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**Colegio de Ciencias Biológicas y Ambientales**

**Effect of land-use change on the community assemblage of  
the landbirds of San Cristobal, Galapagos**

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**Daniel Antonio Velarde Garcez**

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**HOJA DE CALIFICACIÓN  
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**EFFECT OF LAND-USE CHANGE ON THE COMMUNITY  
ASSEMBLAGE OF THE LANDBIRDS OF SAN CRISTOBAL,  
GALAPAGOS**

**Daniel Antonio Velarde Garcez**

Calificación:

Nombre del profesor, Título académico

Diego F. Cisneros-Heredia, Ph.D. (c)

Firma del profesor

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Quito, 29 de mayo de 2018

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Firma del estudiante:

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Nombres y apellidos:

Daniel Antonio Velarde Garcez

Código:

00126292

Cédula de Identidad:

0931025332

Lugar y fecha:

Quito, 29 de mayo de 2018

## RESUMEN

El cambio de hábitat afecta la diversidad de las comunidades de aves, permitiendo la expansión y dominancia de algunos gremios y especies y la disminución o extinción de otros. El objetivo general de la investigación fue entender los cambios en las comunidades de aves por el cambio antropogénico de vegetación en islas del Océano Pacífico, y como diferentes especies son afectadas distinto. Este trabajo de titulación está formado por dos estudios: (1) una revisión sistemática de la literatura sobre el efecto del cambio de hábitat antropogénico en las aves terrestres de las islas del Océano Pacífico; y (2) un estudio observacional del efecto del cambio de uso de suelo en la estructura de la comunidad de aves terrestres de San Cristóbal, Galápagos. La revisión sistemática de la literatura siguió los lineamientos de la declaración PRISMA, y la formulación de la pregunta de investigación siguió la estrategia PICOS (población, intervenciones, comparaciones, resultados, diseño de estudio). La búsqueda de estudios relevantes se hizo en la base de datos Scopus®. La selección, evaluación y extracción de datos se realizaron siguiendo protocolos estándares. Se identificaron en primera instancia 2661 publicaciones potenciales, de las cuales se analizaron 76 estudios que cumplieron con los criterios de inclusión. La mayoría de los estudios fueron observacionales (80%), llevados a cabo en Polinesia (53%) y sobre los efectos de la agricultura (57%). La variable más estudiada en las aves fue abundancia (43%), y se encontraron principalmente resultados mixtos o negativos en esta variable. El estudio observacional se realizó a través de muestreos con transectos y redes de neblina en hábitats en la parte baja (bosque deciduo y áreas verdes urbanas y suburbanas) y alta (bosque siempreverde estacional y áreas agrícolas) de la Isla San Cristóbal. Las comunidades en la parte alta mostraron una gran diferencia en términos de estructura de la comunidad, mas no en abundancia. En la parte alta las especies endémicas de insectívoros se encontraban más restringidas al bosque primario, mientras que los granívoros endémicos y las especies eran extremadamente dominantes en las áreas agrícolas. Ambos estudios tienen implicaciones para las estrategias de conservación y la formulación de políticas ambientales en áreas disturbadas por humanos en islas del Océano Pacífico.

**Palabras clave:** aves terrestres, cambio de uso de suelo, cambio de hábitat, estructura de comunidad, Galápagos, aves, agricultura, urbanización

## ABSTRACT

Habitat change affects diversity of bird communities, allowing the expansion and dominance of some guilds and species, and the decline or even local extinction of others. The general objective of this investigation is understanding the changes on the landbird communities of Pacific Ocean islands due to anthropogenic vegetation alteration, and how different species are affected distinctly. This work consists of two studies: (1) a systematic literature review of the effect of the anthropogenic habitat change on the landbirds of the Pacific Ocean islands; (2) observational study of the effect of the land use change on the community assemblage of the landbirds of San Cristobal, Galápagos. The systematic literature review followed the PRISMA statement, and the study question the PICOS framework (population, intervention, comparison, outcome, study type). The search of relevant studies was performed on the database Scopus®. Selection, evaluation and extraction of data was made through standard protocols. In first instance, 2661 potential publications were identified, of which 76 studies met the inclusion criteria and were analyzed. Most of studies were observational (80%), carried out in Polynesia (53%) and analyzed the effects of agriculture (57%). Most studied variable in birds was abundance (43%), and it was principally reported mixed and negatives results. The observational study comprised of transect and mist nets sampling on different habitats on the lowlands (old-growth lowland deciduous forests and suburban and urban green areas) and on the highlands of the island (old-growth seasonal evergreen forest and agricultural areas). Communities on the highlands showed a greater difference in terms of community assemblage, but not pronounced differences in terms of abundance. On the highlands, insectivorous endemic species were mostly restricted to the old-growth forests, while granivorous endemic species were extremely dominant on agricultural areas, as well as introduced species. Both studies have implications for conservation strategies and policy-making on human-disturbed areas of Pacific Ocean islands.

**Keywords:** landbirds, land-use change, habitat change, community assemblage, Galapagos, birds, agriculture, urbanization

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## EFFECT OF ANTHROPOGENIC HABITAT CHANGES IN THE LANDBIRDS OF THE PACIFIC ISLANDS: A SYSTEMATIC LITERATURE REVIEW

Daniel Velarde<sup>1</sup> & Diego F. Cisneros-Heredia<sup>1,2,3</sup>

<sup>1</sup> Universidad San Francisco de Quito USFQ, Colegio de Ciencias Biológicas & Ambientales, Laboratorio de Zoología Terrestre, Quito 170901, Ecuador

<sup>2</sup> King's College London, Department of Geography, London, UK

<sup>3</sup> Aves&Conservación / BirdLife Ecuador, Quito, Ecuador

### ABSTRACT

Increasing anthropogenic habitat change affects vegetation diversity and structure, which negatively impacts habitat quality and availability for some species of birds. Oceanic islands excel among geographic areas due to their endemism due to their isolation. The objective of this investigation is understanding the effects, study patterns and gaps of knowledge of human-induced habitat change on land birds of Pacific Ocean islands. We performed a systematic literature review in the database SCOPUS to find all the literature of the effect of anthropogenic habitat change on birds of islands of the Pacific Ocean. The review followed the PRISMA statement, and the study question the PICOS framework (population, intervention, comparison, outcome, study type). We used 9 inclusion criteria to discriminate the articles. 2661 potential publications were identified, of which 76 articles accomplished all the criteria and were used for the review. Most of the articles were observational (80%), performed on the Polynesia (53%) and analyzing the effect of agriculture (57%). Most studied variables were bird abundance (43%), habitat use (23%) and richness (27%). Most of the publications reported a negative or mixed result of the variable studied in the birds. The most common pattern found was that exotic species were less affected and even benefit, while native species were negatively impacted more frequently. Behavioural and physiological studies were scarce. The systematic literature review presents important information for the management of highly disturbed Pacific Ocean islands, and the conservation of birds in these.

### INTRODUCTION

Sustained human population growth has severe impacts on the expansion and intensification of urbanization, agricultural landscapes and logging (Laurance *et al.*, 2014). Human population may cause severe land-cover changes through direct and indirect disturbances, like introduction of feral or invasive species (Banko *et al.*, 2013; Warren *et al.*, 2015; Behne *et al.*, 2015; Chi *et al.*, 2017). There is significant and substantial evidence emphasizing the role of land-use change on the decline and extinction of biodiversity (Jetz *et al.*, 2007; Thibault & Cibois, 2012).

Human-induced changes and destruction of the vegetal diversity and structure may diminish available habitat for animals that rely on native ecosystems. Dependence of natural habitats may occur for several reasons, such as the amount and composition of food (Vickery *et al.*, 2001), presence of plants needed for shelter and nesting (Ha *et al.*, 2011) or local climate, like temperature, relative humidity and light intensity (Afrane *et al.*, 2005; Rajpar & Zakaria, 2011). While some animals are highly dependent on native ecosystems, other species are benefited by novel ecosystems produced by anthropogenic impacts. Fragmentation of native forests may also have strong effects on resource availability and mobility (Potter, 1990; Shirley, 2004).

Birds are one of the best-known groups among similar-sized taxa. Extensive amount of information of birds is critical for the overall biodiversity conservation (Pimm, 2001). The great richness and fast adaptation of birds allow them to be used as an “indicator” group in which estimations of their population trends provides valuable data about the human impacts on other groups (Tanalgo *et al.*, 2015; ZoBell & Furnas, 2017). Historically, many studies have reported a relationship between anthropogenic habitat change and several effects on birds. Many of the effect reported are on abundance, richness, habitat use, behaviour, parasitic load or extinction. Effects are distinct according to the species, and apparently are niche-dependent or geographic-origin-dependent, rather than taxonomically-dependent. If the current land-use conversion rate continues at least 400 of the 8 750 land bird species are projected to suffer range reductions higher than 50% by the year 2050 (Jetz, 2007).

Oceanic islands have some of the highest levels on biogeographic endemism among terrestrial areas of the world due to their extreme isolation (Kier *et al.*, 2009). Remote islands of the Pacific Ocean in Polynesia and Micronesia have the highest rates of bird endemism per biogeographic region in the world (68,5% of the known birds are endemi; Brooks *et al.* 2002). Unfortunately, highly endemic species are also more vulnerable to anthropogenic disturbances, and bird species in Pacific Ocean islands are more threatened by extinction (Stattersfield, 1988). Over 90% of bird extinctions occurring over the last 400 years have taken place on oceanic islands (Stattersfield, 1988). For example, 14 of the 44 forest passerines of the Hawaiian Islands are extinct and 20 are listed as endangered (Banko and Banko, 2009).

The work was performed narratively, and not as a meta-analysis, since it was not deemed feasible due to heterogeneity of the data (Rodgers *et al.*, 2009) Effects of anthropogenic habitat changes on birds are highly variable and depend on the species, habitat or geographic region. It is important to compile and evaluate all evidence-based science of the effects on birds by anthropogenic habitat change. This information will help to promote more efficient research and conservation decisions and activities. A systematic literature review of the studies grant interesting information of general trends and reveal gaps of knowledge in this topic. Results in a specific geographic region, like the Pacific Ocean islands, could give a general idea of the effects of human-induced changes on birds on other regions of the world. The current systematic literature review is focussed on the following questions:

1. What are the effects of human-induced habitat change on land birds?
2. What are the study patterns of the effects of human-induced habitat change on land birds?
3. What are the study gaps on the actual knowledge of the effects of human-induced habitat change on land birds?

## METHODS

### *Study question and search strategy*

Even though there are many ways of reporting habitat change, we chose to limit reporting academic literature (peer-reviewed). It was used the PICOS framework (population, intervention, comparison, outcome, study type) to define the study question (Higgins and Green, 2011; see **Table 1**). Searches were conducted on the database native search engine Scopus® developed by Elsevier. Scopus is the largest abstract and citation database of peer-reviewed literature, covering nearly 36 377 titles in all subject fields. Scopus covers mainly primary literatures from the following source types: serial publications with International Standard Serial Number ISSN and non-serial

publications with International Standard Book Number ISBN (Burnham, 2006; Elsevier, 2017).

We searched the database Scopus to identify the original and peer-reviewed studies published in English, Spanish or Portuguese that explicitly address the effect of human-induced habitat change on terrestrial birds in any island of the Pacific Ocean. Search was not limited by date since this topic does not depend on modern technologies or knowledge. Primary search code consisted of a combination of the search terms for population, intervention and geographic range. Combination of words used for population included all synonyms of “bird”; and every scientific and common name of every family of terrestrial birds in the world. All seabirds and aquatic families were excluded. Intervention search code contained every synonyms and causes of habitat change (e.g. Logging, Reforestation, Plantation). Geographic range search code consisted of every synonym of “island”. The complete code used for the search protocol can be found on the **Appendix II**. The search was performed and downloaded in January 17, 2018.

#### *Definition of concepts*

For this review the concept *anthropogenic habitat change* comprehends all the change of vegetation generated by any direct or indirect human action. The term *terrestrial birds* covers every bird that use terrestrial ecosystems as their main feeding and distribution range. This definition includes raptors, most passerines, and many other groups (e.g. Parrots, Hummingbirds, Doves). The family Rallidae was included, but in the case of finding a study with a species highly associated to aquatic habitats, and not to terrestrial forest, the study was removed. In the term “anthropogenic habitat change” we included any type of change, direct or indirect, in the vegetation after any anthropogenic disturbance. For the delimitation of the geographic range we used the definition of Pacific Ocean of the International Hydrographic Organization (IHO, 2002). Any land area without contact with the continents and within the area reported by the IHO as Pacific Ocean was considered as a Pacific Ocean island.

#### *Inclusion process*

For the inclusion process it was followed the PRISMA statement (Moher *et al.*, 2009). The first phase of the inclusion process comprised of a specific search of the mentioning of the inclusion criteria on the abstract of all the citations. Inclusion criteria used are specified on **Table 2**. The third phase of the inclusion process comprised of a screening of the complete publication. Third phase analyzed that the publication was original information; and that it presented evidence of habitat change and at least one measurement of the effect of habitat change in the birds. Only articles that satisfied the 12 inclusion criteria specified on **Table 2** and the third phase of inclusion were selected for the review.

#### *Data extraction*

For the data extraction, the whole publication was read. It was not possible to design categories for every variable since some had a wide possibility of results. These variables were filled with numerical or textual results. The variables extracted from each article were the followings: (1) Authors; (2) Year of Publication; (3) Region of the Pacific Ocean; (4) Archipelago; (5) Island; (6) Size of Island; (7) Level of Study Group; (8) Type of Study; (9) Disturbance; (10) Subcategory of Disturbance; (11) Habitat Change; (12) Effect Measured; (13) Sampling Methods; (14) Result; (15) Years of

Study; (16) Period of Study; (18) Sampling Effort. A description of each variable is contained on the **Table 3**.

## RESULTS

### Overview

The search identified 2661 citation. After screening of title and abstracts, 152 citations were selected and 2509 were discarded as did not meet inclusion criteria. After assessing eligibility by full-text review, 86 citations were identified for data extraction. During data extraction, 9 additional citations were excluded. In total, 76 citations were included (**Figure 1**).

### Study characteristics

Most of studies were performed in Polynesia (40 citations; 53%), significantly larger than the next region, the Coastal Waters of South Alaska and British Columbia (7; 9%). Other regions presented only between 2–6 articles (1–8%) (**Figure 2**). Dominance of Polynesia is mostly explained due to the prominence of New Zealand (18; 23%) and Hawaii (7; 9%). The Coastal Waters of South Alaska and British Columbia were mainly represented by studies in Vancouver Island (3; 4%) and Southern Gulf Islands (2; 3%) (**Figure 3**). Other archipelagos appeared in 1–4 articles (1–5%). Most of the studies were carried out on large islands (area < 10 000 km<sup>2</sup>; 23 citations; 30%). Other types of islands were considerably less present in the review (**Figure 4**).

Type of study was dominated by *Observational* studies (61; 80%), followed by *Modelling* (11; 15%), *Birdwatching* (3; 4%) and *Meta-analysis* (1; 1%) studies (**Figure 5**). Two sampling methods (*Direct Identification Points* and *Direct Identification Transects*) were the most used (28 and 25 articles respectively). Other dominant sampling methods were *Focals* (11), *Modelling* (11) and *Tracking* (6). Further sampling methods were used in 1–5 studies (**Figure 6**). A small quantity of studies covered more than 10 years of sampling (13; 17%) (**Figure 7**). Length of the study (as number of months) showed that most studies lasted between 1–6 months (31; 41%). A high proportion of articles (31%) did not specified the length in months of the study (**Figure 8**). Also a large number of studies (67; 88%) fail to report sampling effort or enough information to calculate it (**Figure 9**).

*Agriculture* was the most commonly studied type of disturbance (43 articles) (**Figure 10**). Within agriculture, most studies were focused on *Plantation Agriculture* (24), with other categories including *Intensive Agriculture* (12), *Livestock* (9) *Subsistence Agriculture* (8) or *Mixed Agriculture* (6) (**Figure 11**). Six of the articles that study *Agriculture* disturbance did not specify the type of agriculture or mentioned enough information to categorize it. Most of the studies lacked proper explanation of the exact type of disturbance which they were studying. Exotic species were only researched in 16 studies, and most were focussed on *Exotic Flora* (11) rather *Exotic Fauna* (6) (**Figure 12**). *Infrastructure* was dominated by *Urbanization* (14), with hardly any presence of other categories (two of *Roads* and one of *Coastal Management*) (**Figure 13**). Most studies investigated the dependent variable of abundance (33 out of 76 studies); while other variables included *Habitat Use* (18), *Richness* (13), *Density* (12), *Community Assemblage* (6) and *Extinction* (5). *Prevalence of Parasites* was studied in one article (**Figure 14**). Most of the articles studied *Land Cover Change* (67), while only few studies were focused on the effect of *Fragmentation* (11) (**Figure 15**).

When analyzing the results of the five disturbances with higher frequency (agriculture, open fields, secondary forest, infrastructure and exotic species) it was found that most had a higher occurrence of *Mixed* results, followed with *Decrease*, and hardly any *Neutral* result (**Figure 16-19**). The secondary forest was the only category that had more *Decrease* results than *Mixed* (**Figure 20**). Only *Agriculture* disturbance revealed an increase result, and only in two articles (**Figure 16**; Wu *et al.*, 2006; Kesler *et al.*, 2012). In *Reforestation* and *Regrowth* there were more *Increase* results, followed by *Mixed* and *Neutral*, and no *Decrease*. It is worth mentioning that this last analysis was conducted only with presence-related dependent variables, like *Abundance*, *Density*, *Habitat Use* or *Richness*. When analyzing the results with the variable *Extinction* all the types of result were *Increase*.

The sample size of the studies was highly variable, covering a range from 4 (Kawakami & Higuchi, 2003) to 1463 (Amar *et al.*, 2008) sampling units. The article of Kawakami and Higuchi uses the number of transects used in all the areas as the sample size, while Amar *et al.* report the number of count points across a seven-year study. Other articles that study *Predation* or *Habitat Use* used the focal or the tracking individuals as the sample size, therefore this variable is extremely inconstant, not systematic, and poorly informative.

### **Effects in Abundance, Habitat Use, Density, Richness, Community Assemblage, Reproductive Success, Distribution, Habitat Suitability and Population Viability**

#### *Increase*

Few investigations have shown that agriculture is not always synonymous of species decline. In Rimatara, on the Austral Islands, it was revealed that Kuhl's Lorikeet (*Vinu kuhlii*) was more abundant on the mixed agricultural area than on the hills and the coconut plantations (McCormack & Künzle, 1996). In Sakishima Islands it was found a relationship between the number of Grey-faced Buzzards (*Butastur indicus*) and the landscape elements (Wu *et al.*, 2006). Results showed that area of farmlands and perimeter of forest were correlated with the number of Buzzards (Wu *et al.*, 2006).

A study conducted in 2010 on Niau investigated the habitat use of translocated and home range Tuamotu Kingfisher (*Todiramphus gertrudae*) (Kesler *et al.*, 2012). Translocated birds used the habitats in proportion of their presence, while home range birds used the habitats disproportionately of the availability. Home range individuals used coconut plantation more than it was available, and native feo forest less than it was available (Kesler *et al.*, 2012).

Armstrong and Ewen determined whether the population of New Zealand Robin (*Petroica australis*) of Tiritiri Matanga was likely to persist until additional habitat became available through maturation of the revegetation and whether it was feasible to reintroduce this species early in the program (Armstrong & Ewen, 2002). They found that it was reasonable the early introduction, spite the little habitat available (Armstrong & Ewen, 2002). Another long-term reforestation study was executed in Tiritiri Manga, New Zealand, from 1987 to 2010. It was recorded an increase in avian abundance and biodiversity in most of the native species, while exotic species and forest passerines declined. They found a faster increase of the bird abundance in reforestation areas than in regrowth areas (Graham, 2013). In a study on Babelthuap, in Palau, it was found that frequency and diversity of bird visitors increase while the regrowing area presents taller and more species of trees and more diverse and abundant food resources (Dendy *et al.*, 2015).

### Mixed

A large amount of literature support that some species are disadvantaged by the human-induced disturbances in the habitat, while others are benefit. A long-term study conducted by Wodzicki *et al.* aimed to understand the effect of the change in an estuary on the bird communities of North Island (Wodzicki *et al.*, 1978). Even though the article does not report a direct relationship between the disturbances and the changes in the composition of the estuary they attributed them to coastal management, urbanization and exotic plant species (Wodzicki *et al.*, 1978). The article reports an increase in five species across time, a decrease in four, and no change in seven (Wodzicki *et al.*, 1978). In a birdwatching study conducted between 1985 and 1988 Blaber assessed the status of the avifauna of New Georgia (Blaber, 1990). He found that seven species occurred only in primary forest and not secondary growth or cleared areas, and hence are likely to be reduced in numbers by logging (Blaber, 1990). Twenty-two species were found in both undisturbed and secondary forest and may be less affected by logging but their degree of dependence on primary forest for breeding is not clear (Blaber, 1990). In the Ha'apai Group, in Tonga, it was found that habitat association of the species vary between those preferring disturbed sites, generalists, and those that increase their abundance in less disturbed forests (Steadman *et al.* 1999). A similar result was found on Tutuila, Samoa Americana, where they found species dependent of native habitat, like Purple-capped fruit-dove (*Ptilinopus porphyraceus*); species that occurred in all habitats, like the Samoan Starling (*Aplonis atrifusca*); and species more abundant in non-native habitats, like Cardinal Honeyeater (*Myzomela cardinalis*) (Freifeld, 1999). A study in the young and old growth in Prince Wales Island found that three species were more common and one was almost exclusive in old-growth forest, while four were more common on young-growth forest (Dellasala *et al.*, 1996). In Bonin Island a similar result was found, where Japanese White-eye (*Zosterops japonicas*) preferred primary forests, while the Bonin White-eye (*Apalopteron familiar*) preferred open fields, but they greatly overlapped in secondary forests (Kawakami & Higuchi, 2003). In Tinian, where only 5% of the island conserved its native forest in 2012, five of the nine native species and one exotic species have increased, while three native species had decreased since 1982 and the spare two remain stable (Camp, 2012).

Some articles propose that endemic species are the most damaged species by human-induced habitat change, while exotic species are advantaged. After sampling habitat selection on the years 1994, 2001 and 2009 on Robinson Crusoe Island it was concluded that endemic birds selected the native forest, whereas the Austral Thrushes (*Thurdus falcklandii*) and the Green-backed Firecrowns (*Sephanoides sephaniodes*) preferred the anthropogenic disturbed areas, like plantations or exotic vegetation (Hahn, 2011). Similar results were found on South Island, where it was studied the effect of patch area and distance to edge in a fragmented forest on native and non-native bird assemblage (Barbaro, 2012). They discovered that native species were more abundant in forest interiors, while exotic species were more abundant at forest edges (Barbaro, 2012). Davies *et al.* supported this hypothesis with his study on Makira, on the Solomon Islands, where they found that overall species richness did not change much between the sites, but endemic-species richness decreased at habitats with more land-uses (Davies *et al.*, 2015). ZoBell and Furnas found in Mo'orea, in the Society Islands, that three non-native species preferred agricultural areas over the forest habitat (ZoBell & Furnas, 2017). Additionally, the calling activity of native birds was inversely proportional to the calling activity of non-native birds (ZoBell & Furnas, 2017). A study in the Fijian island of Viti Levu conducted between 1970 and 1973 concluded that the species that

depended on the rainforest were mainly endemic species or subspecies (Gorman, 1975). Researchers in South Island examined how the succession from grasslands to shrublands affected the abundance of native and exotic terrestrial birds (Wilson *et al.*, 2014). One exotic granivorous-insectivorous decrease his density as the woody-species increased and two non-native birds were more abundant in intermediate woodiness (Wilson *et al.*, 2014). A study on the Socorro island found that, generally, the abundance for all endemic species was higher where feral sheep were absent (Rodriguez-Estrella *et al.*, 1996). In a revegetation study in Tiritiri Matanga it was found that most of native species increased in abundance, while exotic species declined.

When it is analyzed the disturbance effects in the population of birds by natural history of the species it seems that the different niches are affected in distinct proportions, or even benefit. A study of Dvorak *et al.* on Santa Cruz, Galápagos, supports this statement (2012). They found that six of the nine species investigated had declined significantly, and with this decline being more abrupt in the highland, in humid native forest and agricultural area (Dvorak *et al.*, 2012). Five of the six declining species were insectivorous, which could suggest that the habitat loss is causing a decrease in insect availability or abundance (Dvorak *et al.*, 2012). The study of Davies *et al.* on Makira, on the Solomon Islands have similar results (2015). They found a proportional increase in nectarivorous and a decrease in insectivorous in the cocoa plantation. They also observed an increase in the abundance of frugivorous in garden habitats (Davies *et al.*, 2015). A study conducted in the island of Chiloe determined how structural changes in forest, resulting from fire use and logging, affect the species abundance of forest birds in the island of Chiloe (Díaz *et al.*, 2005). The study concluded that Large-tree users and understory birds were most abundant in old-growth stands, vertical-profile generalists were common in both old-growth and mid-successional stands, and shrub-users were only common in early-successional stands (Díaz *et al.*, 2005).

