANPPA.

The variables were recorded monthly during January to October 2014, except vegetation only in: January, May and September; the tracking schemes were established based on the sampling design and in periods of one day for each condition, running parallel to each other. Habitat variables were recorded with the Canfield line according to their percentage occupation length on each line (Canfield, 1941).

The monitoring of the arboreal vegetation using quadrants with central point (Cottam and Curtis, 1956) and shrubs with Embedded Panels (Oosting, 1956). The identification of plant species was carried out in the 'CHAP' herbarium of the Autonomous University Chapingo (UACH). The registration of insects with cutting and shaking of branches (Schowalter, 1994), obtaining

entomological samples of the foliage where the birds exhibited some feeding technique (Johnson *et al.*, 2005) that were identified in the College of Postgraduates and the UACH, where a reference collection of prey was obtained (Gámez-Virués *et al.*, 2007).

Feeding techniques (Remsen and Robinson, 1990) and entomological components in the diets (Rosenberg and Cooper, 1990) of Turdidae in both conditions (BPS and BPP) were obtained by: A) Counting in points with fixed radius of 25 m with intensive search (mixed, Ralph *et al.*, 1996), using 25 x 50 m binoculars (Bushnell) and B). Capture by fog networks by constant effort (Hutto *et al.*, 1986), physically containing the bird to record its morphometry and obtain its excreta by physiological stress, which was placed in 70% alcohol (Whitaker, 1988). In both cases, the identification was made with field guides for birds from Mexico and North America.

They were implemented in a parallel manner because they are complementary and increase the probability of detection in birds that are quiet, silent and conspicuous, reducing the bias in their identification through singing, since they could be searched and located visually (Karr, 1981).

The preference with which the birds occurred in both conditions for: feeding techniques, use and structures of insect substrates that make up their diets (excreta, at the level of order, family) was estimated with the index of frequency of observation (Fo), Antúnez-Ruiz *et al.* (2016), modified for the present in each case of analysis, graphing comparatively in Microsoft Excel (2016).

Differences in bird frequencies recorded for both conditions by: feeding techniques, use and substrate structures, morphology of the birds, registered entomological components with cut and shake branches (sizes) and insects that make up their diets (excreta, type), were determined with Kruskal-Wallis (Zar, 1999) in JMP IN v.14.0.1 (2018). The graphic association, in both conditions, between birds and feeding substrates, types and families of insects consumed, their morphology, was established by multiple correspondence analysis for categorical data (ACM, Greenacre, 2002) in Xlstat v.2018.5 (Addinsoft, 2018).

The average entomological richness, diversity and similarity registered in the diets of the birds, for both conditions, was estimated by analyzing the orders (assumed as species) of insects recorded by sampling by Jackknife of the first order (Jackknife1), Shannon-Wiener, Jaccard, respectively (Magurran, 2004) using EstimateS 9.1.0 (2018) and Microsoft Excel (2016).

To infer whether the proportion of birds is the same in both conditions for: feeding techniques, use and structures of substrates, their morphology, entomological components (sizes, types) that make up their diets, χ^2 tests were developed (Agresti *et al.*, 1990) in JMP IN v.14.0.1 (2018).

Graphic differences in entomological richness (considering families as species) recorded in bird diets, for both conditions, were determined by Cluster analysis considering the Euclidean distance (Hair *et al.*, 1999) in Xlstat v.2018.5 (Addinsoft, 2018).

The association, in both conditions, between the variables (Y): birds (observed), insects (cut and shake of branches), captured birds and the vegetation variables (x_i) were inferred with Poisson regression, using generalized linear models, procedure for the selection of variables and the Akaike criterion (AIC) González-Oreja (2003) in R v.3.5.1 (R, 2018). In all the analyzes, $\alpha= 0.05$ was used.

Results and discussion

The index of frequency of observation (F_o) graphically display the trends in the percentage preferences with which Turdidae birds occurred in each of the variables of interest for both conditions (Figure 2).

