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Relationship of Ecosystem Services and Types of Insect traps in an Agroecosystem

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Abstract*– Insects are a hyperdiverse class, with great relevance in environmental studies, due to the great variety of ecosystem services they provide including regulation, support, provisioning, and cultural services. The objective of this study was to determine the relationship between the types of insect traps and ecosystem services. The evaluation of ecosystem services was carried out in March 2015 using chromatic traps, Van Someren-Rydon, and direct collection in two areas of the San José ecological farm (Citrus and Butterfly). A total of 4918 specimens were found, distributed in 49 families and 191 morphospecies. The most abundant family was Muscidae (55.18%), related to the Van Someren-Rydon trap with decomposing fish, followed by the families Sarcophagidae and Tephritidae. On the other hand, according to the Brillouin index, chromatic traps with attractant were the most homogeneous, while according to the Simpson index no group was predominant at any sampling point. In relation to the trophic position, the most abundant food guild was that of decomposers in Van Someren-Rydon traps with fish bait, with the least abundant being phytophagous and decomposers in direct collections.

***Keywords*—chromatic, cultural, provisioning, regulation, Van Someren.**

I. Introduction

Insects constitute a hyperdiverse class that has more than a million registered species [1] with a large number of species remaining to be described. Their diversity and short life cycles [2] allow knowing the levels of interaction, coexistence, and efficient use of natural resources, as well as the dynamics and degree of vulnerability in the environment and the ecosystem services they provide [3].

Ecosystem services are all the benefits that humans obtain from ecosystems [4,5], and include provisioning services, such as biodiversity and production of tangible goods (food, industrial products and their precursors) [6]; regulation services for environmental conditions, pollination and biological control [1]; support services, such as the decomposition of organic matter, soil formation and nutrient cycling [7]; and cultural services, for educational, aesthetic and spiritual purposes [8]. Ecosystem di-services related to the trophic roles of phytophagous, parasites and disease vectors should also be mentioned [9,10].

Chemical contamination, alteration of biogeochemical cycles and plant cover, impoverishment, and soil erosion, are some of the main problems faced by agroecosystems [11], generating global losses of up to 20.2 billion dollars annually between 1997 and 2011 [12] in decreased ecosystem services and agricultural productivity [13]. In Peru, approximately 128,069 hectares of Amazonian forests are lost annually [14] and in Chanchamayo alone there have been losses of 1,474.41 hectares between 2010 and 2014 due to productive activities, including agriculture [15].

Insects are of vital importance for the balance of agroecosystems and productive activities [16,17]. They are a fundamental component for rural development from the agroecological perspective [18,19], in which it is necessary to maintain diversified management practices that promote environmental conservation and favor the conservation of biological diversity [7].

The objective of this study was to evaluate the diversity of insects and their ecosystem services in the San José agroecosystem, La Merced, Junín, Peru, in order to understand the relationship between collection methods and ecosystem services, and contribute to their knowledge and economic valuation.

II. Material and Methods

A. *Study area*

The study area was located in the San José estate, La Merced, province of Chanchamayo, department of Junín, Peru (11° 04' 15.03' S, 75° 20' 31.85" W, 827 meters above sea level [masl]). This area has a high forest profile with complex, rugged topography and a considerable altitude gradient (1500 m), and it is home to high biological diversity and life zones such as Premontane Humid Mountain Forest, Montane Humid Mountain Forest and Alluvial Plains, among others [20]. The minimum annual temperature is 18°C [21] and the maximum temperature is 32°C [21], with an average annual total precipitation of 2000 mm and relative humidity of between 50% and 60% [21].

B. Research design

A monofactorial design was carried out, in which the only factor evaluated was the type of insect trap. Two levels, represented by two spaces of importance in the ecological farm (Citrus zone and the butterfly farm), were considered for this independent variable. The response variable focused on the relationship between the types of traps used and the ecosystem services. The traps were not set randomly, due to the conditions already established in the space.