Many studies support that some species can advantaged by some type of human disturbances but disadvantaged by others. In a study of the mating preference of the Desmur's Wiretail (*Sylviorthorhynchus demursii*) on different habitat types on the island of Chiloe it was found that they preferred mating in three habitats: native bamboo, gaps of old-growth forest, early successional forests and dense shrublands adjacent to forest fragments (Díaz *et al.*, 2006). It was found in the Southern Gulf Islands that Brown-headed Cowbird (*Molothrus ater*) were three times more likely to occur within 5 km of the nearest urban area than further away (Jewell *et al.*, 2007; Jewell and Acrese, 2008). Cowbirds preferred edge habitats and were present in areas with more cattle and suburban area, but less agriculture and forest (Jewell *et al.*, 2007; Jewell and Acrese, 2008). The model performed for the study also showed that the potential habitat of the cowbird can also be affecting whether host populations grow or decline, since the cowbird is a brood parasite (Jewell and Acrese, 2008). A study conducted in Atiu Island over the years 1989, 1992, 1999, 2001 and 2009 found that Swiflets (*Aerodramus sawtelli*) preferred wetland habitats and subsistence agriculture than plantation agriculture (Fullard, 2010).

On South Island, it was found that South Island Robin (*Petroica australis*), did not presented significant variation in the abundance between Douglas fir plantations and Kanuka-manuka forests, and showed no presence in pine plantation (Borkin *et al.*, 2007). This study concluded that the feeding parameters did not explained the distribution of the species (Borkin *et al.*, 2007). In 2000 and 2001 Walsh *et al.* tracked 18 Kakapos (*Strigops habroptilus*) on Maud Island to estimate their range size and

habitat selection across a modified landscape (Walsh *et al.*, 2006). They found that Kakapos preferred or avoided different habitats according of the season (Walsh *et al.*, 2006). From 2012 to 2014 New Zealand Falcons (*Falco novaeseelandiae ferox*) were tracked on North Island (Horikoshi *et al.*, 2017). It was found that logged areas were the primary hunting habitat, while young pine plantations and the ecotone between young and mature pine plantations were the most occupied despite its low availability (Horikoshi *et al.*, 2017).

Brunton and Stamp concluded that densities of Saddleback (*Philesturnus carunculatus*) on North Island varied more in replanted forest, while in mature forest the density changed less (Brunton & Stamp, 2007). A study published by Forbes and Graig that investigated the revegetation process on Tiririri Matangi and its relationship with the terrestrial birds found a decline in the abundance and richness of the landbirds in revegetated areas highly dominated by the native tree Pohutukawa (*Metrosideros excels*) (Forbes & Craig, 2013).

A study of the reforestation process and the patterns of bird density and distribution in Hawai'i concluded that two generalist species presented the fastest colonization and reached the higher densities; while insectivores showed an intermediate colonization and density; and nectarivorous and frugivorous a slower colonization and lower densities (Paxton *et al.*, 2017). Also, open woodland species were found in the reforestation area for the first years, but when the canopy started closing the species began to decrease (Paxton *et al.*, 2017).

Two studies in Vancouver Island found that several forest interior species were almost exclusive to wider riparian forest fragments, and open-edge species decline dramatically in narrow fragments (Shirley, 2004; Shirley & Smith, 2005). Also, species richness increased with regeneration in the three years of study, while remaining constant in controls (Shirley & Smith, 2005). Besides, species composition in wider fragments were very similar to the control, while narrow fragments differ in half of the species (Shirley, 2004). A study conducted in South Island tested the hypothesis that abundance of native forest birds increases with area of plantation agriculture surrounding remnants of forest, unlike patches surrounded with farm area (Deconchat *et al.*, 2009). Abundance of all species, except one, decreased in relation with area of farm surrounding the sampling points (Deconchat *et al.*, 2009). Abundance increased when increasing the area of native forest surrounding the points (Deconchat *et al.*, 2009).

In a modelling study in the island of Chiloe it was found a significant decrease in abundance for most of the species when fragmentation and forest loss increase, except for species that combine a high dispersal capability and enough plasticity to use the intervening matrix (Magrach *et al.*, 2011). It was found that predation by Black Rats (*Rattus rattus*) in Savai'i; Upolu, in Samoa, was 22% higher in the forest edge near mixed agriculture, than in the edges without plantations (Stirnemann *et al.*, 2015). They did not found any difference in predation between forest edge near mixed agriculture and in the forest interior (Stirnemann *et al.*, 2015). In a study conducted on Minamidaito 94% of the cavity nests of Daito Scops Owl (*Otus elegans interpositus*) were in exotic casuarina trees, and only a few in native palm (Akatani *et al.*, 2011). During the breeding season most used native ficus forests, whereas during nonbreeding season most owls selected edges between open areas and forests (Akatani *et al.*, 2011).

### *Decline*

Most of the literature supports that human-induced disturbance has a negative effect on the number of individuals. A dispersal study of North Brown Kiwi (*Apteryx*



*australis mantelli*, now *A. mantelli*) at North Island in 1981–1982 revealed that individuals stayed in open fields created by logging of pine stands for up to seven weeks, and gradually moved to swamp margins and nearby pine stands (Colbourne, 1983). In a survey of the distribution and abundance of the Mangaia Kingfisher (*Halcyon tuta ruficollaris*) Rowe and Empson found that coastal barringtonia and indigenous forest supported significantly more abundance than secondary forest (Rowe & Empson, 1996). A study on 13 islands of the Ha'apai Group, in Tonga, found that three species were absent or extremely rare on all islands, except on Tofue (Steadman, 1998; Steadman *et al.*, 1999). Overall richness and abundance was higher on this island and may be due to the significant higher area of primary forest (Steadman, 1998; Steadman *et al.*, 1999). Other studies in the same island group found that the overall species richness and relative abundance was higher in native forests than in disturbed habitats (Steadman & Freifeld, 1998; Steadman *et al.*, 1999). A similar study conducted in 1999 on Samoa found that more cultivated and populated island had half the species of the less disturbed island (Freifeld *et al.*, 2001). An investigation of the South Island Takahe (*Porphyrio hochstetteri*) in Tiritiri Matanga Island found that the Takahe used preferentially habitats with abundant grasses and shrubs but avoided anthropogenic open grasslands due to the predation risk by Australasian harriers (Baber & Craig, 2003).

A study carried out in Vancouver Island found that patches with nest were in oldest successional stages, in mature and old forest stages, and in moderately disturbed areas (Hartwig *et al.*, 2004). A study carried out in Chiloe in 1997 and 1998 on Desmur's Wiretail (*Sylviorthorhynchus demursii*) determined that mated individuals occupied 72% of the small territories with high connectivity, 73% of the large fragments, and only 20% in small isolated fragments. There was no significant difference in mating between fragment size (Díaz *et al.*, 2006). In a study for three species in the Fijian island of Viti Levu it was found that the highest densities occurred in the low-to-mid-altitude old-growth forests, while the densities found in the re-growth forest and mahogany plantations were 30% and 50% lower, respectively (Jackson y Jit, 2007). Sugimura *et al.* performed a meta-analysis that covered over 24 years to explain the changes in population size of 20 species of birds (Sugimura *et al.*, 2014). They found that five of these species increased their abundance while logging decrease and when logging started augmenting their abundance began to reduce (Sugimura *et al.*, 2014). A birdwatching study in Wallis and Futuna in 2008, 2011 and 2014 reports the decline of the Lesser Shirkbill (*Clytorhynchus vitiensis*) through the time, probably due to habitat loss (Thibault *et al.*, 2015). Between 1980 and 2000 a study on Taiwan found that bird species richness decreased with road density and percentage of built area (Lee *et al.*, 2004). Dendy *et al.* found on Palau that frequency and diversity of visiting birds increase as patches become more like continuous forest (Dendy *et al.*, 2015)

Between 1999 and 2000 Díaz *et al.* determined how structural changes in forest, resulting from fire use and logging, affect the species richness and abundance of forest birds in the island of Chiloe (Díaz *et al.*, 2005). They recorded 21 bird species in the old-growth forest, 14 in mid-successional and 16 in early-successional forests elements (Díaz *et al.*, 2005). Between 1997-1999 Ha *et al.* conducted a study that found that actual nest sites of the Mariana Crow (*Corvus kubaryi*) presented a higher percentage of canopy cover and were more than 300 m away from buildings, while random points were in average 226,7 m away (Ha *et al.*, 2011). Another study in Amami Ōshima concluded that the Amami Thrush (*Zoothera dauma major*) preferred old growth native forest than younger forests for breeding habitat (Mizuta, 2014; Mizuta *et al.*, 2016).

Also, this species apparently increases its abundance with the regeneration of the forest (Mizuta et al., 2016).

The invasive flora on islands, although it is an indirect human disturbance, has demonstrate to disadvantage significantly the landbird populations. In the island of Hawai'i, the 'amakihi (*Chlorodrepanis virens*) has shown to occurred more on native trees (76%) than in exotic trees and shrubs (23%), even though it seems the exotic plants play an important role in foraging (Steinberg, 2010). In Kauai, the Akikiki (*Oreomystis bairdi*) and the Akekee (*Loxops caeruleirostris*) presented a negative association with the presence of Himalayan ginger (*Hedychium gardnerianum*), a non-native plant species (Behnke et al., 2015). Moreover, in the area where this plant was more abundant they found a decline of native plant species (Behnke et al., 2015). On the endemic Socorro Mockingbird (*Mimodes Greysoni*) it has been found that they mostly use pristine lowland forest, while been scarce in disturbed forests with exotic plant species (Martinez-Gomez et al., 2001).

There is strong evidence that the introduced animals can change the configuration of the vegetation, and with this affect the landbird populations. In the Socorro Island it has been found that the Socorro Wren (*Troglodytes sissonii*), the Tropical Parula (*Parula pitiayumi*), and the Socorro Towhee (*Pipilo socorroensis*) were less abundant in areas were sheep were observed (Rodriguez-Estrella et al., 1996). An exotic species, the northern mockingbird (*Mimus polyglottos*) was more frequent in more disturbed areas (Rodriguez-Estrella et al., 1996). Donlan et al. sampled in 1986, 1987, 2004 and 2005 the recovery of the Galapagos Rail (*Laterallus spilonotus*) following the removal of invasive mammals (2007). On the island where invasive mammals were never present the abundance remains similar, while Isabela, where invasive mammals are still present, the abundance decrease in some plots (Donlan, 2007). A similar result was found on the San Juan Island, where it was found deer-free islands supported the most diverse and abundance communities of birds (Martin et al., 2011). Only the dark-eyed junco (*Junco hyemalis*) preferred islands with moderate to high densities of deer (Martin et al., 2011). In Hawai'i it was found that the sustained browsing by feral ungulates has degraded the habitat, lowering the carrying capacity (Banko et al., 2013). The critically endangered palilla (*Loxioides bailleui*) declined by 79%, and the endangered insectivorous 'Akiapola'au (*Hemignathus munroi*) was not detected after 1998. The generalist 'amakihi (*Hemignathus virens virens*) was the most abundant species and the only native species that maintain an unfluctuating population (Banko et al., 2013). The generalist Japanese white-eye (*Zosterops japonicas*), one of the most common exotic species, also declined (Banko et al., 2013). Yoon found oak coverage was the best predictor for the abundance of the Dusky Orange-crowned warblers (*Oreothypis celata sordida*) in Santa Catalina Island, which has been seriously converted because of anthropogenic fires (Yoon, 2014).

A study in New Britain Island on the population viability of the endemic bird community in response to oil palm plantation showed that the total number of threatened or near-threatened birds increased from 12 to 21 (Buchanan et al., 2008). In a modelling study on White-eye (*Apalopteron familiar*), on the Bonin Islands, it was predicted that there is no extinction risk with the actual distribution of lands, but if the carrying capacity declines 40% because of the expansion of agriculture it could cause the extinction of the species (Kawakami & Higuchi, 2013). In Miaodao Archipelago, in North China, it was found that agriculture, urbanization and exotic vegetation were the principal factors decreasing the overall habitat suitability (Chi et al., 2017).

Macleod performed a modelling study in South Island, New Zealand, to assess whether the management of the habitats in farms could help controlling two exotic pest-birds species, the House Sparrow (*Passer domesticus*) and the Greenfinch (*Carduelis chloris*) (2011). The boundary habitats were the best predictors of the density of both species in the breeding season, showing a positive correlation with the presence of woody vegetation (MacLeod *et al.*, 2011). The house sparrow was associated with high densities of grain. Nevertheless, habitat composition alone did not explain the temporal and spatial variance in the density (MacLeod *et al.*, 2011).

### *Neutral*

Boulton *et al.* tested whether fragment size and connectivity correlated with nest survival rates of the New Zealand endemic species, the North Island Robin (*Petroica longipes*) (2008). They concluded that there was not a negative influence in the survival rates, potentially because of the already high impact of mammalian predators in this system (Boulton *et al.*, 2008). A long-term study in the island Rota that examined trends in the abundance of eight terrestrial birds between 1982 and 2004 found that six of the seven species declined significantly across the years (Amar, 2008). Only the Micronesian Starling increased in abundance. As the declines occurred in native and open fields the authors believe that habitat change is not the cause (Amar, 2008).

### **Effects in ecology**

Díaz *et al.* assessed the rates of post-dispersal seed consumption in rodents and understory birds in the island of Chiloe in 1995 and 1996 (Díaz *et al.*, 1999). They found that more seeds were removed from forest interiors than from canopy gaps (Díaz *et al.*, 1999). The forest margins had an intermediate rate of removal (Díaz *et al.*, 1999). A study on South Island assessed the effect of patch area and distance to edge in a fragmented forest in the rate of insectivory of the birds (Barbaro, 2012). They found that the rates of insectivory were higher at smaller patches and at forest edges (Barbaro, 2012).

Akatani *et al.* studied the relation between habitat and breeding performance on the small oceanic island of Minami-daito (2011). They found that owls with more edge habitat within their range habitat laid eggs earlier than those with smaller are of edge (Akatani *et al.*, 2011).

In 1985 and 1987 Potter tagged 23 North Island Brown Kiwis (*Apteryx australis mantelli*) to understand their home range and movement (Potter, 1990). All patches isolated by less than 80 m of pastures were traveled by Kiwis (Potter, 1990). The maximum distance traveled by a Kiwi was 200 m (Potter, 1990). However, they traveled up to 1.2 km using patches as stopovers (Potter, 1990). Different results were found on a study of the New Zealand Falcon (*Falco novaeseelandiae*) that documented the natal dispersal in a pine plantation on South Island between 2003 and 2006 (Seaton *et al.*, 2008). They concluded that the high emigration rates and favorable breeding conditions make pine plantations a favored habitat where neighboring falcons could immigrate from populations in decline (Seaton *et al.*, 2008).

A study conducted between 2007 and 2014 in Maui, Hawaii, found that home range size of parrotbills (*Pseudonestor xanthophrys*) and ‘alauahio (*Paroreomyza montana*) were larger at the site where ungulates were removed later (Warren *et al.*, 2015).

### **Effects in Immune Function and Prevalence of Parasites**

Zylberberg *et al.* study the prevalence and recovery trend of avianpox in seven species of Galapagos finches by elevation and land-use (Zylberberg *et al.*, 2013). Additionally, they determined if immune function varied with the same variables (Zylberberg *et al.*, 2013). They found that prevalence and proportion of recovered individuals in urban and undeveloped areas did not change between 2008 and 2009 (Zylberberg *et al.*, 2013). In agricultural areas the prevalence increased 8-fold, while recovered individuals from 11% to 18% (Zylberberg *et al.*, 2013). Variation of immune function appears to be correlated with the increase of prevalence and susceptibility (Zylberberg *et al.*, 2013). These suggests that anthropogenic disturbance may underlie immunological changes that contribute to pathogen emergence (Zylberberg *et al.*, 2013).

### **Effects in Extinction**

Several studies support that early human settlements have contributed to the extinction of the island birds. A paleontological study in Mangai, in the Cook Islands, analyzed the erosion, vegetation, burning and terrestrial biota in pre-human and post-human times to understand the human-induced effects (Kirch, 1996). Their results indicate than from the 17 species found on the site, 13 are now extinct (Kirch, 1996). Burney *et al.* provided evidence that before human settlements the lowland of Kaua'i presented birds that now are extinct or only present in cooler and wetter habitats (Burney *et al.*, 2001). James and Price studied in Maui, Kaua'I and O'ahu the potential geographical range of Koa-finches at the time human arrived (James and Price, 2008). They concluded that at least two island extinctions happened due to prehistory and early-history habitat change on the lowlands, and in the same period of time other populations became rare and restricted to the upland (James and Price, 2008). Boyer *et al.* found in New Caledonia a substantial turnover in relative abundance of species in the cave deposit, with edge and open country birds becoming more common through time (2010). These changes may reflect the severe reduction of dry forest habitat during the colonial period (Boyer *et al.*, 2010). A paleontological study on the Gambier islands aimed to show the extinction pattern of birds on the islands since the Polynesian era and until the first half of the twentieth century (Thibault & Cibois, 2012). The results obtained support that extinctions continue uninterrupted since the first human settlements due to the human disturbance on the islands (Thibault & Cibois, 2012).

### **DISCUSSION**

The number of articles published in this topic has grown considerably in the last 11 years (Figure 1). This result coincides with the growing concern about the effects of human disturbances in nature that has appeared in recent years. Also, the oldest articles did not commonly measure the relation between the human disturbance and the change in birds, instead they only propose the possibility of being a cause-effect relation. With the past of time more articles developed a systematic methodology that help support the cause-effect between human disturbance and an effect in birds.

#### *Studies by methodology*

Many articles did not report sampling effort. Almost any article gave enough information to calculate an effort, and even less reported explicitly the effort in hours. Even though most articles did mention the months in which they sampled, many did not report how many days were sampled. This lack of information is critical, since the studies can be presenting six months of sampling with only one day in each month or with three weeks in each month, which drastically change the sturdiness of the results. Besides, information that is not reported makes virtually impossible to replicate the studies. Most of the articles covered a short period of time reported in months, and the

number of studies decrease while progressively increasing the length of the study. The categorization of *Period of time* is biased since it reports the number of months, indifferent of the number of days sampled in the month, but it was the only practical solution since not many studies were more specific than that.

As expected, most of the studies were observational. The wide amount of modelling studies and the presence of one meta-analysis study were a surprise. The three birdwatching studies found have to be taken in account very prudently in consideration that they lack a systematic methodology of sampling and do not perform any kind of statistical results.

#### *Studies by location*

The study effort is still heavily skewed toward the Polynesia. Clearly because of the high presence of articles conducted in New Zealand and Hawaii. The great majority of islands of the Polynesia do not appear even in one article. The difference in the number of studies per region is abysmal, with Polynesia being study over six times more than the other regions. Even though Polynesia presents high endemism and threatening in his bird species, it is important to invest more effort in other areas that have the same characteristic, like Micronesia. In this topic is especially important to develop information in most possible places, since the transferability of results from one island to another is likely to be low. Most of the studies were conducted on islands bigger than 10 000 km<sup>2</sup>, since North Island, South Island, Hawai'i and Vancouver, the three most studied islands, exceed that measure. Possibly, this result happens because most of the biggest settlements of islands are located on the biggest islands.

#### *Studies by disturbance*

*Agriculture* was clearly the most studied disturbance. The result matches with the percentage of each disturbance in an island, since agriculture is the most extended human-induced disturbance. A common problem during the data extraction was that many studies did not explain the exact type of disturbance, and only mention "disturbed area" or "agriculture", without explaining the type of agriculture. Nevertheless, some articles did mention in detail this, and even destined a section to the explanation of each type of habitat sampled. The type of agriculture most studied was plantation agriculture. This was expected, since islands are not frequently used for big monocultures of grasses, but for fruit, palms or pine plantations. The following most studied disturbances were *Secondary Forests* and *Open Fields*, which were in some points difficult to differentiate, for the reason that the articles did not present enough information for an easy categorization. Also, some papers used the term *open fields* for agriculture, and only in one section briefly mention that it was an agricultural land. *Exotic Species* and *Fires* were the only indirect human-induced habitat disturbances. *Fires* was almost absent, but *Exotic Species* was a very studied topic.

#### *Studies by variable studied in birds*

The most studied variables were all that denote changes in the number of individuals between the different habitats. In this category enters abundance, density, richness, community assemblage, habitat use, reproductive success, population viability, habitat suitability and distribution. The least studied were the behavioral variables with no apparent relationship with the density, like movement, breeding ecology and home range. Articles that assessed this category usually only measured number of birds per place, and the most complex studies tracked the birds to understand the differential habitat use. Extinction was one of the most studied single categories and was always

performed with paleontological methodologies. Possibly the behavioral variables were the least studied because of its low relation with the conservation of the species, since the changes they report do not indicate an actual or possible population decrease or increase.

#### *Main results of anthropogenic habitat change in landbirds*

The main conclusion obtained from the data extraction is that the effect on birds depends of the species. The results suggest that there are certain patterns on this effects. The most robust pattern found was the evidence that native birds are usually more negatively affected, while exotic species are benefit by the human-induced disturbances. The negative effect appears to be more drastic in endemic species (Rodríguez-Estrella *et al.*, 1996). When analyzing the effects by the natural history it appears that some niches are more affected by the disturbances. The literature propose that insectivorous species are the most affected, even though there are not many papers that analyze the effects by guilds like in reviews with other geographic limitations (Cisneros-Heredia *et al.*, 2018). This suggest that habitat loss may be associated with the loss of food resources for insectivorous. In many articles it is reported that a single species can react different to distinct type of disturbances. Also, generalist species occurred both in primary forests and disturbed areas, while other species showed to be primary-forest-dependents or open-areas-dependent. This result is highly variable across the species, although there are not so many studies with these conclusions.

Reforestation and regrowth appears to cause an increase on the abundance and richness of the birds. Some articles report that abundance and richness increase as the time of revegetation advance. Secondly, a study concludes that birds were more favored by heterogeneous revegetation, rather than revegetation dominated by one species of tree (Forbes & Craig, 2013). Finally, one article supports that the colonization of a habitat in process of revegetation varies among species across time (Paxton *et al.*, 2017).

Studies that assess the overall abundance or richness of birds in islands show a negative correlation with the area of the disturbances. In the same way, many studies conclude that native forests present a higher abundance and richness than disturbed areas. Also, some studies report a higher reproductive success on old-growth forests than on disturbed areas. Some studies suggest the same pattern previously mentioned, but with exotic species. Many articles present strong evidence that introduced animals change the vegetation, and with this affect the landbird populations (Rodríguez-Estrella *et al.*, 1996; Donlan, 2007; Martin *et al.*, 2011; Banko *et al.*, 2013). Two articles reported that there was no significant effect between the disturbance and the survival rates (Boulton *et al.*, 2008) and abundance (Amar, 2008).

In the two papers of food consumption it was found a higher rate of seed consumption on forest interiors (Díaz *et al.*, 1999), but a higher insectivory on forest edges (Barbaro, 2012). One article reported an earlier breeding time with the disturbance (Akatani *et al.*, 2011). The two studies on movement were contradictory, as one reported disturbances as an obstruction (Potter, 1990) and the other as suitable habitat (Seaton *et al.*, 2008). It is worth mentioning that the differences are probably due to the fact that one study was carried out in Kiwis, while the other one in New Zealand Falcons. The only study on home range reported a bigger home range on more recently disturbed areas (Warren *et al.*, 2015). One article reported a higher prevalence of avianpox and a lower immune function on disturbed areas (Zylberberg *et al.*, 2013).

All the extinction articles reported the same pattern, a higher extinction rate on periods of human settlements and expansion of human-induced habitat changes (Kirch, 1996; Burney *et al.*, 2001; James and Price, 2008; Boyer *et al.*, 2010; Martin *et al.*, 2011; Thibault & Cibois, 2012).

#### *Gaps in the research and future possibilities*

Clearly it is needed to invest more research on other islands aside from New Zealand and Hawaii. The high prevalence of research on these islands are probably due to the large population they harbor. Also, most of the research related with number of individual per habitats lack aggrupation analysis or proper explanation of the results. Perhaps the main improvement needed is to report better the methodologies, so the studies can be replicable. Finally, it is needed to study more the least popular topics, like behavioral changes or diseases. Literature with these perspectives are almost absent on the Pacific Ocean islands. Most of the study effort focus on the abundance, richness or habitat use according to the habitat change.