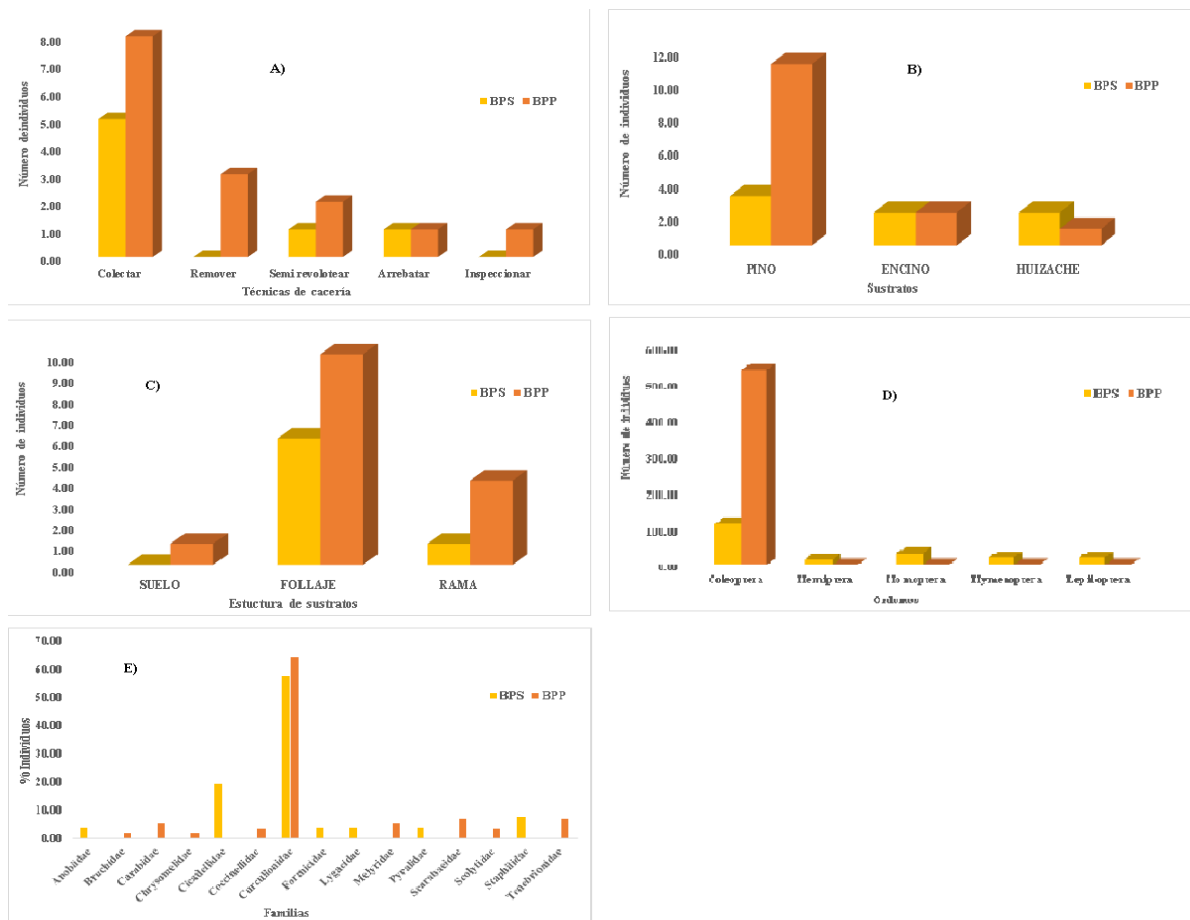


Figure 2. F_o of: A) feeding techniques; B) use; C) substrate structures, insects that make up their diets excreta; D) order; and E) family, for both conditions of the ANPPA.

The Kruskal-Wallis allow us to show that there are no significant differences in each of the variables of interest, therefore, $H_0: B_1= B_2$, at a level of significance of $\alpha= 0.05$ (Table 1), is not rejected. concludes that these are similar in each case for both conditions.

Table 1. Kruskal-Wallis results for both conditions of the ANPPA.

Analysis	Chi square	Degrees of freedom	Prob> Chi square
Feeding techniques	0.9136	1	0.3392
Use	0.0119	1	0.0931
Substrate structures	0.3923	1	0.5311
Bird morphology	0.0528	1	0.8182
Insect sizes	0	1	1
Types of insects	0.75	1	0.3865

The ACMs show graphical association between the variables under study (the first two dimensions, give an account of the total inertia), it can be evidenced the conformation of well-defined groups in each the variables of interest for each case of analysis in both conditions (Figure 3).

