EXOTIC SPECIES AND PEOPLE IN THE GALÁPAGOS ISLANDS: A COMMUNITY ECOLOGY APPROACH AND A SOCIAL PERCEPTION ANALYSIS OF AN INVASIVE PLANT

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<u>Anexos</u>

Título del Trabajo de Grado

Exotic species and people in the Galápagos islands: A community ecology approach and a social perception analysis of an invasive plant species

Pregunta de investigación

¿De qué manera varía la percepción social y las redes ecológicas de artrópodos asociadas a *Leucaena leucocephala* en dos coberturas diferentes en tres de las islas Galápagos?

Objetivos

- Objetivo General

Determinar la variación en la percepción social y las redes ecológicas de artrópodos asociadas a *Leucaena leucocephala* en dos coberturas diferentes en tres de las islas Galápagos.

- Objetivos Específicos

Analizar y comparar los índices de diversidad alfa y beta de los artrópodos asociados a *Leucaena leucocephala* en dos coberturas en tres de las islas Galápagos.

Analizar y comparar la estructura de las redes ecológicas de los artrópodos asociados a *Leucaena leucocephala* en dos coberturas en tres de las islas Galápagos.

Analizar la variación en la percepción social, usos y conocimiento de *Leucaena leucocephala* entre las tres islas.

Exotic species and people of the Galápagos islands: A community ecology approach and a social perception analysis of an invasive plant

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Abstract

The successful establishment of an exotic plant depends primarily on the type and quantity of interactions that these develop with a variety of organisms such as predators, competitors and parasitoids. Since *Leucaena leucocephala* (Lam.) de Wit is the result of intervention processes led by humans in the Galápagos islands, it is important to understand, in addition to the interactions established with other species, the way in which inhabitants from the islands (San Cristóbal, Floreana and Isabela) perceive, know, and use this plant. Informal interviews and 20 questionnaire surveys were conducted per island. Furthermore, arthropod richness and abundance data was collected in two different land covers per island to determine alfa and beta diversity as well as the structure of ecological networks. A new species of *Acanthoscelides* nov sp. (Chrysomelidae: Bruchinae) was found and *Eupelmus cushmani, Pteromalus* Moprhotype 1 and *Pteromalus* Morphotype 2 (Hymenoptera: Chalcidoidea) had never been registered in the Galápagos. Overall species and interaction diversity were highest for San Cristóbal (H=1.62, H=1.82, respectively). San Cristóbal and Floreana are more similar (BC= 0.59) in terms of arthropod composition than to Isabela (BC=0.45). A high degree of niche overlap was evidenced between arthropod communities of San Cristóbal (0.91) and Floreana (0.94). Survey results had a high variation response in Floreana compared to the other two islands. Invasive species are a human issue, with a human cause and a human solution, therefore, an integrated approach using community ecology frameworks and social perception analysis is needed to tackle management strategies and ecological success of invasive plants in the Galápagos islands.

Keywords: Diversity, ecological networks, social perception, invasive plants

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1. Introduction

The Galápagos islands vulnerability to biological invasions is high due to the intentional or accidental introduction of exotic species by humans (Causton et al., 2006; Guézou et al., 2010; Mauchamp, 1997; Peck, Heraty, Landry, & Sinclair, 1998; Shea & Chesson, 2002) which affects the integrity of native ecosystems and the diversity of native species (Mauchamp, 1997). The successful establishment of an exotic plant depends primarily on the type and quantity of interactions that these develop with a variety of organisms such as predators, competitors and parasitoids (Sanabria-Silva & Amarillo-Suárez, 2017). This establishment also depends on the characteristics of the invader and the community invaded (Shea & Chesson, 2002). The understanding of biological invasions from a community ecology perspective offers the possibility to analyze the factors that could promote invasion by integrating factors such as characteristics of invaders, availability of resources and diversity and abundance of natural enemies (Shea & Chesson, 2002).

Introduction of exotic species is one of the main threats to the Galápagos islands (Causton et al., 2006) because of the habitat degradation it has caused (Guézou et al., 2010). Additionally, there is still a lack of knowledge regarding introduced insects in the archipelago (Causton et al., 2006) and its relationship with other groups of organisms. The order Coleoptera comprises approximately 25% of the terrestrial organisms in the Galápagos islands (Peck & Kukalova-Peck, 1990). Specifically, seed beetles (Chrysomelidae: Bruchinae) are well known for their feeding habits on plants of agricultural interest (Johnson, 1984). In the larvae stage these beetles burrow into the seeds and consume them to complete their lifecycle and emerge as adults (Watanabe, 1989, Huignard et al., 1989; Sanabria-Silva & Amarillo-Suárez, 2017). It is clear that seed consumption by organisms has coevolved at the chemical, spatial and temporal levels (Janzen, 1971).Some Bruchinae species have evolved resistance to toxic compounds in Leguminosae plants (Janzen, 1971; Johnson, 1989).

The Leguminosae plants from the genus *Leucaena* (Mimosaceae) contains approximately 22 species, mainly distributed in the neotropics (Hughes, 1998). *Leucaena leucocephala* (Lam.) de Wit is one of the 100 most invasive plants in the world (Sanabria-Silva & Amarillo-Suárez, 2017; Shoba & Olckers, 2010) because of its allelopathic effects (Tuda et al., 2009). Studies have suggested that plots invaded by *L. leucocephala* affect communities by favoring the establishment of exotic plants rather than native ones (Yoshida & Oka, 2004). Habitats composed mostly of exotic plants have a negative effect on the abundance and richness of arthropod communities (van Hengstum, Hooftman, Oostermeijer, & van Tienderen, 2014). Thus, knowledge of the simultaneous effects of natural enemies and host plants on the structure of tritrophic communities in natural conditions is still scarce (Amarillo-Suárez, 2010; Godschalx, Rodríguez-Castañeda, & Rasmann, 2019). The analysis of tritrophic structures results interesting because they shed light into the role of top-down (natural enemies) and bottom-up (resources) forces on insect herbivores (Walker & Hefin Jones, 2001). Harvey et al. (2010) argue that top-down/bottom-up effects should be considered to understand regulation of community structure where exotic species have become established.

The Galápagos islands have a very interesting natural and human history. Just like Darwin saw it, at plain sight the landscape seems to be a very aggressive habitat for the organisms there found (Riou-Green, 2015). Nevertheless, it is impressive to see how the species have adapted and thrived in these conditions. The Galápagos archipelago was never connected to the continent and is composed by many islets and volcanic islands with a total land mass of 8000km^2 (Riou-Green, 2015). Isabela the largest island, with 4670km^2 occupies more than half of the terrestrial area of the archipelago (Peck & Kukalova-Peck, 1990). The first human settlements began in 1832 when it was declared a part of Ecuador (Guezoú et al., 2010; Riou-Green, 2015), but since the discovery of the islands (1535) it was already visited by pirates, whalers and sea lion hunters (Guezoú et al., 2010). The first island to be colonized, was Floreana in 1832 by Ecuadorian General José Villamil and 80 soldiers he saved from execution. The colony experienced moderate success until it failed to prosper in the early 1840´s, and most settlers emigrated to the continent or dispersed to other inhabited islands such as San Cristóbal (Riou-Green, 2015). Even though most settlers dispersed, exotic plants and domesticated animals (goats, pigs and cattle) were left to roam the islands (Kricher, 2006). In the 1860´s the Ecuadorian entrepreneur Manuel J. Cobos and associates created the “Empresa Industrial Orchillana y de Pesca” which ended up exporting goods such as sugar, coffee, leather, fish, meat and turtle oil for 20 years (Riou-Green, 2015). Accompanied by the industrial development of the islands was the growth of the population which dispersed in the nowadays inhabited islands (San Cristóbal, Isabela, Floreana and Santa Cruz). Currently the main economic activities are tourism and artisanal fishing (Trueman, 2014). The Galápagos islands have always been perceived as a pristine system with little to no human intervention (Riou-Green, 2015). Despite this, humans have been altering and modifying virtually all systems in one way or another since first contact in the 16th century.

Since *L. leucocephala* is the result of intervention processes led by humans, it is considered an exotic, naturalized species with no specific use in the Galápagos islands (Guezoú et al., 2010). Because of this, it is important to understand, in addition to the interactions it establishes with other species, the way in which local inhabitants from the islands perceive and manage it. Furthermore, surveys were conducted to understand how inhabitants perceive this plant, what they know, and what it is used for. Relating ecological networks and arthropod communities with social analysis tools concerning the three aspects mentioned may be an approximation to better understand *L. leucocephala´s* associated arthropods and its successful establishment in the archipelago due to human introduction.

Thus, this study aims to answer the following question: ¿How does social perception and arthropod communities associated to *L. leucocephala* vary in two land covers on three of the Galápagos islands? and in order to do so, three objectives were established: (1) Analyze and compare the diversity of arthropods interacting with seeds of *L. leucocephala* on two land covers, on three of the inhabited islands (Isabela, San Cristóbal and Floreana) (2) Analyze and compare the ecological network structure of arthropods associated to seeds of *L. leucocephala* on two land covers, on three of the inhabited islands (3) Analyze the perception, knowledge, and use that the local inhabitants give to *L. leucocephala* on three of the inhabited islands.

2. Materials and methods

2.1 Study area

The archipelago of the Galápagos islands is under Ecuadorian jurisdiction and is located approximately 1000km from the South American coast (Guézou, Pozo, & Buddenhagen, 2007). It is composed by 123 islands of volcanic origin (Guezoú et al., 2010). This is one of the most protected and preserved systems in world (Peck et al., 1998) to the point that The Galápagos National Park, established in 1959, possesses 97% of the terrestrial area on the islands (Gardener, Atkinson, & Rentería, 2010; Guézou et al., 2007). The remaining 3% of the area is urban and agricultural (Gardener et al., 2010). The ecosystems and unique biota in the Galápagos developed in complete isolation for approximately 3.5 million years (Peck et al., 1998). The native flora of the Galápagos is composed by about 553 species, of which 32% are endemic, including seven endemic genus of plants (Mauchamp, 1997; Guezou et al., 2007). According to Gardener et al. (2010), there are approximately 888 exotic plant species, from which 31 are invasive, 267 naturalized and 590 and non-naturalized. These plants represent 59% of the total introduced species in Galápagos registered until now (Gardener et al., 2010).

The archipelago is characterized by one rainy season between January and May, and a dry season from May to December. The temperature ranges between 22ºC-29ºC (Peck & Kukalová-Peck, 1990). The highest altitude in the islands is 1700msnm (Guezoú et al., 2010), corresponding to Fernandina island which is a volcano. This study was conducted on three of the inhabited islands in the Galápagos: Isabela, San Cristóbal and Floreana which have an area of 4670km^2, 552km^2 and 171km^2 respectively. According to the vegetation map of Galápagos (ESRI, 2016), there are 16 different land covers in the islands, including urban and agricultural areas. The tropical dry forest is classified under deciduous forest (ESRI, 2016). Field work was done in the arid and transition zones considering the classification established previously by the Galápagos National Park (Riou-Green, 2015). To have a more precise classification of microsites sampled, a personal criteria classification was established (and will be explained further), which leads us to the following land covers where seed pods from *L. leucocephala* were collected: mixed forest, land occupied by agriculture and green urban areas all of them located within the deciduous forest (Figure 1).