C. Sampling

In March 2015, traps for collecting insects were installed for 48 h in two important areas of the San José farm: (1) “El Mariposario”, a recreational and educational tourist center oriented to awareness and care of the environment (11° 04' 16” S, 75° 20' 32" W, 841 masl), with an area of 4000 m2, located 80m from the Ecolodge del Fundo; and (2) the “Citrus” crop area in which projects for the recovery of forest areas are currently being developed (11° 04' 12” S, 75° 20' 30” W, 790 masl) with an area of 7,800 m2, located 140 m from the Ecolodge. In each zone, six chromatic traps of yellow trays [22] of 31cm x 45 cm, with a 10:2:0.2 solution of distilled water, liquid soap and 10% formaldehyde, respectively, were placed [23]. These chromatic traps were divided into two groups: three without attractant (CRS: chromatic traps without attractant), and three traps with attractant (1% sucrose, CRC: chromatic traps with attractant). Additionally, four Van Someren-Rydon traps [24] were installed, divided into two groups: two with fruit bait (VSF: Van Someren-Rydon fruit traps) and two traps with decomposing fish bait (VSP: Van Someren-Rydon fish traps; Fig. 1; Fig. 2).

Repetitions of each of the traps used (VSP, VSF, CRC and CRS) did not present significant differences in abundance and richness, and were therefore considered as a single group in the analysis of the results. Direct collection was carried out on 13 randomly chosen trees, using the foliage beating or beating method [25] only in the citrus area, by energetically beating one of the branches of the tree with a 60 cm stick to collect the specimens in a white net of 1.35m x 2m. The results presented as A-I, correspond to the sum of the first five trees evaluated; A-II, from tree six to tree ten; and A-III, from tree 11 to tree 13. This grouping was developed based on data that did not present significant differences.

D. Analysis and classification of ecosytem services

The biological samples were preserved in 70% ethyl alcohol and transferred to the Environmental Engineering Laboratory of the Universidad Científica del Sur, Lima, Peru to be classified at the morphospecies level following the taxonomic keys of Triplehorn & Johnson [26] and Albertino et al. [27]. The classification of ecosystem services in insects was based on the method proposed by Flores-Rios et al. [28], and classifying di-services was performed using the method proposed by Vélez-Azañero et al. [9]; For both cases, the anatomy of the oral apparatus was examined and corroborated with the life history of each group. The final classification of insect ecosystem services was as pollinators, control or regulation, and decomposition and the di-services were classified as phytophagous and vectors.

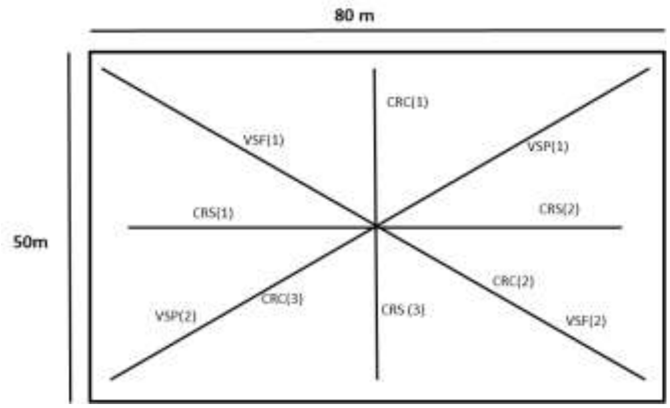

Fig. 1 Distribution of insect traps in the “El Mariposario” area (CRS, CRC, VSF, VSP). The number in parentheses indicates repetitions. CRS: chromatic traps without attractant. CRC: chromatic traps with attractant. VSF: Van Someren-Rydon fruit traps. VSP: Van Someren-Rydon fish traps.