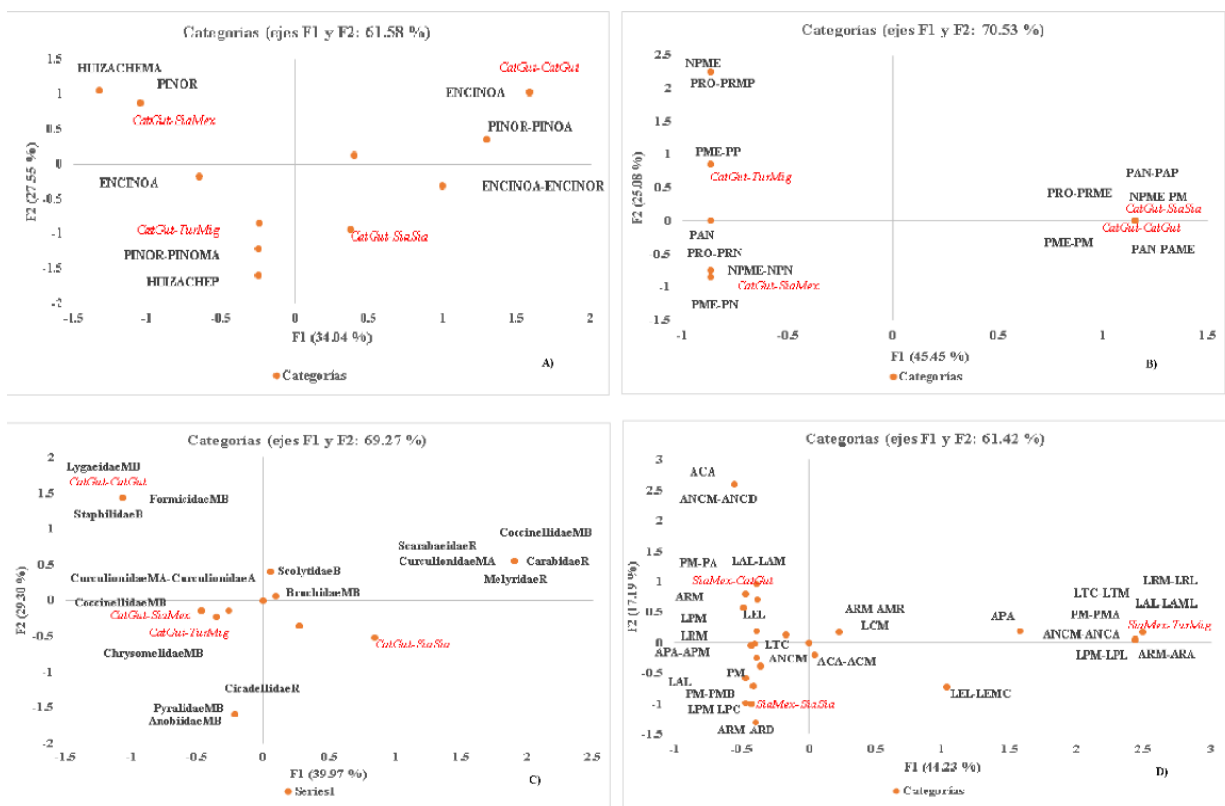


Figure 3. Graphic representation of the ACM shows the association between birds. A) feeding substrates; B) types and C) families of insects consumed; D) its morphology, for both conditions of the ANPPA. Codes for substrates: little (P); regular (R); high (A); very high (MA); types of insects= nothing (N); very little (MP); medium (Me); a lot (M); medium. Acronyms= plague (P); no plague (NP); predator (Pr); parasite (PA); insect families: null (N); very low (MB); low (B); regular (R); high (A); very high (MA); morphology: weight (P); wing length (LA); span length (LE); total length (LT); body width (AC); peak length (LP); peak width (AP). Birds: *Catharus guttatus* (CatGut), *Sialia mexicana* (SiaMex), *Sialia sialis* (SiaSia) and *Turdus migratorius* (TurMig). There are combinations of categories.