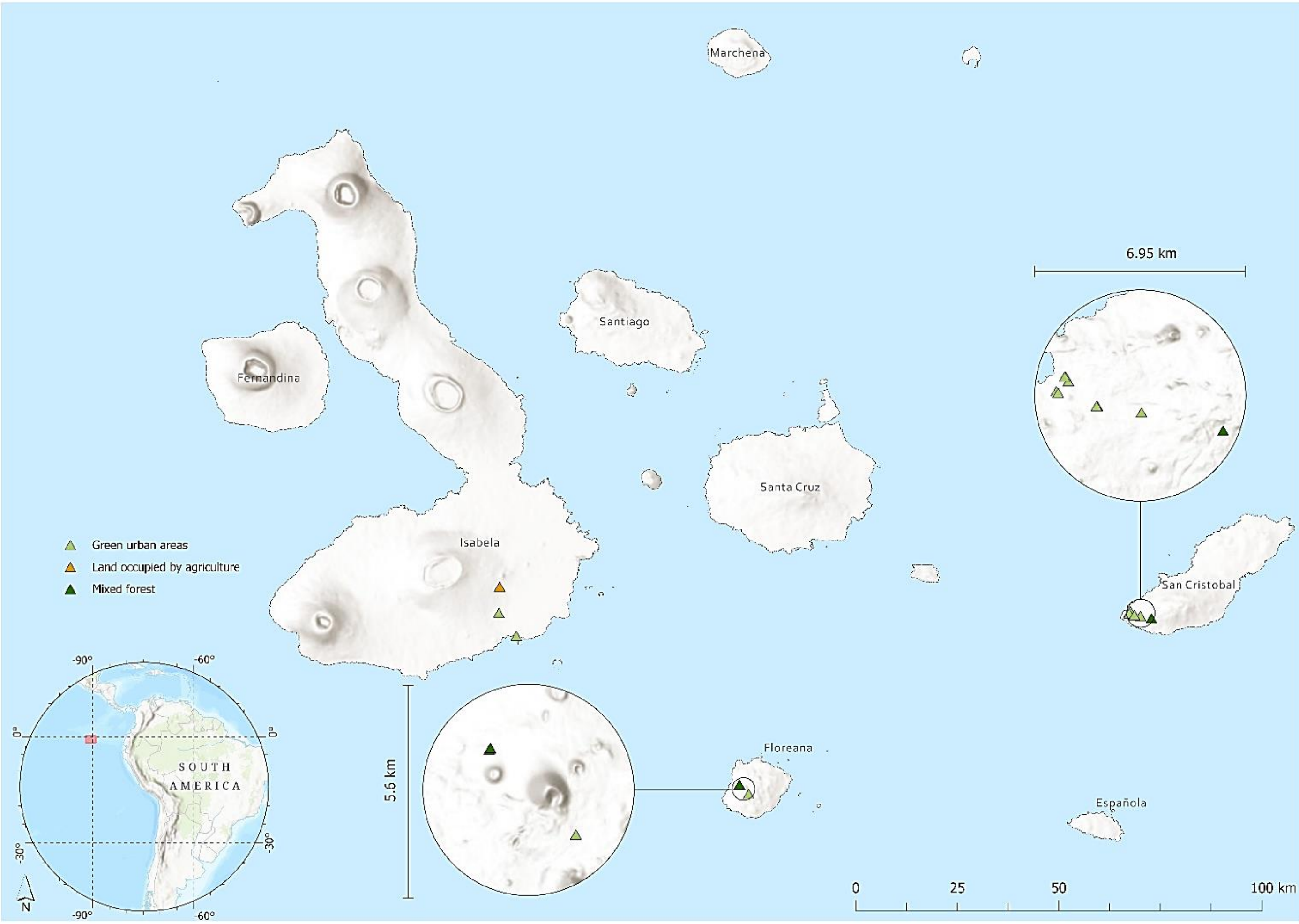

Figure 1. Map of the Galápagos islands. Islands where data collection took place have triangle figures representing the sampling sites. Light green triangles account for the sites where green urban land cover was sampled. Orange triangles portray sites that belong to the land occupied by agriculture land cover. Dark green triangles depict sampling sites in the mixed forest land cover.

2.2 Study species: *L. leucocephala*

L. leucocephala is an exotic and invasive Leguminosae plant (Family: Mimosaceae) native to Mexico and Central America which has been introduced and naturalized in approximately 105 countries (Shoba & Olckers, 2010; Tuda et al., 2009). It has also become established in various Pacific Islands where it forms dense populations in disturbed areas (Yoshida & Oka, 2004). Many exotic plants have been catalogued as “wonder species” because of the properties and services they offer. *L. leucocephala* is one of these species because of their rapid growth rate and the multiple uses attributed to the plant (wood, erosion control, shade for certain crops and cattle feeding) (Richardson, 1998). Nevertheless, it is listed in the world’s 100 most invasive plants and of high risk due to its dispersion capability and huge seed production throughout the year (approx. 1700 seed pods/plant, 20 seeds/seed pod)

(Tuda et al., 2009; Shoba & Olckers, 2010; Baptiste et al., 2010). *L. leucocephala* is a tree with a round canopy and varies between 3-12m in height (Lyons & Miller, 1999). Since it produces mimosine (toxic compound), an allelopathic effect occurs by displacing plants that grow close to it (Tuda et al., 2009). An eradication process of *L. leucocephala* was implemented in the islands Isabela, San Cristóbal and Floreana, but failed due to the lack of information in the distribution of the species (Isabela & San Cristóbal) and the need for more time to complete the eradication of the species in Floreana (Gardener et al., 2010).

2.3 Field work and data collection

Field work was executed between May 5 and July 15, 2019 under the permission number PC 42-19 emitted by The Galápagos National Park. To analyze the diversity and the network structure of the arthropods interacting with seeds of *L. leucocephala* on two land covers according to species presence, on three of the inhabited islands (Isabela, San Cristóbal and Floreana), first, the land covers with presence of *L. leucocephala* were identified on each island. This was done by exploring the main and secondary roads by car and the pedestrian pathways by foot. Once the land cover was identified, and the presence of *L. leucocephala* guaranteed, the recollection of mature seed pods began in the available trees. The sites of seed pod collection were composed mainly by more than one tree of *L. leucocephala*, and at least one bag of 1000cc of seed pods was gathered from each individual. After the seed pods were recollected, they were split open and seeds were deposited in closed jars. The seeds were checked every 24 hours for approximately 16 days to collect the arthropods emerging from the seeds and to assure that most arthropods emerged. The arthropods were preserved in vials with 97% alcohol for latter identification in the laboratory. Arthropod identification was achieved using the keys developed by Borror and White (1970). Hymenopteran parasitoids and bruchinae beetles were identified by expert taxonomists. Arthropods that could not be identified were grouped into morphotypes.

A total of 5,057 arthropods were collected in all three islands in two different land covers per each island: (1) Green urban areas, determined as sites where human infrastructure was present, roadsides included, (2) Mixed forest were those in which the canopy of the forest was visible and there was no human infrastructure, and (3) Land occupied by agriculture, determined as sites where agriculture activities were predominant, was included for Isabela island because *L. leucocephala* was not found in a mixed forest land cover. Sampling was done in a total of 11 sites for San Cristóbal, 4 in Floreana and 3 in Isabela (Table 1).

In order to understand how the human population of Galápagos perceives *L. leucocephala*, what they know and how they use it, informal interviews and 20 questionnaire surveys composed of 18 questions were conducted in each island with local inhabitants from different genders and ages ranging from 20 to 77. Thus, a mixed-method approach is applied because it involves the analysis of quantitative and qualitative data. Social science paradigms exist because of the way we interpret and use the information gathered (Kuhn, 1996). An interpretative paradigm was employed to discover the meaning of human actions by learning the personal views of the individual and what impulses certain behaviors (González, 2003). This way it is possible to analyze invasion processes of L. leucocephala according to human factors concerning their views towards this plant.

Island	Sites	Latitud	Longitud	Altitud (mamsl)	Predominant land cover	Land cover
San Cristóbal	One	S 00º54'18.90"	W 89º36'29.34"	26	Dry tropical forest	Green urban areas
	Two	S 00º54'01.08"	W 89º36'21.35"	25	Dry tropical forest	Green urban areas
	Three	S 00°54'06.05"	W 89°36'17.96"	37	Dry tropical forest	Green urban areas
	Four	S 00º54'39.39"	W 89°35'00.16"	126	Dry tropical forest	Green urban areas
	Five	S 00º54'16.70"	W 89º36'31.10"	17	Dry tropical forest	Green urban areas
	Six	S 00º54'32.89"	W 89º35'46.74"	75	Dry tropical forest	Green urban areas
	Seven	S 00°54'18.90"	W 89° 56'48.75"	26	Dry tropical forest	Green urban areas
	Eight	S 00°54'01.08"	W 89°36'21.5"	26	Dry tropical forest	Green urban areas
	Nine	S 00°54'18.40"	W 89°36'28.89"	27	Dry tropical forest	Green urban areas
	Ten	S 00°54'58.71"	W 89°33'33.1"	245	Dry tropical forest	Mixed forest
	Eleven	S 00°54'32.60"	W 89°35'48.21"	74	Dry tropical forest	Green urban areas
Floreana	One	S 01°18'16.6"	W 90°27'02.9"	322	Dry tropical forest	Green urban areas
	Two	S 01°17'03.2"	W 90°28'16.3"	156	Dry tropical forest	Mixed forest
	Three	S 01°17'04.3"	W 90°28'17.5"	160	Dry tropical forest	Mixed forest
	Four	S 01°17'02.8"	W 90°28'16.3"	155	Dry tropical forest	Mixed forest
Isabela	One	S 00°50'46.5"	W 91°00'07.0"	204	Dry tropical forest	Land occupied by agriculture
	Two	S 00°57'17.7"	W 90°57'55.1"	8	Dry tropical forest	Green urban areas
	Three	S 00°54'16.7"	W 91°00'12.8"	68	Dry tropical forest	Green urban areas

Table 1. Sampling sites on each island and land cover. Each site has their respective coordinates corresponding to a land cover. Sampling was done according to *L. leucocephala* presence thus making green urban areas the land cover that was most sampled followed by mixed forest and land occupied by agriculture.

2.4 Ecological data analysis

To obtain the diversity and the structure of ecological networks, the abundance and species richness data was recorded by island and land cover. Since species richness estimates depend on sampling effort (Magurran, 2004), species accumulation curves were developed to ensure that most species were included in data recollection. After creating the data base, we used the open access programs R and Past to estimate alpha diversity with the Shannon index and beta diversity with the Bray-Curtis index. We also obtained the bipartite ecological networks using R package bipartite. The Shannon index expresses uniformity and assumes that almost all species are represented to observe a general pattern of heterogeneity (Shannon, 1948). Bray-Curtis is a similarity index that analyses differences in composition (presence and absence data) or turnover between two or more localities (Bray & Curtis, 1957).

In contrast to food webs, bipartite ecological networks represent mutualist or antagonist interactions between groups (e.g. plant-animal) (Blüthgen, 2010). Ecological networks have an array of different metrics that can be measured depending on research interest (Blüthgen, Fründ, Vázquez, Menzel, & V, 2008; Dormann, Frund, Bluthgen, & Gruber, 2009). In this study, we estimated the following parameters of the networks: Connectance, which represents redundancy in interactions that compose the network; in other words, in what proportion are the links connected; nestedness refers to the groups or compartments found in the network, according to interaction density which may represent distinct functionalities (Bascompte, Jordano, Melián, & Olesen, 2003); diversity (Shannon index) represents how diverse the network is (Bascompte et al., 2003; Dormann et al., 2009); Interaction evenness estimates a network-level specialization based on interaction proportions (Dormann et al., 2009); Interaction strength asymmetry which quantifies the imbalance between interaction strengths of a species pair (Bascompte et al., 2003); Generality, which is the mean number of prey species per predator; Vulnerability which is the mean number of predators per prey and; Niche overlap which is the mean similarity in interactions patterns between species of the same trophic level (Dormann et al., 2009).

2.5 Social survey analysis

To assess how the local inhabitants, perceive, use, and how much they know about *L. leucocephala*, survey data was transformed into codes. We assigned numerical values to different answers of the survey. Transforming information into symbols makes the tabulation and numerical description process possible (Seid, 2016). Before the accumulation of answers, questions were grouped in three different categories according to their similar properties (use, knowledge and perception) (Lumley, 2004). Annex 1 shows the survey questions and further in the results they are grouped into the mentioned categories. To process the quantitative data, a matrix made (in Excel) ranked with 1s and 0s for yes or no questions respectively, and from 0 through 4 to questions with multiple responses. Once the numerical description of the information was gathered, we calculated averages per answer (Herreras, 2005). Population data in traditional survey statistics is understood as a fixed variable and randomness comes from the sampling procedure (Lumley, 2004). Since time was limited a quota and convenience sampling was applied (Newing, Eagle, Puri, & Watson, 2010). Quota sampling consists of setting a proportion of sample units which in this case is 20 individuals per island. Convenience sampling involves interviewing and surveying anyone that fits the broad criteria established; “local inhabitant”.

Since the population number of each inhabited island in the Galápagos is very different (approx.12,000 San Cristóbal, 8,000 Isabela, 120 Floreana) (Gardener et al., 2010; Guézou et al., 2007; Riou-Green, 2015; Trueman, 2014) informal interviews and 20 surveys per island were not representative to obtain the general perception, knowledge and use around *L. leucocephala* on each island and that is why a quota and convenience sampling was applied since it is used mainly for exploratory phases (Newing et al., 2010). So, instead of analyzing social survey data separately, the whole set of surveys (60) was processed to have a more robust approximation towards how the public perceives, knows and uses this exotic and invasive plant. Even if sample size is not entirely representative, the answers can still provide a useful indication of the characteristics searched for in this investigation. Questionnaires are often only composed of closed questions which obligates the interviewer to strictly ask the items in the survey. This highlights a weakness in questionnaires which is the failure to obtain meaningful responses which come from personal experience (Newing et al., 2010). So, to avoid loss of valuable testimonies, informal interviews were performed to provide complementary information about the invasive species in Galápagos and *L. leucocephala.* Nevertheless, questions that had response variations in the survey by island, were highlighted, and will be mentioned separately.