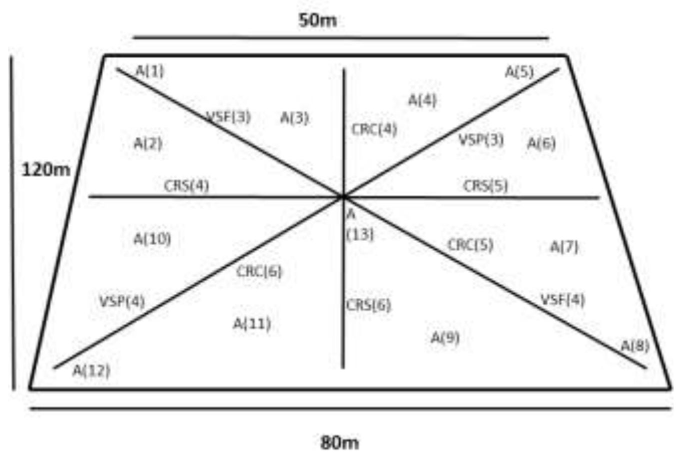

Fig. 2 Distribution of insect traps in the “Citrus” growing area (CRS, CRC, VSF, VSP). CRS: chromatic traps without attractant. CRC: chromatic traps with attractant. VSF: Van Someren-Rydon fruit traps. VSP: Van Someren-Rydon fish traps. A = Tree shaking method. The number in parentheses indicates repetitions.

The Margalef, Brillouin, Pielou, Simpson and Chao-1 indices were used to evaluate alpha diversity through the paleontological statistical package PAST version 3.14. To analyze the relationship between the collection methods based on the similarity of morphospecies, a hierarchical cluster analysis was performed with the Jaccard distance matrix grouped using the UPGMA method (Unweighted Pair Group Method with Arithmetic Mean). This evaluation was performed using the statistical software R Project version 3.3.2. The bar graphs to compare the richness and abundance with the type of collection of each ecosystem service were made with the statistical program Graphpad Prism version 5.

II. Results

A total of 49 families, 191 morphospecies and 4918 insect specimens were identified. The most abundant family was Muscidae with 1729 individuals (35.16%), with 55.18% being found in the VSP trap. Likewise, the morphospecies with less abundance were from the Aphididae, Arctiidae, Cixiidae, Lepidoptera, Richardiidae, Sciaridae and Tenebrionidae families with one individual each.

The CRC trap was the most homogeneous according to the Brillouin index, and the Simpson index demonstrated that no group predominated at any sampling point (Table I). The results of the cluster analysis elaborated from the Jaccard distance matrix, grouped using the UPGMA method (Fig. 3) showed that the populations obtained from the baited and unbaited chromatic traps were the most similar (24.68%); In addition, point A-III was the most isolated with respect to the rest of the groupings.

TABLE I
ALPHA DIVERSITY INDICES WITH THE DIFFERENT COLLECTION METHODS

Indices	CRS	CRC	VSP	VSF	AI	AII	AIII
Richness	57	39	42	37	44	36	72
Abundance	573	353	1683	1314	346	106	539
Margalef	8.81	6.47	5.51	5.01	7.35	7.50	11.29
Brillouin	2.19	2.81	1.90	1.87	2.00	2.68	2.34
Pielou	0.57	0.81	0.52	0.53	0.57	0.86	0.58
Simpson	0.27	0.07	0.27	0.22	0.26	0.07	0.17

CRS: chromatic traps without attractant. CRC: chromatic traps with attractant. VSF: Van Someren-Rydon fruit traps. VSP: Van Someren-Rydon fish traps. AI - AIII = Tree shaking method.

The highest richness was obtained in A-III, which was confirmed by the highest value for the Margalef index, due to the high presence of pollinating and phytophagous species. On the other hand, the lowest richness was found in A-II, although this method was closest to reaching maximum diversity, according to the Pielou index. In addition, no pollinating species were recorded at this point, and the richness was mainly represented by the groups of phytophagous and decomposers.

The VSF collection method recorded the highest abundance of insects fulfilling the ecosystem service of pollination, and was notably higher than the rest of the methods, which presented poor or almost null abundances, as in the case of the CRC method with the presence of a single individual (Fig. 4). However, the richness or number of species was higher in the direct collection from the trees (Fig. 5).

