UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

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Quantifying the impacts of introduced on the native biodiversity of the Galápagos Islands using the EICAT framework

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RESUMEN

Las especies introducidas invasoras son la primera causa de extinción de organismos nativos en islas. En las Galápagos, existen estudios sobre la ecología de especies introducidas invasoras EII. Sin embargo, las investigaciones generadas en el archipiélago no se han evaluado bajo una metodología estructurada, donde se categorice a las EII por la magnitud de su impacto. La Clasificación de Impactos Ambientales para Taxones Exóticos, EICAT, es un estándar internacional que cuantifica el impacto reportado para una EII y la clasifica dentro de una de cinco categorías de amenaza. Para evaluar la magnitud de los impactos ecológicos de las EII de plantas, vertebrados e invertebrados terrestres reportados para las Islas Galápagos, se utilizó por primera vez para este archipiélago la metodología EICAT. Específicamente, se condujo primero, una búsqueda sistemática de información de impactos; segundo, se validó la información generada por esta búsqueda con expertos y; tercero, se realizaron listas de especies prioritarias según el nivel de impacto más alto reportado por los estudios. Se analizaron más de tres mil artículos, de los cuales solo 90 reportaban información relevante sobre impactos. Los invertebrados y vertebrados representaron el 77% de la información válida, mientras que las plantas fueron el grupo con menos información de impactos. Particularmente, *Philornis downsi, Rattus rattus* y *Rubus niveus* fueron las especies donde se encontraron más estudios relevantes para EICAT. Este análisis constituye la primera aproximación para entender cuánta información sobre impactos se ha generado en las Islas Galápagos y en qué grupos se ha concentrado. Además, los datos generados constituyen una línea base importante para dirigir las decisiones de manejo generadas por el Parque Nacional Galápagos y otras instituciones de conservación presentes en las islas.

Palabras clave: EICAT, Galápagos, EII, revisión, plantas, vertebrados, invertebrados, clasificación, impactos

ABSTRACT

Invasive alien species are the main cause of extinction of native organisms on islands. In Galapagos, there are studies on the ecology of invasive alien species, IAS. However, the research generated in the archipelago has not been evaluated following a structured methodology that categorizes each IAS by the magnitude of its impact. The Environmental Impact Classification for Exotic Taxa, EICAT, is an international standard that quantifies the reported impact of an IAS and classifies it into one of five ecological impact categories. To assess the magnitude of the ecological impacts of introduced terrestrial plants, vertebrates, and invertebrates, for the Galapagos Islands, the EICAT methodology was used for the first time for this archipelago. First, a systematic search for impact information was conducted; second, the information generated by this search was validated with experts; and third, priority species were listed according to the highest level of impact reported by the studies. More than three thousand articles were analyzed, of which only 90 reported relevant information on impacts. Invertebrates and vertebrates accounted for 77% of the valid information, while plants were the group with the least impact information. Particularly, *Philornis downsi*, *Rattus rattus* and *Rubus niveus* were the species for which more studies relevant to EICAT were found. This analysis constitutes the first attempt to understand how much information on impacts has been generated in the Galapagos Islands following the EICAT framework, and in which groups it has been concentrated. In addition, the data presented in this study constitute an important baseline to guide management decisions generated by the Galapagos National Park and other conservation institutions present in the islands.

Key words: EICAT, Galapagos, IAS, review, plants, vertebrates, invertebrates, classification, impacts.

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INTRODUCTION

When species are moved by human activities from their native geographic range to areas where they were not present before, they are defined as alien or introduced species (Lockwood et al., 2013). If these alien species cause negative impacts in their newly encountered ecosystems, we call them Invasive Alien Species (IAS) (Lockwood et al., 2013). IAS can cause ecological and socioeconomic impacts, which may vary in magnitude, and affect either a specific taxonomic group or an entire ecosystem (Kumschick & Richardson, 2013). This is why, it is increasingly important to have methodologies that can allow us to characterize and standardize IAS impact information, in order to compare heterogeneous alien species impact data (Evans et al., 2016).