3.Results

3.1 Species accumulation curves and diversity

A total of 4,030 arthropods were collected in San Cristóbal, 987 in Floreana and 40 in Isabela, all from distinct taxonomic groups (approx. 24 families within 9 orders). The most abundant arthropod species associated with *L. leucocephala* seeds and seed pods in San Cristóbal was the seed feeder *Acanthoscelides* nov *sp.* (Coleoptera), the parasitoids (Hymenoptera) *Pteromalus* Morphotype 2, *Eupelmus cushmani*, *Pteromalus* Morphotype 1 and the xylophagous *Rhizophagus sp.* (Coleoptera) *(*Table 2). A similar result was observed for for Floreana in which the most abundant species was again *Rhizophagus sp.,* followed by *Acanthoscelides* nov *sp*., and *Hypothenemus* sp (Coleoptera). Isabela differed from the other islands since the most abundant species were the Thysanoptera from the Phloeothripidae family, followed by spiders and *Rhizophagus sp.* It is important to mention that bruchinae beetles were not found in Isabela, and parasitoid wasps were found only in San Cristóbal. Also, *Acanthoscelides* nov sp. is a new species for the bruchinae group and *Eupelmus cushmani, Pteromalus* Morphotype 1 and *Pteromalus* Morphotype 2 had never been registered in the islands (Noyes, 2019), therefore these two are new registers for the Galápagos islands. Genetic and morphological analysis is being executed to assure the identification of the new *Acanthoscelides* species (Morse et al., in press). According to the accumulation curve, San Cristóbal is the island with a more complete sampling in comparison to the other two islands. This is evidenced by the fact that this island has reached an asymptote throughout the sampling sites meaning most species are accounted for (Figure 2).

Arthropods			Abundance		
Order	**Family**	**Species**	**San Cristóbal**	**Floreana**	**Isabela**
Coleoptera					
	Chrysomelidae	*Acanthoscelides* nov sp.	1888	235	
	Rhizophagidae	*Rhizophagus* sp.	318	453	4
	Staphylinidae	Staphylinidae Morphotype 1	30	16	
	Coccinellidae	*Paraneda pallidula*	14	3	
	Curculionidae	*Hypothenemus* sp.	8	228	1
	Carabidae	Carabidae Morphotype 1	7	2	3
	Anthribidae	*Araecerus aff. fasciculatus*	6	13	3
	Nitidulidae	Nitidulidae Morphotype 1	5		
	Coccinellidae	*Cheilomenes sexmaculata*	1		
	Coccinellidae	*Cycloneda sanguinea*	1		
Hymenoptera					
	Pteromalidae	*Pteromalus* Morphotype 2	659		
	Eupelmidae	*Eupelmus cushmani*	535		
	Pteromalidae	*Pteromalus* Morphotype 1	431		
	Formicidae	Formicidae Morphotype 1	43		
	Evaniidae	*Evania* appendigaster	1		
Aranae					
	Aranae	Aranae Morphotype 1	2	3	2
	Aranae	Aranae Morphotype 2	2		5
	Aranae	Aranae Morphotype 3	1		3
	Aranae	Aranae Morphotype 4	2		1
Diptera					
	Drosophilidae	Drosophilidae Morphotype 1	1		
	Cecidomyiidae	Cecidomyiidae Morphotype 1		1	
Lepidoptera					
	Gracillariidae	Gracillariidae Morphotype 1	48	24	
Psocoptera					
	Polypsocidae	Polypsocidae Morphotype 1		4	
Miriapoda					
	Miriapoda	Miriapoda Morphotype 1	6		
Thysanoptera					
	Phloeotrhipidae	Phloeothripidae Morphotype 1	12	4	18
Hemiptera					
	Anthocoridae	Anthocoridae Morphotype 1	8	2	

Table 2. List of arthropods associated to *L. leucocephala* on each island with their respective abundance. Empty boxes mean that those organisms were not found in that respective island. *Acanthoscelides* nov sp. is the most abundant species, followed by parasitoids (Hymenoptera), *Rhizophagus* sp. and *Hypothenemus* sp. (Both from Coleoptera).

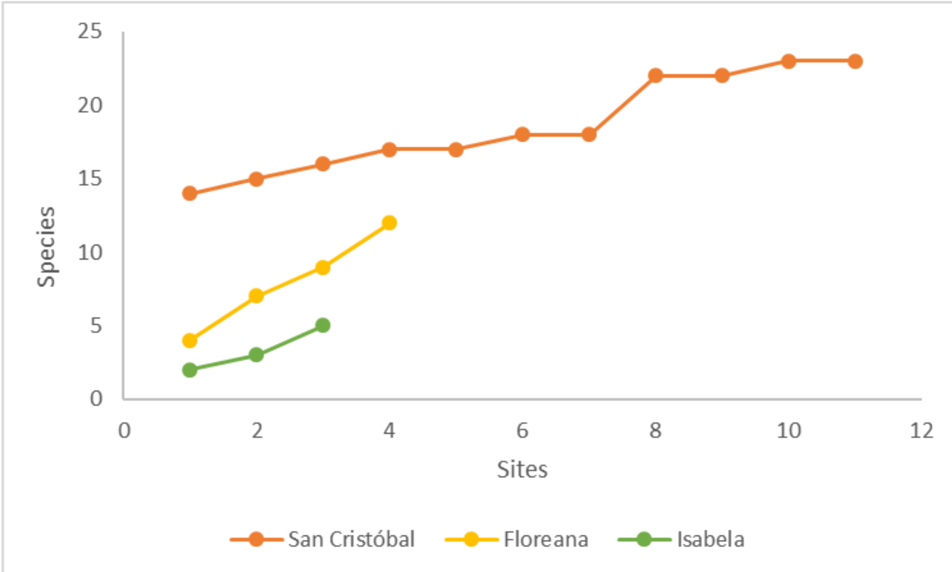

Figure 2. Species accumulation curves of the arthropods associated to *L. leucocephala* plotted against the sampling sites on each island. San Cristóbal is the only island that reached an asymptote with 23 species.

The diversity in San Cristobal and Isabela was higher in green urban areas than in mixed forest or land occupied by agriculture. Contrary to this, in Floreana, diversity was higher in mixed forest than in green urban areas. In terms of general diversity for each island and not by land cover, San Cristóbal proved to be the most diverse island followed by Isabela, then Floreana. As for beta diversity, the highest similarity between covers was in San Cristóbal followed by Floreana, and last Isabela. Beta diversity between islands indicates that San Cristóbal and Floreana are more similar to each other (0.59) than to Isabela (0.45) (Table 3).

Island	Land Cover	Shannon/Land cover	Bray-Curtis/Land cover	Shannon/Island	Bray-Curtis/Island
San Cristóbal	Green urban areas	1.63	0.48	1.62	0.59
	Mixed forest	0.88			
Floreana	Green urban area	1.23	0.47	1.36	0.59
	Mixed forest	1.37			
Isabela	Green urban area	1.15	0.38	1.55	0.45
	Land occupied by agriculture	0.68			

Table 3. Alfa and Beta diversity of arthropods associated to *L. leucocephala*. Shannon/Land cover and Bray-Curtis/Land cover are the alfa and beta diversity of arthropods corresponding only to the land covers on each island. Shannon/Island and Bray-Curtis/Island stand for the alfa and beta diversity corresponding to the whole sample of arthropods on each island and not separated by land cover.

3.2 Ecological network analysis

The study of ecological networks has created a bridge between how species adapt to physical environments, their interactions and how local and/or regional ecosystems are organized into biogeographic patterns (Dáttilo & Rico-Gray, 2018). Understanding complex networks of interaction will be helpful to assess patterns of evolution in generalization-specialization in mutualisms which is a subject related to niche variation and community assembly processes (Bascompte & Jordano, 2014). Plant-animal interactions are the structures that support many terrestrial ecosystems (Bähner, Zweig, Leal, & Wirth, 2017; Price, 2002). Therefore, three different ecological networks (one per island) were obtained from the richness and abundance data collected in field work. Figure 2 shows the arthropod communities associated to *L. leucocephala* associated to the land cover and island. Ecological metric values have different ranges depending on the one that is used. As mentioned before, the metrics measured in this investigation were connectance, nestedness, diversity, interaction evenness, interaction strength asymmetry, generality, vulnerability, and niche overlap (Table 4). San Cristóbal, Floreana and Isabela obtained intermediate connectance values. Nestedness was low for San Cristóbal, Floreana and intermediate for Isabela. Interaction diversity was highest for San Cristóbal in contrast to the other two islands, this was also the result in general alfa estimates (Table 3). Interaction evenness was greater in Isabela contrary to San Cristóbal and Floreana but not in significant proportions. Interaction strength asymmetry or ´dependance´ was greater for Isabela than the other two islands. Generality and vulnerability were greater in San Cristóbal in comparison to the other islands. The lowest value of niche overlap estimated was in the case of Isabela.

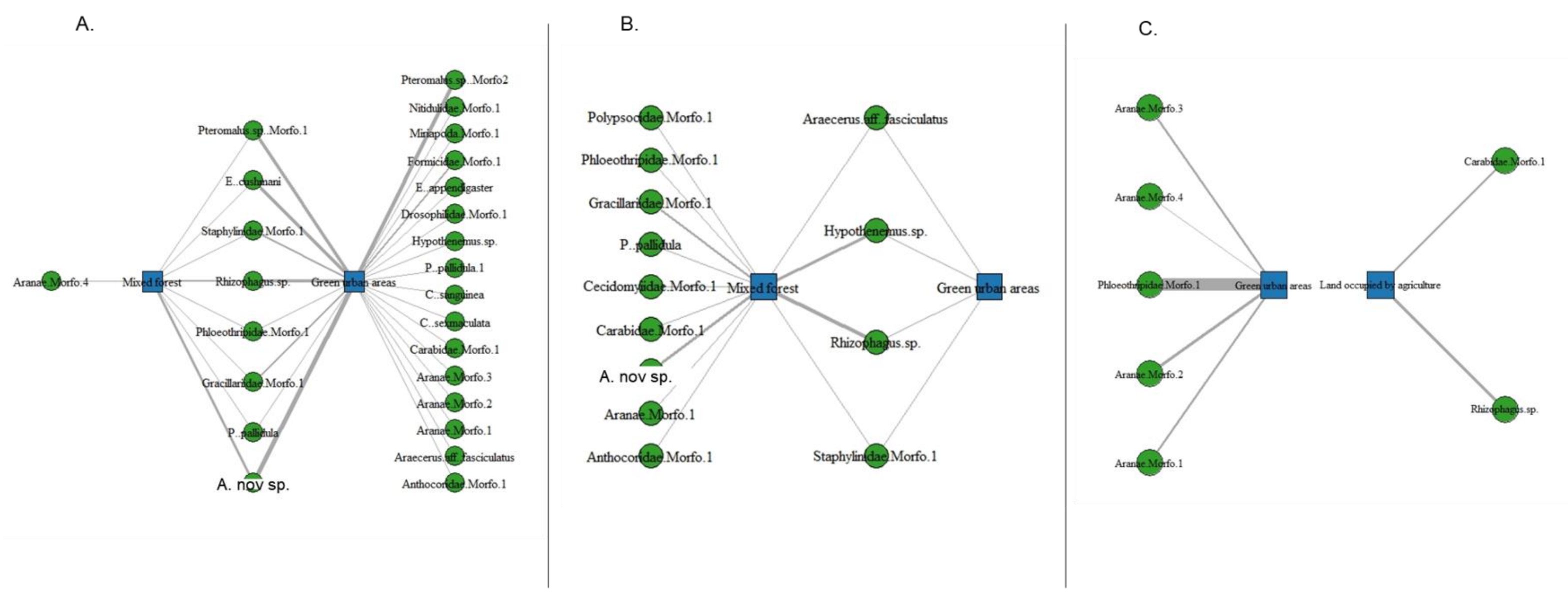

Figure 2. Ecological networks of each island with their corresponding land covers. A) San Cristóbal. B) Floreana. C). Isabela. Green balls portray arthropod species and blue squares represent each land cover. Thicker links refer to a higher

abundance of that specific arthropod. The most abundant species in San Cristóbal was *Acanthoscelides* nov sp. and was present in both land covers. The most abundant species in Floreana was *Rhizophagus* sp. and was also present in both land covers. The most abundant species in Isabela were from the Phloeothripidae family and were only present in the land occupied by agriculture land cover.