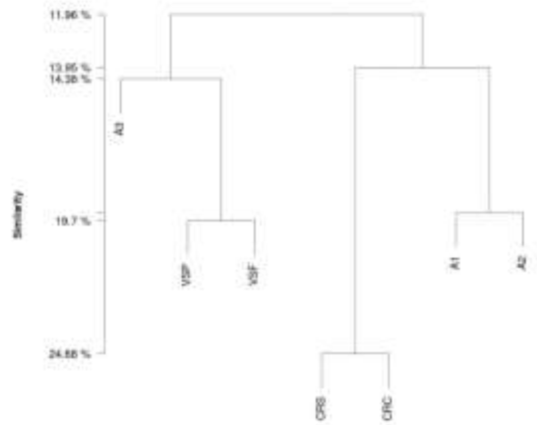

Fig. 3 Dendrogram generated with the Jaccard coefficient, pooled by the UPGMA method. CRS: chromatic traps without attractant. CRC: chromatic traps with attractant. VSF: Van Someren-Rydon fruit traps. VSP: Van Someren-Rydon fish traps. A = Tree shaking method.

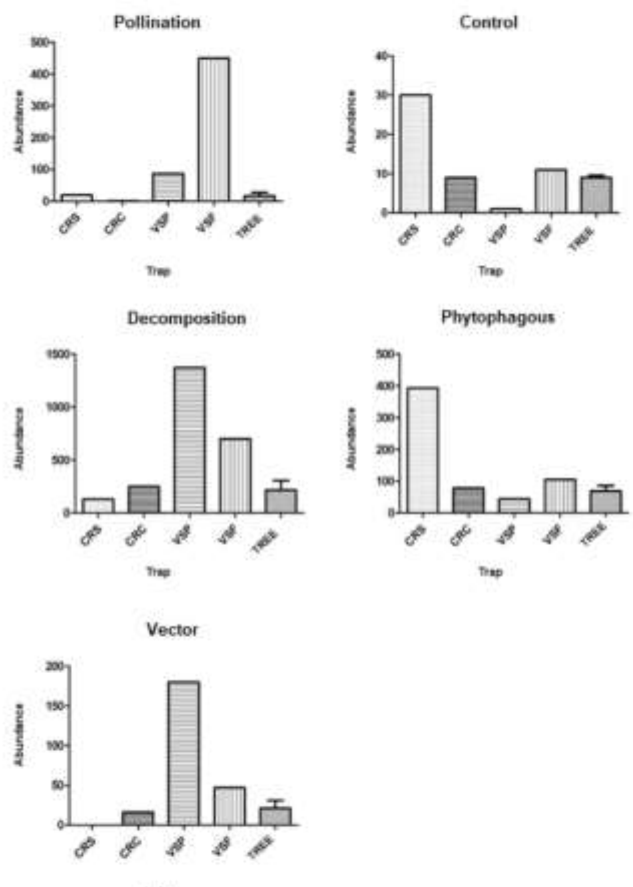

Fig. 4 Abundance of arthropods in each collection method according to ecosystem services. CRS: chromatic traps without attractant. CRC: chromatic traps with attractant. VSF: Van Someren-Rydon fruit traps. VSP: Van Someren-Rydon fish traps. Tree = Tree shaking method.