A standardized novel method to categorize IAS impacts is the Environmental Impact Classification of Alien Taxa, EICAT. As proposed for the first time by Blackburn et al. (2014), EICAT allows an objective analysis, exclusively considering information on impacts as previously reported in peer-reviewed scientific articles, books, and gray literature such as theses, reports, IAS databases, or unpublished articles. Although secondary sources of information, personal opinions, and impact predictions are relevant in another context, according to the EICAT guidelines they are not considered a valid source of information and are therefore not to be used within this standard. (Blackburn et al., 2014; Hawkins et al., 2015). Based on this systematic review, each of the impacts reported by the primary data sources are assigned to one of the five EICAT impact categories, and each IAS is categorized according to the harmful magnitude of the reported environmental impacts.

On the other hand, Hawkins et al., (2015) developed standardized guidelines for EICAT. Their objective was that no matter the location of IAS and species analyzed, if it is an animal or a plant, the information generated can be globally compared. In this sense, can be applied at a local, regional, or global scale, allowing to show patterns and establish a priority list of invasive species with quantified impacts, which are relevant in terms of IAS management. Moreover, the EICAT methodology has been adopted since 2020 as the official IUCN IAS impact classification system and implemented as the official standard by the Global Invasive Species Database (GISD), and by the Species Survival Commission (SSC).

Currently, there are many articles that classify IAS of different taxa based on this assessment. Evans et al. (2016) first applied the EICAT methodology to worldwide introduced birds and were able to report the main mechanisms of alien bird invasion. Additionally, it allowed to discover of important data gaps concerning this group thanks to the EICAT standard (Evans et al., 2018). Other groups analyzed in the last years using the EICAT methodology were amphibians (Kumschick et al., 2017), New England alien plants (Coville et al., 2021), gastropods (Kesner & Kumschick, 2018), and introduced Acacias in South Africa (Jansen & Kumschick, 2022), among others. All these EICAT impact studies have been proven to be relevant for more focused conservation management decisions by generating lists of priority species (Henry & Sorte, 2022). The EICAT assessment by Roy et al., 2019) currently is accepted by the Parliament of the European Union as the leading baseline list of alien species that could threaten the European biodiversity and ecosystems and is used to make management decisions to mitigate future alien species impacts. Until now, EICAT has not been applied to quantify the impacts of alien species on the Galapagos Islands.

The Galapagos Islands are known for their natural appeal, their highly endemism biodiversity, and interesting natural history. However, their biodiversity is being threatened by the presence of close to 1,500 introduced species that act on ecological and socioeconomic levels (Toral-Granda et al., 2017). This concern has motivated research focused on understanding the effects of foreign taxa on the native communities of the island. Nevertheless, they have mainly focused on the introduced vertebrates impacts (Cisneros-Heredia, 2018). Despite the availability of a significant amount of information on these impacts such as reproduction, feeding, population declines, and even extinctions of native Galapagos species caused by the presence of introduced taxa (Rivas-Torres & Rivas, 2018; Wauters et al., 2014; Phillips et al., 2012), this information has not been organized and categorized following the EICAT assessment, which impedes the development of accurate and efficient management actions.

Consequently, this study aims to answer the research question ¿How much information on ecological impacts of introduced plant, vertebrate and invertebrate species has been published in the Galapagos Islands until 2021, and what is the magnitude of their impacts according to EICAT assessment? Specially, this study aims to: (1) to conduct a systematic search for information on impacts of introduced terrestrial plants, vertebrates, and invertebrates reported for the archipelago and identify information gaps between and within groups; (2) to create a database with impact data from primary sources of information relevant to EICAT; (3) to assess the magnitude of the reported impacts; and (4) to-do-lists of priority species based on the highest magnitude of reported impacts and the invasion mechanisms used by each analyzed IAS. This information will allow for the first time to compile and assess the available information on the impacts of invasive species reported in the Galapagos Islands in compliance with the international IUCN standard, EICAT.