Island	Connectance	Nestedness	Shannon Diversity	Interaction evenness	Interaction strength asymmetry	Generality	Vulnerability	Niche overlap
San Cristóbal	0.66	8.28	1.82	0.46	0.60	1.23	4.98	0.91
Floreana	0.65	2.7	1.40	0.43	0.62	1.05	3.77	0.94
Isabela	0.55	56.24	1.55	0.58	0.71	1	2.94	0.52

Table 4. Values of the metrics measured for each ecological network per island.

3.3 Social surveys

Questionnaire results indicate that 100% of the surveyed public know and recognize *L. leucocephala*, 52% know it is exotic, 35% know it is used as food for cattle, and only 22% have an approximated date of how long this species has been present in the islands. 52% of the surveyed people perceived *L. leucocephala* as a harmful species, but 43% feel indifferent towards its presence. 75% think it is not an important species for the islands, and even though 88% do not feel any appreciation for this plant, 53% believe it should not be eradicated. One testimony recorded in the informal interview said, "*I would not grow Leucaena, but if I had cattle I would*" (Max, 45yo). In the beginning of the analysis it was not understood why people would still grow this species after more than half of the surveyed public know it is exotic and that exotics are harmful (82%). This was until another testimony explained, "*In the MAGAP* (Ministerio de agricultura, ganadería, acuacultura y pesca) *courses given in the island (Floreana) they recommended cattle ranchers to grow L. leucocephala because of its protein value for feeding livestock*" (Francisco, 32yo). Even though there is a general idea that exotic species are harmful and people are aware of it (98%), many people stated that no matter the origin of the species it would always provide some service like shade, aesthetic or food for the population, "*no plant is bad because they all provide services*" (Antonio, 57yo), "*yes exotic species are bad, but it all depends on the service they provide, like orange trees, they are never bad*" (Emerita, 40yo).

Response variations according to percentage results in surveys are presented in table 6 and discussed further. The island with the highest variation for one question concerning perception, two questions concerning knowledge and one question linked to use was Floreana in comparison to the other two islands. These answers were highlighted because of their importance and the fact that they can lead to establish some tendencies of thought inside the islands.

Perception	Yes	No	Food for cattle	No	Disfavorable	Favorable	Indifferent
1. Do you think Leucaena is harmful?	52%	48%					
2. Do you think this plant enhances the environment in any way?	30%	70%					
3. Do you think it is an important plant for the islands?	25%	75%					
4. What opinion do you have concerning the presence of this species?					33%	23%	43%
5. Do you feel any appreciation for this plant?	12%	88%					
6. Do you think this plant should be eradicated?	47%	53%					
7. Do you think more information about this plant should exist?	98%	2%					
Knowledge							
1. Do you know which plant L. Luecocephala is?	100%	0%					
2. Do you know if this plant has any commercial use?	18%	72%					
3. Do you know if this is a native species or an exotic species?	52%	48%					
4. Do you know of any introduced species in the island?	98%	2%					
5. Do you know if exotic species are harmful?	82%	18%					
6. Do you know how long Leucaena has been present in the area?	22%	78%					
7. Have you seen animals on this plant?	75%	25%					
Use							
1. Would you grow this species?	25%	75%					
2. Do you know what people use this plant for?			35%	65%			
3. Have you ever tried planting this species?	2%	98%					
4. Have you seen anyone trying to grow it?	0%	100%					

Table 5. Social survey questions and answers grouped by categories (perception, knowledge and use). A total of 18 questions were asked to 20 local inhabitants of the islands San Cristóbal, Floreana and Isabela concerning the categories mentioned. This tables shows the general results for all 60 surveys.

Questions	San Cristóbal		Floreana		Isabela	
Perception	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
1. Do you think Leucaena is harmful?	55%	45%	65%	35%	35%	65%
Knowledge						
2. Do you know if this plant has any commercial use	0%	100%	55%	45%	0%	100%
3. Do you know if this is an exotic species or a native species?	45%	55%	70%	30%	40%	60%
	Food for cattle	**No**	**Food for cattle**	**No**	**Food for cattle**	**No**
Use						
4. Do you know what people use this plant for?	35%	65%	65%	35%	5%	95%

Table 6. Highlighted Q&As because of their variation in response depending on the island. The island that most varied in responses concerning the questions in the table was Floreana especially for questions 2, 3 and 4.

4. Discussion

According to the results, alfa diversity was higher in green urban areas than in mixed forest and land occupied by agriculture for San Cristóbal and Isabela but not for Floreana. Nevertheless, these values are low values of diversity since all of them (except for green urban areas in San Cristóbal) are below 1.5, which in turn, represents low diversity in a community (Shannon, 1948). Low diversity results indicate in this case, a very high dominance of only a few species in the communities, a low degree of evenness and a high level of competition (Magurran, 2004). This could be because higher abundance of *L. leucocephala* were found in green urban areas in contrast to mixed forest and land occupied by agriculture which influenced arthropod species richness and abundance data. Contrary to this, Floreanas´ diversity is greater in mixed forest because higher densities of *L. leucocephala* were found in this land cover. Also, in the case of San Cristóbal, the highlands, where the mixed forest land cover was sampled, were cleared into grasslands around the 1900s for cattle to roam free. This was accompanied by the introduction of invasive plant species which ended up spreading and dominating the landscape (Trueman, 2014). It has been documented that high levels of plant invasion diminish local arthropod abundance and richness (van Hengstum et al., 2014). The reduction in biodiversity caused by invasive species may become an obstacle to the proper distribution of important ecosystem services like nutrient cycling and biological control of plant and insect pests (Harvey, Bukovinszky, & van der Putten, 2010). An invasive species with few specialist natural enemies that results in high population densities can maintain generalist natural enemies that have a negative impact on native communities (Shea & Chesson, 2002). Although a comparative analysis between native species and exotic species arthropod composition was not done here, this is a clear example of the low levels of diversity constrained in exotic plant-arthropod interactions.

Given the fact that the highest value comparing the diversity between land covers is 0.48 it demonstrates the low similarity between land covers in all islands. However, even if the differences are not significant, arthropod communities in San Cristóbal and Floreana share a more similar composition in their land covers than Isabela. This is most likely due to the fact the land covers in Isabela did not share any arthropod species. Elevation and habitat structure could be one of the causes for the difference in the arthropod community composition. It has been well documented that herbivore and parasitoid richness for example, is lower in higher elevations due to pressures of climatic variables on enzymatic rates (Godschalx et al., 2019). This is the case for San Cristóbal, where higher abundance and richness of parasitoids was registered in the lower altitudes. Habitat structure has also been known to influence ecological community dynamics and richness (Hernandez, Frankie, & Thorp, 2009) mostly through resources, the physical environment and competitive interactions which vary in time and space (Shea & Chesson, 2002). In the Galápagos, ecosystem transformation and the widespread of invasive plants was facilitated by urbanization, agricultural clearing, and seed dispersion since settlements began to be established (Trueman, 2014). The fact that more abundances of *L. leucocephala* and alfa diversity were found in urban settings except for Floreana could be explained by the arrangement of native, non-native and horticultural species that represent resource exploitation possibilities for generalist arthropods (Hernandez et al., 2009). Exotic species which are introduced in diverse habitats affect species composition and interactions (Sanabria-Silva & Amarillo-Suárez, 2017), however, species are not equally common in every environment (Magurran, 2004) which is evidenced in the fact that each island has different arthropod communities associated to *L. leucocephala* and only share a few species between islands.

Species accumulation curves were plotted against sampling sites on each island, San Cristobal (11), Floreana (4), Isabela (3). The use of this method is recommended to asses whether a community has been sampled properly and all species are accounted for (Dáttilo & Rico-Gray, 2018). Proper sampling is evidenced in the shape of the plot, if it reaches an asymptote this means it is stabilizing and one can assume that most species in a community are represented. Taking this into account, San Cristóbal was the only island to reach an asymptote with 23 species representing a well sampled community. However, Floreana and Isabela did not reach an asymptote which leads to the assumption that not all arthropods associated to *L. leucocephala* are represented. In comparison to San Cristóbal, Floreana and Isabela had a much lower abundance of *L. leucocephala* in the sampling sites which, as mentioned before, has an influence on overall richness and abundance of arthropods recorded. Isabela island has a very intricated roadway in the highlands which made it difficult to reach all areas where *L. leucocephala* might be present, nevertheless sampling effort was the same in all three islands in terms of time (not space). If sampling is repeated in the sites for a longer period of time, species accumulation curves might reach an asymptote for Isabela and Floreana.

One of the best ways to describe plant-arthropod interactions in a community is through the analysis of ecological networks (Bascompte & Jordano, 2014). Describing ecological networks based on their metrics may help to unravel patterns of community organization and heterogeneity in trophic associations (Blüthgen et al., 2008). The connectance metric values range from 0 to 1 and is usually interpreted as the degree of generalization or redundancy in a system (Dáttilo & Rico-Gray, 2018). High connectance values have consequences in community stability due to an increase in interspecific competition and low degrees of coexistence (Bascompte & Jordano, 2014). The results obtained from the connectance metric indicate that there are intermediate levels of competition and coexistence and the fact that these results did not reach a value of 1, indicates that not all species in the network are redundant. In the case of nestedness, the values for this metric range from 0 to 100 and low degrees indicate niche overlaps between species and that not many subgroups are formed inside of the network (Dáttilo & Rico-Gray, 2018). Isabela, which obtained the highest value of nestedness indicates that subgroups have been formed, this occurred because each land cover in this island had their own arthropod composition and did not share any species, which is also evidenced by the Bray-Curtis results (Table 2). Shannon diversity in ecological networks is used to characterize the diversity of associations based on interaction frequencies (Blüthgen et al., 2008). Congruent with general alfa results, San Cristóbal had the highest diversity result followed by Isabela and Floreana in order, nevertheless, as mentioned before, a value of 1.82 (San Cristóbal) is still considered a low diversity result (Shannon, 1948). Interaction evenness ranges from 0 to 1, values closer to 0 indicate no specialization and closer to 1, high specialization. This pattern depicts the heterogeneity of the interactions between trophic levels but not necessarily specialization (Blüthgen et al., 2008). This metric was highest for Isabela but not in significant proportions, low evenness values have often been linked to habitat disturbance which in turn affects overall arthropod diversity. As mentioned before and according to these results there could be a higher habitat disturbance in San Cristóbal and Floreana than in Isabela due to the fact that these islands have had human presence for a longer period of time (Trueman, 2014). Interaction strength asymmetry quantifies the imbalance between the interaction strengths of a species pair, thus, for example, a specialized organism in a plant-animal interaction will have a value of 1 and a generalist organism will be closer to 0 (Dormann et al., 2009). This metric has a weakness because singleton species can automatically be assigned the value of 1 due to its abundance, indicating high dependence when in fact it represents a rare species. This explains the values obtained for Isabela (0.71) where singleton species represented 28% of the data and increased imbalance in the associated species generates higher asymmetry. In the case of San Cristóbal and Floreana where singleton species were not significantly abundant, interaction strength asymmetry values indicate that species contribute to a small fraction of visits and a have a low dependence (Blüthgen et al., 2008). Generality and vulnerability are analogous metrics which in this case represent the mean number of arthropod interactions and the mean number of *L. leucocephala* interactions respectively. The results for these two metrics concords with arthropod diversity and connectance values since mean interactions in both groups were highest in San Cristóbal, followed by Floreana and Isabela. The last metric evaluated was niche overlap where values near 1 indicate niche overlap (Dormann et al., 2009). San Cristóbal and Floreana obtained the highest niche overlap results, congruent with low degree values of nestedness. This is due to the fact that in San Cristóbal and Floreana there are very dominant species in the community in terms of their abundance as stated before, thus resulting in very overlapped niches for these two arthropod communities.