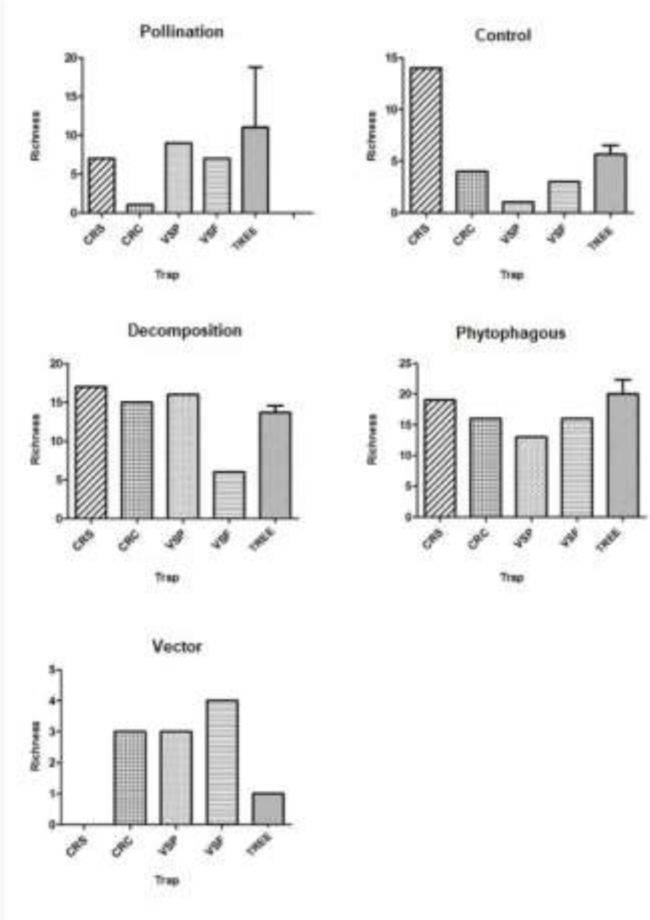

Fig. 5 Arthropod richness in each collection method according to ecosystem services. CRS: chromatic traps without attractant. CRC: chromatic traps with attractant. VSF: Van Someren-Rydon fruit traps. VSP: Van Someren-Rydon fish traps. A = Tree shaking method.

For insects with the ecosystem service of decomposition or support, the greatest abundance was captured by the VSP method, the difference being notable compared with the other collection methods (Fig. 4). The level of richness presented by almost all the methods was homogeneous, with between 12 and 17 species, except for the VSF method that only registered six species (Fig. 5).

Insects with the phytophagous di-service were notably more abundant with the CRS method, compared to the very low abundances with the other methods. However, this group of insects did not present significant differences in terms of the number of species per collection method, although the greatest richness was recorded in the direct collection from the trees. Finally, the insects with the di-service vectors were more abundant with VSP, and were much less representative with the other methods, with an absence of individuals in CRS. Richness did not significantly differ among the different capture methods, due to the low number of morphospecies found (Fig. 5).

III. Discussion

In tropical regions such as the San José farm, it is common to observe a great adaptive radiation of insects, due to the great heterogeneity of available habitats, and the high biological diversity present [29]. In the Peruvian jungle, insects are the most representative group (both in richness and abundance), and the endemism of insects seems countless [30-32]. In the Amazon, the tops of the tallest trees are home to the treasure of a universe of arthropods not yet discovered, many of which have never even been seen [31,32], and which represent the greatest diversity that exists today, thereby justifying the greater richness recorded by the direct collection method from trees described in this study.

Direct collection is widely used and usually has a greater advantage over other methods [33] because it allows recording the location and exact time of capture, although other authors maintain that it is less efficient in larger investigations [34]. On the other hand, the collection method using chromatic traps depends on the size and color used to capture insects, since each group of insects is attracted to specific colors [35]. Indeed, one of the limitations of our study was the use of a single color for this capture method, which could have reduced the diversity of insects obtained. However, some studies have reported that the use of yellow traps provides the greatest richness and abundance of insects by this method [36]

As a result of the collections made, a high abundance was recorded for the morphospecies of the Muscidae family, related to areas with high rainfall and abundant vegetation [37] and showing higher peaks in autumn [38]. Likewise, it is common to capture these insects in Van Someren-Rydon traps with decomposing fish [39-41] in which they usually lay eggs due to the abundance of water and nutrients [42]. The presence of these individuals in the study area (agroecosystem) could, therefore, serve as an indicator of organic matter recycling, providing an ecosystem support service for the entire food chain. However, certain species of this family (*Atherigona soccata* Rondani, *Atherigona naquii* Steyskal, *Atherigona* spp.) oviposit on the underside of the leaves, and tend to develop phytophagous di-services, affecting the development of plants in their early phenological stages [43]. Their diverse feeding habits give them different functions in an ecosystem (phytophagous, decomposers, disease vectors; [44]), which may explain their great abundance in Van Someren-Rydon traps baited with fish, fruit and the tree shake. The abundance of these species may also be related to sampling having been performed in the forest canopy (VSP and VSF; [45]).