METHODS

Study area

The Galapagos Islands form an archipelago located 972 km from the Pacific coast of Ecuador. Thirteen of their islands are considered larger (>10 km^2), nine medium isles and more than 100 are defined as islets, which were formed 3.5 to 4 million years ago by the movement of the Nazca plate (Hedrick, 2019). Due to their volcanic origin, they have never been linked to the mainland of South America. However, most of the native and endemic species present in the islands have an ancestor originating in South America (Grehan, 2001). In the case of plants, the wind and sea currents could have benefited the arrival of small and easily dispersed seeds, which conferred high levels of resistance to salinity and desiccation (Vargas et al., 2012). They could also arrive hidden in the feathers or beaks of the first birds that flew to the island; or in the fur of small mammals that survived in small rafts until they found this archipelago (Hedrick, 2019).

The species that managed to colonize the islands had to face selective pressures due to the changing climatic conditions of the archipelago. During the months of June to November, a cold and dry climate is expected, influenced by the Humboldt Current (Fundación Charles Darwin (FCD) and WWF-Ecuador, 2018). In December, the rainy season begins with the arrival of warmer currents (Fundación Charles Darwin (FCD) and WWF-Ecuador, 2018). In addition, extreme climatic phenomena such as "El Niño" cause heavy rainfall that greens originally dry areas and increases the availability of food for birds and terrestrial reptiles, but affects the survival of other species, mainly plants with weak root systems such as cacti (Hedrick, 2019). On the other hand, the drought caused by "La Niña" decreases the vegetation cover and food available for bird and reptile populations (Hedrick, 2019). This, added to the isolation of each island, gave rise to species with unique evolutionary patterns that respond to the needs of their habitat, turning the Galapagos into a “Natural Laboratory”. However, the unique Galapagos species face negative pressure because of new introductions directly or indirectly mediated by humans.

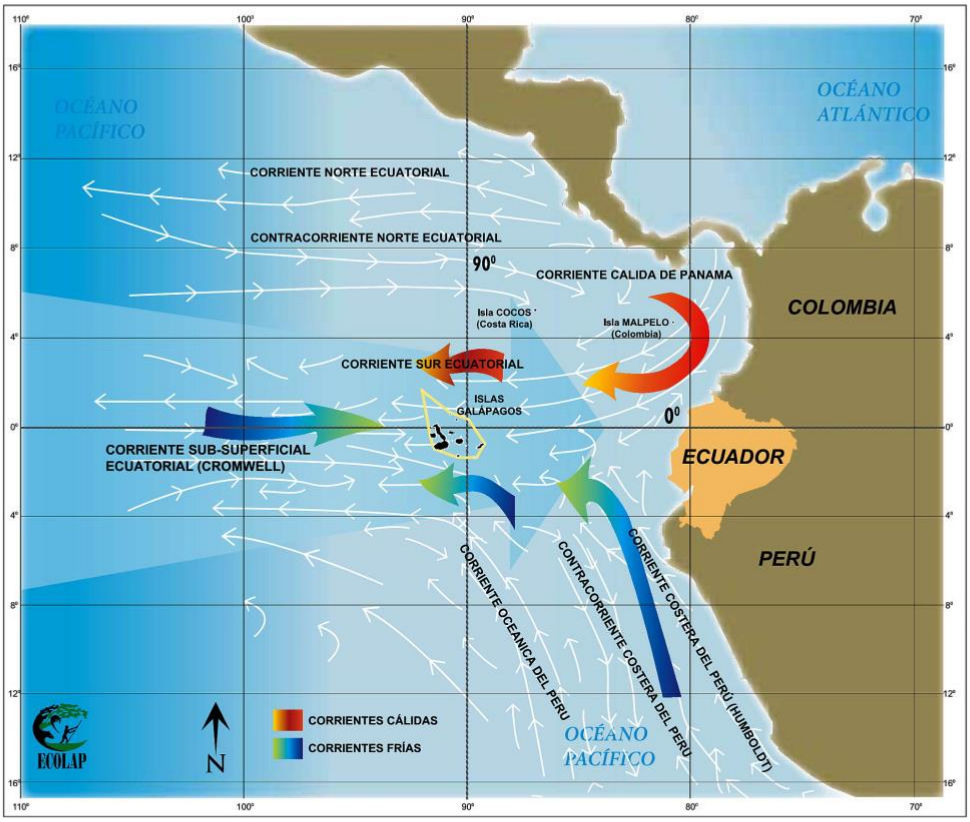

Figure 1. Map of Galapagos Ocean currents, created by ECOLAP.