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**APPENDIX I.** Figures and tables.**Table 1.** PICOS framework used to define the study question

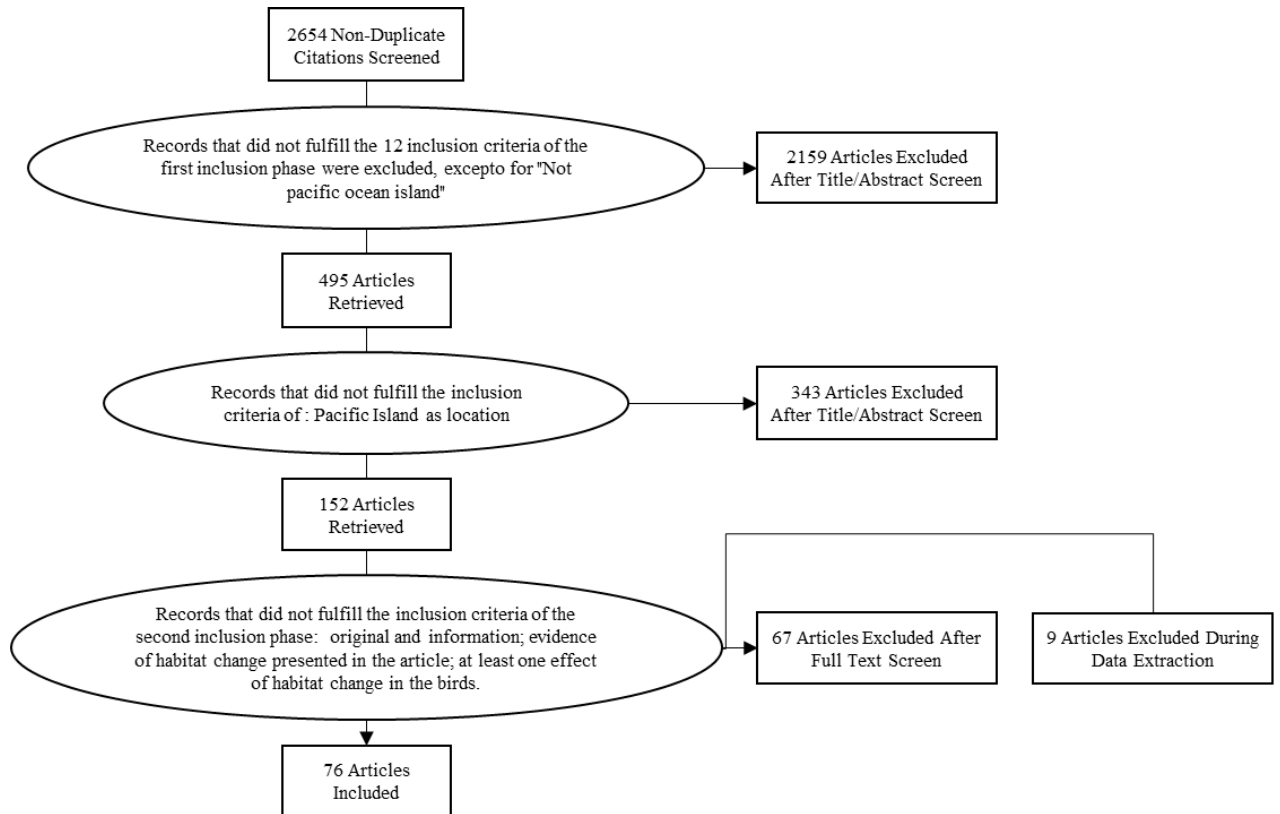
Population	Terrestrial birds
Intervention	Land use change
Comparators	Any
Outcomes	Any
Study type	Primary information

**Table 2.** Explanation of the 12 inclusion criteria used to select the citations for the review.

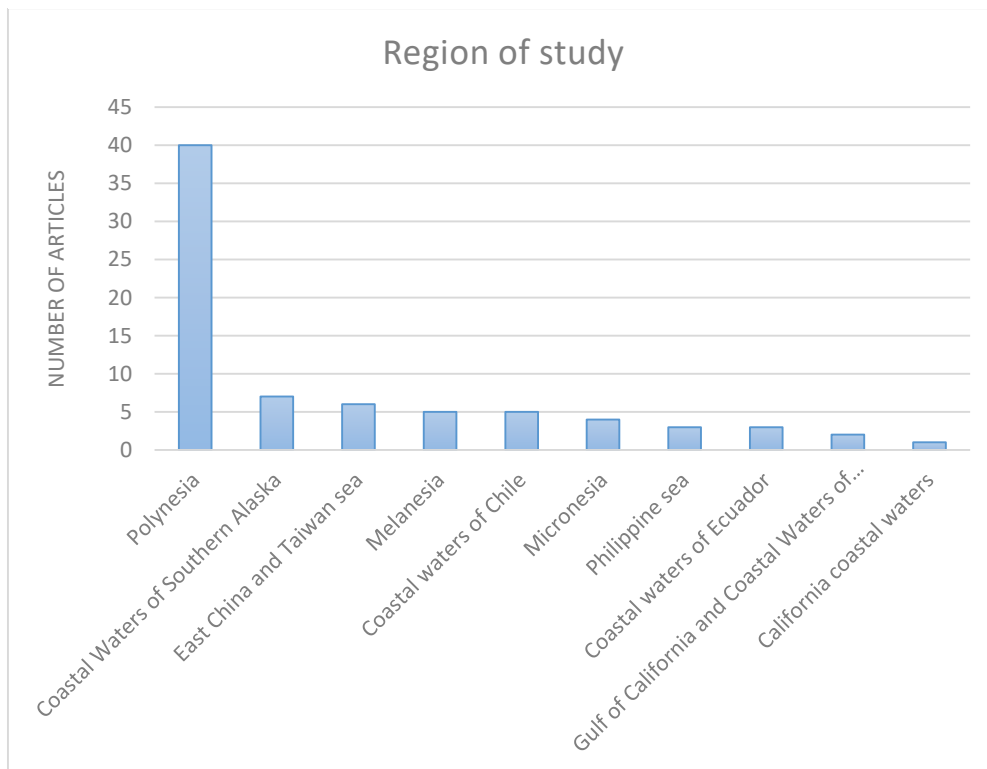
Category	Exclusion criteria	Notes
0. Null entries, duplicates, not in the language of interest, abstract is reported elsewhere and not in the time period of interest	01 - Null entries	No information is reported in title and abstract fields.
	02 - Duplicates	Duplicate of an existing entry.
	03 - Language of interest	Not in English, Spanish or Portugues
	04 - Abstract that is reported elsewhere	Abstracts and contents that have been reported in another publication will be excluded. It should be noted that this criterion should only be applied if the numerical values are the same in the full publication.
1 - Study population	10 - Not animal	Focussing on plants, fungi, unicelulars or other groups of biodiversity, but not animals
	11 - Not vertebrate animal	Focussing on invertebrates as response variable
	12 - Not birds	Focussing on mammals, reptiles, amphibians or fishes as response variable
	13 - Not terrestrial birds	Focussing on marine or aquatic birds as response variable
	14 - Not island	Focussing on continents as response variable
2 - Not including land use change	15 - Not oceanic island	Focussing on continental island as response variable
	20 - Not including land use change	The endpoints of interest are: impacts by habitat and land use change
3 - Potential	21 - Not including community or populational change	The endpoints of interest are: impacts in the community, population, diversity or abundance, population genetics, movement
	30 - Potencial	Citation with selected population and outcomes
Cannot decide	CANNOT DECIDE	The title and abstract cannot provide enough information for a decision

**Table 3.** Explanation of the variables extracted from each publication used on the systematic literature review.

Variable extracted	Type	Description/Categories
Authors	Textual	Name of all the authors of the publication
Publishing year	Numerical	Year he article was published
Region of Pacific Ocean	Categorical	Micronesia; Polynesia; Melanesia; Philippine sea; East China and Taiwan Sea; Coastal Waters of Southern Alaska and British Columbia; Gulf of California and Coastal Waters of Mexico; Coastal Waters of Colombia; Ecuador and Peru; and Coastal waters of Chile
Archipelago	Textual	Name of the archipelago in which the investigation was carry out
Island	Textual	Name of the island(s) in which the investigation was carry out
Size of island (sq.km)	Numerical	Size of the island in square kilometers
level of study group	Categorical	Population; Populations; Community
Type of study	Categorical	Observational; Experimental; Modelling; Birdwatching; Meta-analysis
Disturbance	Categorical	Agriculture; Exotic species; Infrastructure; Reforestation; Regrowth; Secondary-forest; Mixed matrix; Open field
	Subcategorical	Plantation Agriculture; Intensive Agriculture; Subsistence Agriculture; Mixed Agriculture; Livestock; Exotic Fauna Species; Exotic Flora Species; Urbanization; Roads; Coastal Management
Habitat change	Categorical	Land Cover Change; Fragmentation
Effect measured	Categorical	Habitat suitability; Habitat use; Density; Abundance; Home range; Richness; Community assemblage; Population viability; Immune function and prevalence of parasites; Food consumption; Extinction; Breeding ecology; Reproductive success; Movement; Distribution
Sampling methods	Categorical	Live-trap; Tracking; Direct identification transects; Direct identification points; Acoustic recording points; Call broadcasting; Mist nets; Birdwatching; Modelling; Focals; Blood immune analysis; Prevalence of parasites; Palaeontology; Historical information
Result	Categorical	Increase; Decrease; Mixed; Neutral
Years of study	Numerical	Years in which it was made at least one data collection
Period of study	Numerical	Number of months in which it was made at least one data collection
Sampling effort	Numerical	Hours sampled in the study

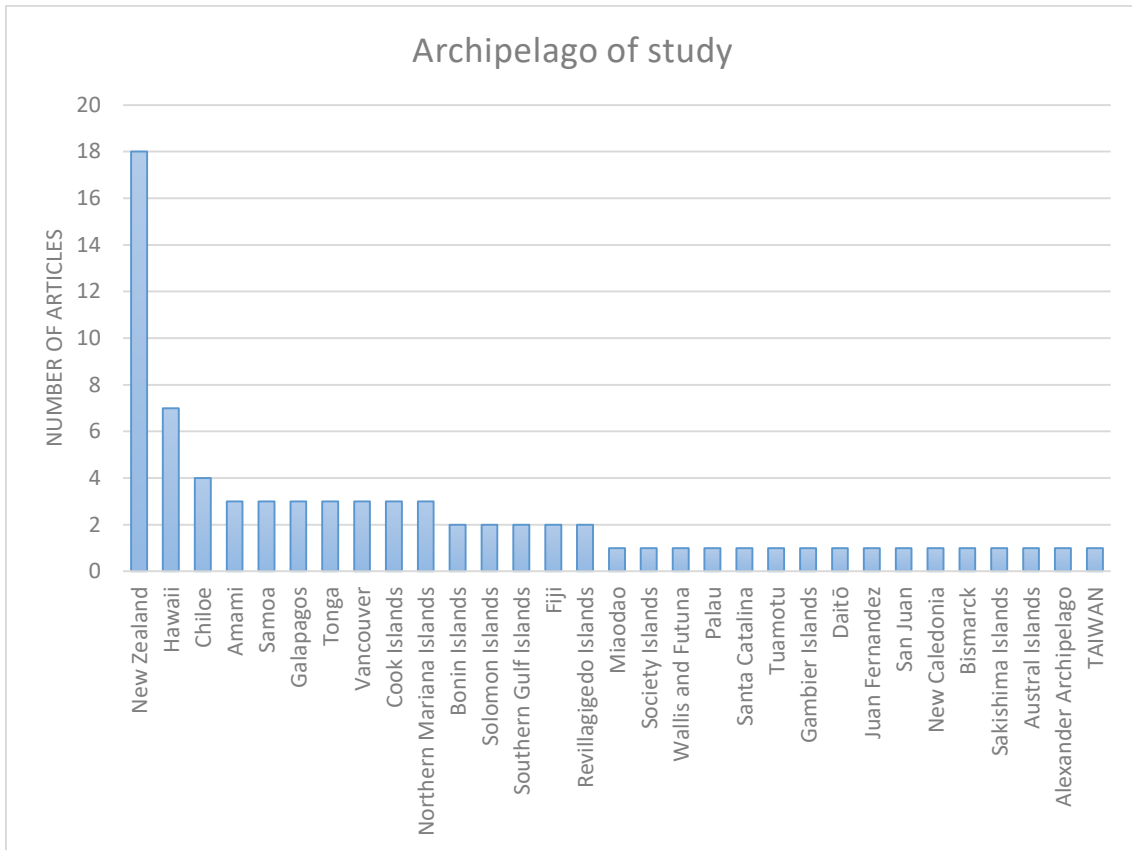


**Figure 1.** PRISMA flow diagram of the inclusion process and the results obtained in each phase.

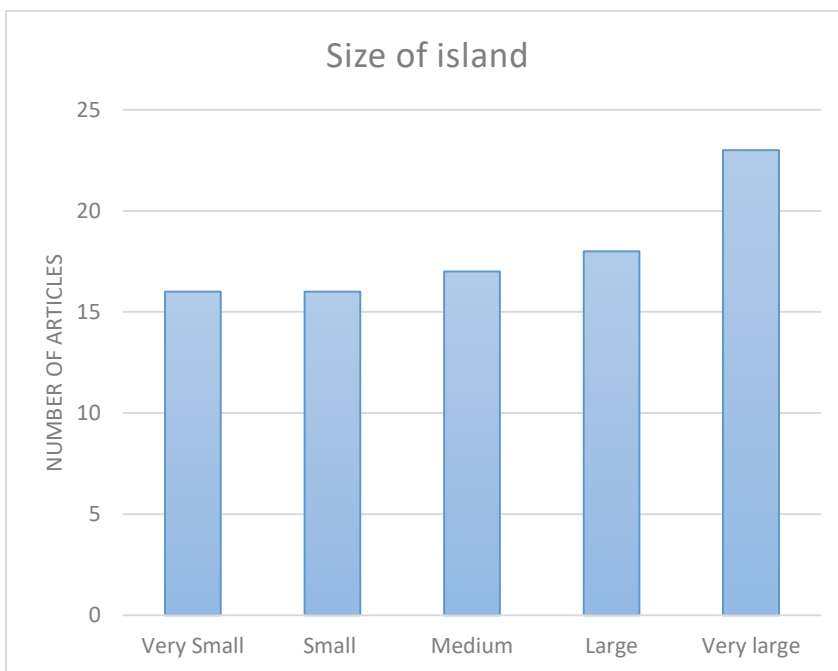


**Figure 2.** Number of articles found for each region of the Pacific Ocean.

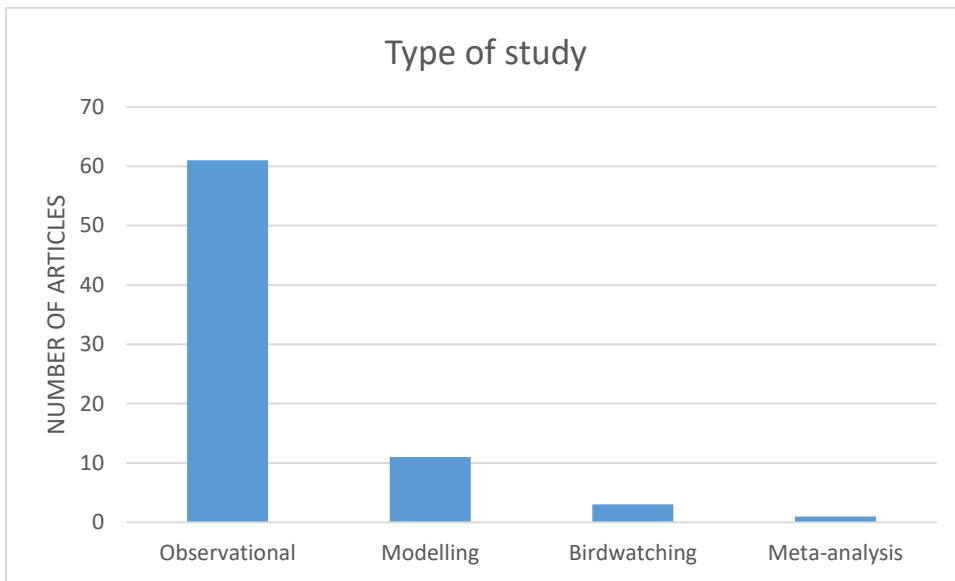




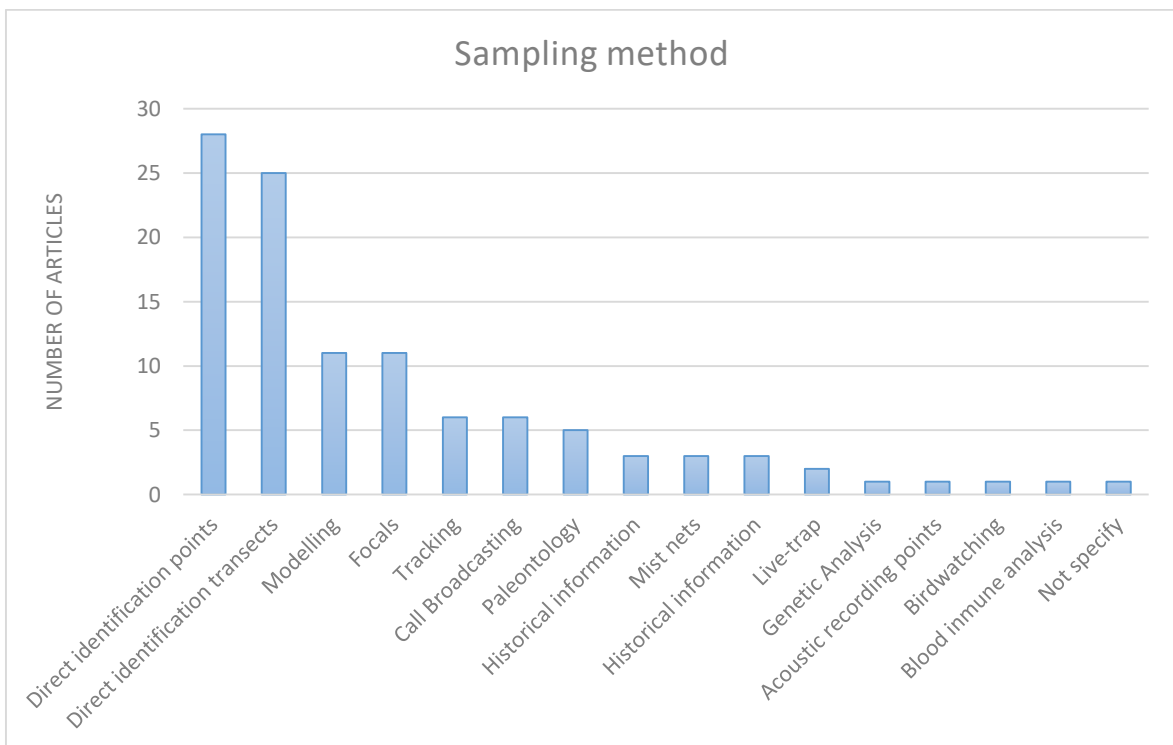
**Figure 3.** Number of articles found for each archipelago on the Pacific Ocean.



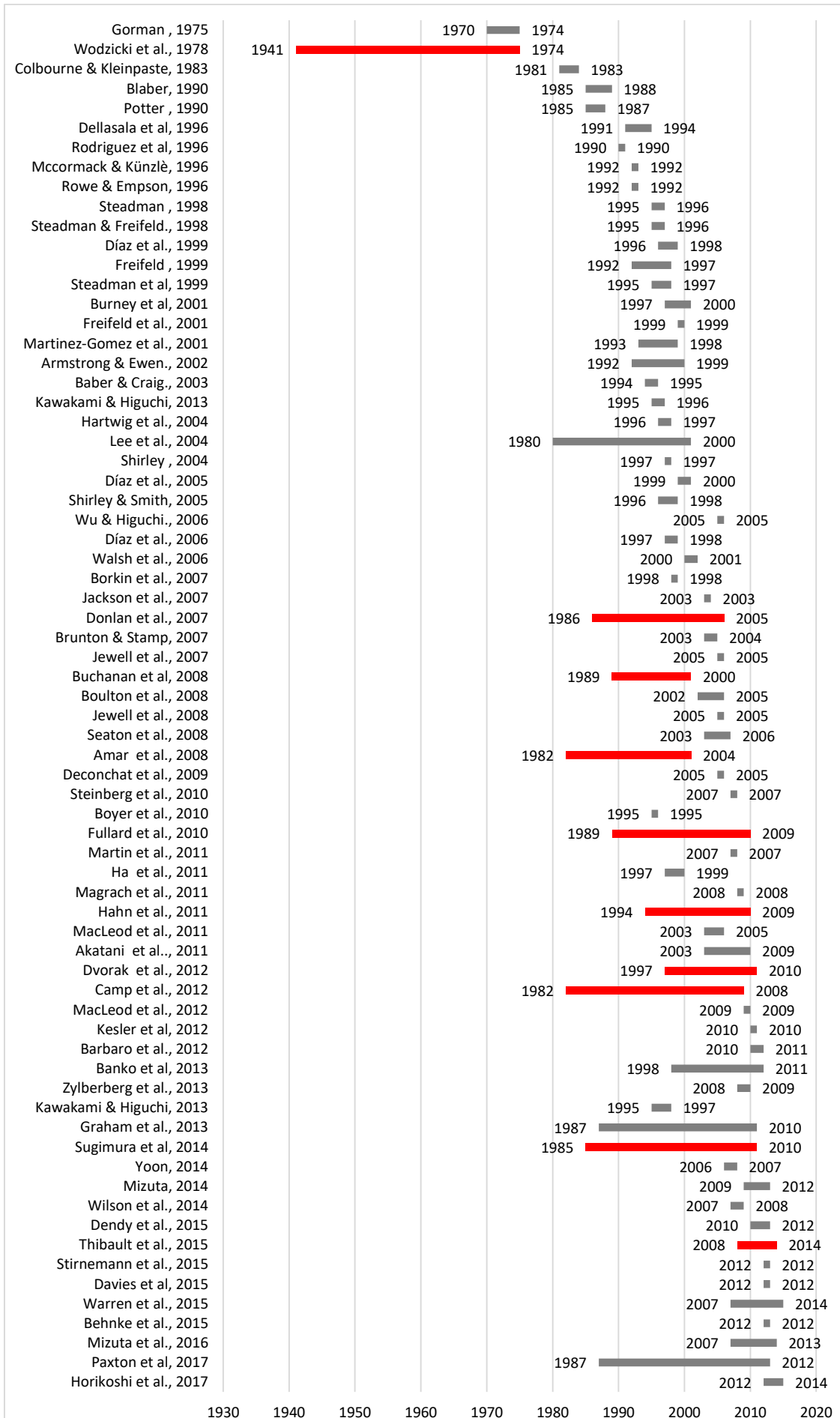
**Figure 4.** Number of articles found for the size of the islands. Very small islands covered an area smaller than 10 km<sup>2</sup>, small islands 10 – 100 km<sup>2</sup>, medium islands 100 – 1000 km<sup>2</sup>, large islands 1000 – 10 000 km<sup>2</sup>, and very large islands more than 10 000 km<sup>2</sup>.