The Jackknife1 estimator for both conditions showed that the average number of species (entomological orders) exhibited an increase in the rarefaction curve. Shannon-Wiener presented an average entomological diversity value (insect orders) of $H' = 1.8$, differences between BPS and BPP can be seen. Jaccard shows a similarity of 36% (Figure 4).

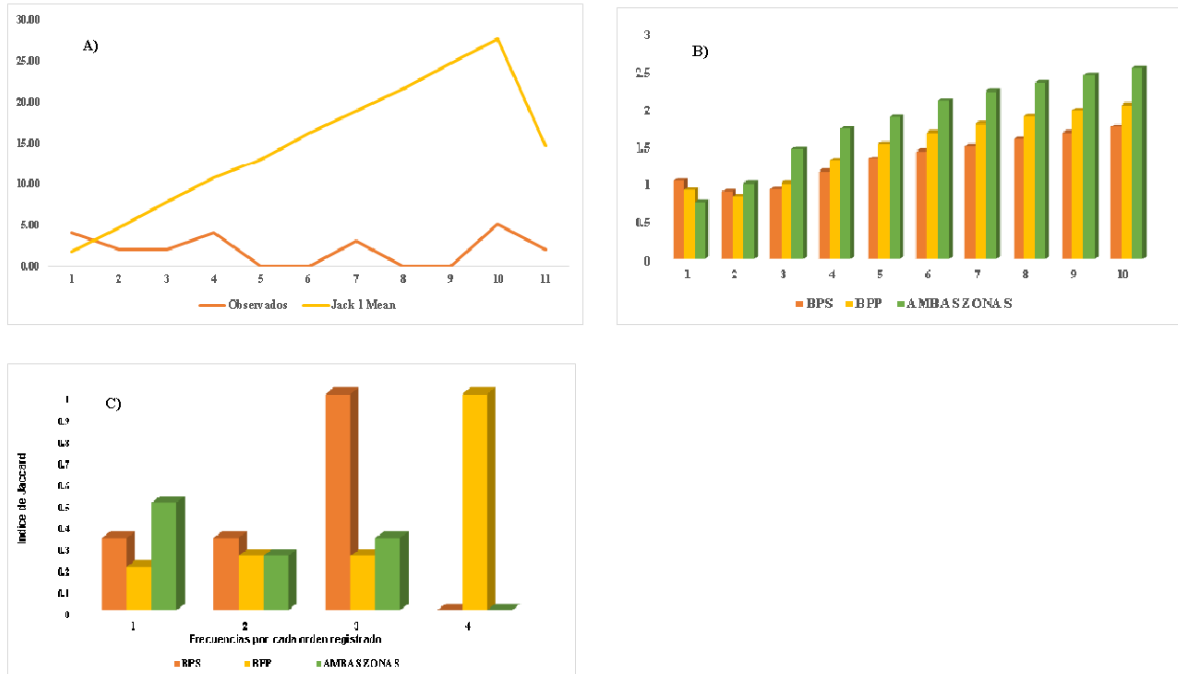


Figure 4. Results A) Jackknife1; B) Shannon-Wiener; and C) Jaccard for entomological orders (assumed as species) recorded by sampling for both conditions of the ANPPA.

The χ^2 suggest that the values obtained were lower than the contrast values, which suggests that the proportion of individuals registered for Turdidae birds are statistically different; that is, the observed values are different from those expected for each variable of interest (Table 2).

Table 2. Results of χ^2 for both conditions of the ANPPA.

Analysis	N	gl	R ² (U)	Ji ² (Pearson)	Prov>ji ² (Pearson)	χ^2 of tables (Pearson)
Feeding techniques	22	5	0.1143	4.268	0.5091	11.0705
Use	10	4	0.1586	3.333	0.5037	9.4877
Substrate structures	12	4	0.1452	3.143	0.5342	9.4877
Morphology	22	21	0.2242	22	0.3995	32.6706
Insect sizes	8	7	0.3333	8	0.3326	14.0671
Types of insects	8	7	0.3333	8	0.3326	14.0671

The Clusters show the dendrogram resulting from the classification for families of insects (conceived as species) registered in bird diets, which shows the conformation of several amalgamations, note the break of scale in the axis of dissimilarity (Figure 5).