On the other hand, the morphospecies of the Arctiidae family registered a low abundance related to the altitude at which this study was carried out (780 nm – 850 msnm; [46]).

Under similar conditions to those of our study, other authors also found a low abundance of this family with respect to the rest of the groups evaluated. On the other hand, other studies have reported a great abundance for this family at between 1448 masl and 2200 masl [47].

Another of the families that registered a low abundance was the Richardiidae family, which generally shows a low abundance in ecosystems impacted by humans, as in the case of agroecosystems [45,48]. In natural environments this family presents focused populations [49], which could justify the number of individuals found in our research. Its presence is associated with organic matter [50] and it fulfills the ecosystem service of support or decomposition, which is why its capture was related to the Van Someren-Rydon capture method with decomposing organic matter (VSP).

Regarding the Sciaridae family, it is a group rich in species, some of which are usually very abundant according to the habitat [51]. The greatest richness of this family occurs in cloud forests [52], and in forest areas [53,54], with its diversity decreasing in environments with low tree density [55]. This would explain why the diversity of this family of insects was low in our research, and the only morphospecies was recorded by the method of direct collection in trees.

The morphospecies of the family Tenebrionidae presents greater specific richness in tropical regions [56-58], preferably environments with great vegetation [59,60]. This suggests that the presence of these morphospecies would be abundant in study areas such as that used in the present study, yet we found the opposite. This finding supports the mobility of this type of insect according to the seasons of the year [31].

The Arctiidae, Hesperiidae, Syrphidae and Nymphalidae families are insects that perform the ecosystem service of pollination, and are generally not interested in fruit traps [61]. This would explain why no pollinators from most of these families were recorded in the VSF traps, although other authors have reported that the largest number of specimens of the Nymphalidae family can be collected with Van Someren traps with fruit bait [62-64], due to their wide distribution, richness and abundance [64], in addition to their different eating habits [62,65]. The presence of this family was very poor in our study, which may be related to seasonality that can affect sampling methods for the species of this family and that their greatest richness and abundance are related to the rainy seasons [66].

On the other hand, the greater abundance of individuals within the pollination ecosystem service was associated with the Apidae family, specifically with the VSF method since these individuals are easily attracted by nectars and fruits [67], which are essential for the survival of the species of the family [68]. There are reports that direct collection is the most appropriate method to evaluate pollinating insects, because it allows knowing the feeding habits, seasonal occurrence [33], and monitoring inaccessible areas for other collection methods [31,32].

Chromatic traps did not record individuals of the Chrysopidae, Ichneumonidae, Sphecidae, Staphylinidae or Tipulidae families, which provide the ecosystem service of control or regulation and are common in agroforestry systems [69]. These groups have mainly predatory habits and have a low rate of attraction to chromatic traps (green, yellow and blue; [70,71]) with sucrose. Nonetheless, other authors have reported that the use of sucrose increases the efficiency of the capture [72], demonstrating a greater abundance in the capture of control insects, such as those that are part of the Vespidae family, with white trays with attractant being the most effective.

Individuals of the Ciidae family provide an ecosystem support service in neotropical forests, being considered an excellent indicator of environmental quality and balance [73]. However, the presence of only a single individual of this family in our study may be associated with the absence of decomposing woody debris, litter, or the presence of associated fungi [74]. On the other hand, it is likely that a greater sampling effort is required to obtain a significant abundance of this group of insects.

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