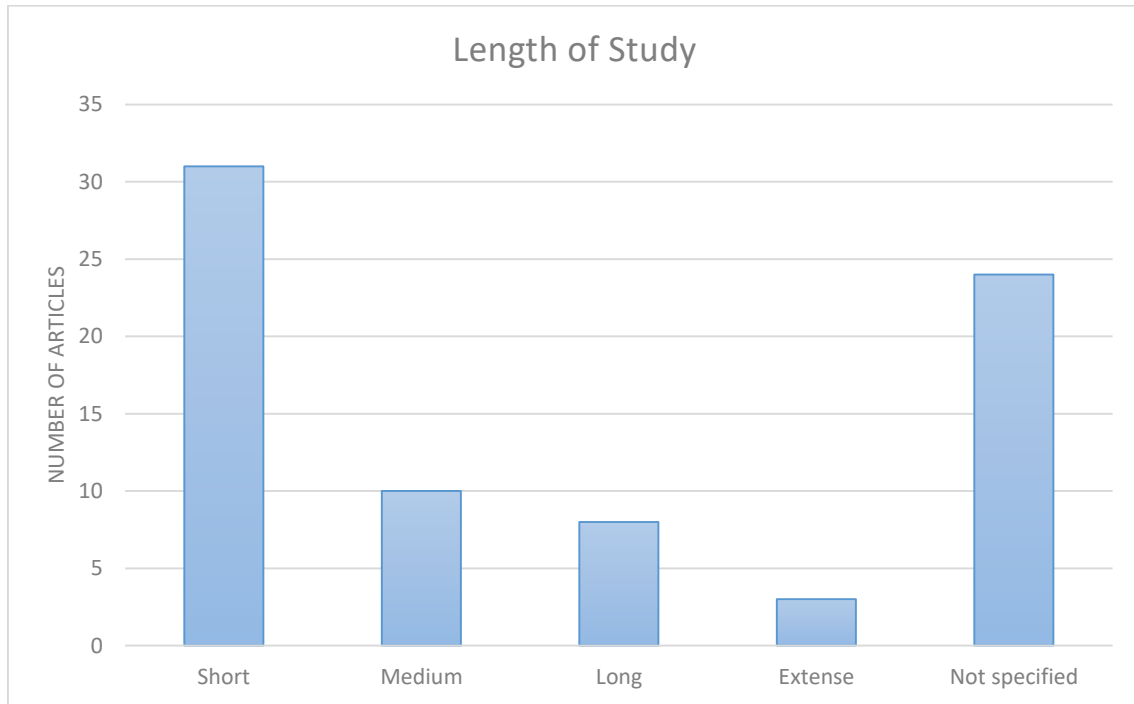
**Figure 5.** Number of articles found for each type of study.



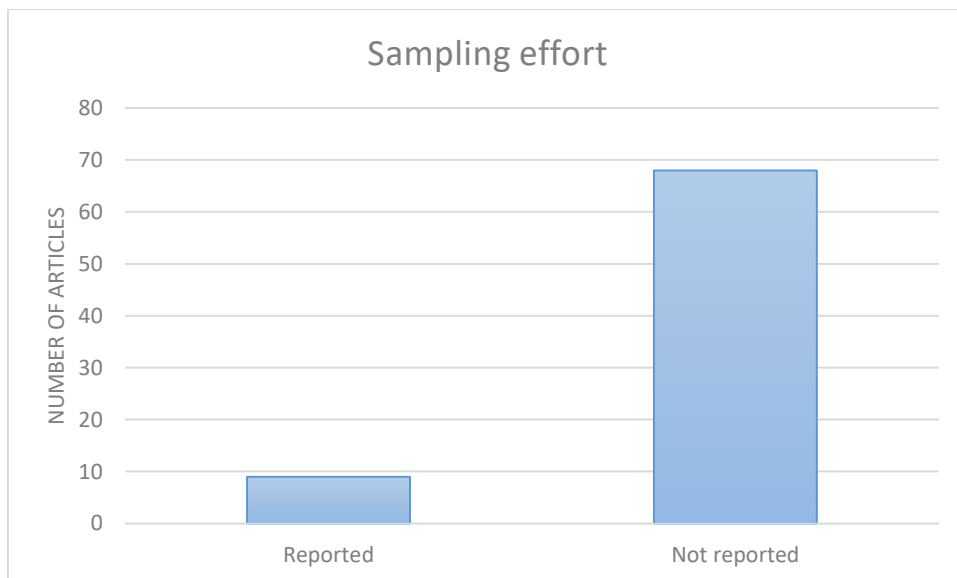
**Figure 6.** Number of articles found for each sampling method.



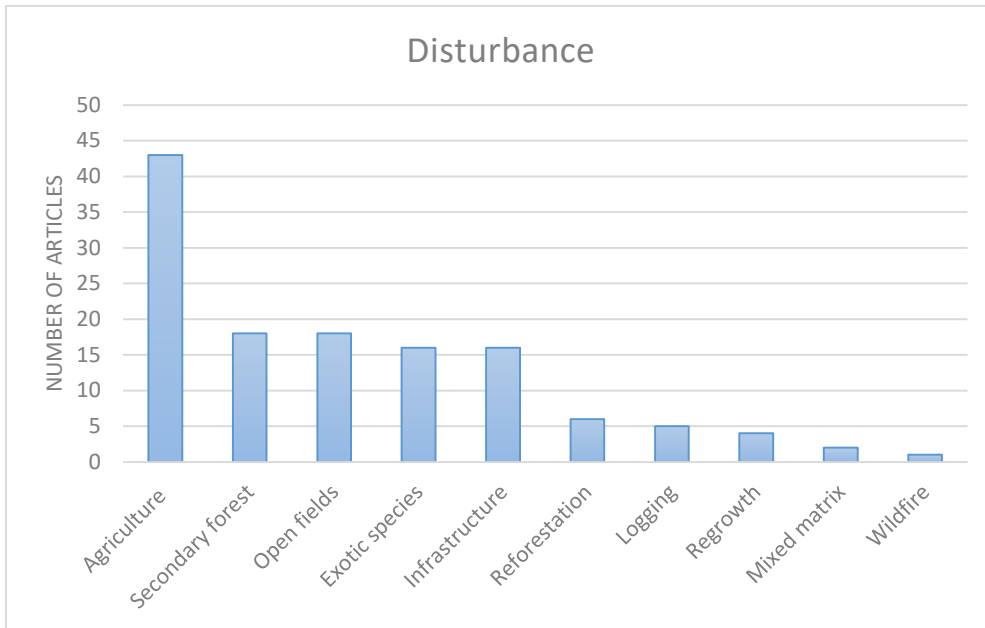
**Figure 7.** Studies according to the sampling years covered. The six studies that did not report this data were excluded from the figure. Grey bars represent the studies that sampled at least once a year. Red bars represent studies that did not sampled at least one year during their time range.



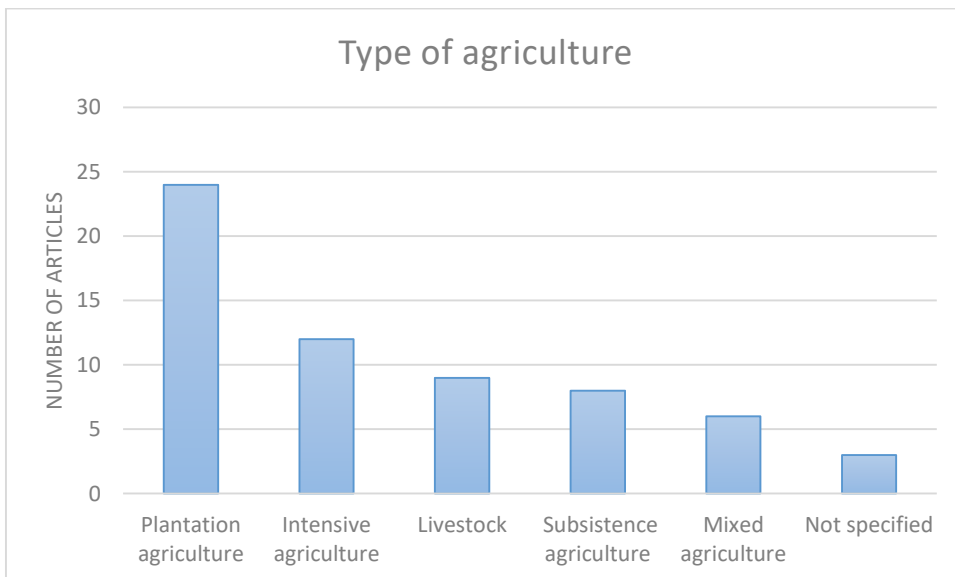
**Figure 8.** Number of articles found for length of the study.



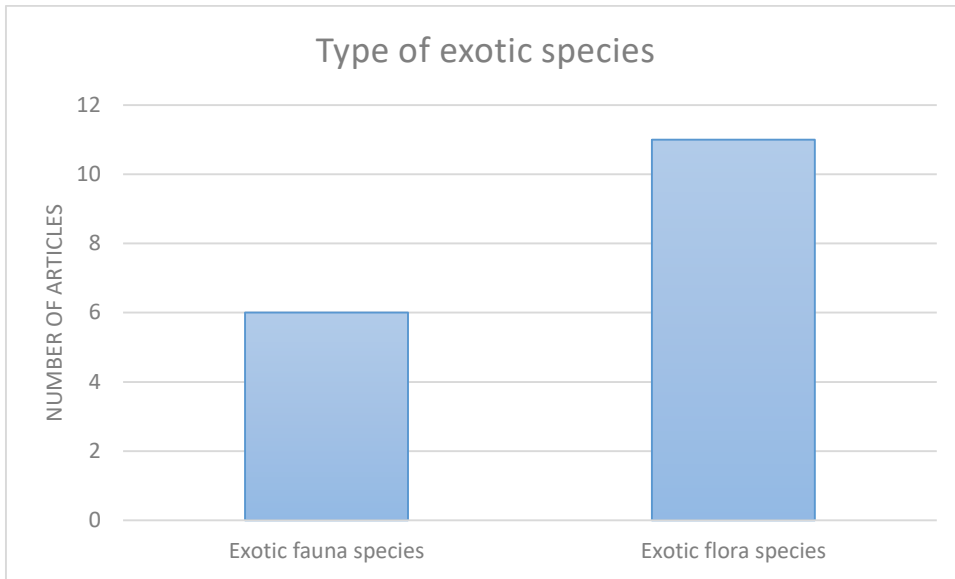
**Figure 9.** Number of articles found for reported or not reported sampling effort.



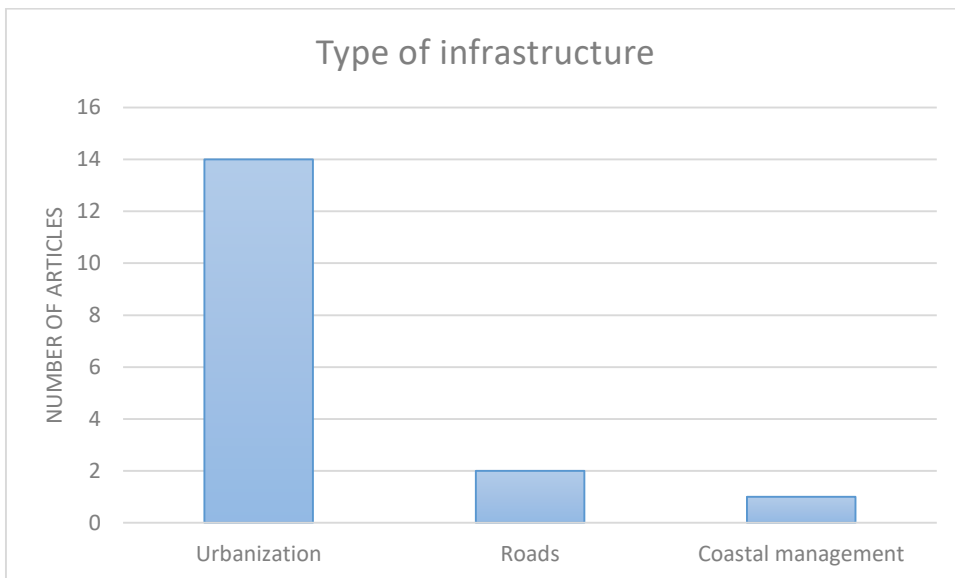
**Figure 10.** Number of articles found for each disturbance.



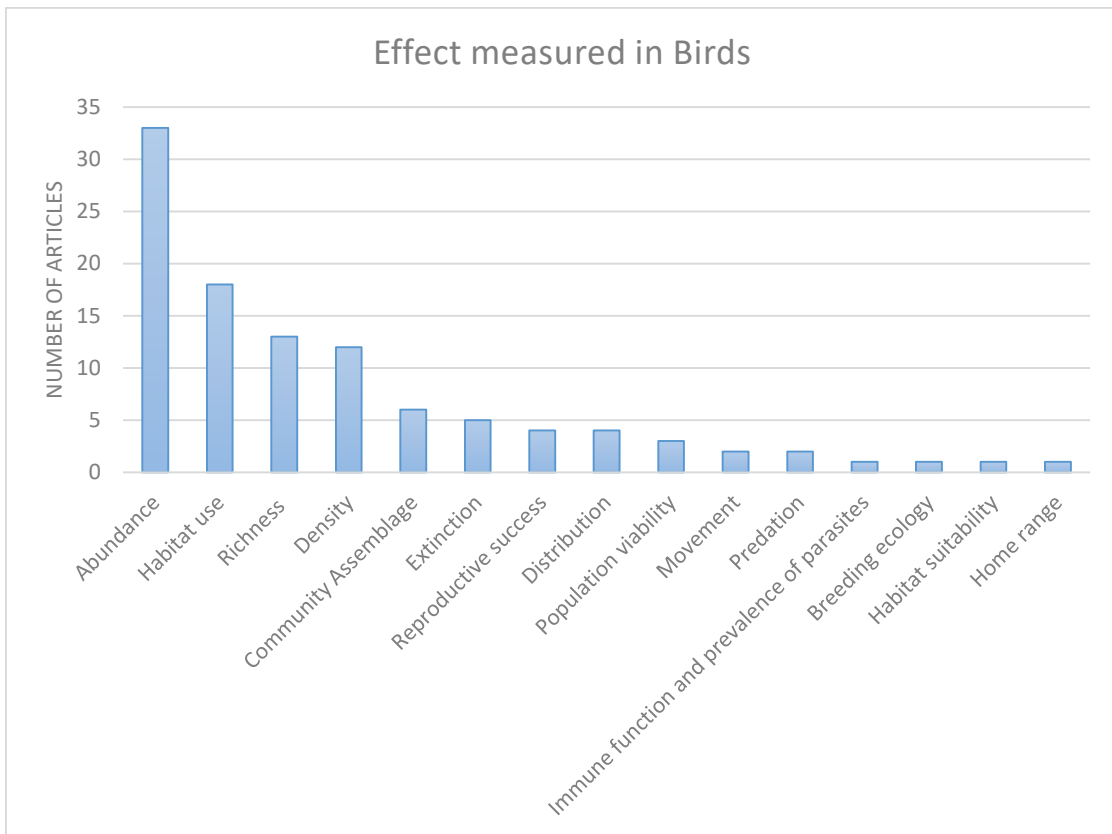
**Figure 11.** Number of articles found for type of agriculture.



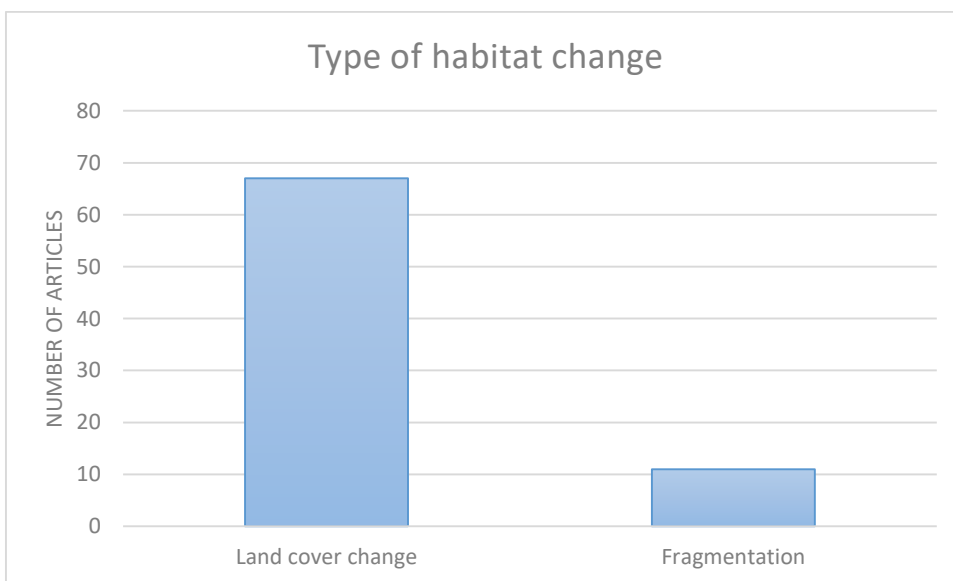
**Figure 12.** Number of articles found for type of exotic species.



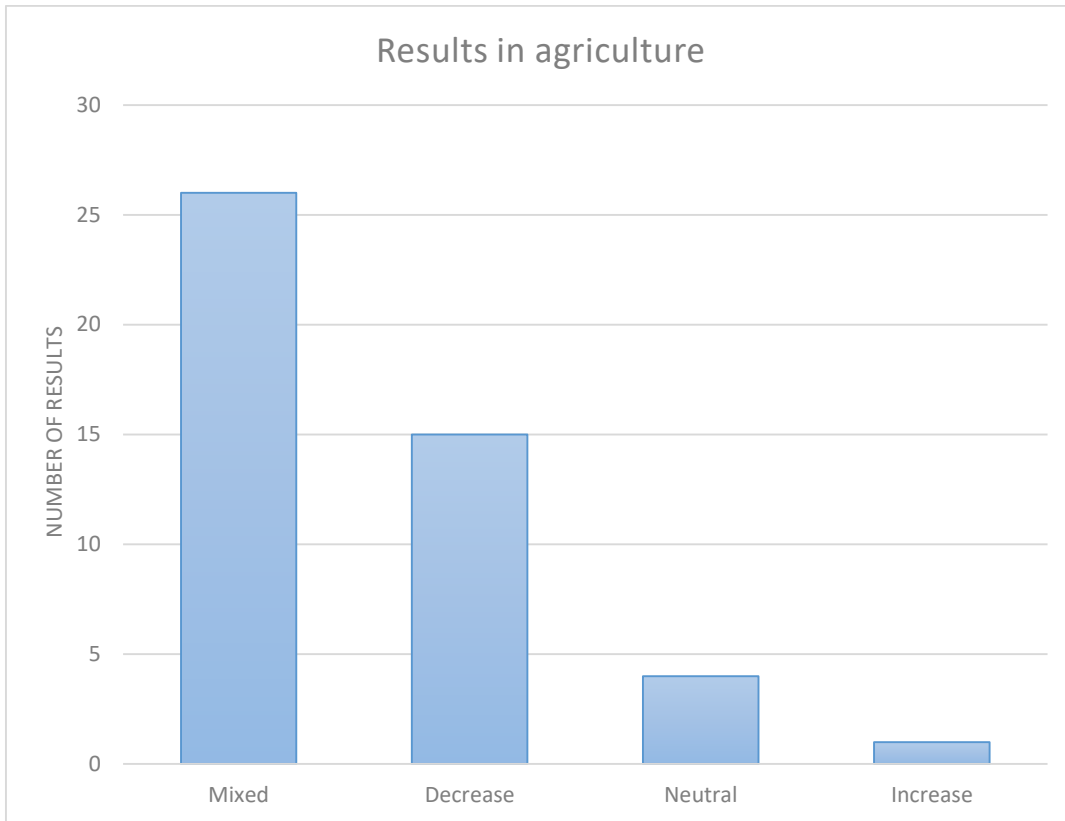
**Figure 13.** Number of articles found for type of infrastructure.



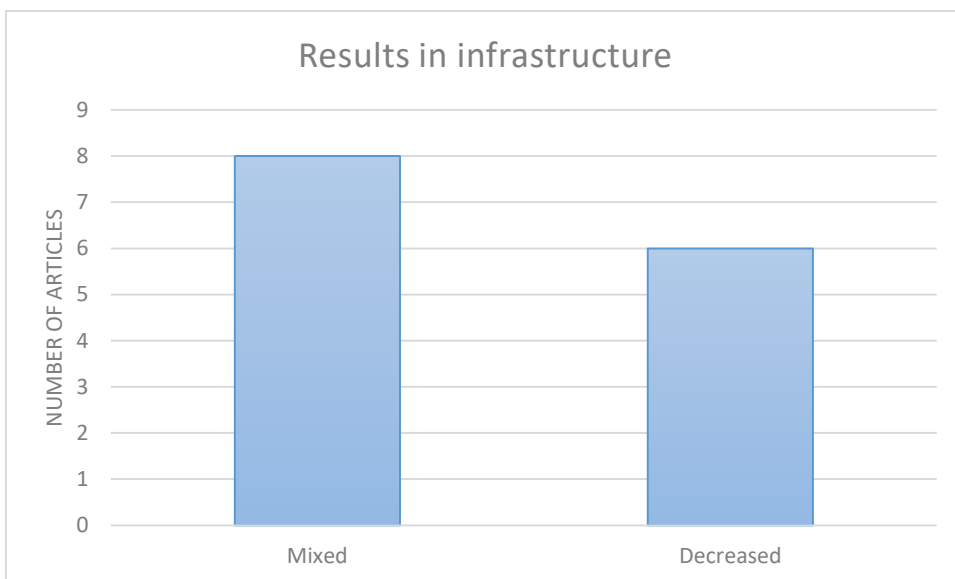
**Figure 14.** Number of articles found for type of effect measured in birds.