Human presence on the islands has started since their official discovery in 1535 by Tomas de Berlanga (Fundación Charles Darwin (FCD) and WWF-Ecuador, 2018). However, it was not until 1830 around the time that the Galapagos became an official part of Ecuador, that the first human settlements arrived and increased exponentially as well as the demand for the settlement resources arriving by sea or by air. Nowadays, the Galapagos Islands welcome close to 300.000 tourists per year (pre-COVID tourist data), making tourism of vital importance for the internal economy of the Galapagos (Toral-

Granda et al., 2017). Nevertheless, this increases the pathways for the introduction of species such as rats or insects that arrived in the archipelago accidentally on boats or blackberries, like other agricultural cultivars were intentionally brought to the islands as a new food source (Toral-Granda et al., 2017). Currently, Galapagos record 870 introduced plant species, 679 introduced invertebrates, and 41 introduced vertebrates (Causton et al., 2014; Guézou et al., 2014; Jiménez-Uzcátegui et al., 1758).

About EICAT

To perform the EICAT assessment, an exhaustive literature review of the impacts reported for an introduced species in the biogeographic region of interest, in our case Galapagos, must be carried out. If the information available for a given taxon is insufficient to determine the level of impact, a Data Deficient (DD) category is assigned. Otherwise, one of the five impact magnitudes described by Blackburn et al. (2014) and Hawkins et al. (2015) for EICAT is assigned (Figure 2). To determine each of these impacts, Hawkins et al., 2015 describe twelve mechanisms that must be identified before conducting the EICAT assessment. The mechanisms mentioned are (1) Competition, (2) Predation, (3) Hybridization, (4) Transmission of diseases, (5) Parasitism, (6) Poisoning/toxicity (7) Biofouling (8) Grazing/ herbivory/ browsing (9) Chemical impacts on ecosystems (10) Physical impacts on ecosystems (11) Structural impacts on ecosystems (12) Indirect impacts through interaction with other species.

Once the mechanisms have been defined, introduced species can be classified as Minimal Concern (MC) when the reported impacts are negligible; in case the survival or reproduction of a species is affected we assign the category Minor (MN); if this effect on the survival of a species is causing population reductions we are talking about a Moderate impact (MO); and if there is evidence of the extinction of at least one taxon due to the presence of the introduced species we assign the categories Major (MR) when we are talking about extinctions that are naturally reversible when the IAS taxon is eliminated; or Massive (MV) in the case of an irreversible extinction.

In addition, the EICAT methodology allows to identify the probability that the assigned category is highly correct (High confidence) or may belong to a lower or higher category (Medium and Low confidence). This assessment is based on the quality of the data generated by the study design, the presence of confounding effects, and the consistency between the results and conclusions presented (Blackburn et al., 2014; Hawkins et al., 2015).

Taxonomic groups analyzed

For plants, I created a list using: 1) the checklist reported by Jaramillo Díaz et al., (2018) and filtering the introduced Fabaceae species; 2) the list of transforming species reported by Gardener et al., (2013); and 3) the list of invasive species reported by Tye (2001). For vertebrates, introduced amphibians, birds, mammals, and reptiles were selected to conduct our assessment; and for invertebrates, the available information for Arachnida, Coleoptera, Diptera, Hemiptera and Hymenoptera introduce species were analyzed.

Data analysis for EICAT

Systematic review.

A preliminary search was carried out in Google Scholar, Scopus, Scielo and Web of Science using search strings described on Annex B. Based on this information, the search terms were targeted towards these specific taxonomic groups. Due to the high number of introduced species, the focus of the search efforts on groups that can provide significant information on the ecological impacts of alien species on the original Galapagos biodiversity.