Parasitoids (Hymenoptera: Chalcidoidea) were only recorded in San Cristóbal and were identified by a taxonomist expert as *Eupelmus cushmani*, *Pteromalus* morphotype 1 and *Pteromalus* Morphotype 2. Parasitoids are known for their ability to regulate host populations and act as biological control agents. Even though there have been records of high specificity to their hosts, for example one Chalcidid parasites one bruchinae species (Hetz & Johnson, 1988; Pérez-Benavides et al., 2019), Hetz & Johnson (1988) reported that *Eupelmus amicus* a synonym of *E. cushmani* parasite five Bruchinae species, seven Lepidopterans, four Coleopterans and two Hymenopterans. Nowadays, it is considered a parasitoid and hyperparasitoid of 34 species in 14 families in 5 orders, including the Pteromalidae family (Hymenoptera: Chalcidoidea) and three confirmed *Acanthoscelides* species; *A. floridae*, *A. obtectus* and *A. alboscutellatus* (Gibson, 2011)The role of parasitoids in host-parasitoids interactions normally has two components which are the degree of depression in a host population due to high observed levels of parasitism and the degree of stability of this interaction in a long term (Hassell & Waage, 1984). According to Hudson et al. (2006) a healthy system is one that is rich in parasitic organisms. Bruchinae beetles are targeted by these parasitoids and used as a resource to complete their lifecycle. Bruchinae are often specific to Leguminosae plants in the neotropics (Basset et al., 2018) and ecologically the adult female has a stomach capacity equal to her daily fecundity which in a lifetime adds up to approximately 50-100 eggs (Janzen, 1971). In San Cristóbal, the bruchinae beetle *Acanthoscelides* nov sp had a total abundance of 1888 individuals which was the highest value of abundance in comparison to all other species. After this species the most abundant organisms in order were parasitoids and *Rhizophagus* sp.. Although parasitoid-bruchinae relationships cannot be established confidently because these insects were not reared in a lab or the moment of parasitism was not recorded, the fact that the total abundance of parasitoids is almost the same as bruchinae and of another herbivorous insect (*Rhizophagus* sp.) could represent a certain population control. Evidence has shown that an increase in parasitoid species diversity improves ecosystem functioning (Hudson, Dobson, & Lafferty, 2006) Also, according to Cagnolo et al. (2011) host-parasitoid interactions are likely to switch between closely related organisms, which could be the case for *Eupelmus cushmani*. Furthermore, species natural abundance may determine interaction probability leading to random encounters between organisms which could be determining plant-insect-parasitoid relationships over time for *L. leucocephala* in the Galápagos.

The combination of top-down/bottom-up and lateral interactions (competition) generally represent negative feedback, stabilizing networks and reducing the possibility that populations increase to levels that threaten their resources and other species supported by these resources. Nevertheless, Sanabria-Silva & Amarillo-Suárez (2017) found that bruchinae beetles can enhance plant growth in *L. leucocephala* by increasing its probability of germination. This is because the seeds from this plant are hard, protected by a wax coat and holes made by beetles facilitate water intake and therefore germination. In this case, bruchinae beetles are not a favorable control agent for *L. leucocephala*. Instead they have the opposite effect which can lead to higher population densities of this invasive plant which in turn will have a deleterious influence over communities and their diversity. Although several hypotheses have been proposed to explain exotic plant invasion success, the two principal theories based on differences in the ecological communities associated to the invader as a result of displacement are the enemy release hypothesis (ERH) and the novel weapons hypothesis (NWH) (Harvey et al., 2010). The ERH assumes that plants are controlled by a suite of co-evolved natural enemies in their native range and when displaced, they escape from these enemies that are part of their natural community. The NWM assumes that toxic secondary compounds in plants exhibit higher potency in their exotic range because new competitors or attackers have not had the opportunity to evolve and thus adapt to them (Harvey et al., 2010; Shea & Chesson, 2002). Since bruchinae beetles might not be the best control agent for *L. leucocephala*, it becomes necessary to analyze secondary compounds in this plant, establish parasitoid relationships to see if hymenopterans are controlling bruchinae, and to test other theories to evaluate the success of establishment in the Galápagos islands.

The human population is an important source of introduction and spread of invasive species (Van Der Wal, Fischer, Selge, & Larson, 2014), still, if well informed, a public can help prevent further introductions of invasive species and have a major role in helping to control or mitigate them. Nevertheless, this seems not to be the case in the Galápagos islands where 98% of the surveyed people know that there are introduced species in the islands but separate testimonies indicate that people need some of these species to have a better life quality "*yes exotic species are harmful, but fruits are necessary*" (Máximo, 77yo) or are driven by some local authorities (Ministerio de agricultura, ganadería, acuacultura y pesca) and people which helped in the introduction of *L. leucocephala* "*My father brought this plant 30 to 35 years ago (Floreana) to feed the cattle in the farm"* (Aura, 65yo) . Davis et al.

(2011) identified that the impact introduced species have on the economy and/or nature has a greater influence on decision making processes than the "nativeness" of the species. Survey results indicate that even though 52% of the public know *L. leucocephala* is exotic, if it provides a service, it should not be eradicated (53%).

As mentioned before, *L. leucocephala* has a negative impact on diversity, its allelopathic effects also harms other organisms (Tuda et al., 2009; Yoshida & Oka, 2004), and eradication projects were established on the three islands (Isabela, San Cristóbal and Floreana) but failed due to lack of information and time (Gardener et al., 2010). There is still a need to make clearer and more accessible information to the public regarding effective management and control of this species. For example, in Floreana, the eradication process was almost successful, but a lack of time prevented this project from succeeding. Nevertheless, Floreana presented the highest variation in response to some questions concerning perception, use, and knowledge (Table 6). Taking into account the variation in responses exposed in Table 5, it can be assumed that for these questions in particular, the public from Floreana was more well informed about *L. leucocephala* than the other islands. According to Gardener et al. (2010) invasive species are a human issue, with a human cause and a human solution. On uninhabited islands, the human involvement may be restricted to scientists and conservation managers; but on inhabited islands, the human dimension should be always considered. Public awareness activities need to be carefully evaluated to develop sustainable management programs for exotic and invasive species. Most of the drivers of environmental change are social and many of the biggest and urgent challenges facing conservationists are linked in addition to ecological and biological systems, to social, political and economic systems (Newing et al., 2010). It is crucial to integrate social and natural history of a specific area to better understand the complex human-nature relationships that have been formed because of the way ecosystems are perceived and understood. Having a community ecology approach and social analysis tools is a way to understand species invasion success through ecologic, socio-political and economic outcomes which determine the way in which societies organize their landscape (Grimm, Grove, Pickett, & Redman, 2000).

5. Conclusion

In conclusion, a new species of a seed beetle from the genus *Acanthoscelides* was found in San Cristóbal and Floreana. Also, three species of Hymenoptera parasitoids were found in San Cristóbal and registered for the first time in Ecuador and Galápagos: *Eupelmus cushmani*, *Pteromalus* Morphotype 1, *Pteromalus* Morphotype 2. The sampling effort in San Cristóbal was representative and obtained the highest values for species and interaction diversity. Sampling in Isabela and Floreana should increase in terms of time and space to assure that all species in the arthropod communities associated to *L. leucocephala* are represented. San Cristóbal and Floreana are more similar between each other in terms of arthropod composition than to Isabela. Ecological network metrics are congruent with each other and due to low diversity values and very high abundances in few species there is a high degree of dominance and niche overlap in arthropod communities associated to *L. Leucocephala* in San Cristóbal and Floreana. This investigation has limitations concerning comparative analysis between native and exotic plants and spatiotemporal aspects because arthropod communities can vary according to plant species, seasonality and the locations sampled. It is recommended to sample native Leguminosae plants to analyze differences with exotic species, the arthropods associated to *L. leucocephala* in different seasons and determine the spatial distribution of this species in the islands, so all individuals of this plant are accounted for and variations in community structures can be analyzed. Additionally, this can be used to determine exotic arthropod species effects over native arthropods. Social perception, knowledge and use of *L. Leucocephala* in Floreana had response variations in comparison to the other two islands. *L. leucocephala* and exotic species are perceived as harmful species but can still provide a service. According to informal interviews it seems to be that the surveyed population is more concerned with this aspect (service) than the origin of the species. More surveys should be established contemplating a representative population sample to obtain detailed personal views towards exotic species in the Galápagos islands. It is also important to mention that the "perception, knowledge and use" in a society is mediated by sensorial, historical and contextual factors that should be analyzed in greater depth and with a representative population to be determined completely. Nevertheless, this study is an approximation to the general views concerning exotic plant species and the ecological interactions these comprise. It can also serve as a base or guideline to create a more robust investigation concerning exotic species and people in the Galápagos islands since, an integrated approach using community ecology frameworks and social perception analysis may shed light on management strategies and ecological success of invasive plants in the Galápagos islands.

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8. Annex 1. Questionnaire made to the local inhabitants of San Cristóbal, Floreana and Isabela in the Galápagos islands to better understand how they perceive, use and what they know about *L. leucocephala*.

1. Do you know the plant *Leucaena leucocephala* (Leucaena, ipei)?
   - Yes
   - No
2. Do you know if this plant has any commercial use?
   - ¿Yes, Which?
   - No
3. Would you grow this plant?
   - Yes
   - No
4. Do you know if this plant is exotic or native?
   - ¿Yes, Which?
   - No
5. Do you know any introduced species in the islands?
   - ¿Yes, Which ones?
   - no
6. Do you know if exotic species are harmful?
   - Yes
   - No
7. Do you think leucaena is harmful?
   - ¿Yes, Why?
   - No
8. Do you think this plant enhances the environment in anyway?
   - Yes
   - No
9. Do you know what this plant is used for?
   - Ornamental
   - Food for cattle
   - Medicinal
   - None
   - ¿Another, Which?
10. Have you tried growing this plant?
    - Yes
    - No
11. Have you seen anyone growing this plant?
    - Yes
    - No
12. Do you know since how long this species has been in the area?

- ¿Yes, how long?
- No

13. Have you seen animals on this plant?
    - Insects
    - Mammals
    - Birds
    - ¿Another, Which?
14. Do you think it is an important species for the island?
    - Yes
    - No
15. What opinión do you have concerning the presence of this species?
    - Favorable
    - Disfavorable
    - Indifferent
16. Do you feel any appreciation for this species?
    - Yes
    - No
17. Do you think this plant should be eradicated from the islands?
    - Yes
    - No
18. Do you think more information about this plant should exist?
    - Yes
    - No
    - Indifferent

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ANEXOS

1. MARCO REFERENCIAL

1.1. Marco teórico

Este trabajo se basa en 5 categorías teóricas; ecología de comunidades, invasiones biológicas, interacciones animal-planta, coevolución y parasitoides, todas estas son base fundamental para la elaboración de esta investigación. A continuación, en la figura 1 serán presentadas las relaciones conceptuales entre los diferentes componentes y conceptos.

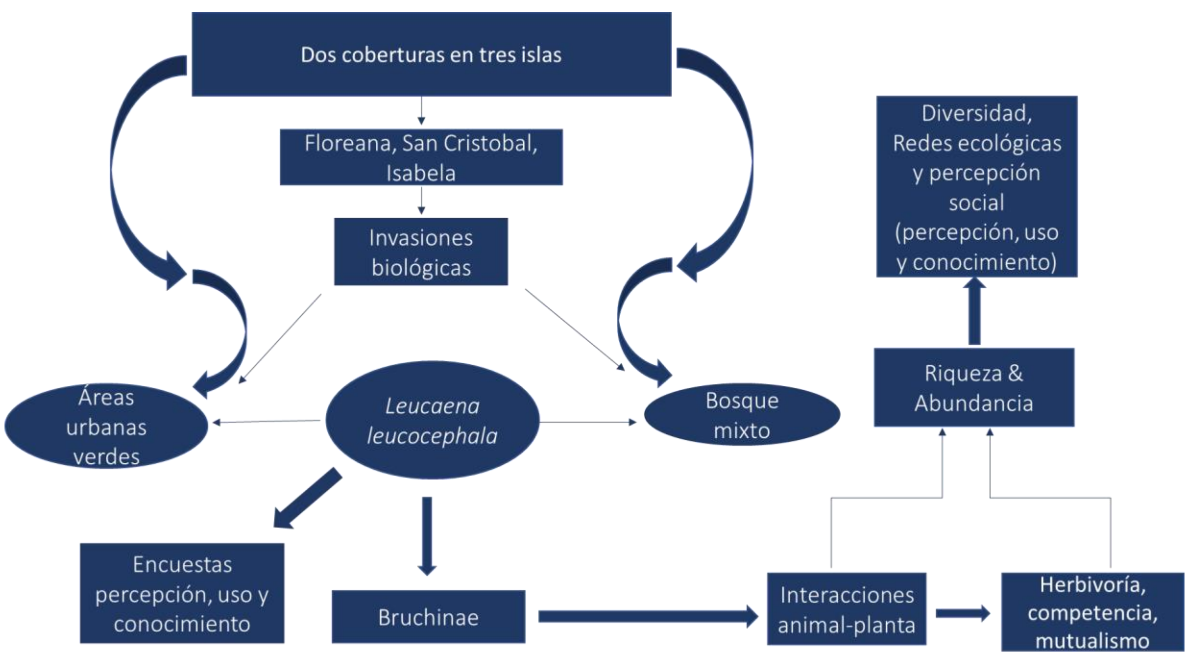

Figura 1. Diagrama conceptual de los conceptos y sus relaciones

1.1.1 Ecología de Comunidades

Según Clarke (1963) una comunidad está compuesta por poblaciones que han compartido historias de vida y ocupan un tiempo y espacio determinado, estas están definidas por los grupos de organismos que lograron establecerse y sobrevivir en un área determinada y el desempeño de estos depende de sus capacidades adaptativas a factores bióticos y abióticos a nivel de individuo (Clarke, 1963). Además tienen estructuras tróficas características, patrones de flujos de energía (Odum, 1959) y poblaciones dinámicas que interactúan en todos los niveles tróficos (Clarke, 1963). La ecología de comunidades es el estudio tanto de los componentes de una comunidad como de sus interacciones (Jaksic & Marone, 2006).