**Figure 15.** Number of articles found for each type of habitat change.

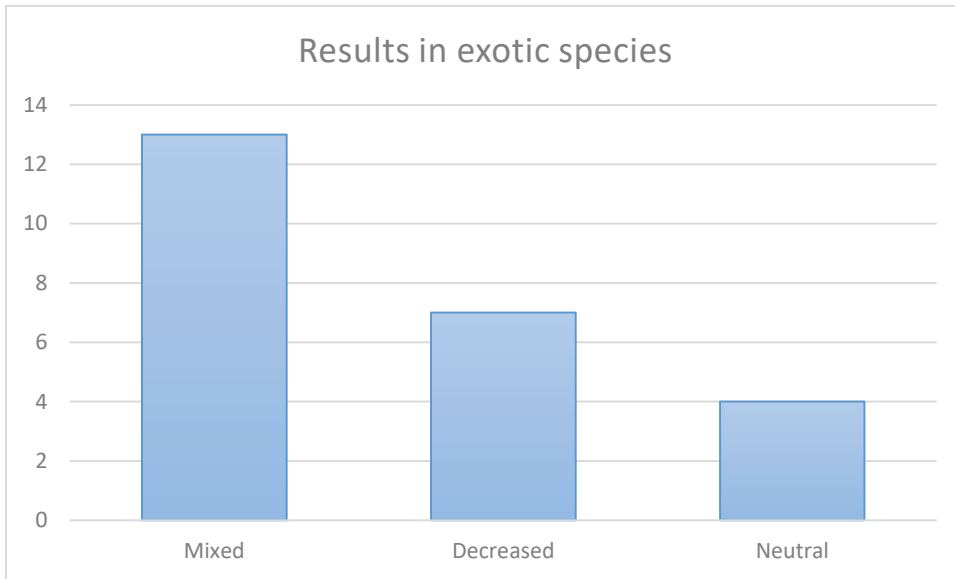


**Figure 16.** Number of articles found for results in agriculture

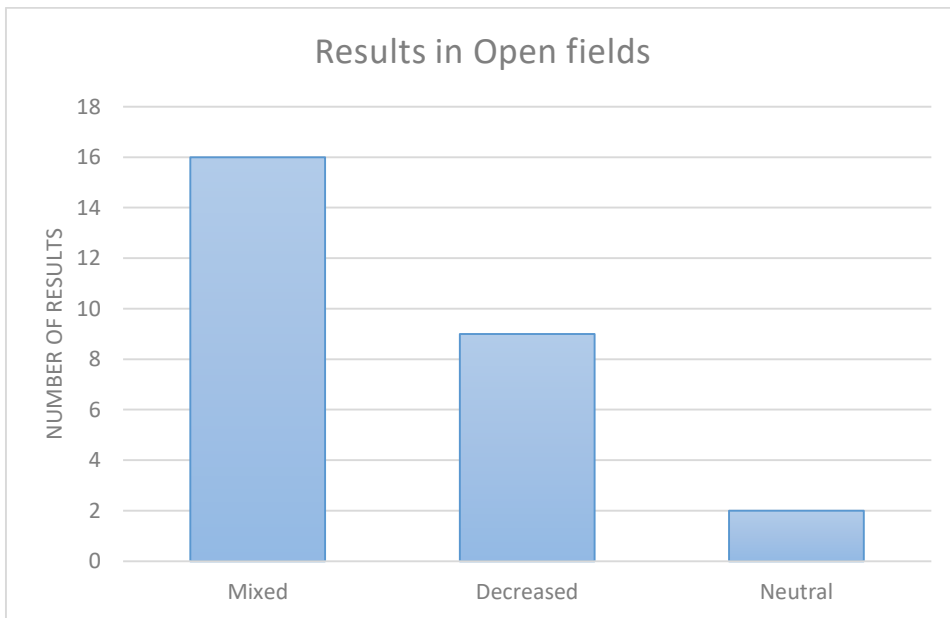


**Figure 17.** Number of articles found for results in infrastructure.

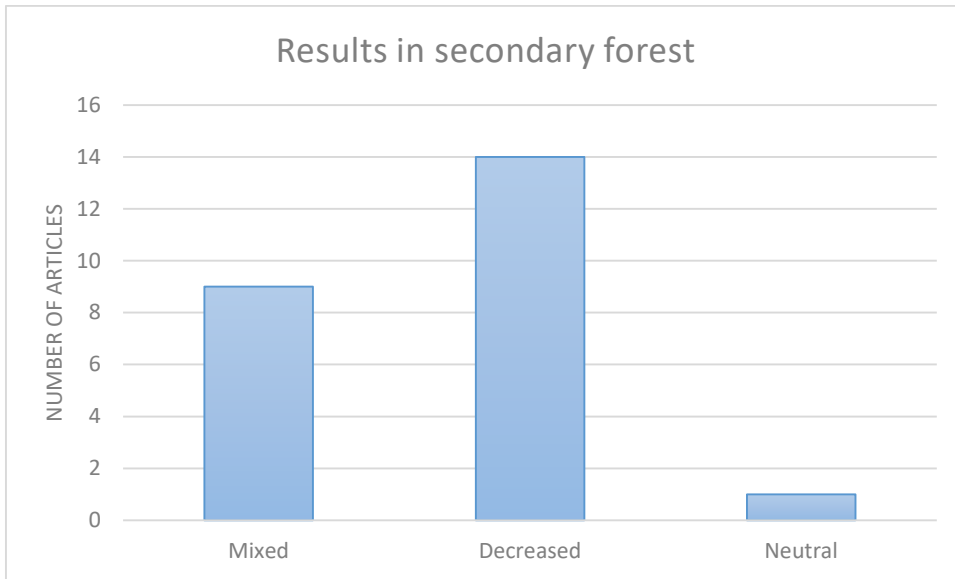




**Figure 18.** Number of articles found for results in exotic species.



**Figure 19.** Number of articles found for results in open fields.



**Figure 20.** Number of articles found for results in secondary forest.

**Table 4.** Extraction table with all the variables extracted from the 76 articles obtained in the systematic search.

Article information		Locality				Study group	Methods						Results		Time	
		Region	Archipelago	Island	Size of island (sq.km)	Level of study group	Type of study	Disturbance		Habitat change	Effect measured	Bird Sampling method	N	Result	Year of study	Period of study (number of months)
Authors	Publishing year	Categorical	Textual	Textual	Numerical	Categorical	Categorical	Categorical	Subcategorical	Categorical	Categorical	Categorical	Numerical	Categorical	Numerical	Numerical
Chi Y., Shi H., Zheng W., Guo Z., Liu Y.	2017	East China and Taiwan sea	Miaodao	16 islands	15-1321	Community	Modelling	Agriculture; Infrastructure; Exotic species	Intensive agriculture; Urbanization; Exotic flora species	Land cover change	Habitat suitability	Modelling	-	Decrease	-	-
Horikoshi C., Battley P.F., Seaton R., Minot E.O.	2017	Polynesia	New Zealand	North Island	111582,8	Population	Observational	Logging; Agriculture	Plantation agriculture	Land cover change	Habitat use	Tracking; Direct identification transects	36	Mixed	2012 - 2014	15
Paxton E.H., Yelenik S.G., Borneman T.E., Rose E.T., Camp R.J., Kendall S.J.	2017	Polynesia	Hawaii	Hawai'i	10434	Community	Observational	Reforestation	-	Land cover change	Density; Distribution	Direct identification points	30	Increase; Increase	1987 - 2012	-
ZoBell V.M., Furnas B.J.	2017	Polynesia	Society Islands	Mo'orea	132	Community	Observational	Agriculture	Intensive agriculture; Mixed agriculture	Land cover change	Habitat use; Abundance	Acoustic recording points	15	Mixed; Mixed	-	-
Mizuta T., Takashi M., Torikai H., Watanabe T., Fukasawa K.	2016	East China and Taiwan sea	Amami	Amami Ōshima	712,35	Population	Observational	Regrowth; Secondary forest	-	Land cover change	Abundance	Direct identification transects; Direct identification points	-	Increase; Decrease	2007 - 2013	-
Behnke L.A.H., Pejchar L., Crampton L.H.	2015	Polynesia	Hawaii	Kaua'i	1434,6	Populations	Observational	Exotic species	Exotic flora species	Land cover change	Abundance	Direct identification points; Call broadcasting	70-96	Decrease	2012	5

Warren C.C., Motyka P.J., Mounce H.L.	2015	Polynesia	Hawaii	Maui	1903,3	Populations	Modelling	Exotic species	Exotic fauna species	Land cover change	Home range	Mist nets; Call broadcasting; Banding; Direct identification transects; Modelling	25; 130	Decrease	2007 - 2014	30
Davies T.E., Clarke R.H., Ewen J.G., Fazey I.R.A., Pettorelli N., Cresswell W.	2015	Melanesia	Solomon Islands	Makira	3190	Community	Observational	Secondary forest; Agriculture	Subsistence agriculture; Mixed agriculture; Plantation agriculture	Land cover change	Richness; Community assemblage	Direct identification transects	10	Mixed; Change-Mixed; Change	2012	6
Stirnemann R.L., Potter M.A., Butler D., Minot E.O.	2015	Polynesia	Samoa	Savai'i; Upolu	1717,6; 1125,1	Community	Observational	Agriculture	Mixed agriculture	Fragmentation	Reproductive success	Focals	60	Decrease	2012	3
Thibault J.-C., Cibois A., Meyer J.-Y.	2015	Polynesia	Wallis and Futuna	Uvea, Alfie Futuna	82,4; 62,3; 32	Community	Birdwatching	Agriculture; Secondary forest; Infrastructure	Subsistence agriculture; Intensive agriculture; Urbanization	Land cover change	Abundance	Birdwatching	-	Mixed	2008; 2011; 2014	4
Dendy J., Cordell S., Giardina C.P., Hwang B., Polloi E., Rengulbai K.	2015	Micronesia	Palau	Babelthuap	374,1	Community	Observational	Open fields; Reforestation	-	Fragmentation; Land cover change	Habitat use	Direct identification transects	32	Decrease; Increase	2010 - 2012	10
Wilson D.J., Norbury G., Walker S.	2014	Polynesia	New Zealand	South Island	145836,4	Community	Observational	Secondary forest	-	Land cover change	Density	Direct identification transects	-	Mixed	2007 - 2008	3
Mizuta T.	2014	East China and Taiwan sea	Amami	Amami Ōshima	712,35	Population	Observational	Secondary forest; Agriculture;	Mixed agriculture; Intensive agriculture	Land cover change	Habitat use	Focals	11	Decrease	2009 - 2012	-
Yoon J.	2014	California coastal waters	Santa Catalina	Santa Catalina	193,2	Population	Modelling	Wildfire	-	Land cover change	Density	Focals; modelling	193	Decrease	2006-2007	4

Sugimura K., Ishida K., Abe S., Nagai Y., Watari Y., Tatara M., Takashi M., Hashimoto T., Yamada F.	2014	East China and Taiwan sea	Amami	Amami Ōshima	712,35	Community	Meta-analysis	Logging	-	Land-cover change	Abundance	Direct identification transects, Direct identification points; Live-traps	8	Decrease	1985; 1986; 1993; 1994; 2001; 2002; 2009; 2010	-
Graham M., Veitch D., Aguilar G., Galbraith M.	2013	Polynesia	New Zealand	Tiritiri Matangi	2,2	Community	Observational	Reforestation; Regrowth	-	Land-cover change	Abundance; Richness	Direct identification transects, Direct identification points	7	Increase; Increase; Increase	1987-2010	45
Forbes A.R., Craig J.L.	2013	Polynesia	New Zealand	Tiritiri Matangi	2,2	Community	Observational	Reforestation	-	Land-cover change	Abundance; Richness	Direct identification points	36	Mixed; Mixed	-	5
Kawakami K., Higuchi H.	2013	Philippine sea	Bonin Islands	Hahajima; Mukohjima; Imotojima	21,9; 2,54; 1,22;	Population	Modelling	Secondary forest; Agriculture	-	Land-cover change	Population viability	Direct identification transects; Modelling	-	Neutral	1995-1997	12
Zylberberg M., Lee K.A., Klasing K.C., Wikelski M.	2013	Coastal waters of Ecuador	Galapagos	Santa Cruz	979,3	Community	Observational	Infrastructure; Agriculture; Mixed matrix	Subsistence agriculture; Plantation agriculture	Land-cover change	Immune function; Prevalence of parasites	Mist nets; Blood immune analysis	545	Decrease; Increase	2008-2009	4
Banko P.C., Camp R.J., Farmer C., Brinck K.W., Leonard D.L., Stephens R.M.	2013	Polynesia	Hawaii	Hawai'i	10434	Community	Observational	Exotic species	Exotic fauna species	Land-cover change	Abundance	Direct identification transects	355-418	Mixed	1998-2011	-
Barbaro L., Brockerhoff E.G., Giffard B., van Halder I.	2012	Polynesia	New Zealand	South Island	145836,4	Community	Observational	Exotic species; Agriculture	Exotic flora species; Plantation agriculture	Fragmentation	Abundance; Richness; Community assemblage; Predation	Direct identification points	26	Mixed; Mixed; Change; Increase; Neutral; Neutral; Increase	2010-2011	4
Kesler D.C., Cox A.S., Albar G., Gouni A., Mejeur J.	2012	Polynesia	Tuamotu	Niau	20	Population	Observational	Agriculture; Mixed matrix	Plantation agriculture	Land cover change	Habitat use	Tracking	23	Mixed	2010	3

PlassÃ© C.																	
MacLeod C.J., Tinkler G., Gormley A.M., Spurr E.B.	2012	Polynesia	New Zealand	South Island	145836,4	Population	Observational	Infrastructure	Urban green areas	Land cover change	Habitat use	Direct identification points	140	Decrease	2009	7	
Camp R.J., Amidon F.A., Marshall A.P., Pratt T.K.	2012	Micronesia	Northern Mariana Islands	Tinian	102	Community	Observational	Secondary forest; Open field; Exotic species	Exotic flora species	Land cover change	Density; Abundance	Direct identification points	253	Mixed	1982; 1996; 2008	5	
Thibault J.-C., Cibois A.	2012	Polynesia	Gambier Islands	-	29,6	Community	Observational	Agriculture; logging	-	Land cover change	Extinction	Paleontology; Historical information	-	Increase	-	-	
Dvorak M., Fessler B., Nemeth E., Kleindorfer S., Tebbich S.	2012	Coastal waters of Ecuador	Galapagos	Santa Cruz	979,3	Community	Observational	Agriculture; Exotic species	Intensive agriculture; Livestock; Exotic flora species	Land cover change	Abundance	Direct identification points	-	Mixed; Mixed	1997; 1998; 2008; 2010	8	
Akatani K., Matsuo T., Takagi M.	2011	Philippine sea	Daitō	Minami Daitō	30,6	Population	Observational	Exotic species; Open fields; Infrastructure; Agriculture	Exotic flora species; Urbanization; roads; Plantation agriculture	Land cover change	Habitat use; Breeding ecology	Call Broadcasting; Mist nets; Tracking; Focals	49; 95	Mixed; Change	; 2003-2009	14	
MacLeod C.J., Tompkins D.M., Drew K.W., Pyke N.	2011	Polynesia	New Zealand	South Island	145836,4	Populations	Modelling	Agriculture; Open fields	Intensive agriculture; Livestock	Land cover change	Density	Direct identification transect; Modelling	19	Decrease	2003-2005	16	
Hahn I.J., Vergara P.M., Ramírez U.	2011	Coastal waters of Chile	Juan Fernandez	Robinson Crusoe Island	93	Populations	Observational	Agriculture; Infrastructure; Open fields; Exotic species	Plantation agriculture; Subsistence agriculture; Urban green areas; exotic flora species	Land cover change	Density; Habitat use	Direct identification transects	46	Mixed; Mixed	1994; 2001; 2009	9	

Magrath A., Larrinaga A.R., Santamaría L.	2011	Coastal waters of Chile	Chiloe	Chiloe	8477,5	Populations	Observational	Agriculture; Open fields	Plantation agriculture	Fragmentation	Density	Direct identification points	22	Neutral; Mixed; Mixed; Mixed	2008	3
Ha R.R., Morton J.M., Ha J.C., Berry L., Plentovich S.	2011	Micronesia	Northern Mariana Islands	Rota	86	Population	Observational	Secondary forest; Open fields; Infrastructure	Urbanization; Roads;	Land cover change	Habitat use; Reproductive success	Focals	115	Decrease; Decrease - Not measured	1997-1999	-
Martin T.G., Arcese P., Scheerder N.	2011	Coastal Waters of Southern Alaska and British Columbia	San Juan Islands	-	1765,7	Community	Observational	Exotic species	Exotic fauna species	Land cover change	Abundance	Direct identification points	18	Mixed	2007	2
Fullard J.H., Barclay R.M.R., Thomas D.W.	2010	Polynesia	Cook Islands	Atiu	29,1	Population	Observational	Agriculture	Subsistence agriculture; Plantation agriculture	Land cover change	Habitat use	Direct identification transects	-	Mixed	1989; 1992; 1999; 2001; 2009	6
Boyer A.G., James H.F., Olson S.L., Grant-Mackie J.A.	2010	Melanesia	New Caledonia	New Caledonia	16648,4	Community	Observational	Agriculture; Open fields	Intensive agriculture	Land cover change	Extinction	Paleontology; Historical information	-	Increase	1995	-
Steinberg M.K., Sugishita J., Kinney K.M.	2010	Polynesia	Hawaii	Hawai'i	10434	Population	Observational	Exotic species	Exotic flora species	Land cover change	Habitat use	Direct identification transects; Direct identification points	852	Decrease	2007	2
Deonchat M., Brockerhoff E.G., Barbaro L.	2009	Polynesia	New Zealand	South Island	145836,4	Community	Observational	Agriculture	Plantation agriculture; Mixed agriculture	Fragmentation; Land cover change	Abundance	Direct identification points	238	Mixed; Mixed	2005	2
Amar A., Amidon F., Arroyo B., Esselstyn J.A., Marshall A.P.	2008	Micronesia	Northern Mariana Islands	Rota	86	Community	Observational	Open fields	-	Land cover change	Abundance	Direct identification points	1463	Mixed	1982; 1987; 1994; 1995; 1998; 2003; 2004	21

Seaton R., Holland J.D., O.minot E., P.springett B.	2008	Polynesia	New Zealand	South Island	145836,4	Population	Observational	Agriculture	Plantation agriculture	Land change	cover	Movement	Banding; Tracking	22	Neutral	2003- 2006	-
Jewell K.J., Arcese P.	2008	Coastal Waters of Alaska and British Columbia	Southern Gulf Islands	-	0 - 186	Populations	Modelling	Agriculture; Infrastructure	Urbanization; Livestock; Intensive	Land change	cover	Abundance	Direct identification points; Focals; Modelling	477	Mixed	2005	3
James H.F., Price J.P.	2008	Polynesia	Hawaii	Maui; Kaua'i; O'ahu	1902,3; 1434,6; 1583,3	Populations	Modelling	Open fields; Agriculture	-	Land change	cover	Extinction; Distribution	Paleontology; Museum records; Modelling	8	Increase	-	-
Boulton R.L., Richard Y., Armstrong D.P.	2008	Polynesia	New Zealand	North Island	111582,8	Population	Observational	Exotic species; Agriculture	Exotic flora species; Exotic fauna species; Livestock	Fragmentation		Reproductive success	Banding; Focals	203	Decrease; Neutral; Neutral	2002- 2005	21
Buchanan G.M., Butchart S.H.M., Dutson G., Pilgrim J.D., Steininger M.K., Bishop K.D., Mayaux P.	2008	Melanesia	Bismarck	New Britain	35144,6	Community	Modelling	Agriculture	Subsistence agriculture; Plantation agriculture	Land change	cover	Population viability	Modelling	-	Decrease	1989; 2000	-
Jewell K.J., Arcese P., Gergel S.E.	2007	Coastal Waters of Alaska and British Columbia	Southern Gulf Islands	-	0 - 186	Population	Modelling	Open fields; Agriculture; Infrastructure	Urbanization; Livestock; Intensive	Land change	cover	Abundance	Direct identification points; modelling	447	Mixed; Mixed	2005	3
Brunton D.H., Stamp R.	2007	Polynesia	New Zealand	Tiritiri Matangi	2,2	Population	Observational	Reforestation	-	Land change	cover	Abundance	Direct identification transects	15	Change	2003- 2004	12
Donlan C.J., Campbell K., Cabrera W., Lavoie C., Carrion	2007	Coastal Waters of Ecuador	Galapagos	Isabela; Santiago; Fernandina	4711,3; 576,7; 628,5	Population	Observational	Exotic species	Exotic fauna species	Land change	cover	Abundance	Call broadcasting; Direct identification points	574	Decrease	1986; 1987; 2004; 2005	4



V., Cruz F.																	
Jackson D.B., Jit R.	2007	Melanesia	Fiji	Viti Levu	10531	Populations	Observational	Agriculture; Regrowth	Plantation agriculture	Land change	cover	Density	Direct identification transects	18	Decrease	2003	6
Borkin K.M., Goodman A.J., Mayhew K., Smith E.	2007	Polynesia	New Zealand	South Island	145836,4	Population	Observational	Agriculture	Plantation agriculture	Land change	cover	Abundance; Distribution; Abundance	Call broadcasting; Direct identification points	30	Decrease	1998	1
Walsh J., Wilson K.-J., Elliott G.P.	2006	Polynesia	New Zealand	Maud	3,2	Population	Observational	Agriculture; Open fields	Plantation agriculture; Livestock	Land change	cover	Habitat use	Tracking	18	Mixed	2000-2001	8
D'Áaz I.A., Armesto J.J., Willson M.F.	2006	Coastal waters of Chile	Chiloe	Chiloe	8477,5	Population	Observational	Open fields	-	Fragmentation		Reproductive success	Focals	28	Neutral; Decrease; Mixed	1997-1998	5
Wu Y., Fujita G., Higuchi H.	2006	East China and Taiwan sea	Sakishima Islands	-	818,5	Population	Observational	Agriculture	Intensive agriculture; Livestock	Land change	cover	Habitat use	Direct identification transects	281	Increase	2005	3
Shirley S.M., Smith J.N.M.	2005	Coastal Waters of Alaska and British Columbia	-	Vancouver	31848,6	Community	Observational	Agriculture; Regrowth	-	Fragmentation		Richness; Abundance; Community assemblage	Direct identification transects	9	Decrease; Decrease; Change	1996-1998	-
D'Áaz I.A., Armesto J.J., Reid S., Sieving K.E., Willson M.F.	2005	Coastal waters of Chile	Chiloe	Chiloe	8477,5	Community	Observational	Secondary forest	-	Land change	cover	Richness; Abundance; Community assemblage	Direct identification points	15	Mixed; Mixed; Mixed	1999-2000	11
Shirley S.	2004	Coastal Waters of Alaska and British Columbia	-	Vancouver	31848,6	Community	Observational	Agriculture	-	Fragmentation		Richness; Abundance; Community assemblage	Direct identification transects	20	Mixed; Mixed; Mixed	1997	-
Lee P.-F., Ding T.-S., Hsu F.-H., Geng S.	2004	East China and Taiwan sea	-	Taiwan	34506,6	Community	Modelling	Infrastructure	Urbanization; Roads	Land change	cover	Richness	Historical information; Modelling	674	Decrease	1980-2000	-

Hartwig C.L., Eastman D.S., Harestad A.S.	2004	Coastal Waters of Alaska and Southern British Columbia	-	Vancouver	31848,6	Population	Observational	Secondary forest	-	Land change	cover	Habitat use	Focals	76	Decrease	1996-1997	-
Kawakami K., Higuchi H.	2003	Philippine sea	Bonin Islands	Hahajima; Chichijima	21,9; 23,5	Populations	Observational	Agriculture; Open field; Secondary forest	-	Land change	cover	Density; Habitat use	Direct identification transects	4	Mixed	1995-1996	16
Baber M.J., Craig J.L.	2003	Polynesia	New Zealand	Tiritiri Matangi	2,2	Population	Observational	Open fields	-	Land change	cover	Habitat use	Banding; Focals	10	Decrease	1994-1995	12
Armstrong D.P., Ewen J.G.	2002	Polynesia	New Zealand	Tiritiri Matangi	2,2	Population	Modelling	Reforestation	-	Land change	cover	Population viability	Direct identification transects; Banding; modelling	206	Neutral	1992-1998	-
Martinez-Gomez J.E., Flores-Palacios A., Curry R.L.	2001	Gulf of California and Coastal Waters of Mexico	Revillagigedo Islands	Socorro	132	Population	Observational	Exotic species	Exotic flora	Land change	cover	Habitat use	Direct identification points	165	Decrease	1993-1997	18
Freifeld H.B., Steadman D.W., Sailer J.K.	2001	Polynesia	Samoa	Nu'usafe'e; Nu'ulopa; Fanuatapu; Namua; Nu'utele; Apolima; Manono	0,02-2,90	Community	Birdwatching	Agriculture	Plantation agriculture	Land change	cover	Abundance; Richness; Distribution	Direct identification transects	-	Decrease	1999	1
Burney D.A., James H.F., Burney L.P., Olson S.L., Kikuchi W., Wagner W.L., Burney M., McCloskey D., Kikuchi D., Grady F.V., Gage II R., Nishek R.	2001	Polynesia	Hawaii	Kaua'i	1434,6	Community	Observational	Agriculture	Plantation agriculture; Intensive agriculture; Livestock	Land change	cover	Extinction; Distribution	Paleontology	-	Increase; Decrease	1997-1999	-

Steadman D.W., Franklin J., Drake D.R., Freifeld H.B., Bolick L.A., Smith D.S., Motley T.J.	1999	Polynesia	Tonga	Vava 'u Island Group (17 islands)	0,02-96	Community	Observational	Secondary forest; Infrastructure; Agriculture	Urbanization; Plantation agriculture	Land cover change	Abundance	Direct identification points	329	Mixed	1995-1996	3
Freifeld H.B.	1999	Polynesia	Samoa	Tutuila	142,3	Community	Observational	Infrastructure; Agriculture	Urbanization; Plantation agriculture	Land cover change	Abundance	Direct identification points	57	Mixed	1992-1996	47
D'Áz I., Pápic C., Armesto J.J.	1999	Coastal waters of Chile	Chiloe	Chiloe	8477,5	Community	Observational	Open fields; Secondary forest	-	Fragmentation	Predation	Focals	618	Decrease	1996-1997	6
Steadman D.W., Freifeld H.B.	1998	Polynesia	Tonga	Vava 'u Group (16 islands)	0,02-96	Community	Observational	Secondary forest; Infrastructure; Agriculture	Urbanization; Plantation agriculture	Land cover change	Abundance; Richness	Direct identification points	-	Decrease; Decrease	1995-1996	3
Steadman D.W.	1998	Polynesia	Tonga	Ha'apai Group (13 islands)	0,15-46,6	Community	Observational	Secondary forest; Open fields; Agriculture	Plantation agriculture; Intensive agriculture	Land cover change	Abundance; Richness	Direct identification points	-	Decrease; Decrease	1995-1996	2
Kirch P.V.	1996	Polynesia	Cook Islands	Mangaia	52	Community	Observational	Agriculture	Plantation agriculture	Land cover change	Extinction	Paleontology	795	Increase	-	-
Rowe S., Empson R.	1996	Polynesia	Cook Islands	Mangaia	52	Population	Observational	Secondary forest	-	Land cover change	Abundance; Density	Call broadcasting; Direct identification points	-	Decrease; Decrease	1992	2
McCormack G., KÄ¼anzlÄ© J.	1996	Polynesia	Austral Islands	Rimatara	8,4	Population	Observational	Agriculture; Infrastructure	Plantation agriculture; Mixed Agriculture; Urbanization	Land cover change	Abundance; Density	Direct identification transects	263	Mixed; Mixed	1992	2
Rodriguez-Estrella R., De La Luz J.L.L., Breceda A., Castellanos	1996	Gulf of California and Coastal Waters of Mexico	Revillagigedo Islands	Socorro	132	Community	Observational	Exotic species	Exotic fauna species	Land cover change	Abundance; Density	Direct identification points	6	Mixed; Mixed	1990	1