Then, a targeted search was conducted for plant species using the search engines: "Scientific name" AND galapagos AND impact on Google Scholar, BioOne, COBUEC, CABI, EBSCO, ScienceDirect, ProQuest, Scopus and Scielo. For invertebrates and vertebrates, the search engines Google Scholar, Scopus and Scielo were used to encounter sources informing about the taxonomic groups Arachnida, Coleoptera, Diptera, Hemiptera, Hymenoptera (invertebrates), amphibians, birds, mammals, and reptiles (vertebrates), using search strings described on Annex B. When a source of information matching our search profile was encountered in Scielo or Scopus, an automatic CSV export Excel was downloaded. In case of Google Scholar information sources, this information was manually included in a metadata Excel file, containing the following information about each record: Title, Author(s), Journal, Language, Publication Year, Full text URL, Abstract, Decision, #PDF (downloaded full text in the *.pdf format for archiving purposes), Impacts, Localities, and Observations.

Preliminary Database.

To decide whether to include an article in the Preliminary Database (Figure 3), the title and abstract of the articles were checked to ensure that the research is focused on the Galapagos Islands and reports at least one impact for one of the taxonomic groups to be analyzed. The articles that cited information from the Galapagos, but to evaluate the impacts of a taxon not belonging to this region were discarded. Articles describing impacts reported by previous studies (secondary source of information) were also discarded and the primary source of information was sought. The EICAT methodology only accepts the original impact sources, and the search was directed towards those primary referencing sources.

Thus, only articles with relevant impact information to EICAT assessment were selected for the Preliminary Database; opinions and predictions were not included. Furthermore, more information was included in the metadata spreadsheet, like the bibliographic information of each article (year of reference, language, type of source and methodological overview), the impact mechanism, the excerpt of the text containing the impact, the native taxon affected, and the taxonomic information of the IAS (Figure 2). Moreover, a preliminary EICAT category was assigned to each impact, following Hawkins et al., 2015 methodology (Review Annex A and Figure 3)

EICAT assessment.

A second follow-up literature review was conducted including expert assessment. This step is important to verify the preliminary assessment. The validity of the articles was tested using the EICAT methodology described by Hawkins et al., 2015 and each impact mentioned in a record was assigned to one of the five standardized EICAT impact levels, with MO, MR and MV being the most harmful (Annex A and Figure 2). When the same species had multiple records with impact scores, the highest reported impact category was selected as the leading impact score for a certain alien species at the Galapagos. The last step before finishing the impact categorization, was to determine the confidence level of the information encountered.

Priority List.

For each of the three taxonomic groups analyzed, the species with the highest impact scores with MO, MR and MV scores, which are considered harmful alien species, were selected (Annex A). We create a priority list, with information of the number of articles and impacts reported, the EICAT category assign to each taxon and the level of confidence. (Table 4, 5 and 6).

RESULTS

Systematic review

A total number of 3364 articles were analyzed, of which 47% published information on either spiders or arthropods (1604 articles), 43% for vertebrates (1449) and 9% for plants (311). Of this literature, only 4.63% (184 articles: 37 for plants, 68 for vertebrates and 79 for invertebrates) were used to build the preliminary database information (Figure 3).

Preliminary Database

Preliminary Database reported information of 295 introduced species (108 plants, 13 vertebrates and 174 invertebrates) (Table 1). We found 184 filtered articles, which mentioned 638 impact records. For plants, there are 37 articles with information of 111 impacts (17 for Fabaceae and 94 for species classified as transformants/invasive); for vertebrates, 68 articles with 202 impact records were found (of which 166 mammals, 30 birds, 4 amphibians and 2 reptiles); and 79 articles reported information of 325 impacts about invertebrates (146 Hymenoptera, 87 Hemiptera, 43 Coleoptera and 49 Diptera) (Table 1). Nevertheless, 39% of those records were classified as Data Deficient (DD) information, and therefore not relevant for the EICAT assessment. In addition, most DD impacts corresponded to invertebrates (161 records) followed by plants (50 records) and vertebrates (38 records) (Figure 4). Furthermore, the harmful impacts (MO, MR and MV) were dominated by vertebrates (Figure 4). Despite the large number of publications on spiders, not even one reported or specific impact information about any of the twenty Arachnid species previously reported as introduced alien species at the Galapagos, according to our literature research.