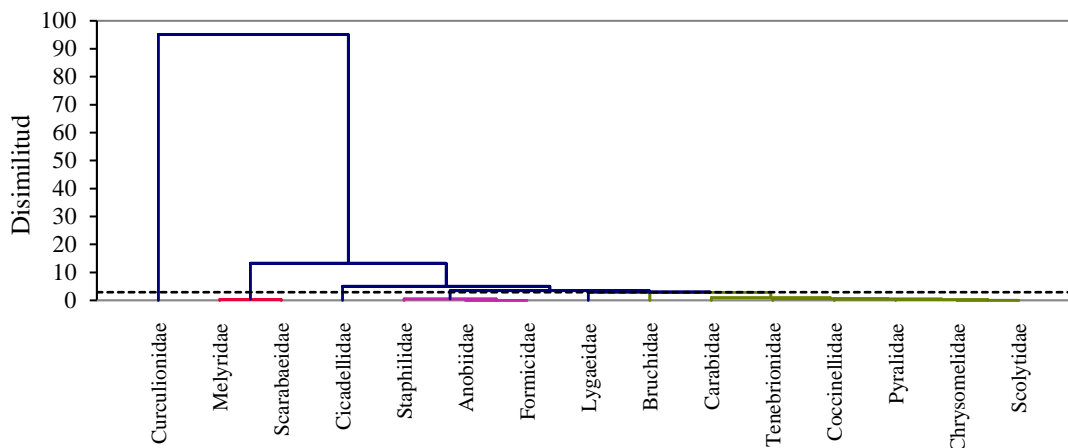


Figure 5. Classification for families (species) of insects registered in the Turdidae diets, carried out on the matrix of similarity of their incidence for both conditions of the ANPPA.

The ARPs (Table 3) show some variables (x_i) of the vegetation that had some effect (in terms of statistically significant coefficients) on each (Y) of interest, for each case of analysis; with its respective AIC, which denoted the best adjustment of the GLM in each of them.

Table 3. Results of the ARP using GLM models for both conditions of the ANPPA.

Coefficients	Estimate	Std. Error	z value	Pr(> z)
Frequencies of Turdidae birds (observation)				
(Intercept)	0.77259	0.20268	3.812	0.000138
Alth	1.56871	0.58951	2.661	0.00779
Coba1	2.54733	0.49874	5.108	3.26E-07
Coba2	-1.22492	0.45211	-2.709	0.006742
Quadrant	-0.23797	0.07795	-3.053	0.002267
No. of insect individuals (cutting and shaking of branches)				
(Intercept)	-2.186819	1.007184	-2.171	0.02991
Altfustelimpio	0.055407	0.026445	2.095	0.03616
Coba2	26.206683	2.929844	8.945	< 2e-16
Cobar1	-0.109207	0.024039	-4.543	5.55E-06
Cobar2	0.192335	0.021393	8.99	< 2e-16
Cobh1	-25.088683	4.809564	-5.216	1.82E-07
Cobh2	57.820814	5.635687	10.26	< 2e-16
Diana	-55.573266	4.779572	-11.627	< 2e-16
Dist	0.096708	0.014878	6.5	8.02E-11
Date	-0.258311	0.051035	-5.061	4.16E-07
N. indveg	-1.600049	0.136182	-11.749	< 2e-16
No. branches	0.052769	0.010491	5.03	4.91E-07
Point	-0.007282	0.001678	-4.341	1.42E-05
(%) hojasmuevasxrama	0.034107	0.012639	2.699	0.00696
(%) hojasmuevasxrama	0.055981	0.014076	3.977	6.98E-05