A., Cancino J., Llinas J.																	
Dellasala D.A., Hagar J.C., Engel K.A., McComb W.C., Fairbanks R.L., Campbell E.G.	1996	Coastal Waters of Alaska and Southern British Columbia	Alexander Archipelago	Prince Wales Island	6674	Community	Observational	Secondary forest	-	Land cover change	Abundance	Direct identification points	20	Mixed	1991-1993	8	
Potter M.A.	1990	Polynesia	New Zealand	North Island	111582,8	Population	Observational	Agriculture; Logging; Open fields	-	Fragmentation	Movement	Banding; Tracking	23	Decrease	1985-1987	-	
Blaber S.J.M.	1990	Melanesia	Solomon Islands	New Georgia; Vonavona; Arundel	2037; 180; 103	Community	Birdwatching	Agriculture; Open fields; Infrastructure	Plantation agriculture; Urbanization	Land cover change	Abundance; Richness	-	-	Mixed	1985-1988	-	
Colbourne R., Kleinpaste R.	1983	Polynesia	New Zealand	North Island	111582,8	Population	Observational	Logging	-	Land cover change	Habitat use	Banding	84	Decrease	1981-1982	17	
Wodzicki K., Kennedy P., Falconer M.	1978	Polynesia	New Zealand	North Island	111582,8	Community	Observational	Infrastructure; Exotic species	Coastal manage; Urbanization; Exotic flora species	Land cover change	Abundance	Direct identification transects	-	Mixed	1941; 1942; 1943; 1956; 1967; 1971; 1972; 1974	-	
Gorman M.L.	1975	Polynesia	Fiji	Viti Levu	10388	Community	Observational	Secondary forest	-	Land cover change	Richness	Direct identification transects	-	Decrease	1970-1973	-	

**APPENDIX II.** Search code for the systematic literature review.

(( TITLE-ABS-KEY ( struthionidae )) OR ( title-abs KEY ( casuariidae )) OR ( TITLE-ABS-KEY ( apterygidae )) OR ( TITLE-ABS-KEY ( megapodiidae )) OR ( TITLE-ABS-KEY ( numididae )) OR ( TITLE-ABS-KEY ( phasianidae )) OR ( TITLE-ABS-KEY ( rhynochetidae )) OR ( TITLE-ABS-KEY ( mesitornithidae )) OR ( TITLE-ABS-KEY ( pteroclididae )) OR ( TITLE-ABS-KEY ( podargidae )) OR ( TITLE-ABS-KEY ( aegothelidae )) OR ( TITLE-ABS-KEY ( hemiprocnidae )) OR ( TITLE-ABS-KEY ( otididae )) OR ( TITLE-ABS-KEY ( musophagidae )) OR ( TITLE-ABS-KEY ( recurvirostridae )) OR ( TITLE-ABS-KEY ( pedionomidae )) OR ( TITLE-ABS-KEY ( turnicidae )) OR ( TITLE-ABS-KEY ( glareolidae )) OR ( TITLE-ABS-KEY ( sagittariidae )) OR ( title-abs KEY ( colidae )) OR ( TITLE-ABS-KEY ( leptosomidae )) OR ( TITLE-ABS-KEY ( bucerotidae )) OR ( TITLE-ABS-KEY ( upupidae )) OR ( TITLE-ABS-KEY ( phoeniculidae )) OR ( TITLE-ABS-KEY ( meropidae )) OR ( TITLE-ABS-KEY ( coraciidae )) OR ( TITLE-ABS-KEY ( brachypteraciidae )) OR ( TITLE-ABS-KEY ( todidae )) OR ( TITLE-ABS-KEY ( semnormithidae )) OR ( TITLE-ABS-KEY ( megalaimidae )) OR ( TITLE-ABS-KEY ( lybiidae )) OR ( TITLE-ABS-KEY ( indicatoridae )) OR ( TITLE-ABS-KEY ( cariamidae )) OR ( TITLE-ABS-KEY ( strigopidae )) OR ( TITLE-ABS-KEY ( cacatuidae )) OR ( TITLE-ABS-KEY ( acanthisittidae )) OR ( title-abs KEY ( pittidae )) OR ( TITLE-ABS-KEY ( philepittidae )) OR ( TITLE-ABS-KEY ( eurylaimidae )) OR ( TITLE-ABS-KEY ( sapayoidae )) OR ( TITLE-ABS-KEY ( calyptomenidae )) OR ( TITLE-ABS-KEY ( melanopareidae )) OR ( TITLE-ABS-KEY ( grallariidae )) OR ( TITLE-ABS-KEY ( tityridae )) OR ( TITLE-ABS-KEY ( menuridae )) OR ( TITLE-ABS-KEY ( ptilonorhynchidae )) OR ( TITLE-ABS-KEY ( climacteridae )) OR ( TITLE-ABS-KEY ( maluridae )) OR ( TITLE-ABS-KEY ( dasyornithidae )) OR ( TITLE-ABS-KEY ( meliphagidae )) OR ( TITLE-ABS-KEY ( pardalotidae )) OR ( TITLE-ABS-KEY ( acanthizidae )) OR ( TITLE-ABS-KEY ( orthonychidae )) OR ( TITLE-ABS-KEY ( pomatostomidae )) OR ( title-abs KEY ( mohouidae )) OR ( TITLE-ABS-KEY ( eulacestomidae )) OR ( TITLE-ABS-KEY ( neosittidae )) OR ( TITLE-ABS-KEY ( oriolidae )) OR ( TITLE-ABS-KEY ( paramythiidae )) OR ( TITLE-ABS-KEY ( oreoicidae )) OR ( TITLE-ABS-KEY ( cinclosomatidae )) OR ( TITLE-ABS-KEY ( falcunculidae )) OR ( TITLE-ABS-KEY ( pachycephalidae )) OR ( TITLE-ABS-KEY ( psophodidae )) OR ( TITLE-ABS-KEY ( campephagidae )) OR ( TITLE-ABS-KEY ( rhagologidae )) OR ( TITLE-ABS-KEY ( artamidae )) OR ( TITLE-ABS-KEY ( machaerirhynchidae )) OR ( TITLE-ABS-KEY ( vangidae )) OR ( TITLE-ABS-KEY ( platysteiridae )) OR ( TITLE-ABS-KEY ( aegithinidae )) OR ( title-abs KEY ( pityriasidae )) OR ( TITLE-ABS-KEY ( malaconotidae )) OR ( TITLE-ABS-KEY ( rhipiduridae )) OR ( TITLE-ABS-KEY ( dicuridae )) OR ( TITLE-ABS-KEY ( ifritidae )) OR ( TITLE-ABS-KEY ( monarchidae )) OR ( TITLE-ABS-KEY ( platylophidae )) OR ( TITLE-ABS-KEY ( laniidae )) OR ( TITLE-ABS-KEY ( melampittidae )) OR ( TITLE-ABS-KEY ( corcoracidae )) OR ( TITLE-ABS-KEY ( paradisaeidae )) OR ( TITLE-ABS-KEY ( callaeidae )) OR ( TITLE-ABS-KEY ( notiomystidae )) OR ( TITLE-ABS-KEY ( melanocharitidae )) OR ( TITLE-ABS-KEY ( cnemophilidae )) OR ( TITLE-ABS-KEY ( picathartidae )) OR ( TITLE-

ABS-KEY ( eupetidae ) ) OR ( TITLE-ABS-KEY ( chaetopidae ) ) OR ( title-  
 abs KEY ( petroicidae ) ) OR ( TITLE-ABS-KEY ( hylotidae ) ) OR ( TITLE-ABS-  
 KEY ( stenostiridae ) ) OR ( TITLE-ABS-KEY ( paridae ) ) OR ( TITLE-ABS-  
 KEY ( remizidae ) ) OR ( TITLE-ABS-KEY ( alaudidae ) ) OR ( TITLE-ABS-  
 KEY ( panuridae ) ) OR ( TITLE-ABS-KEY ( nicatoridae ) ) OR ( TITLE-ABS-  
 KEY ( macrosphenidae ) ) OR ( TITLE-ABS-KEY ( cisticolidae ) ) OR ( TITLE-ABS-  
 KEY ( acrocephalidae ) ) OR ( TITLE-ABS-KEY ( pnoepyidae ) ) OR ( TITLE-  
 ABS-KEY ( donacobiidae ) ) OR ( TITLE-ABS-KEY ( bernieridae ) ) OR ( title-abs-  
 key AND pycnonotidae ) ) OR ( TITLE-ABS-  
 KEY ( phylloscopidae ) ) OR ( TITLE-ABS-KEY ( scotocercidae ) ) OR ( TITLE-  
 ABS-KEY ( aegithalidae ) ) OR ( TITLE-ABS-KEY ( sylviidae ) ) OR ( TITLE-  
 ABS-KEY ( zosteropidae ) ) OR ( TITLE-ABS-KEY ( timaliidae ) ) OR ( TITLE-  
 ABS-KEY ( pellorneidae ) ) OR ( TITLE-ABS-KEY ( leiotrichidae ) ) OR ( TITLE-  
 ABS-KEY ( certhiidae ) ) OR ( TITLE-ABS-KEY ( sittidae ) ) OR ( TITLE-ABS-  
 KEY ( polioptilidae ) ) OR ( TITLE-ABS-KEY ( cinclidae ) ) OR ( TITLE-ABS-  
 KEY ( buphagidae ) ) OR ( TITLE-ABS-KEY ( sturnidae ) ) OR ( TITLE-ABS-  
 KEY ( muscipidae ) ) OR ( TITLE-ABS-KEY ( regulidae ) ) OR ( TITLE-ABS-  
 KEY ( dulidae ) ) OR ( TITLE-ABS-KEY ( hypocoliidae ) ) OR ( TITLE-ABS-  
 KEY ( hylocitridae ) ) OR ( TITLE-ABS-KEY ( bombycillidae ) ) OR ( TITLE-  
 ABS-KEY ( ptiliogonidae ) ) OR ( TITLE-ABS-KEY ( mohoidae ) ) OR ( TITLE-  
 ABS-KEY ( elachuridae ) ) OR ( TITLE-ABS-KEY ( promeropidae ) ) OR ( title-  
 abs KEY ( modulatricidae ) ) OR ( TITLE-ABS-KEY ( irenidae ) ) OR ( TITLE-  
 ABS-KEY ( chloropseidae ) ) OR ( TITLE-ABS-KEY ( dicaeidae ) ) OR ( TITLE-  
 ABS-KEY ( nectariniidae ) ) OR ( TITLE-ABS-KEY ( prunellidae ) ) OR ( TITLE-  
 ABS-KEY ( peucedramidae ) ) OR ( TITLE-ABS-  
 KEY ( urocynchramidae ) ) OR ( TITLE-ABS-KEY ( ploceidae ) ) OR ( TITLE-  
 ABS-KEY ( estrildidae ) ) OR ( TITLE-ABS-KEY ( viduidae ) ) OR ( TITLE-ABS-  
 KEY ( passeridae ) ) OR ( TITLE-ABS-KEY ( motacillidae ) ) OR ( TITLE-ABS-  
 KEY ( calcariidae ) ) OR ( TITLE-ABS-KEY ( rhodinocichlidae ) ) OR ( TITLE-  
 ABS-KEY ( passerellidae ) ) OR ( TITLE-ABS-KEY ( zeledoniidae ) ) OR ( TITLE-  
 ABS-KEY ( teretistridae ) ) OR ( TITLE-ABS-  
 KEY ( phaenicophilidae ) ) OR ( TITLE-ABS-KEY ( spindalidae ) ) OR ( TITLE-  
 ABS-KEY ( nesospingidae ) ) OR ( TITLE-ABS-  
 KEY ( calyptophilidae ) ) OR ( TITLE-ABS-KEY ( mitrospingidae ) ) OR ( TITLE-  
 ABS-KEY ( ostrich\* ) ) OR ( TITLE-ABS-KEY ( cassowary ) ) OR ( TITLE-ABS-  
 KEY ( cassowaries ) ) OR ( title-abs KEY ( emu\* ) ) OR ( TITLE-ABS-  
 KEY ( kiwi\* ) ) OR ( TITLE-ABS-KEY ( megapode\* ) ) OR ( TITLE-ABS-  
 KEY ( guineafowl AND \* ) ) OR ( TITLE-ABS-KEY ( pheasant\* ) ) OR ( TITLE-  
 ABS-KEY ( partridge\* ) ) OR ( TITLE-ABS-KEY ( turkey\* ) ) OR ( TITLE-ABS-  
 KEY ( grouse\* ) ) OR ( TITLE-ABS-KEY ( kagu\* ) ) OR ( TITLE-ABS-  
 KEY ( cagou\* ) ) OR ( TITLE-ABS-KEY ( mesite\* ) ) OR ( TITLE-ABS-  
 KEY ( sandgrouse\* ) ) OR ( TITLE-ABS-KEY ( frogmouth\* ) ) OR ( TITLE-ABS-  
 KEY ( bustard\* ) ) OR ( TITLE-ABS-KEY ( turaco\* ) ) OR ( TITLE-ABS-  
 KEY ( avocet\* ) ) OR ( TITLE-ABS-KEY ( stilt\* ) ) OR ( TITLE-ABS-  
 KEY ( plainwanderer\* ) ) OR ( TITLE-ABS-KEY ( wanderer\* ) ) OR ( TITLE-ABS-  
 KEY ( buttonquail\* ) ) OR ( TITLE-ABS-KEY ( courser\* ) ) OR ( TITLE-ABS-  
 KEY ( pratincole\* ) ) OR ( title-abs KEY ( secretarybird\* ) ) OR ( TITLE-ABS-  
 KEY ( mousebird\* ) ) OR ( TITLE-ABS-KEY ( cuccoroller\* ) ) OR ( TITLE-ABS-  
 KEY ( hornbill\* ) ) OR ( TITLE-ABS-KEY ( hoopoe\* ) ) OR ( TITLE-ABS-  
 KEY ( woodhoopo\* ) ) OR ( TITLE-ABS-KEY ( bee-eater\* ) ) OR ( TITLE-ABS-

KEY ( roller\* ) OR ( TITLE-ABS-KEY ( ground-roller\* ) ) OR ( TITLE-ABS-KEY ( todies ) ) OR ( TITLE-ABS-KEY ( tody ) ) OR ( TITLE-ABS-KEY ( parrot\* ) ) OR ( TITLE-ABS-KEY ( honeyguide\* ) ) OR ( TITLE-ABS-KEY ( seriema\* ) ) OR ( TITLE-ABS-KEY ( pitta\* ) ) OR ( title-abs KEY ( asity ) ) OR ( TITLE-ABS-KEY ( asities ) ) OR ( TITLE-ABS-KEY ( broadbill\* ) ) OR ( TITLE-ABS-KEY ( sapayoa\* ) ) OR ( TITLE-ABS-KEY ( crescentchest\* ) ) OR ( TITLE-ABS-KEY ( antpitta\* ) ) OR ( TITLE-ABS-KEY ( tityra\* ) ) OR ( TITLE-ABS-KEY ( allie\* ) ) OR ( TITLE-ABS-KEY ( lyrebird\* ) ) OR ( TITLE-ABS-KEY ( scrub-bird\* ) ) OR ( TITLE-ABS-KEY ( scrubbird\* ) ) OR ( TITLE-ABS-KEY ( bowerbird\* ) ) OR ( TITLE-ABS-KEY ( treecreepers ) ) OR ( TITLE-ABS-KEY ( wren\* ) ) OR ( TITLE-ABS-KEY ( honeyeater\* ) ) OR ( TITLE-ABS-KEY ( bristlebird\* ) ) OR ( TITLE-ABS-KEY ( frairywren\* ) ) OR ( TITLE-ABS-KEY ( pardalote\* ) ) OR ( title-abs KEY ( thornbill\* ) ) OR ( TITLE-ABS-KEY ( logrunner\* ) ) OR ( TITLE-ABS-KEY ( babbler\* ) ) OR ( TITLE-ABS-KEY ( mohoua\* ) ) OR ( TITLE-ABS-KEY ( ploughbill\* ) ) OR ( TITLE-ABS-KEY ( sittella\* ) ) OR ( TITLE-ABS-KEY ( oriole\* ) ) OR ( TITLE-ABS-KEY ( berrypecker\* ) ) OR ( TITLE-ABS-KEY ( bellbird\* ) ) OR ( TITLE-ABS-KEY ( jewelbabbler\* ) ) OR ( TITLE-ABS-KEY ( quailthrush\* ) ) OR ( TITLE-ABS-KEY ( shriketit\* ) ) OR ( TITLE-ABS-KEY ( tit ) ) OR ( TITLE-ABS-KEY ( tits ) ) OR ( TITLE-ABS-KEY ( whistler\* ) ) OR ( TITLE-ABS-KEY ( whipbird\* ) ) OR ( TITLE-ABS-KEY ( wedgebill\* ) ) OR ( TITLE-ABS-KEY ( vireo\* ) ) OR ( TITLE-ABS-KEY ( cuckooshrike\* ) ) OR ( TITLE-ABS-KEY ( berryhunter\* ) ) OR ( TITLE-ABS-KEY ( berrypecker\* ) ) OR ( TITLE-ABS-KEY ( woodswallow AND \* ) ) OR ( TITLE-ABS-KEY ( butcherbird\* ) ) OR ( TITLE-ABS-KEY ( boatbill\* ) ) OR ( TITLE-ABS-KEY ( vanga\* ) ) OR ( TITLE-ABS-KEY ( "Wattle-eyes" ) ) OR ( TITLE-ABS-KEY ( batis ) ) OR ( TITLE-ABS-KEY ( batises ) ) OR ( TITLE-ABS-KEY ( "Wattle-eye" ) ) OR ( TITLE-ABS-KEY ( lora\* ) ) OR ( title-abs KEY ( bristlehead\* ) ) OR ( TITLE-ABS-KEY ( "Brush-shrike" ) ) OR ( TITLE-ABS-KEY ( "Brush-shrikes" ) ) OR ( TITLE-ABS-KEY ( fantail\* ) ) OR ( TITLE-ABS-KEY ( drongo\* ) ) OR ( TITLE-ABS-KEY ( ifrit\* ) ) OR ( TITLE-ABS-KEY ( shrike\* ) ) OR ( TITLE-ABS-KEY ( melampitta\* ) ) OR ( TITLE-ABS-KEY ( mudnester\* ) ) OR ( TITLE-ABS-KEY ( "Bird-of-paradise" ) ) OR ( TITLE-ABS-KEY ( "Bird of paradise" ) ) OR ( TITLE-ABS-KEY ( "Birds of paradise" ) ) OR ( TITLE-ABS-KEY ( "Birds-of-paradise" ) ) OR ( TITLE-ABS-KEY ( wattlebird\* ) ) OR ( TITLE-ABS-KEY ( stitchbird\* ) ) OR ( TITLE-ABS-KEY ( berrypecker\* ) ) OR ( TITLE-ABS-KEY ( longbill\* ) ) OR ( TITLE-ABS-KEY ( satinbird\* ) ) OR ( title-abs KEY ( picatharte\* ) ) OR ( TITLE-ABS-KEY ( rockjumper\* ) ) OR ( TITLE-ABS-KEY ( robin\* ) ) OR ( TITLE-ABS-KEY ( hyliota\* ) ) OR ( TITLE-ABS-KEY ( chickadee\* ) ) OR ( TITLE-ABS-KEY ( lark\* ) ) OR ( TITLE-ABS-KEY ( bearded AND reedling\* ) ) OR ( TITLE-ABS-KEY ( nicator\* ) ) OR ( TITLE-ABS-KEY ( crombec\* ) ) OR ( TITLE-ABS-KEY ( allie\* ) ) OR ( TITLE-ABS-KEY ( cisticola\* ) ) OR ( TITLE-ABS-KEY ( parrotbill\* ) ) OR ( TITLE-ABS-KEY ( "white-eye" ) ) OR ( TITLE-ABS-KEY ( cupwing\* ) ) OR ( TITLE-ABS-KEY ( "white-eyes" ) ) OR ( TITLE-ABS-KEY ( grassbird\* ) ) OR ( TITLE-ABS-KEY ( donacobius ) ) OR ( TITLE-ABS-KEY ( tetraka\* ) ) OR ( TITLE-ABS-KEY ( bulbul\* ) ) OR ( TITLE-ABS-KEY ( yuhina\* ) ) OR ( TITLE-ABS-KEY ( laughingthrush\* ) ) OR ( TITLE-ABS-KEY ( nuthatch\* ) ) OR ( TITLE-ABS-KEY ( gnatcatcher\* ) ) OR ( TITLE-ABS-

KEY (dipper\*) ) OR ( TITLE-ABS-KEY ( oxpecker\* ) ) OR ( TITLE-ABS-KEY ( "starling" ) ) OR ( TITLE-ABS-KEY ( chat\* ) ) OR ( TITLE-ABS-KEY ( kinglet\* ) ) OR ( TITLE-ABS-KEY ( firecrest\* ) ) OR ( TITLE-ABS-KEY ( hypocolius ) ) OR ( TITLE-ABS-KEY ( hylocitra\* ) ) OR ( TITLE-ABS-KEY ( waxwing\* ) ) OR ( TITLE-ABS-KEY ( oos ) ) OR ( TITLE-ABS-KEY ( elachura\* ) ) OR ( TITLE-ABS-KEY ( sugarbird\* ) ) OR ( TITLE-ABS-KEY ( "spot-throat" ) ) OR ( title-abs KEY ( leafbird\* ) ) OR ( TITLE-ABS-KEY ( flowerpecker\* ) ) OR ( TITLE-ABS-KEY ( sunbird\* ) ) OR ( TITLE-ABS-KEY ( accentor\* ) ) OR ( TITLE-ABS-KEY ( rosefinch\* ) ) OR ( TITLE-ABS-KEY ( weaver\* ) ) OR ( TITLE-ABS-KEY ( waxbill\* ) ) OR ( TITLE-ABS-KEY ( whydah\* ) ) OR ( TITLE-ABS-KEY ( indigobird\* ) ) OR ( TITLE-ABS-KEY ( pipit\* ) ) OR ( TITLE-ABS-KEY ( wagtail\* ) ) OR ( TITLE-ABS-KEY ( longspur\* ) ) OR ( TITLE-ABS-KEY ( wrenthrush\* ) ) OR ( TITLE-ABS-KEY ( spindalis\* ) ) OR ( TITLE-ABS-KEY ( anhinga\* ) ) OR ( TITLE-ABS-KEY ( antbird\* ) ) OR ( TITLE-ABS-KEY ( avian\* ) ) OR ( TITLE-ABS-KEY ( avifauna\* ) ) OR ( TITLE-ABS-KEY ( barbet\* ) ) OR ( TITLE-ABS-KEY ( bird\* ) ) OR ( TITLE-ABS-KEY ( blackbird\* ) ) OR ( TITLE-ABS-KEY ( bunting\* ) ) OR ( TITLE-ABS-KEY ( caracara\* ) ) OR ( TITLE-ABS-KEY ( cardinal\* ) ) OR ( TITLE-ABS-KEY ( chachalaca\* ) ) OR ( TITLE-ABS-KEY ( cotinga\* ) ) OR ( TITLE-ABS-KEY ( cuckoo\* ) ) OR ( TITLE-ABS-KEY ( crow\* ) ) OR ( TITLE-ABS-KEY ( curassow\* ) ) OR ( TITLE-ABS-KEY ( dipper ) ) OR ( TITLE-ABS-KEY ( dippers ) ) OR ( TITLE-ABS-KEY ( dove ) ) OR ( TITLE-ABS-KEY ( doves ) ) OR ( TITLE-ABS-KEY ( eagle ) ) OR ( TITLE-ABS-KEY ( eagles ) ) OR ( TITLE-ABS-KEY ( falcon\* ) ) OR ( TITLE-ABS-KEY ( finch\* ) ) OR ( TITLE-ABS-KEY ( finfoot\* ) ) OR ( TITLE-ABS-KEY ( flycatcher\* ) ) OR ( TITLE-ABS-KEY ( gnatcatcher\* ) ) OR ( TITLE-ABS-KEY ( gnateater\* ) ) OR ( TITLE-ABS-KEY ( hawk\* ) ) OR ( TITLE-ABS-KEY ( hoatzin\* ) ) OR ( TITLE-ABS-KEY ( hummingbird\* ) ) OR ( TITLE-ABS-KEY ( icterid\* ) ) OR ( TITLE-ABS-KEY ( jacamar\* ) ) OR ( TITLE-ABS-KEY ( jacana\* ) ) OR ( TITLE-ABS-KEY ( jay ) ) OR ( TITLE-ABS-KEY ( jays ) ) OR ( TITLE-ABS-KEY ( guan ) ) OR ( TITLE-ABS-KEY ( guans ) ) OR ( TITLE-ABS-KEY ( manakin\* ) ) OR ( TITLE-ABS-KEY ( kite ) ) OR ( TITLE-ABS-KEY ( kites ) ) OR ( TITLE-ABS-KEY ( mockingbird\* ) ) OR ( TITLE-ABS-KEY ( motmot\* ) ) OR ( TITLE-ABS-KEY ( nighthawk\* ) ) OR ( TITLE-ABS-KEY ( nightjar\* ) ) OR ( TITLE-ABS-KEY ( oilbird\* ) ) OR ( TITLE-ABS-KEY ( ornithological ) ) OR ( TITLE-ABS-KEY ( oscine\* ) ) OR ( TITLE-ABS-KEY ( osprey\* ) ) OR ( TITLE-ABS-KEY ( ovenbird\* ) ) OR ( TITLE-ABS-KEY ( furnarid\* ) ) OR ( TITLE-ABS-KEY ( owl\* ) ) OR ( TITLE-ABS-KEY ( parrot\* ) ) OR ( TITLE-ABS-KEY ( passerine\* ) ) OR ( TITLE-ABS-KEY ( pigeon\* ) ) OR ( TITLE-ABS-KEY ( pitpit\* ) ) OR ( TITLE-ABS-KEY ( potoo\* ) ) OR ( TITLE-ABS-KEY ( puffbird\* ) ) OR ( TITLE-ABS-KEY ( quail\* ) ) OR ( TITLE-ABS-KEY ( rail ) ) OR ( TITLE-ABS-KEY ( rails ) ) OR ( TITLE-ABS-KEY ( rallid\* ) ) OR ( TITLE-ABS-KEY ( rhea\* ) ) OR ( TITLE-ABS-KEY ( sapayoa\* ) ) OR ( TITLE-ABS-KEY ( screamer\* ) ) OR ( TITLE-ABS-KEY ( seedsnipe\* ) ) OR ( TITLE-ABS-KEY ( sparrow\* ) ) OR ( TITLE-ABS-KEY ( suboscine\* ) ) OR ( TITLE-ABS-KEY ( swallow\* ) ) OR ( TITLE-ABS-KEY ( swift\* ) ) OR ( TITLE-ABS-KEY ( tanager\* ) ) OR ( TITLE-ABS-KEY ( tapaculo\* ) ) OR ( TITLE-ABS-KEY ( thrasher\* ) ) OR ( TITLE-ABS-KEY ( thrush\* ) ) OR ( TITLE-ABS-KEY ( tinamou\* ) ) OR ( TITLE-ABS-