Table 1. Number of articles reviewed, impacts found, and IAS reported in the first and second reviews by taxonomic group.

Taxonomic information		Revised Articles	1	First Revision			2	Second Revision		
				# species	# articles	# impacts		# species	# articles	# impacts
Plants		**311**		**108**	**37**	**111**		**27**	**20**	**53**
	Fabaceae	104		70	7 (4)	17		4	3 (3)	10
	Invasive spp.	207		41	34 (4)	94		23	20 (3)	43
Vertebrates		**1449**		**13**	**68**	**202**		**8**	**34**	**70**
	Amphibian	99		1	4 (2)	4		0	0	0
	Birds	982		2	5 (2)	30		1	1	2
	Mammals	255		8	60 (2)	166		7	33	68
	Reptiles	113		2	1 (2)	2		0	0	0
Invertebrates		**1604**		**174**	**79**	**325**		**11**	**36**	**57**
	Araneae	328		20	0	0		0	0	0
	Coleoptera	585		34	7 (2)	43		2	3	3
	Diptera	30		9	33 (2)	49		2	20	25
	Hemiptera	15		79	6 (2)	87		1	2	2
	Hymenoptera	646		33	35 (2)	146		6	11	27

EICAT assessment

Once the second review with experts was completed, 49% of 184 articles were classified to possess relevant information to continue the EICAT assessment. Ninety-four articles were classified as "Data deficient (DD)" and therefore removed from the EICAT metadata spreadsheet. Comparing the evaluation results of the articles that met the selection criteria subsequent EICAT assessment, plants represented 11% of the approved impact articles found, while information sources on impacts of alien vertebrates and invertebrates represented 18% and 20%, respectively (Figure 5). Regarding the number of different impacts within the approved papers, we found 27 alien species as mentioned in 20 relevant articles that reported a total of 53 different impacts that corresponded mainly to species annotated to the plant families: Poaceae (6 species), Fabaceae (4 species) and Solanaceae (3 species). The other 14 species were members if the families Agavaceae, Capparaceae, Commelinaceae, Convolvulaceae, Crassulaceae, Cucurbitaceae, Euphorbiaceae, Juglandaceae, Meliaceae, Myrtaceae, Passifloraceae, Rosaceae, Rubiaceae, and Verbenaceae.

Additionally, 34 articles regarding 8 vertebrate alien species passed the selection criteria offering information of a total of 70 impacts. Out of these eight species, seven are known mammals, and we discovered one article with information about the impacts of the Smooth-billed Ani (*Crotophaga ani),* the only bird species reported to have an ecological impact according to the analysis performed here.

For invertebrates, 36 articles were found presenting information of 57 impacts for 11 species. Amongst the groups with the highest number of evaluated in this study, there are 15 articles with information of 6 Hymenoptera species and regarding *Philornis downsi* (Diptera), there are twenty articles that report relevant impacts and were selected for further EICAT assessment. We also found information for two Coleoptera species, one Hemiptera and another Diptera species.

Furthermore, our assessment discovered information on 180 different impacts of which 36% were assigned to the Minor (MN) category. This category is mainly represented by invertebrates (31 impacts) and plants (25 impacts). Vertebrates, on the other hand, presented impacts categorized mostly within one of the "harmful" categories MO, MR and MV with a proven negative ecological effect. Interestingly, ninety-one percent of the impacts categorized as Major (MR) are related to vertebrates, with only goats (*Capra hircus)* evaluated to have a Massive (MV) impact on their environment, due to its grazing lifestyle which heavily affects the native flora of the islands. On the other hand, plant impacts were concentrated in the Minimal Concern (14 "MC" impacts) and Minor (25 "MN" impacts) categories (Figure 6).