Sin embargo, no siempre ha sido así, ya que en un inicio la ecología de comunidades surgió con el único propósito de identificar y listar a las especies encontradas en localidades particulares (Clements 1916), lo cual sirvió como base importante para la creación de patrones comunitarios y distribuciones espaciotemporales (Watt 1947). No obstante, los estudios actuales se basan en estudios de gradientes de diversidad lati1tudinal o altitudinal, sucesión y detección de tendencias de riqueza de especies (Jaksic & Marone, 2006). Así como también en los diferentes procesos que al operar a diferentes escalas temporales pueden influenciar tanto el número como la identidad de las especies en las comunidades (Morin, 2009).

Por otra parte, otro enfoque que tienen muchos estudios en ecología de comunidades son las relaciones alimentarias entre organismos las cuales pueden describir patrones de flujo de materia y energía en las comunidades, ya que se pueden establecer los enlaces alimentarios entre consumidores y las especies que ellos consumen (Morin, 2009). Cómo establece Clarke (1963) la existencia de otra especie puede ser de importancia decisiva para: obtención de alimento, protección y algunas otras necesidades, es por esto que existen diferentes tipos de interacciones denominadas interespecíficas ya que son entre especies, las cuales pueden llegar a ser benéficas, neutrales o perjudiciales.

Finalmente, en cualquier estudio basado en ecología de comunidades es importante tener en cuenta su propósito y en el caso de esta investigación se tomó como base teórica para el análisis de las interacciones alrededor de una especie invasora.

1.1.2 Invasiones Biológicas

Cualquier especie que a través de la intervención humana fue (voluntaria o involuntariamente) transportada a un área que no corresponde a su área de origen natural, se puede llegar a considerar como una especie exótica (Vilà y col. 2008), y cuando estas especies llegan a un nuevo sitio pueden potencialmente asentarse y reproducirse, a veces de forma muy acelerada, llegando a constituir una invasión biológica (Gastón, 2009).

Existen ciertas características comunes en las invasiones biológicas tales cómo: las especies presentan una alta densidad y gran número de individuos, se establecen en grandes áreas en unas pocas generaciones, tienen una reproducción y crecimiento rápido y pueden llegar a producir la extinción de especies nativas (Gastón, 2009). No obstante, aún no existen criterios exactos que definen cuando una especie exótica debe considerarse invasora ya que en muchos casos estas especies o no logran reproducirse o las condiciones no son favorables para su asentamiento, por lo que no se genera una invasión (Gastón, 2009).

Actualmente las invasiones biológicas y las especies exóticas son base de diversas investigaciones debido a su abundancia, rápida dispersión, establecimiento en variados ecosistemas (Gastón, 2009) y en especial por los efectos que pueden generar tanto socioeconómicos (Mooney & Hobbs, 2000) como sobre especies nativas, y ecosistemas globales resaltando que estas están generando una homogeneización biótica con pérdida de identidad de los ecosistemas nativos (Mauchamp, 1997; Peck et al., 1998; Gastón 2009; Guézou et al., 2010;) lo que ha generado que hayan llegado a ser consideradas una amenaza y que esten catalogadas cómo la tercera causa de pérdida de biodiversidad global (Gastón, 2009; Williamson, 1996).

Debido a esto, a partir del creciente interés por esta problemática se empezaron a generar revisiones actuales sobre las invasiones abordando distintos puntos de vista cómo los establecidos por Shea & Chesson (2002) entre los cuales se destacan; las características del invasor y la comunidad invadida, recursos, enemigos naturales, entre otros, aunque para estos investigadores estos puntos de vista deberían ser abarcados bajo un marco de ecología de comunidades y no por separado.

En cuanto a la investigación realizada cabe resaltar la importancia del entendimiento de esta categoria teórica debido a que la especie vegetal en cuestión (*Leucaena leucocephala)* es una especie invasora y algunos de los insectos con los que interactúa también lo son, y cómo mencionaron Guezoú et al. en el 2010, las plantas invasoras están causando una degradación del hábitat en las Islas Galápagos y adicionalmente las especies de insectos introducidos no sólo son una de las amenazas principales para las islas sino que también hay un fuerte vacio de información conciernente a los presentes en el archipiélago (Causton et al., 2006).

1.1.3 Interacciones animal-planta

Ningún animal podría vivir aislado por sí mismo, ya que por una parte muchos de ellos dependen de otros animales y por otra un gran número de especies animales dependen de los recursos que las plantas proveen alrededor de sus estructuras reproductivas (flores, frutos, etc.) (Jordano et al. 2009). Es por esto que la presencia de organismos de diferentes especies en un mismo espacio es un factor inevitable y necesario en un ambiente natural (Clarke,1963), y la coexistencia genera una gran diversidad de interacciones interespecificas las cuales generan alto impacto sobre los patrones de adaptación, variación de las especies, estabilidad y organización de las comunidades (Rico-Gray & Oliveira, 2007).

Las diferentes interacciones pueden ser desde relaciones vitales y permanentes hasta causales y puramente temporales, además pueden ser tanto perjudiciales o benéficas para ambas partes, como perjudiciales o benéficas para una de las dos partes e indeferente para la otra (Clarke, 1963). Adicionalmente Clarke (1963) establece que las interacciones se pueden agrupar en dos categorias principales: 1. Simbiosis: es decir en donde una o ambas especies resultan beneficiadas y ninguna perjudicada y 2. Antagonismo: en cuyo caso por lo menos una de las dos especies resulta perjudicada. La simbiosis a su vez tiene dos subcategorias: mutualismo y comensalismo, mientras que las relaciones antagónicas pueden dividirse en cuatro subcategorías; parasitismo, herbivoría, depredación y competencia (Rico-Gray & Oliveira, 2007).

En el caso específico de una interacción planta – animal Magurran (1988) establece que al analizar este tipo de interacciones se procede de manera similar a cuando se muestrean especies para caracterizar diversidad. Es decir, se acumulan observaciones que permitan registrar las especies animales con las que interactúa cada especie de planta y viceversa (Jordano et al. 2009). Por ejemplo, un estudio realizado de la interacción planta- escarabajos depredadores de semillas de hojas establecen que es una interacción antagónica, lo que indica que el fitness de un grupo incrementa mientras que el fitness del grupo con el cual interactúa disminuye (Rico Gray & Oliveira, 2007).

Por otra parte, Jordano et al. (2009) utiliza en su investigación un enfoque de redes en el estudio de interaccións ecológicas y establece que no se puede comprender el funcionamento de sistemas comunitarios diversos centrándose en el estudio de especies aisladas, debido a que es el comportamiento de todo el sistema el que se debe analizar y no sólo la suma de las partes. Teniendo en cuenta lo anterior, las redes ecológicas permiten una mayor comprensión sobre la composición de un sistema en cuanto a su comunidad, disrupciones tróficas y/o simplificación de los ecosistemas que están sujetas a procesos antrópicos (Banher et al., 2017) y además ofrece herramientas integradoras de diferentes campos del conocimiento (Jordano et al. 2009).

1.1.4 Coevolución

Ehrlich and Raven's (1964) fueron los primeros en investigar procesos coevolutivos, sin embargo, no definieron el término, este fue definido posteriormente por diversos investigadores; Calvente (2007) por ejemplo definió la coevolución como el proceso de cambio evolutivo y adaptativo recíproco que se da entre especies interactuantes incluso en diferentes escalas espaciales y temporales. Para Futyma (2009) en cambio, eran los cambios genéticos en las características de las especies interactuantes lo cual es el resultado de una selección natural impuesta cada una sobre la otra, es decir una adaptación reciproca. Mientras que para Janzen (1980) era el cambio evolutivo en un rasgo de los individuos de una población en respuesta a un rasgo de los individuos de una segunda población, seguido por una respuesta evolutiva en la segunda población debido al cambio en la primera.

De manera que se puede entender como la evolución conjunta de dos o más especies, debido a sus interacciones y se ha evidenciado que ha ejercido fuertes efectos tanto en la diversidad de los organismos como en la evolución de sus características (Futuyma, 2009). No obstante, según Thompson (2005) se está aún lejos de comprender cómo la coevolución funciona en interacciones caracterizadas por una alta diversidad y baja especificidad, especialmente cuando se habla de interacciones entre especies de vida libre tales como plantas y sus polinizadores, dispersores de semillas, herbívoros, etc.

Es claro que los patrones de depredación de semillas están altamente estructurados y han coevolucionado al nivel químico, temporal y espacial (Janzen, 1971) y a nivel más específico los bruchinae adultos son depredadores de semillas que depositan sus huevos sobre el alimento (semillas) (Watanabe, 1989). Estos depositan alrededor de 50-100 huevos durante su etapa adulta (Janzen, 1971).

Ser un depredador de semillas es una característica tiempo-dependiente debido a que la obtención del recurso depende de la disponibilidad del mismo producto de los ciclos de producción de semillas de la planta hospedera (Janzen, 1971). Así mismo, como la disponibilidad de recursos controla las poblaciones de organismos, los parasitoides y enemigos naturales también ejercen una presión sobre los insectos depredadores de semillas (Amarillo-Suárez, 2010).

1.1.5 Parasitoides

La superfamilia Chalcidoidea de himenopteros apócritos contiene un tercio de todas las especies de parasitoides himenopteros y biológicamente es tan diversa como todas las demás avispas parasitoides juntas (Pérez-Benavides, Hernández-Baz &Riverón, 2019). Los parasitoides son conocidos por su habilidad para regular poblaciones hospederas y actúan como agentes de control biológico.

Tenido en cuenta como un grupo, los parasitoides componen alrededor del 14% de los insectos conocidos (Hassell & Waage, 1984). La mayor diversidad de parasitoides se encuentra en el orden Hymenoptera con aproximadamente 200,000 especies pertenecientes a este gremio (Hassell & Waage, 1984) y estudios determinaron que las parasitoides hembras adultas se alimentan activamente y ponen sus huevos dentro, sobre o cerca de los individuos huéspedes y hay registro de que esta superfamilia ataca a los organismos en todas las etapas de la vida (Hassell & Waage, 1984; Pérez-Benavides et al., 2019).

Por último, según Hassell & Waage (1984) las abundancias en las poblaciones de insectos herbívoros son controladas de alguna manera por enfermedades, enemigos naturales y variaciones en las condiciones ambientales apropiadas. Sin embargo, se ha demostrado que los parasitoides, depredadores o las enfermedades parecen actuar de manera directa sobre las densidades poblaciones de los insectos herbívoros (Hassell & Waage, 1984). Así mismo, estas interacciones y la proliferación de fitófagos juegan un papel fundamental en la estabilización de los sistemas que se enfrentan a invasiones biológicas.

1.2. Antecedentes

1.2.1 Antecedentes Temáticos

El estudio de la subfamilia bruchinae (Familia: Chrysomelidae) fue liderado por los europeos debido a que la colecta, identificación y curación fue realizada por éstos durante el final de 1700 e inicios de 1800 (Kingsolver, 1989). Linneo inició el estudio taxonómico de los bruchinae al establecer el género *Bruchus* y dos especies que lo comprendían en 1767 (Kingsolver, 1989). Adicionalmente, Huignard et al. (1989) y Johnson (1989) también realizaron estudio de las especies pertenecientes a la subfamilia bruchinae y se pudeo establecer que estas son considerados especialistas ya que las interacciones con sus plantas hospederas son estrictas en algunos casos, así como también otras investigaciones hipotetizan que alrededor del 80 - 90% de las especies de bruchinae tienen de uno a tres plantas hospederas (Johnson & Slobodchikoff, 1979; Johnson 1981; Rasplus, 1988).

Janzen (1971) también realizó un estudio en el que sugirió que los patrones de depredación de semillas han coevolucionado a nivel químico y espaciotemporal debido a sus características tiempo dependientes (disponibilidad del recurso). Sin embargo, cabe resaltar que aún se deben realizar más investigaciones para aclarar y establecer procesos coevolutivos entre bruchinae-plantas hospederas (Johnson, 1989). Aun así, se ha establecido que la utilización de compuestos secundarios como nutrientes para el desarrollo del ciclo de vida es un ejemplo de la relación coevolutiva entre organismos (Johnson, 1989).