Coefficients	Estimate	Std. Error	z value	Pr(> z)
No. of individuals of Turdidae birds by sex				
(Intercept)	1.827685	0.146741	12.455	< 2e-16
Coba2	0.896276	0.281814	3.18	0.00147
(%) hojasmuevasxrama	-0.018168	0.002475	-7.342	2.11E-13
(%) hojasmviejasxrama	-0.018109	0.003359	-5.392	6.97E-08
No. of individuals of Turdidae birds by age				
(Intercept)	1.482553	0.142001	10.44	< 2e-16
Coba2	1.041351	0.220541	4.722	2.3376E-06
Point	0.005679	0.001869	3.039	0.00238
(%) hojasmuevasxrama	0.019117	0.002121	-9.012	< 2e-16
(%) hojasmviejasxrama	0.016094	0.002746	-5.86	4.62E-09
No. of individuals of Turdidae birds by body condition or fat				
(Intercept)	1.77935	0.160919	11.057	< 2e-16
High	0.963289	0.370774	2.598	0.00938
(%) hojasmuevasxrama	-0.018845	0.00268	-7.032	2.04E-12
(%) hojasmviejasxrama	-0.019644	0.002969	-6.617	3.66E-11

Nota= coefficients ($p < 0.05$) of ARPs, obtained by means of a logarithm as a link function between Y and x_i ; with AIC= 364.14, 1894.2, 305.45, 507.46, 319.12, respectively.

Trends in abundance may be associated with the availability of food resources and plant physiognomy, specifically in the vertical and horizontal planes, which apparently are different (at the canopy level) under the conditions evaluated, to which MacArthur and Levins (1964) point out that these factors condition the establishment of diverse faunal trophic communities and guilds due to the resources they provide; particularly insectivorous birds; even Murdoch *et al.* (1972) have shown a close relationship between the diversity of Homoptera, the number of strata and floristic composition.

However, the opening condition in the canopy did not seem to have an effect on them, according to Arguedas and Cespedes (2014), these birds can be established in this type of systems depending on the dams available for their consumption, despite anthropogenic pressure. Certain forests receive, as suggested by bird records for the present, whose trends are similar to those recorded in adverse environments, as reported by Almazán-Núñez *et al.* (2009) for pine-oak forest at different ecological succession conditions, this supports the idea put forward by Platt *et al.* (1984) who point out that abundance is often used to make ecological interpretations of the state that ecosystems keep since it is more sensitive to environmental distortions, even than species richness alone, so that this could potentially be positively affected or negatively, depending on the degree of disturbance or disturbance that said system exhibits, thus in the present, the synonyms in said estimator could be due to what was reported by Stiles (1978) who mentions that the structural complexity and the floristic composition determine the foraging substrates, as well as the availability of food, specifically in areas with different disturbance gradients, which according to Lambert (1992) are more preferred by opportunistic and generalist species.

The registers for feeding behaviors showed that the evaluated birds can coexist, because in a gregarious or solitary way, during their feeding they use several prey capture techniques on the different vegetable substrates, in this way, Fandiño *et al.* (2010) point out that said taxonomic group performs an adequate allocation of resources, which allows them to reduce trophic segregation; thus, strategies for their conservation under the conditions analyzed should focus on habitat improvement, promoting a greater number of feeding niches.

Sainz-Borgo (2015) suggests contemplating the feeding behavior of avifauna and its occurrence on vegetation. This is imperative, since the availability of plant strata influences the presence of certain larvae and prey insects and therefore on the trophic ethology of the birds. In this sense, the height at which these Turdidae were fed determined the distribution of their prey and consequently the deployment of their feeding techniques, as mentioned by Latta and Wunderle (1998) finding that some species of avifauna feed on transitions of certain strata and substrates, so these factors allow the separation of ecological niches, as reported by Necedal (1984) who states that such use in temperate forests is selective to different structures of various substrates, including the canopy (foliage), place from where the species studied located their prey and defined which feeding technique to exhibit.

In this context, Ostrand (1999) supports that these eventually form feeding groups that function as catalytic indicators; that is, they show other species the location of areas with high density of prey, which attract different predators that interact with each other, establishing feeding strategies that allow them to ensure their permanence and trophically displace others that are not able to compete for the same resource. This agrees with Mills (1998) who mentions that this behavior explains the visual recruitment by means of which, individuals who use prolonged feeding techniques attract others for what said gregariousness, according to Guariguata and Kattan (2002) promotes the establishment of guilds that they demand similar resources, this explains part of the trophic coexistence in the birds evaluated.