KEY ( toucan\* ) OR ( TITLE-ABS-KEY ( trogon\* ) ) OR ( TITLE-ABS-KEY ( warbler\* ) ) OR ( TITLE-ABS-KEY ( waxwing\* ) ) OR ( TITLE-ABS-KEY ( woodcreeper\* ) ) OR ( TITLE-ABS-KEY ( woodpecker\* ) ) OR ( TITLE-ABS-KEY ( wren\* ) ) OR ( TITLE-ABS-KEY ( aves ) ) OR ( TITLE-ABS-KEY ( tinamidae ) ) OR ( TITLE-ABS-KEY ( cracidae ) ) OR ( TITLE-ABS-KEY ( odontophoridae ) ) OR ( TITLE-ABS-KEY ( columbidae ) ) OR ( TITLE-ABS-KEY ( steatornithidae ) ) OR ( TITLE-ABS-KEY ( nyctibiidae ) ) OR ( TITLE-ABS-KEY ( caprimulgidae ) ) OR ( TITLE-ABS-KEY ( apodidae ) ) OR ( TITLE-ABS-KEY ( trochilidae ) ) OR ( TITLE-ABS-KEY ( opisthocomidae ) ) OR ( TITLE-ABS-KEY ( cuculidae ) ) OR ( TITLE-ABS-KEY ( rallidae ) ) OR ( TITLE-ABS-KEY ( psophiidae ) ) OR ( TITLE-ABS-KEY ( thinocoridae ) ) OR ( TITLE-ABS-KEY ( tytonidae ) ) OR ( TITLE-ABS-KEY ( strigidae ) ) OR ( TITLE-ABS-KEY ( cathartidae ) ) OR ( TITLE-ABS-KEY ( pandionidae ) ) OR ( TITLE-ABS-KEY ( accipitridae ) ) OR ( TITLE-ABS-KEY ( trogonidae ) ) OR ( TITLE-ABS-KEY ( momotidae ) ) OR ( TITLE-ABS-KEY ( alcedinidae ) ) OR ( TITLE-ABS-KEY ( galbulidae ) ) OR ( TITLE-ABS-KEY ( bucconidae ) ) OR ( TITLE-ABS-KEY ( ramphastidae ) ) OR ( TITLE-ABS-KEY ( capitonidae ) ) OR ( TITLE-ABS-KEY ( semnornithidae ) ) OR ( TITLE-ABS-KEY ( picidae ) ) OR ( TITLE-ABS-KEY ( falconidae ) ) OR ( TITLE-ABS-KEY ( psittacidae ) ) OR ( TITLE-ABS-KEY ( furnariidae ) ) OR ( TITLE-ABS-KEY ( dendrocolaptidae ) ) OR ( TITLE-ABS-KEY ( thamnophilidae ) ) OR ( TITLE-ABS-KEY ( formicariidae ) ) OR ( TITLE-ABS-KEY ( conopophagidae ) ) OR ( TITLE-ABS-KEY ( rhinocryptidae ) ) OR ( TITLE-ABS-KEY ( cotingidae ) ) OR ( TITLE-ABS-KEY ( pipridae ) ) OR ( TITLE-ABS-KEY ( tyrannidae ) ) OR ( TITLE-ABS-KEY ( hirundinidae ) ) OR ( TITLE-ABS-KEY ( motacillidae ) ) OR ( TITLE-ABS-KEY ( bombycillidae ) ) OR ( TITLE-ABS-KEY ( troglodytidae ) ) OR ( TITLE-ABS-KEY ( mimidae ) ) OR ( TITLE-ABS-KEY ( turdidae ) ) OR ( TITLE-ABS-KEY ( polioptilidae ) ) OR ( TITLE-ABS-KEY ( corvidae ) ) OR ( TITLE-ABS-KEY ( vireonidae ) ) OR ( TITLE-ABS-KEY ( fringillidae ) ) OR ( TITLE-ABS-KEY ( parulidae ) ) OR ( TITLE-ABS-KEY ( thraupidae ) ) OR ( TITLE-ABS-KEY ( emberizidae ) ) OR ( TITLE-ABS-KEY ( cardinalidae ) ) OR ( TITLE-ABS-KEY ( icteridae ) ) OR ( TITLE-ABS-KEY ( passeriformes ) ) OR ( TITLE-ABS-KEY ( songbird\* ) ) OR ( TITLE-ABS-KEY ( vertebrates ) ) ) AND ( ( TITLE-ABS-KEY ( "habitat change" ) ) OR ( TITLE-ABS-KEY ( "habitat loss" ) ) OR ( TITLE-ABS-KEY ( "habitat degradation" ) ) OR ( TITLE-ABS-KEY ( "habitat fragmentation" ) ) OR ( TITLE-ABS-KEY ( "habitat clearance" ) ) OR ( TITLE-ABS-KEY ( "habitat disturbance" ) ) OR ( TITLE-ABS-KEY ( "habitat conversion" ) ) OR ( TITLE-ABS-KEY ( "habitat transformation" ) ) OR ( TITLE-ABS-KEY ( "habitat recovery" ) ) OR ( TITLE-ABS-KEY ( "habitat restoration" ) ) OR ( TITLE-ABS-KEY ( "habitat rehabilitation" ) ) OR ( TITLE-ABS-KEY ( "forest change" ) ) OR ( TITLE-ABS-KEY ( "forest degeneration" ) ) OR ( TITLE-ABS-KEY ( "forest regeneration" ) ) OR ( TITLE-ABS-KEY ( "disturbed forest" ) ) OR ( TITLE-ABS-KEY ( "forest disturbance" ) ) OR ( TITLE-ABS-KEY ( "forest fragmentation" ) ) OR ( TITLE-ABS-KEY ( "forest conversion" ) ) OR ( TITLE-ABS-KEY ( "forest transformation" ) ) OR ( TITLE-ABS-KEY ( "forest loss" ) ) OR ( TITLE-ABS-KEY ( "forest recovery" ) ) OR ( TITLE-ABS-KEY ( "forest restoration" ) ) OR ( TITLE-ABS-KEY ( "forest rehabilitation" ) ) OR ( TITLE-ABS-KEY ( "secondarisation" ) ) ) OR ( TITLE-ABS-

KEY ("secondarization" )) OR ( TITLE-ABS-KEY ( "land  
 conversion" )) OR ( TITLE-ABS-KEY ( "agricultural expansion" )) OR ( TITLE-  
 ABS-KEY ( "agroforestry" )) OR ( TITLE-ABS-KEY ( "selective  
 logging" )) OR ( TITLE-ABS-KEY ( "plantations" )) OR ( TITLE-ABS-  
 KEY ( "forestry" )) OR ( TITLE-ABS-KEY ( "deforestation" )) OR ( TITLE-ABS-  
 KEY ( "reforestation" )) OR ( TITLE-ABS-KEY ( "revegetation" )) OR ( TITLE-  
 ABS-KEY ( "infrastructure development" )) OR ( TITLE-ABS-KEY ( "dam  
 construction" )) OR ( TITLE-ABS-KEY ( plantations )) OR ( TITLE-ABS-  
 KEY ( cropping )) OR ( TITLE-ABS-KEY ( "secondary forest" )) OR ( TITLE-  
 ABS-KEY ( "human modified" )) OR ( TITLE-ABS-KEY ( "habitat  
 remnant" )) OR ( TITLE-ABS-KEY ( "forest remnant" )) OR ( TITLE-ABS-  
 KEY ( "land transformation" )) OR ( TITLE-ABS-KEY ( "land  
 clearance" )) OR ( TITLE-ABS-KEY ( "land use" )) OR ( TITLE-ABS-  
 KEY ( "urban expansion" )) OR ( TITLE-ABS-KEY ( urbanisation )) OR ( TITLE-  
 ABS-KEY ( urbanization )) OR ( TITLE-ABS-KEY ( disturbance\* )) OR ( TITLE-  
 ABS-KEY ( "edge effect" )) OR ( TITLE-ABS-KEY ( "fire" )) OR ( TITLE-ABS-  
 KEY ( "logging" )) OR ( TITLE-ABS-KEY ( harvesting )) AND ( TITLE-ABS-  
 KEY ( island )) OR ( TITLE-ABS-KEY ( isle )) OR ( TITLE-ABS-  
 KEY ( archipelago )) OR ( TITLE-ABS-KEY ( islet )) OR ( TITLE-ABS-  
 KEY ( atoll )) OR ( TITLE-ABS-KEY ( isla )) OR ( TITLE-ABS-  
 KEY ( islote )) ( TITLE-ABS-KEY ( archipelago )) OR ( TITLE-ABS-  
 KEY ( atolon ))

## EFFECT OF LAND-USE CHANGE ON THE COMMUNITY ASSEMBLAGE OF THE LANDBIRDS OF SAN CRISTOBAL, GALAPAGOS

Daniel Velarde-Garcez<sup>1</sup> & Diego F. Cisneros-Heredia<sup>1,2,3</sup>

<sup>1</sup> Universidad San Francisco de Quito USFQ, Colegio de Ciencias Biológicas & Ambientales, Laboratorio de Zoología Terrestre, Quito 170901, Ecuador

<sup>2</sup> King's College London, Department of Geography, London, UK

<sup>3</sup> Aves&Conservación / BirdLife Ecuador, Quito, Ecuador

### ABSTRACT

Habitat change affects diversity of bird communities, allowing the expansion and dominance of some guilds and species, and the decline or even local extinction of others. This study analyzed differences in the diversity of bird communities in the San Cristobal island, Galapagos archipelago, Ecuador, between different habitats on the lowlands (old-growth lowland deciduous forests and suburban and urban green areas) and on the highlands of the island (old-growth seasonal evergreen forest and agricultural areas). We sampled each habitat using visual transects and mist netting. Communities on the highlands showed a greater difference in terms of community assemblage, but not pronounced differences in terms of abundance. On the highlands, insectivorous endemic species were mostly restricted to the old-growth forests, while granivorous endemic species were extremely dominant on agricultural areas, as well as introduced species (Smooth-billed Ani *Crotophaga ani*). On the lowlands, species communities were fairly similar in terms of their species richness. Yellow Warbler (*Setophaga petechia aureola*) was the only species that showed no variation in their abundance and frequency across all habitats. This study has strong implications for the formulation of conservation strategies and policy-making focused on the management of urban and agricultural areas in San Cristobal Island.

**Keywords:** landbirds, land-use change, habitat change, community assemblage, Galapagos, agriculture, urbanization

### INTRODUCTION

Human population growth has a positive correlation with the expansion of agriculture, urbanization, logging, and introduction of exotic animals and plants (Meyer & Turner, 1992; Bagan & Yamagata, 2015). Locally, land-cover change alters the vegetation, and subsequently the availability of resources which entail different types of variations on biodiversity (Scholtz *et al.*, 2017; Yohannes *et al.*, 2017). Resource dependency for a type of vegetation could occur for several reasons, like amount or composition of food (Graham *et al.*, 2013; Mizuta, 2014), vegetation needed for nesting and sheltering (Baber & Craig, 2003; Stirnemann *et al.*, 2015), or local climate, like temperatura, relative humidity and light intensity (Lindell *et al.*, 2004; Afrane *et al.*, 2005; Rajpar & Zakaria, 2011). Evidence published and common sense generally supports that anthropogenic land-cover change has only negative effects on biodiversity richness and abundance (Díaz *et al.*, 2005; Reidsma *et al.*, 2006; Flynn *et al.*, 2009), however, a considerable amount of literature exhibits that this relation is far more complex, and that it changes between species (Dellasala *et al.*, 1996; Camp *et al.*, 2012) and type of land-cover disturbance (Jewell & Arcese, 2008; Fullard *et al.*, 2010).

Birds are one of the most studied groups due to their relatively fast adaptation, high capacity of dispersal, large richness and easy detectability. Results of the population trends in birds contribute valuable information to understand the human-induced impacts on other groups of animals (Pimm, 2001; ZoBell & Furnas, 2017). Evidence suggest that in birds the most affected species are native species, and especially endemic species (Hahn, 2011; Barbaro, 2012; Wilson *et al.*, 2014; ZoBell & Furnas, 2017). Exotic species are more likely to be benefited by human-induced land-cover disturbances (Hahn, 2011; Barbaro, 2012; Wilson *et al.*, 2014; ZoBell & Furnas, 2017). Insectivorous appear to be the most affected feeding-guild, while granivorous are benefited in many cases (Dvorak *et al.*, 2012; Davies *et al.*, 2015). Impacts on home-range size (Warren *et al.*, 2015), food consumption (Díaz *et al.*, 1999; Barbaro, 2012), reproductive success (Ha *et al.*, 2011; Stirnemann *et al.*, 2015), prevalence of diseases (Zylberberg *et al.*, 2013), reproduction time (Akatani *et al.*, 2011), movement (Potter, 1990; Seaton *et al.*, 2008) and extinction (Boyer *et al.*, 2010; Thibault & Cibois, 2012) have been evidenced when anthropogenic land-cover occurs.

Among all geographic areas oceanic islands stand out, due to their high endemism on account of their isolation (Kier *et al.*, 2009). Island populations of birds have been damaged more than mainland populations. As evidence, over 90% of bird extinctions on the past 400 years have occurred on islands (Stattersfield, 1988). This trend is mainly due to introduced mammals, the sum of this with their reduced distribution makes them more prone to extinction. Most threatened islandbirds are forest-dwellings that use seasonal or temperate forests, so it is considered that habitat destruction represents now the biggest threat to islandbirds (Johnson & Stattersfield, 1990). For the Galapagos Islands it is believed that the situation is a little different, since it appears that most of its avifauna remains unaltered (Wiedenfled, & Jiménez-Uzcátegui, 2008). Only the San Cristobal Vermilion Flycatcher (*Pyrocephalus dibus*) has become globally extinct on the archipelago since historical times, even though more extinctions have occurred locally on islands, like the Galapagos Hawk (*Buteo galapagensis*) on San Cristobal or the Grey Warbler-Finch (*Certhidea fusca*) on Floreana (Grant *et al.*, 2005; Dvorak *et al.*, 2017). Local extinctions in this archipelago are mainly attributed to habitat conversion, especially on the highly agricultural highlands, and introduction of species (Dvorak *et al.*, 2017).

Evolution of Galapagos' birds has been extensively studied, but their ecology has always been left apart. In Santa Cruz and Floreana exists extensive surveys of landbirds that report local extinctions or worryingly population declines that are attributed to habitat loss, but these types of studies are missing on San Cristobal (Dvorak *et al.*, 2012; Dvorak *et al.*, 2017). However, there are no studies that have tested the relationship between habitat change and the community assemblage on the Galapagos birds. Because of this, our study aims to understand the effects of the land-use change on the landbirds of San Cristobal, on the Galapagos Island, rather than giving an actual estimation of the population size or threat status.

## METHODS

### *Study sites*

We conducted this study on San Cristobal island, a volcanic island of 558 km<sup>2</sup>, in the Galapagos Islands. It is the fourth island in size and one of the oldest of the archipelago (Gordillo & Work Kendrick, 1989). It was colonized around 1866, on the southwest of the island, and since then began one of the more drastic human-induced land cover alterations of the archipelago (Gordillo & Work Kendrick, 1989). It is the

island with the largest percentage of agricultural area (15%) in Galapagos, all concentrated on the highlands (Rivas-Torres *et al.*, 2018). The two native highland ecosystems, the evergreen seasonal forest and shrubland (3.3%), and the evergreen forest and shrubland (0.1%), present a very reduced relative area on San Cristobal (Rivas-Torres *et al.*, 2018). The most extensive ecosystem on the island is the Deciduous forest (58%). Urban area (0.3%) is mostly concentrated in the lowland, although it also exists a small settlement in the highland. The island has serious problems with invasive plant species, especially *Psidium* (Guava; 0.3%) and *Cedrela* (Cedar; 0.04%).

Our bird surveys were conducted on the southwest lowland and on the west of the highland. We sampled on three points on the Deciduous forest, three on Green urban areas, three on Evergreen seasonal forest, and three on Agricultural area. For the exact coordinates of the sampling sites see **Table 1**. The Green urban areas were two points on the periphery of Puerto Baquerizo Moreno, and one point on a small green corridor inside the city (see **Figure 1**). Agricultural areas on the highlands were grazing pastures with low density of citrus trees. Sites were selected using the vegetation map of Galapagos (Rivas-Torres *et al.* 2018) and according to the accessibility to the locations.

#### *Data collection*

Surveys were conducted during 36 days between 21 June and 11 August, 2017. We sampled each point for three days, in the morning and in the afternoon. The morning period started with a transect of 500 m performed by one investigator at 6h00. Identification along transects was visual, and up to 50 meters off the transect approximately. In every sighting it was registered: species, sex, age, time, behavior and approximate distance to transect.

At 6h30 it was conducted 3.5 hours of mist nets. We used three nets of 6 meters of height and 2.6 meters of width. In every capture of the mist nets the following data was recorded: species, sex, age, reproductive state, incubation patch, cloacal bump, furcular fat, weight, wing length, beak length, beak width, beak height, tarsus length, moult, number of pox pustules, time of capture and number of net.

In the afternoon the sequence of survey was the same, but starting with the mist nets at 14h30, and doing the transect at 18h00. Total sampling effort of on each habitat was of 94.5 net-hours and 9 hours on transects. A total of 378 net hours and 36 hours of transects was covered in the study.

#### *Data analysis*

A chi-square was performed to assess the difference in the community assemblage (abundance of all the species) between the zones. This analysis was conducted with species and with the feeding-guilds. Chi-square was also used to analyze differences in abundance between zones for each species. It was only used the identified records, since several individuals just passed flying briefly and were unable to be identified. ANOVAs were used to evaluate if there was any difference in the all measurements between the zones. To analyze alpha-diversity we used a Shannon index analysis, and for beta-diversity a Jaccard similarity analysis. All the results were performed with the data collected with mist nets and with transects. Finally, we performed a Pearson correlation between the mist nets and the transect results to assess if the methodologies agreed. All analysis were performed on RStudio Version 1.1.383 and Past 3.16.

## RESULTS

### *Comparison of methods*

When plotting the relationship of the log abundance of the species according to both methods the results show coherence ( $R = 0.95$ ;  $p = 0.001$ ). For this analysis it was excluded the introduced Smooth-billed Ani and the endemic San Cristobal Mockingbird, since it presented a position biased towards transects. Both species were commonly registered on the transect sampling, but were rarely caught in the nets.

### *Community assemblage*

According to mist nets, difference in abundance between deciduous forest and urban area was drastic. On deciduous forest 115 individuals were captured, while only 33 on urban area ( $p < 0.005$ ). Abundance of transect counts was similar across the sites, with 467 individuals on deciduous forest and 468 on urban area. Community assemblages in the two zones were not significantly different, neither with transects nor with mist nets (see **Figure 3**). Yellow Warbler and Small Ground-finch were significantly more abundant on deciduous forests ( $p = 0.049$ ;  $p < 0.001$ ), but their relative abundance did not differ (see **Table 2**). According to transect counts the only species that differ in the abundance between both zones was Small Tree Finch, that was significantly less abundant on the urban area ( $p = 0.005$ ).

We obtained 83 captures on the seasonal evergreen forest, while 133 on the agricultural area. With transects abundance was significantly higher on the agricultural area than on seasonal evergreen forest ( $p < 0.001$ ). On agricultural area 898 individuals were sighted, and on seasonal evergreen forest 344. Community assemblage between the two habitats were significantly different with mist nets and transects ( $p = 0.006$ ;  $p < 0.001$ ) (see **Figure 3B**). Grey Warbler-finch was more abundant on the seasonal evergreen forest than on the agricultural area when analyzing mist nets and transects ( $p = 0.018$ ;  $p < 0.001$ ). Small Ground finches were especially abundant on the agricultural area, while being very scarce on the seasonal evergreen forest with the data of both methods ( $p < 0.001$ ;  $p < 0.001$ ). Medium ground Finches were significantly more present on the agricultural area than on seasonal evergreen forest only with the mist nets results ( $p < 0.05$ ). When analyzing transects, Galapagos Flycatcher was slightly more abundant on seasonal evergreen forest ( $p = 0.04$ ). Small Tree Finch and Smooth-Billed Ani were slightly more present on the agricultural area ( $p < 0.001$ ;  $p = 0.01$ ), both with mist nets and transects (see **Table 2** and **Figure 3**).

When grouping species into trophic-guilds, the results were similar than with species. It was found that the urban green area and deciduous forest do not differ on community assemblage, while the two highland zones differ ( $p < 0.001$ ). Both results were supported by transects and mist nets. On the seasonal evergreen forest, the insectivorous were the most captured guild (63.9%), while on the agricultural land they were the second most captured (26.3%). Agricultural land had a high dominance of the granivorous (58.7%), and seasonal evergreen forest a lower presence of this guild (24.1%). The other guilds were similar between the two zones.

On seasonal evergreen forest we obtained a Shannon index of 2.79, on agricultural area 2.47, on urban area 1.99 and on deciduous forest 1.97 with mist nets. The Shannon index with transects were the same than by mist nets, except that the deciduous forest had a higher index than the urban area. Similarity trees with transects

and mist nets clustered the sites of every habitat, supporting that community assemblages were more similar within habitats than between them (see **Figure 2**).

### *Measurements*

Measurements comparisons between habitats were only performed for Small Ground-finch and Yellow-Warbler, since they were the only ones with a representative sample in all sites. Small Ground-finch presented more weight on both highland habitats and on the urban area (SEF =  $15.5 \pm 0.79$  g; AA =  $15.13 \pm 0.96$  g;  $15.22 \pm 0.85$  g) than on deciduous forest ( $13.73 \pm 1.14$  g). Tarsus length was significantly lower on urban area ( $1.93 \pm 0.05$  cm) than on seasonal evergreen forest ( $2.2 \pm 0.19$  cm;  $p = 0.004$ ). The beak was longer on the deciduous forest ( $0.63 \pm 0.16$  cm) and on seasonal evergreen forest ( $0.67 \pm 0.12$  cm) than on urban ( $0.49 \pm 0.06$  cm) and agricultural ( $0.52 \pm 0.07$  cm) areas. The Yellow Warbler was significantly lighter on deciduous forest ( $11.22 \pm 0.85$  g) than on agricultural area ( $11.22 \pm 0.83$  g) and seasonal evergreen forest ( $12.58 \pm 0.81$  g). The beak was wider on the deciduous forest ( $0.43 \pm 0.04$  g) than on urban ( $0.37 \pm 0.037$  cm) and agricultural ( $0.37 \pm 0.04$  cm) area. The measurements for all the species are reported on **Table 3**.