Priority List

When the information was curated by experts, lists of priority species were established. For plants, we found 9 species with high impact categories (MO, MR and MV) (Annex D: Table 4). Only *Rubus niveus* had a MR category, which indicates that it is causing loss of richness in the analyzed area. In addition, this blackberry species was the species with the highest number of articles (n=5) and impacts (n=7) that met all criteria for EICAT assessment. *Lantana camara* and *Cinchona pubescens* are the next species with a greater number of impacts, 5 and 4 respectively. We also categorized 10 species with “MN” impact and 8 with “MC” impact (Review Annex D: Table 4). The main mechanisms that these plants use are: “changes in structural ecosystem characteristics”, “competition”, “changes in physical ecosystem characteristics”, and “indirect impacts through interaction with other species”. Besides, most of the assigned categories had a low and very low confidence rating.

For vertebrates, we found 8 species with “harmful” impacts (Annex D: Table 5). Only *Capra hircus* had a MV category, which indicates that it caused the extinction of at least one native species. However, the species with the highest number of articles (n=10) and impacts (n=28) was *Rattus rattus*, categorized with a “MR” impact. There are 5 more species with “MR” impact. *Canis familiaris* have information of 10 impacts and, *Equus asinus,* Felis catus and *Sus scrofa* have 6 impacts for the last three species. *Crotophaga ani* was classified with a “MO” impact (Review Annex D: Table 5). The mainly mechanism that this species used are: “predation”, “grazing/herbivory”, “competition” and “transmission of disease to native species”. Besides, all assigned categories had a low confidence rating.

Finally, five invertebrate species were classified in the "harmful" categories (Annex D: Table 6). *Camponotus conspicuus zonatus* and *Wasmannia auropunctata* were classify as “MR” species, which indicates that they are causing loss of native richness in Galapagos. Nevertheless, the species with the highest number of articles (n=20) and impacts (n=24) was *Philornis downsi*, categorized as “Moderate (MO)”. Other species with high impact information are *Wasmannia auropunctata* (6 articles and 11 impacts) and *Solenopsis geminata* (5 articles and 11 impacts), the latter classified as “Minor (MN)” species. Only one invertebrate specie is report as “Minimal Concern (MC)”, *Rodolia cardinalis* (Annex D: Table 6).

DISCUSSION

Systematic review analysis

The literature search phase allowed us to determine that most information was focused on terrestrial vertebrates and terrestrial invertebrates, while information on plants was minimal. However, Toral-Granda et al., report that there are at least 821 species of introduced terrestrial plants, 545 species of invertebrates and 22 species of vertebrates (2017). Although the number of introduced plant species is higher vertebrates and invertebrates, the research generated to learn more about the presence and impacts of these introduced taxa does not seem to respond to the need to learn more in groups where there are more species, but rather to other motivations.

Preliminary Database and EICAT assessment analysis

Terrestrial plants’ analysis.

From 27 plant species that showed at least one impact, 48% belonged to the Poaceae, Fabaceae and Solanaceae families, although they have been categorized into the lowest impact categories ("MC" and "MN"). These families have been reported by other authors as most widespread and naturalized, mainly on tropical habitat like our study area (Arianoutsou et al., 2010; Pyšek & Pysek, 1998; Wu et al., 2004). The reasons why Poaceae, Fabaceae and Solanaceae have a high number of species with impacts in Galápagos, may be because they are families with species of interest for the agricultural sector of the islands. This may increase propagule pressure, increasing the probability that they will naturalize and eventually generate an impact (Lockwood et al., 2013).

However, Asteraceae also tends to be a species with a high richness of introduced species (Arianoutsou et al., 2010; Pyšek & Pysek, 1998; Wu et al., 2004). Jaramillo Díaz et al., (2018) reports the presence of 55 introduced species of this family, but my EICAT analysis did not show any impact for this group. This may be because the introductions of these species are recent or that the niches available for these plants to colonize successfully are already occupied by native species. In Galapagos, Asteraceae is one of the most representative families due to the evolutionary patterns observed in the species of this genus. Three of the six endemic genera of Galapagos plants, are Asteraceae (Léon-Yánez et al., 2011).

Terrestrial vertebrates' analysis.