Finalmente, en el estudio realizado por Huignard et al. (1989) se determinó que principalmente los bruchinae interactúan con las especies de plantas que son leguminosas, y con respecto a la leguminosa *Leucaena leucocephala* (Lam.)

también se han hecho investigaciones cómo la realizada en el 2010 por Shoba & Olckers en la que mencionan que es una planta nativa de México y Centro América. Sin embargo, según Tuda et al. (2008) ya se ha introducido en más de 105 países y al contener compuestos de mimosine genera un efecto alelopático al desplazar químicamente las plantas que crecen alrededor. Por último, se ha determinado además que su producción desmesurada de semillas (aprox. 1700 vainas/planta, 20 semillas/vaina) la ha convertido en una de las 100 plantas más invasoras del mundo (Tuda et al., 2008; Shoba & Olckers, 2010).

1.2.2 Antecedentes de Contexto

En las islas Galápagos se han realizado una gran cantidad de estudios que conciernen a casi todos los grupos biológicos (Peck & Kukalová-Peck, 2011). Para el presente trabajo solo se tendrán en cuenta las investigaciones relacionadas con bruchinae, plantas invasoras y trabajos de percepción social, un ejemplo es el informe de ecosistemas de Galápagos (2016) el cual informa que una de las coberturas predominantes es el bosque deciduo, conocido también como bosque seco tropical (Cuasapaz-Sarabia & Salas, 2019). El bosque seco tropical (BST) es uno de los ecosistemas menos estudiados y cuenta con pocas investigaciones relacionadas con la composición de comunidades, aspectos funcionales de los insectos y sobre los invertebrados en general que se encuentran en estos sistemas (Ramírez et al., 2002).

El estudio de las dinámicas de los coleópteros del BST en las islas Galápagos es aún escaso (Peck & Kukalová-Peck, 1990). Tanto así que existen alrededor de tres especies de coleópteros igual de diversos a los pinzones de Darwin, pero solo cuentan con estudios taxonómicos α (Peck & Kukalová-Peck, 1990) y no entre islas o sitios. Los primeros registros que se tienen sobre algunas especies de coleópteros presentes en las islas fueron realizados por Darwin en 1835 (Darwin, 1845). No obstante, cabe resaltar que, aunque Darwin tenía un interés por los coleópteros en general, éstos no fueron de gran importancia para él durante su expedición en el HMS Beagle (Peck & Kukalová-Peck, 2011).

Finalmente, en el estudio realizado por Kingsolver (1989) se establece que actualmente existen alrededor de 750 especies y según Kingsolver & Ribeiro-Costa (2001) en las islas Galápagos se tiene registro de 10 especies de bruchinae pertenecientes a seis géneros.

2. MATERIALES Y MÉTODOS

2.1 Diagrama de flujo: Procedimiento metodológico

A continuación, en la figura 2 se presenta el diagrama metodológico, en el cual se pueden evidenciar las fases del proyecto, los procesos, los productos, insumos, y los métodos para la realización de la investigación.

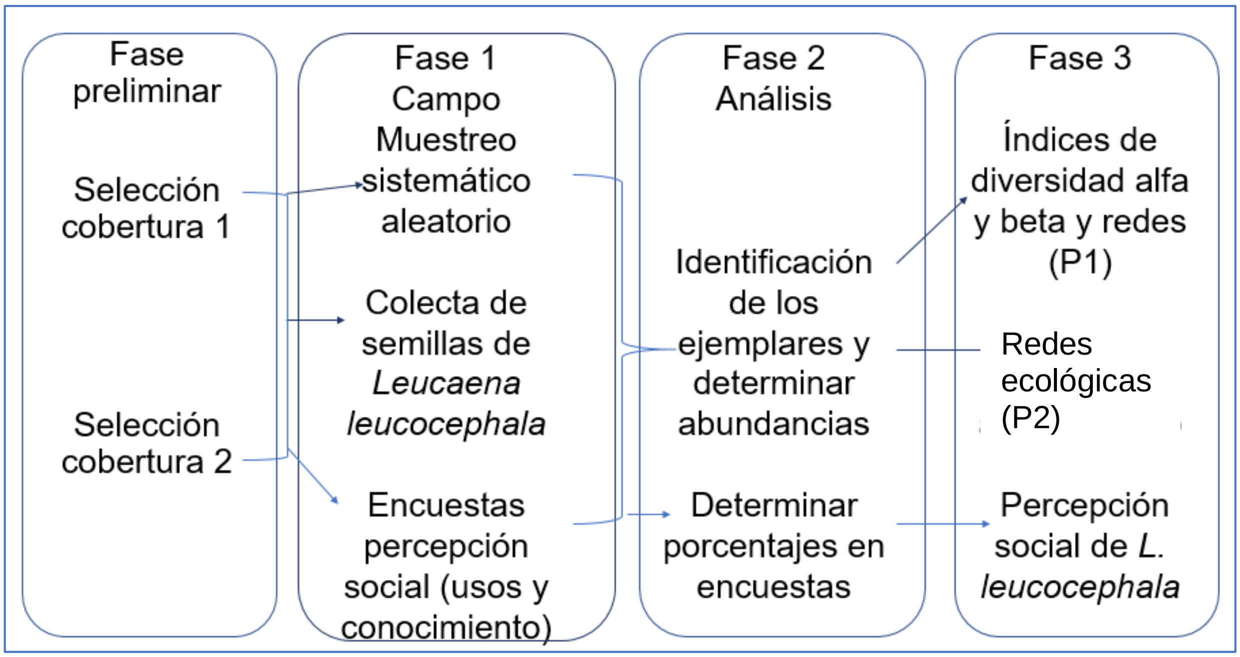

Figura 2. Diagrama del procedimiento metodológico del proyecto.

2.1.1 <u>Fase 1 →</u> Trabajo de campo

La primera fase de la investigación consistió en un reconocimiento de las coberturas de las islas San Cristóbal, Floreana e isabela, previo a la colecta de semillas de *Leucaena leucocephala*. Según el informe de ecosistemas de Galápagos (ESRI, 2016) existen alrededor de 16 coberturas del archipiélago incluyendo zonas agrícolas y urbanas. Las colectas se realizaron en las coberturas de zona árida y zonas de transición teniendo en cuenta la clasificación previamente establecida. Dentro de las coberturas mencionadas se buscó realizar las colectas en zonas perturbadas y no-perturbadas donde estuviera presente *L. leucocephala*. Posteriormente, se llevó a cabo un muestreo sistemático aleatorio en ambas coberturas colectando las semillas de *L. leucocephala* a medida que se fueron encontrando distribuidas en el espacio.

2.1.2 <u>Fase 2 →</u> Análisis

La segunda fase de la investigación se basa en la recolección de los datos necesarios de abundancia y riqueza de artrópodos. Tras realizar el muestreo de vainas y semillas de *L. leucocephala* se procedió a recolectar todos los artrópodos que estuvieran presentas en las vainas y semillas para luego preservarlos en alcohol al 97% e identificarlos en el laboratorio. Adicionalmente y con el fin de conocer aspectos sobre uso, conocimiento y percepción alrededor de L. leucocephala entrevistas informales y 20 encuestas se realizaron por isla sujetas a las categorías mencionadas.

2.1.3 Fase 3 → Análisis

Una vez recopilada toda la información necesaria que concierne la abundancia, riqueza de artrópodos y la percepción social de *L. leucocephala* se llevará a cabo el análisis de datos en función de la variación de cada elemento dependiendo de la cobertura (riqueza & abundancia) y la isla (riqueza, abundancia y percepción social). Los elementos se analizarán de manera independiente teniendo en cuenta la procedencia del material recolectado comparando las diferencias en la diversidad de artrópodos y redes ecológicas asociadas a *L. leucocephala* de acuerdo con la cobertura e isla. Al determinar los elementos mencionados se podrá realizar un análisis de la vulnerabilidad de las islas (San Cristóbal, Floreana, Isabela) frente al establecimiento de una de las 100 especies más invasoras del mundo y su naturalización en el archipiélago. Adicionalmente se debe analizar las tendencias y porcentajes de respuestas de las encuestas que conciernen las percepciones sociales del uso y conocimiento que se tiene sobre *Leucaena leucocephala.*

2.2 Métodos de Recolección de Datos

Para analizar la diversidad y la estructura de red de los artrópodos que interactúan con las semillas de *L. leucocephala* en dos cubiertas terrestres, en tres de las islas habitadas en Galápagos (Isabela, San Cristóbal y Floreana), primero, las coberturas terrestres con presencia de *L. leucocephala* fueron identificadas en cada isla. Esto se hizo explorando las carreteras principales y secundarias en automóvil y las vías peatonales a pie. Una vez que se identificó la cobertura y se garantizó la presencia de *L. leucocephala,* se inició la recolección de vainas de semillas maduras en los árboles disponibles. Los sitios de recolección de vainas de semillas estaban compuestos principalmente por más de un árbol de L. leucocephala, y se recolectó al menos una bolsa de 1000 cc de vainas de semillas de cada individuo. Después de recoger las vainas de semillas, se abrieron y las semillas se depositaron en frascos cerrados. Las semillas se revisaron cada 24 horas durante aproximadamente 16 días para recolectar los artrópodos que emergieron de las semillas y para asegurar que surgió la mayoría de los artrópodos. Los artrópodos se conservaron en viales con alcohol al 97% para su posterior identificación en el laboratorio. La identificación de artrópodos se logró utilizando las claves desarrolladas por Borror y White (1970). Los parasitoides himenópteros y los escarabajos bruchinae fueron identificados por taxonomistas expertos. Los artrópodos que no pudieron identificarse se agruparon en morfotipos.

2.3 Métodos de Análisis de datos

Para estimar la diversidad y la estructura de las redes ecológicas, se registraron los datos de abundancia y riqueza de especies por isla y cobertura terrestre. Dado que las estimaciones de riqueza de especies dependen del esfuerzo de muestreo (Magurran, 2004), se desarrollaron curvas de acumulación de especies para garantizar que la mayoría de las especies se incluyeran en la recolección de datos. Después de crear la base de datos, utilizamos los programas de libre acceso R® y Past para estimar la diversidad alfa con el índice Shannon y la diversidad beta con el índice Bray-Curtis. También obtuvimos las redes ecológicas bipartitas usando el paquete R® bipartite. El índice de Shannon expresa uniformidad y supone que casi todas las especies están representadas para observar un patrón general de heterogeneidad (Shannon, 1948). Bray-Curtis es un índice de similitud que analiza las diferencias en la composición (datos de presencia y ausencia) o rotación entre dos o más localidades (Bray y Curtis, 1957).

A diferencia de las redes alimenticias, las redes ecológicas bipartitas representan interacciones mutualistas o antagonistas entre grupos (por ejemplo, planta-animal) (Blüthgen, 2010). Las redes ecológicas tienen una variedad de métricas diferentes que se pueden medir según el interés de la investigación (Blüthgen, Fründ, Vázquez, Menzel y V, 2008; Dormann, Frund, Bluthgen y Gruber, 2009). En este estudio, estimamos los siguientes parámetros de las redes: conectividad, que representa la redundancia en las interacciones que componen la red; en otras palabras, en qué proporción están conectados los enlaces; anidamiento se refiere a los grupos o compartimientos encontrados en la red, de acuerdo con la densidad de interacción que puede representar distintas funcionalidades (Bascompte, Jordano, Melián y Olesen, 2003); la diversidad (índice de Shannon) representa la diversidad de la red (Bascompte et al., 2003; Dormann et al., 2009); La equitatividad de interacción estima una especialización a nivel de red basada en proporciones de interacción (Dormann et al., 2009); Fuerza de interacción asimétrica que cuantifica el desequilibrio entre las fuerzas de interacción de un par de especies (Bascompte et al., 2003); Generalidad, que es el número promedio de especies de presas por depredador; Vulnerabilidad, que es el número promedio de depredadores por presa y; Superposición de nicho, que es la similitud promedio en los patrones de interacción entre especies del mismo nivel trófico (Dormann et al., 2009).