The feeding techniques shown seem to be associated with the morphology of the birds analyzed, which is explained by Chávez *et al.* (2012) who suggest that the morphometry of the beak and legs are determinants for the acquisition of prey, in the same way Pyke *et al.* (1977) point out that predators avoid excessive energy expenditure by obtaining nearby prey that will provide them with sufficient energy for their vital physiological functions. In this way, the feeding techniques registered here are similar to that reported by Adamík and Korňan (2004) who point out that in some birds, the most common trophic behavior is collecting.

In contrast, Somasundaram and Vijayan (2008) suggest that others not necessarily insectivorous, support more versatile diets, which explains a lesser use of other techniques for more specific trophic niches, which allow them to be established almost all year round, due to the fact that seasonally and phenologically, they can obtain various larvae and insects, above and below the substrates, using different feeding techniques, which diminish the negative ecological interactions, promoting their food coexistence.

The substrates and their structures most used in the present by the birds showed that they coexist because they have an association with various feeding substrates; however, this seems to respond to the dominance of pinnaceae, feeding behavior and morphometry of birds, which provide some advantages to take advantage of specific trophic niches, this is supported by Becerra and Grigera (2005) who report the use of diverse substrates based on their availability, which provide them with food throughout the year. The trophic plasticity exhibited by these birds, showed how they optimized their trophic ecology in function of the use of different substrates and structures of them food carriers, adjusting their hunting techniques; nevertheless, the substrate most used seems to respond in a similar way to that reported by Somasundaram and Vijayan (2008) who assure that this trophic niche not only provides them with food, but also provides protection and coverage.

However, Lešo and Kropil (2007) point out that in other regions there are substrates and structures that can provide entomological resources in greater quantity and better energy quality, the registered substrates play a seasonally preponderant role over the registered feeding techniques; because it provided them, in a gregarious manner, a greater number of energy-efficient dams of different types as suggested by Albrecht and Gotelli (2001), which explains the presence of specialized and generalist birds in the use of disturbed habitats.

Trends in insect consumption by size and type coincide partially with that published by Rosas-Espinoza *et al.* (2008) who point out that some bird species consume insects that are detrimental or possibly considered forest pests, so they contribute to their biological control via depredation; it is imperative to point out that the records of insects in the Turdidae diets for the present, could be explained considering the physiological processes of digestion of each species and the time of consumption prior to obtaining the excreta and its relationship with the type and size of prey consumed, so the presence of these birds in the ANPPA has a controlling effect on certain pest insect populations as suggested by Gámez-Virúés *et al.* (2007).

The condition of the birds showed a differential use in the procurement of food resources, feeding techniques, consumption and use of insects between gender; that is, their morphological structures were adapted to the taxa and sizes of the insects they consumed, so evolutionarily the peak is the key adaptation in the consumption of prey, slight variations in its dimensions influence the rate of ingestion, as well as the type and length of the legs, determine the consumption of various food resources on various substrates as suggested by Montaldo (2005) on the morphometry of birds and their relationship with food consumption.

These patterns have been demonstrated in frugivorous birds; in which the morphology of the peak and other structures depend on the size, shape, texture and type of food consumed and vice versa, therefore, the results of the present support the point made by Levey and Stiles (1994) who point out that these structures are adaptations key, so its size, shape and strength will affect your diet, as happened in this study between the morphology of birds and the consumption of insects of various sizes.

The physiological stress of the plants could increase the presence of amino acids and therefore the proliferation of insect pests, which progressively decimate the leaf density, favoring the opening of the foliage and the penetration of light, causing an increase in the vegetable substrates available for phytophagous insects, coupled with this, diurnal fluctuations in temperature exert an effect on insect dynamics (they are poikilotherms), therefore, in insectivorous birds. The insects in the present depended on various ANPPA events determined by their structure and floristic composition, as indicated by Medianero *et al.* (2003) based on principles on diversity, structure and microclimates for insects.

Conclusions

The techniques of feeding, use and structures of substrates used by Turdidae were differential. The entomological components that make up their diets and the morphometry were similar. There is an effect of some vegetation variables on insects and birds. Patterns of trophic coexistence were determined in two canopy opening conditions of the ANPP, specifically the role of the disturbance on the canopy in the presence of prey insects, said avifauna is relevant since within its trophic spectrum they consume harmful insects and pests, contributing in the biological control certain forestry undesirable entomological groups.

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