### *Pox prevalence*

Only 17 of the 345 individuals captured with the nets presented pox-like pustules on their legs. One individual presented five pustules, other had three, two had two, and the rest presented only one pustule. Ten of the individuals with pox were Small Ground-finch, three were Medium Ground-finch, other three were Small Tree-finch, and one was a Yellow Warbler. 14 of the individuals were captured on the deciduous forest, two on the urban area, one on the agricultural area and none on the seasonal evergreen forest.

## **DISCUSSION**

The comparison of the results of the two methods suggest that both methodologies agreed. By sampling with two methods we believe that our results are more conclusive than if we had only selected one. The similarity trees seem to indicate that the bird communities of the sites were actually more similar within habitats than between them (see **Figure 2**). This result suggests that the communities were equivalent between the sites of a habitat.

Results suggest that the land conversion to agriculture in the highland has changed the assemblage of the community of landbirds, by increasing the abundance of some species and reducing of others. This result was supported by the mist nets and transects sampling methods. Apparently, in the lowland there is no change on the community assemblage of the birds due to urbanization, however evidence support an alteration of the community in the highland due to agriculture (see **Figure 3**). Many studies report that the conversion of the land-cover to pasture benefit the granivorous birds due to the increase of seeds feed (Waltert *et al.*, 2005; Wilson *et al.*, 2014), which is also observed in our study. In the agricultural area we found an increase of Small Ground-finches, which are predominantly granivorous, but also feed of arthropods and buds. Small Tree-finch and exotic Smooth-billed Ani were also more abundant on the agricultural area, but to a lesser extent than the Small Ground-finch. The higher abundance of Smooth-billed Ani agrees with the literature that suggests that exotic species are more likely to be benefit by the land-use change (Hahn, 2011; Barbaro, 2012; Wilson *et al.*, 2014; ZoBell & Furnas, 2017). Two insectivorous were significantly more common on seasonal evergreen forest, Grey Warbler-finch and

Galapagos Flycatcher. This results agree with a vast quantity of literature that propose that insectivorous are the most affected feeding-guild, due to the loss of vegetation that supports the arthropods of which they feed (Waltert *et al.*, 2005; Dvorak *et al.*, 2012; Davies *et al.*, 2015). The situation is more critical for the Grey Warbler-finch, since it was uncommon on the lowland, and was the species with the biggest reduction of abundance on agriculture on the highlands. Also this species has been declared extinct in Floreana (Grant *et al.*, 2005; Dvorak *et al.*, 2017). Even though it is suggested that the cause of the decline and increase of the abundance of some species is the change in the food resource that subsequently reduce or increase the carrying capacity, in this study we evaluated if there was a community change and the pattern of it, and not the cause of the community change. Analysis of food consumption, food availability or habitat use should be made to understand if this is actually the cause of the change in the abundance (Díaz *et al.*, 1999; Barbaro, 2012).

In the lowland there is no clear evidence of alterations in the community with any of the methods (see **Figure 3**). Even though mist nets reported an abrupt change in abundance between the urban area and the deciduous (see **Figure 3B**) forest this result was not supported by transects, probably due to the structure of the vegetation on the urban area. The urban and suburban green areas were more open than the deciduous forest, what could have made the mist nets easier to detect or reduce the movement of birds (Jenni *et al.*, 1996).

Since our objective was to test the effect of land-use change on the community of birds, and not to evaluate the population status of the birds through density or population estimations, we did not try to sample a larger portion of the island. On the other hand, we think it is important to report the general patterns of the presence of the birds. We did not observe any Galapagos Dove (*Zenaida galapagoensis*), San Cristobal Vermillion Flycatcher (*Pyrocephalus dibius*), Galapagos Hawk (*Buteo galapagoensis*), nor Galapagos Crakes (*Laterallus spilonotus*), either during the samplings or outside the sampling time. Vargas also did not find these species in his trip to the island on 1997 (Vargas, 1997). Although the Galapagos Dove and the Galapagos Crake are not extinct in the island, they seem to be very rare (Vargas, 1997). Paint-billed Crake (*Neocrex erythrops*) was not observed, except for one dead individual in the road to El Junco. Barn Owl (*Tyto alba*) was seen twice at two different sites of the highland while returning to the camp in the night, after closing the nets. Vegetarian Finch (*Platospiza crassirostris*) was observed in all the habitats, but at very low rates. Woodpecker Finch (*Geospiza pallida*) was only registered on the highland, being slightly more common on the seasonal evergreen forest, but the difference was not significant, probably due to the low sampling. The other species: Yellow Warbler (*Setophaga petechial*), Galapagos Flycatcher (*Myiarchus magnirostris*), San Cristobal Mockingbird (*Mimus melanotis*), Small Tree-Finch (*Geospiza parvula*), Small Ground-finch (*Geospiza fuliginosa*), Medium Ground-finch (*Geospiza fortis*), Grey Warbler-finch (*Certhidea fusca*) and Smooth-billed Ani (*Crotophaga ani*) were fairly common in all habitats.

It was found that both species, Small Ground-finch and Yellow Warbler weighed less on the deciduous forest than on both highland habitats. Many uncontrolled variables could be the explanation for this difference. Some articles have reported a loss on the body mass due to a decrease of the availability of food (Owen & Cook, 1977; Schochat, 2004; Anderson, 2006; Liker *et al.*, 2008), increase of stress (Piersma & Ramenofsky, 1998), of temperature (Kelly *et al.*, 2002), or of dioxide pollution (Vincent, 2005). These environmental conditions could originate a substantial difference during the nestling development (Liker *et al.*, 2008). In Hawaii it has been



found that avipox virus could contribute to apparent loss of weight due to reduced feed consumption (Tripathy *et al.*, 2000). On deciduous forest the avipox prevalence was higher, what could explain the difference of weight. One study found a consistence reduction of the tarsus length in more urbanized areas, but they fail to explain a cause (Liker *et al.*, 2008), which agrees with our find of the smaller tarsus of the Small Ground-finch on the urban area. The beak size is correlated with the diet of the finch. In particular, the average beak size of a population increase when abundance of small or soft seeds decline (Grant & Grant, 1995; Grant & Grant, 2002). It is probable that the seeds of the deciduous forest are bigger or harder, what could had led to a bigger beak on the deciduous forest population of Small Ground-finch, although we cannot conclude this since we did not study the diet or food availability.

A higher prevalence of pox-virus on the low and mid-elevations has also been found on Santa Cruz (Kleindorfer & Dudaniec, 2006) and on Hawai'i (VanderWerf, 2001; van Riper *et al.*, 2002; Atkinson *et al.*, 2005). They report that this distribution could be due to the higher activity of the mosquito vectors (VanderWerf, 2001; van Riper *et al.*, 2002; Atkinson *et al.*, 2005). The higher prevalence of pox-like virus on the deciduous forest than on the urban area may be due to the lower number of captures on the latter.

Even though this article presents results of only one year it shows preliminary patterns that will be sampled deeper in further years, since we are developing a long-term study in the island. The results of this study are truly important for the policy-making of the management of urban and agricultural areas on San Cristobal, and all Galapagos. Grey Warbler-finch, the species that showed to be the most affected by agriculture, had been reported as absent in Floreana since 2005. Probably, the disappearance of this species in Floreana happened because of the habitat loss (Grant *et al.*, 2005; Dvorak *et al.*, 2017). This is worryingly for San Cristobal, since it is the most agricultural island of the archipelago. San Cristobal could follow that fate if certain measures are not taken. Besides, San Cristobal is the only island of the archipelago that has suffered a bird global extinction, and at least the local extinction of the Galapagos Hawk, although it probably also existed a population of Sharp-beaked Finch (*Geospiza difficilis*) (Harris, 1973; Vargas, 1997; Wiedenfeld, 2006). A reforestation campaign of the agricultural area on the highland should be started to appease the disturbances of the land-cover changes on the avifauna of the island (Forbes & Craig, 2013; Paxton *et al.*, 2017).

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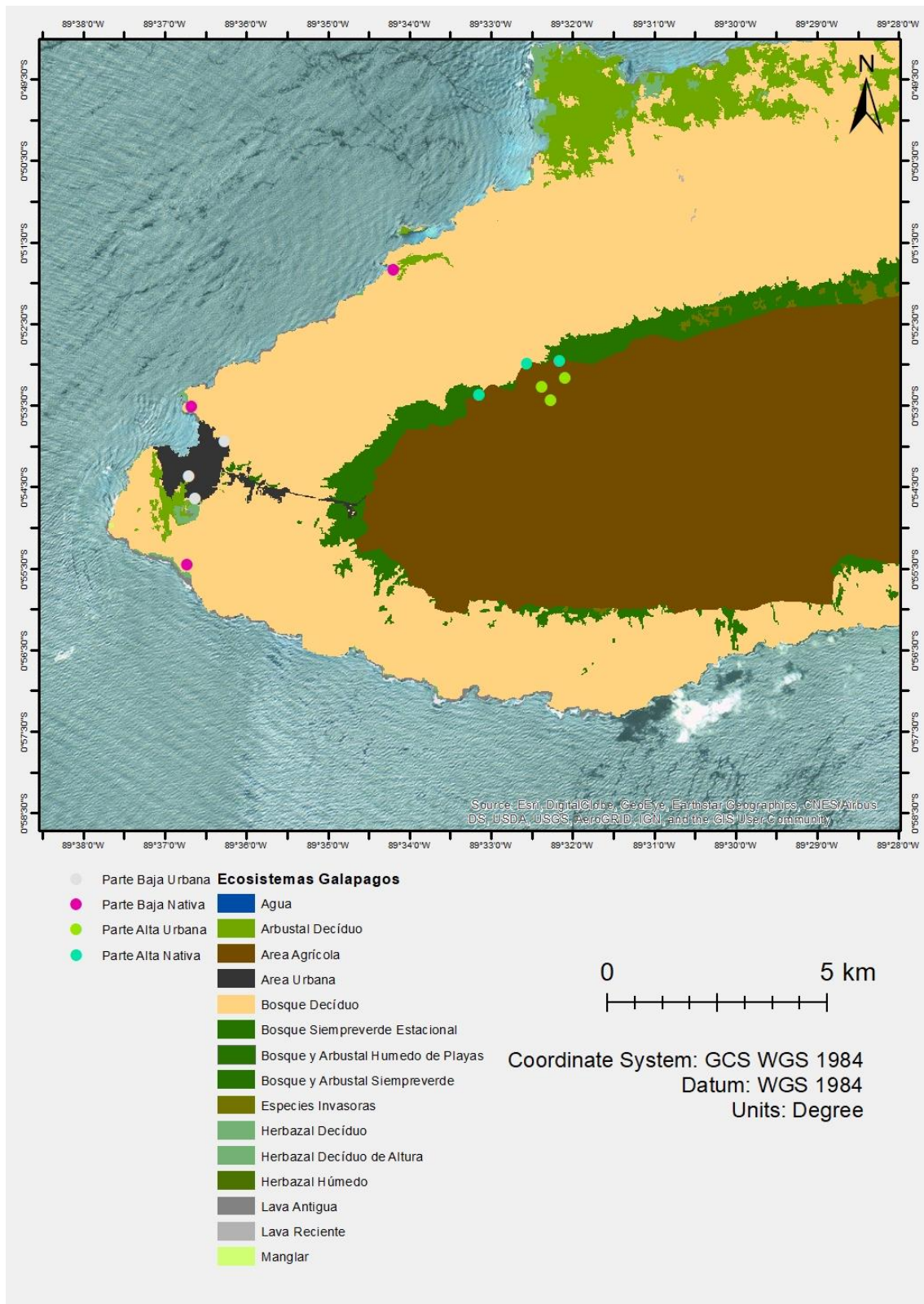
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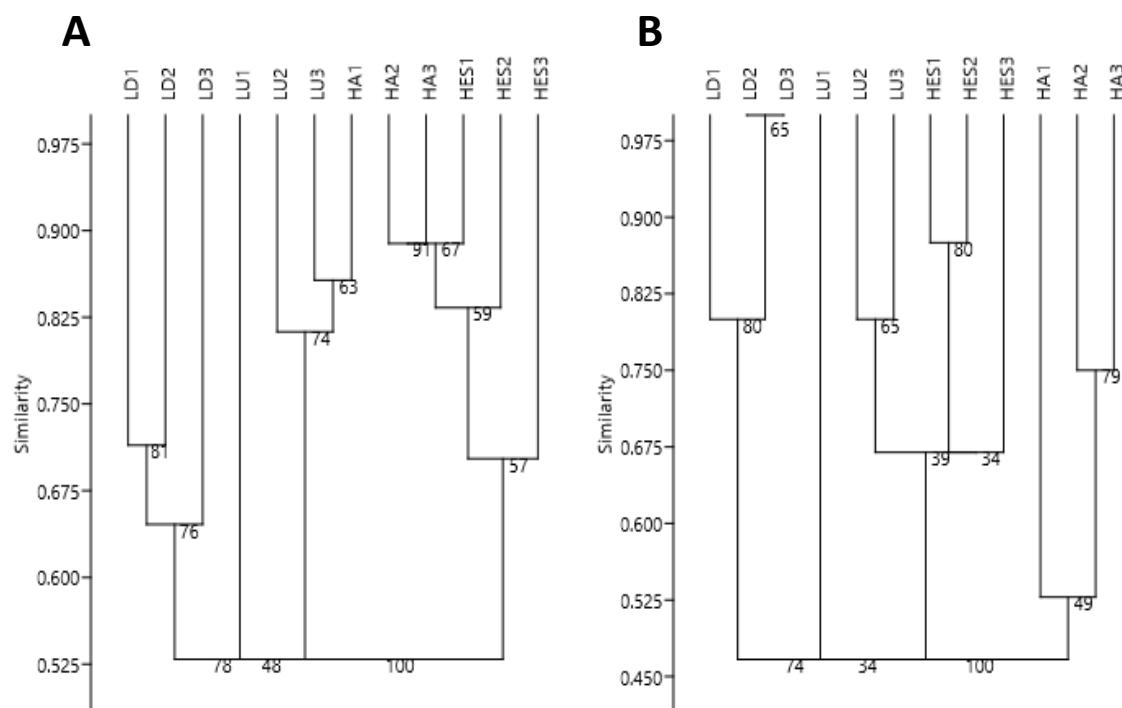
## APPENDIX. Figures and tables.



**Figure 1.** Map of the vegetation of San Cristobal obtained from Rivas-Torres *et al.*, 2018 with the sampling points of the study.

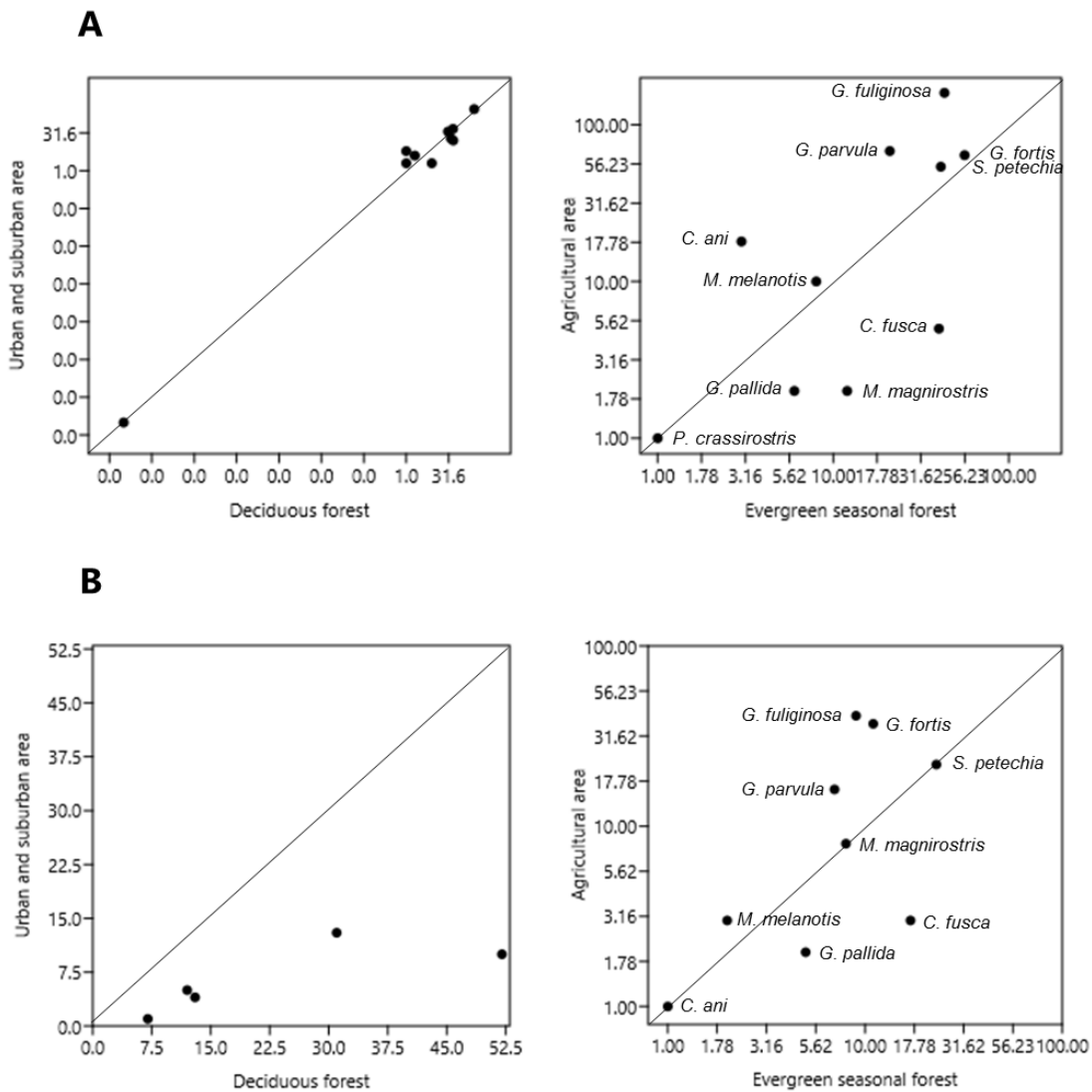
**Table 1.** Coordinates of the 12 sites sampled for the study. LD = sites of the Lowland Deciduous forest. LU = sites of the Lowland Urban and Suburban Area. HES = sites of Highland Evergreen Seasonal Forest. HA = sites of the Highland Agricultural Area.

Lowland deciduous	LD1	-0° 53' 31.02", -89° 36' 40.5"
	LD2	-0° 51' 50.36", -89° 34' 11.89"
	LD3	-0° 53' 56.69", -89° 36' 15.95"
Green urban areas	LU1	-0° 55' 27.25", -89° 36' 43.65"
	LU2	-0° 54' 22.1", -89° 36' 42.43"
	LU3	-0° 54' 38.41", -89° 36' 37.52"
Agricultural area	HA1	-0° 53' 16.3", -89° 32' 22.49"
	HA2	-0° 53' 9.53", -89° 32' 5.53"
	HA3	-0° 53' 25.98", -89° 32' 15.83"
Evergreen seasonal forest	HES1	-0° 52' 56.96", -89° 32' 9.6"
	HES2	-0° 53' 22.24", -89° 33' 8.42"
	HES3	-0° 52' 59.12", -89° 32' 33.32"



**Figure 2.** A. Similarity analysis between the 12 study sites in the four habitats performed with the transect results. B. Similarity analysis between the 12 study sites in the four habitats performed with the mist nets results. LD = sites of the Lowland Deciduous forest. LU = sites of the Lowland Urban and Suburban Area. HES = sites of Highland Evergreen Seasonal Forest. HA = sites of the Highland Agricultural Area.





**Figure 3.** A. Comparison of the landbird community assemblage between native and human-disturbed habitats in the lowland and in the highland performed with transects. B. Comparison of the landbird community assemblage between native and human-disturbed habitats in the lowland and in the highland performed with mist nets. Comparisons were made with log abundance of each species.

**Table 2.** Abundance and frequency of the species in the four habitats with mist net and transect sampling. Un-identified individuals are not reported on the table.

Species	Mist Nets								Transects							
	Seasonal evergreen forest		Agricultural area		Deciduous forest		Urban and suburban green areas		Seasonal evergreen forest		Agricultural area		Deciduous forest		Urban and suburban green areas	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
<i>Setophaga petechia</i>	23	27,7%	22	16,5%	31	27,0%	13	39,4%	41	17,7%	54	14,1%	45	10,6%	46	11,2%
<i>Myiarchus magnirostris</i>	8	9,6%	8	6,0%	7	6,1%	1	3,0%	12	5,2%	2	0,5%	8	1,9%	2	0,5%
<i>Mimus melanotis</i>	2	2,4%	3	2,3%	-	-	-	-	8	3,5%	10	2,6%	1	0,2%	6	1,5%
<i>Geospiza parvula</i>	7	8,4%	16	12,0%	12	10,4%	5	15,2%	21	9,1%	68	17,7%	46	10,9%	16	3,9%
<i>Geospiza pallida</i>	5	6,0%	2	1,5%	-	-	-	-	6	2,6%	2	0,5%	-	-	-	-
<i>Geospiza fuliginosa</i>	9	10,8%	41	30,8%	52	45,2%	10	30,3%	43	18,6%	160	41,7%	252	59,6%	280	68,1%
<i>Geospiza fortis</i>	11	13,3%	37	27,8%	13	11,3%	4	12,1%	56	24,2%	64	16,7%	38	9,0%	19	4,6%
<i>Crotophaga ani</i>	1	1,2%	1	0,8%	-	-	-	-	3	1,3%	18	4,7%	30	7,1%	36	8,8%
<i>Certhidea fusca</i>	17	20,5%	3	2,3%	-	-	-	-	40	17,3%	5	1,3%	2	0,5%	4	1,0%
<i>Plataspiza crassirostris</i>	-	-	-	-	-	-	-	-	1	0,4%	1	0,3%	1	0,2%	2	0,5%
<b>Total</b>	83	100%	133	100%	115	100%	33	100%	231	100%	384	100%	423	100%	411	100%

**Table 3.** Measurements of the birds in the four habitats. WL = Wing length. TL = Tarsus length. BL = Beak length. BW = Beak width. BD = Beak depth.

	Weight (g)	WL (cm)	TL (cm)	BL (cm)	BW (cm)	BD (cm)
<i>Setophaga petechia</i> (n=53)	9,8-14,25 (11,69±1,04)	5,8-6,7 (6,30±0,24)	1,9-2,5 (2,12±0,13)	0,7-1,3 (0,93±0,15)	0,3-0,51 (0,41±0,06)	0,25-0,58 (0,34±0,05)
<i>Myiarchus magnirostris</i> (n=18)	10,2-14,5 (12,81±1,07)	5,2-6,8 (5,95±0,45)	1,95-2,7 (2,21±0,22)	0,9-1,7 (1,15±0,22)	0,4-0,7 (0,57±0,069)	0,4-0,5 (0,44±0,04)
<i>Mimus melanotis</i> (n=2)	44-49,2 (46,6±3,68)	9,9-10,7 (10±0,50)	3,5-3,8 (3,65±0,13)	1,4-1,6 (1,51±0,08)	0,4-0,5 (0,45±0,05)	0,5-0,55 (0,52±0,03)
<i>Geospiza parvula</i> (n=32)	12-17 (14,1±-1,04)	5,4-7,3 (6,28±0,39)	1,97-2,6 (2,2±0,19)	0,4-1 (0,77±0,10)	0,4-0,7 (0,58±0,075)	0,6-0,8 (0,73±0,06)
<i>Geospiza pallida</i> (n=5)	19,8-21,75 (20,55±0,78)	6,3-7,2 (6,8±0,32)	2,2-3 (2,67±0,37)	0,9-1,1 (0,97±0,088)	0,55-0,8 (0,64±0,1)	0,5-0,95 (0,77±0,16)
<i>Geospiza fuliginosa</i> (n=75)	11,5-17,5 (14,35±1,33)	5,5-6,9 (6,04±0,25)	1,8-2,9 (2,06±0,18)	0,7-1,1 (0,90±0,08)	0,4-0,75 (0,59±0,09)	0,4-0,85 (0,71±0,09)
<i>Geospiza fortis</i> (n=36)	19-25,75 (22,46±1,48)	6-7,7 (6,93±0,38)	1,9-2,8 (2,31±0,19)	1-1,4 (1,19±0,10)	0,6-1,3 (0,90±0,16)	0,9-1,4 (1,14±0,11)
<i>Certhidea fusca</i> (n=12)	8,25-11 (9,16±0,82)	4,3-5,5 (4,88±0,35)	1,9-2,45 (2,19±0,18)	0,63-0,8 (0,716±0,05)	0,3-0,42 (0,32±0,03)	0,3-0,4 (0,36±0,03)