Para evaluar cómo los habitantes locales perciben, usan y cuánto saben sobre *L. leucocephala,* los datos de la encuesta se transformaron en códigos. Asignamos valores numéricos a diferentes respuestas de la encuesta. La transformación de la información en símbolos hace posible el proceso de tabulación y descripción numérica (Seid, 2016). Antes de la acumulación de respuestas, las preguntas se agruparon en tres categorías diferentes de acuerdo con sus propiedades similares (uso, conocimiento y percepción) (Lumley, 2004). El Anexo 1 muestra las preguntas de la encuesta por categorías. Para procesar los datos cuantitativos, una matriz hecha en Excel compuesta por 1s y 0s para preguntas de sí o no respectivamente, y de 0 a 4 para preguntas con respuestas múltiples. Una vez que se recopiló la descripción numérica de la información, calculamos los promedios por respuesta (Herreras, 2005). Los datos de una población en las estadísticas de encuestas tradicionales se entienden como una variable fija y la aleatoriedad proviene del procedimiento de muestreo (Lumley, 2004). Como el tiempo era limitado, se aplicó un muestreo de cuotas y conveniencia (Newing, Eagle, Puri y Watson, 2010). El muestreo de cuota consiste en establecer una proporción de unidades de muestra que en este caso es de 20 individuos por isla. El muestreo de conveniencia implica entrevistar y encuestar a cualquiera que cumpla con los criterios generales establecidos; "Habitante local". Dado que el número de población de cada isla habitada en Galápagos es muy diferente (aproximadamente 12,000 San Cristóbal, 8,000 Isabela, 120 Floreana) (Gardener et al., 2010; Guézou et al., 2007; Riou-Green, 2015; Trueman, 2014) las entrevistas informales y 20 encuestas por isla no fueron representativas para obtener la percepción general, el conocimiento y el uso de L. leucocephala en cada isla. Entonces, en lugar de analizar los datos de las encuestas sociales por separado, todo el conjunto de encuestas (60) se procesó para tener una aproximación más sólida de cómo el público percibe, conoce y usa esta planta exótica e invasiva. Incluso si el tamaño de la muestra no es totalmente representativo, las respuestas pueden proporcionar una indicación útil de las características buscadas en esta investigación. Los cuestionarios a menudo solo se componen de preguntas cerradas que obligan al entrevistador a preguntar estrictamente los elementos de la encuesta. Esto pone de relieve una debilidad en los cuestionarios, que es la imposibilidad de obtener respuestas significativas que provienen de la experiencia personal (Newing et al., 2010). Por lo tanto, para evitar la pérdida de valiosos testimonios, se realizaron entrevistas informales para proporcionar información complementaria sobre las especies invasoras en Galápagos y *L. leucocephala.*

3. ÁREA DE ESTUDIO

3.1 <u>Mapa de la Ubicación</u>

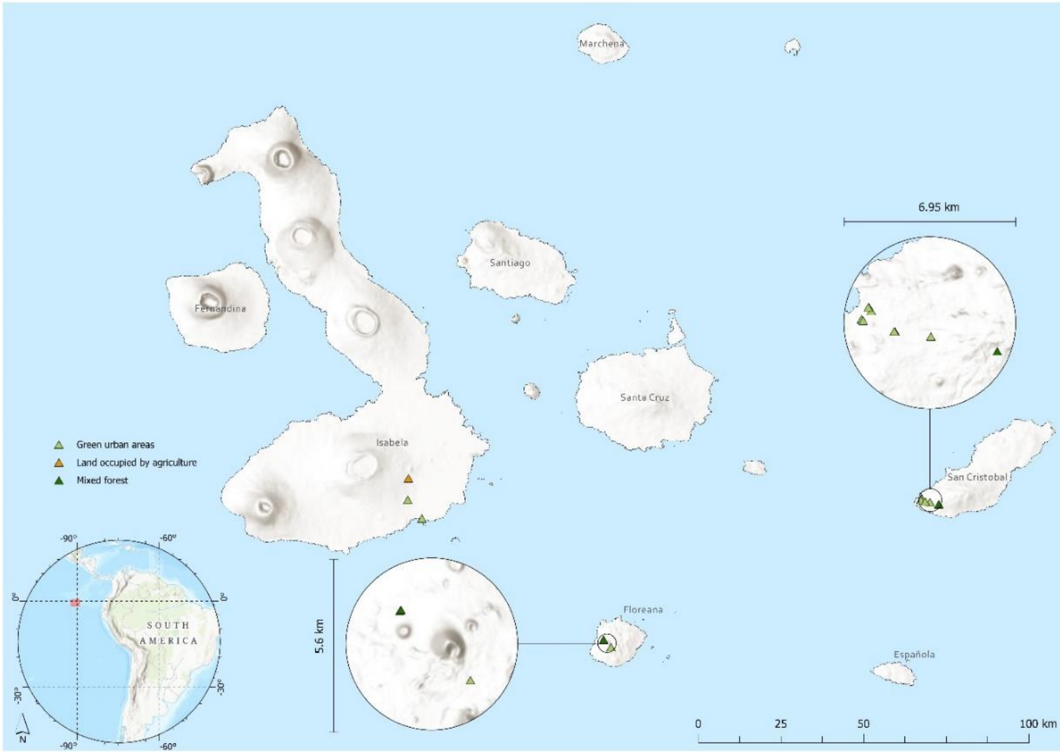

Figura 3. Mapa de las islas Galápagos. Las islas donde se realizó la recolección de datos (San Cristóbal, Floreana e Isabela) tienen figuras triangulares que representan los puntos de muestreo. Los triángulos de color verde claro representan los sitios donde se muestreó la cobertura de áreas verdes urbanas. Los triángulos naranjas representan sitios que pertenecen a la cobertura agrícola. Los triángulos de color verde oscuro representan sitios de muestreo en la cobertura de bosque mixto.

3.2 Contexto geográfico, biofísico y socio-económico

El archipiélago de las islas Galápagos está bajo jurisdicción ecuatoriana y se encuentra aproximadamente a 1000 km de la costa sudamericana (Guézou, Pozo y Buddenhagen, 2007). Está compuesta por 123 islas de origen volcánico (Guezoú et al., 2010). Este es uno de los sistemas más protegidos y preservados del mundo (Peck et al., 1998) hasta el punto de que el Parque Nacional Galápagos, establecido en 1959, posee el 97% del área terrestre en las islas (8000km^2) (Gardener, Atkinson y Rentería, 2010; Guézou et al., 2007). El 3% restante del área es urbana y agrícola (Gardener et al., 2010). Los ecosistemas y la biota única en las Galápagos se desarrollaron en completo aislamiento durante aproximadamente 3.5 millones de años (Peck et al., 1998). La flora nativa de las Galápagos está compuesta por aproximadamente 553 especies, de las cuales el 32% son endémicas, incluidos siete géneros endémicos de plantas (Mauchamp, 1997; Guezou et al., 2007). De acuerdo con Gardener et al. (2010) hay aproximadamente 888 especies de plantas exóticas, de las cuales 31 son invasoras, 267 naturalizadas y 590 y no naturalizadas. Estas plantas representan el 59% del total de especies introducidas en Galápagos registradas hasta ahora (Gardener et al., 2010). El archipiélago se caracteriza por una estación lluviosa entre enero y mayo, y una estación seca de mayo a diciembre. La temperatura oscila entre 22ºC y 29ºC (Peck y Kukalová-Peck, 1990). La altitud más alta en las islas es de 1700 msnm (Guezoú et al., 2010), correspondiente a la isla Fernandina, que es un volcán.

Comercio, servicios y manufactura son las tres principales fuentes económicas de las islas Galápagos. Estos se dividen en servicios que se le provee a la población local y aquellos destinados al turismo. Entre estas la pesca es una de las principales fuentes de ingreso. También existe una industria de fabricación de productos metálicos para construcción de infraestructura. El archipiélago cuenta con una población aproximada de 20,000 habitantes según el censo del 2010 (Gardener et al., 2010; Guézou et al., 2007; Riou-Green, 2015; Trueman, 2014).

4. CONCLUSIONES Y RECOMENDACIONES

Se encontró una nueva especie de escarabajo perteneciente al género *Acanthoscelides* y tres nuevos registros de avispas parasitoides para Ecuador y Galápagos: *Eupelmus cushmani*, *Pteromalus* MF1 y *Pteromalus* MF2. En San Cristóbal el muestreo fue representativo y resultó ser la isla más diversa en términos taxonómicos y de interacciones. Se deben realizar más muestreos en términos de espacio y tiempo en Floreana e Isabela para que la comunidad de artrópodos asociados a *L. leucocephala* sea representativa. San Cristóbal y Floreana son más similares en su composición de artrópodos en comparación con Isabela. Se evidenció una alta dominancia de pocas especies de artrópodos partiendo de los resultados de abundancia, diversidad alfa y superposición de nicho. Según las encuestas y las entrevistas no-estructuradas la percepción, uso y conocimiento con respecto a *L. leucocephala* varió más que en las otras dos islas. Adicionalmente, el servicio que las plantas proveen parece tener un mayor impacto sobre la percepción de los encuestados que el origen de éstas. Cabe resaltar que aspectos como la percepción, uso y conocimiento tienen una influencia sensorial, histórica y contextual que deben ser analizados en mayor para profundidad y contar con una muestra poblacional representativa para realmente determinar éstas. Se recomienda realizar encuestas con una muestra poblacional representativa para obtener una visión más detallada sobre las especies exóticas. Teniendo en cuenta que los humanos estamos presentes en los ecosistemas globales, se vuelve vital la integración de estudios sociales y ecológicos para una mayor comprensión del mundo natural y las relaciones sociedad-naturaleza en cuestión (Grimm et al., 2000). No debemos sesgarnos a realizar estudios únicamente teniendo en cuenta las entidades naturales e ignorar los procesos y expresiones de la vegetación producto de las actividades humanas (Tansley, 1935). Para entender las influencias humanas sobre los ecosistemas es importante acercarse desde las ciencias sociales principalmente debido a que las acciones y percepciones sociales normalmente son el fenómeno que fomentan las decisiones políticas, económicas o culturales que impulsan o responden a un cambio en los sistemas ecológicos (Grimm et al., 2000). Partiendo desde la ecología urbana (Tanner et al., 2014) los habitantes en conjunto con los investigadores pueden ser mucho más efectivos en la divulgación de información científica al público. Teniendo en cuenta lo anterior, incluir la herramienta social en el análisis de redes ecológicas permite una aproximación biológica y social al conocimiento y uso de *L. leucocephala* y la circulación adecuada de información que concierne especies exóticas en las islas Galápagos.

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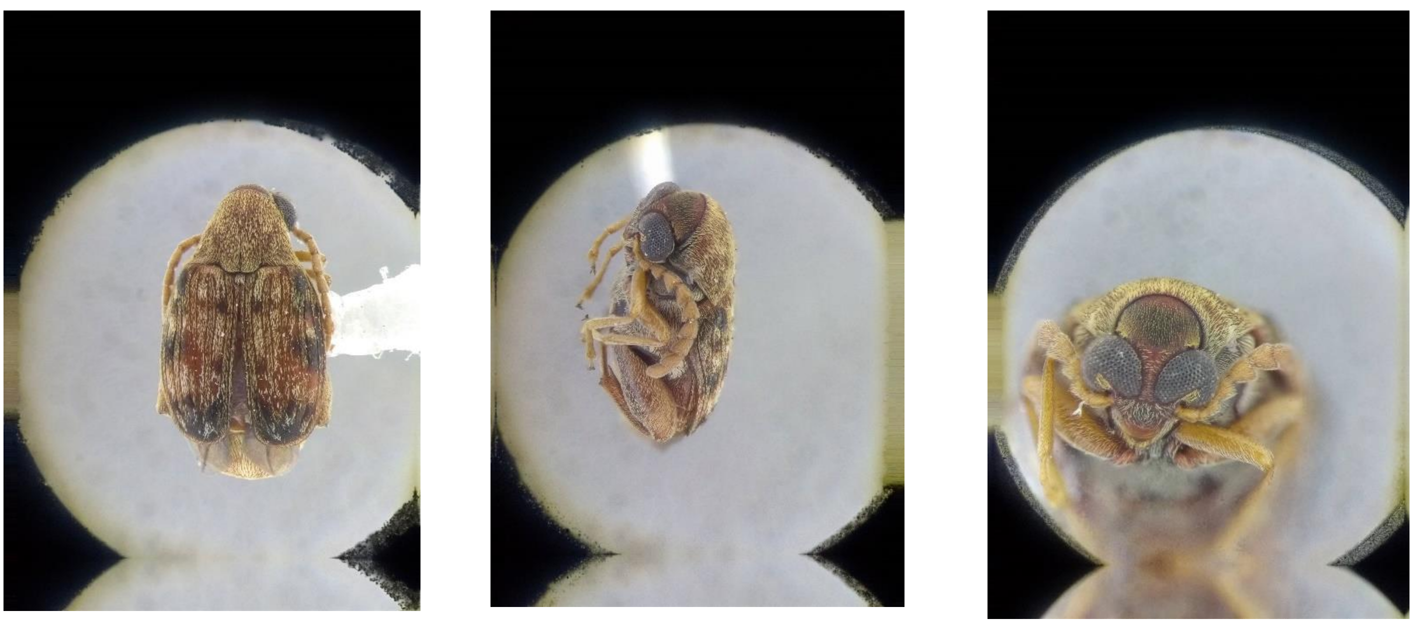
6. ANEXOS

Material Fotográfico de Soporte

***Leucaena leucocephala* (Lam.) de Wit**



***Acanthoscelides* nov sp.**

Ecuador, Galápagos, Floreana