Vertebrates were the group with the most and best valid information for the EICAT assessment. In Galapagos there are at least 30 species of vertebrates established on the islands: 1 amphibian, 11 birds, 4 reptiles and 13 mammals (Jiménez-Uzcátegui et al., 1758). However, we found information for only 8 of them, of which 7 were mammals. According to Spatz et al., vertebrates have significantly fewer invasive species, they tend to have more detrimental impacts. In addition, it is indicated that mammals are the most common vertebrates, present in 97% of the islands.

Other common vertebrates are birds and reptiles (Spatz et al., 2017). However, no information on relevant impacts was found for the latter, neither for amphibians. Although the number of introduced species of reptiles and amphibians in Galapagos is significantly lower than that reported for mammals and birds, it would be expected to have at least one study to report whether these species are controlled or generate any significant impact on the archipelago. Even for birds, there are only one article with impact information of *Crotophaga ani,*

Terrestrial invertebrates' analysis.

For invertebrates, spiders were the least studied group. Not only was no impact information found, but many species reported by Baert et al., (2008) and (2018) as introduced may actually be native. According to Buchholz et al., for 40% of the spider species reported in Galapagos, it has not been defined whether they are native or introduced. In addition, it is mentioned that about half of the native spider species are endemic to the island, but their survival may be affected by the increasing distribution of cosmopolitan species, present on most of the inhabited islands such as Santa Cruz (2020). In our study we found at least 20 introduced spider species but were unable to determine if they had a significant impact that threatens the survival of other species.

Priority List analysis

Terrestrial plants' analysis.

"Major" and "Moderate" impacts were reported for *Rubus, Lantana, Cinchona*, *Psidium* species and additional 5 species. In Galapagos, Gardener et al., report that "*Cinchona pubescens* and *R. niveus* are the two best studied transformer species" (2013), a pattern that is also observed in our analysis. The impacts of *Cinchona* include, structural changes and loss of biodiversity in the plant communities of the Miconia and Fern-Sedge Zones (Jäger et al., 2007, 2009), alteration of soil nutrient cycling (Jäger et al., 2013) and loss of native dispersers on the island (Shriver et al., 2011).

For Rubus, it is reported the formation of dense "impenetrable" thickets that affect turtle feeding and prevent the growth of native plants (Blake et al., 2015; Gardener et al., 2013; Tye, 2001) changing the species composition into areas with less richness and biodiversity (Heleno et al., 2013; Renteria, 2011; Rentería et al., 2012). Although there is no consensus on the characteristics that make a species more invasive (higher invasiveness), the mentioned species have small and light seeds that may easily transport by wind (or mediated by animals), rapid growth and the possibility of reproducing. both sexually and asexually (Jäger, 2015; Renteria et al., 2012) characteristics that allow rapid colonization and better fitness than the native species.

Terrestrial vertebrates' analysis.

Rattus rattus is the species with the highest number of records on islands. In Galápagos introduced rats feed on the eggs and chicks of native birds such as petrels (Cruz & Cruz, 1987; Cruz-Delgado et al., 2010; MacFarland et al., 1974) affecting the reproduction of these birds and compete for resources with native mice, *Nesoryzomys swarthi* (Harris & Macdonald, 2007). For *Crotophaga ani,* the only bird species with EICAT impact information, the article report the predation of endemic species of Lepidoptera and of *Xylocopa darwini* (Cooke et al., 2020), which affects the survival and abundance of these native species.

Moreover, most of the introduced mammal species are domestic and are important in the economy of the families living on the islands (Jiménez-Uzcátegui et al., 2008), which makes eradication and control strategies for these species difficult. Even so, there are successful examples of eradication of cats, goats, pigeons, donkeys and pigs from some islands (Jiménez-Uzcátegui et al., 2008).

Terrestrial invertebrates' analysis.

At the Galapagos Islands, insects constitute 90% of the introduced invertebrate species. It is not surprising that most articles with relevant information on impacts mention species of this group. The report by Causton & Sevilla mentions *Wasmannia auropunctata, Solenopsis geminata, Brachygastra lecheguana, Polistes versicolor*, *Icerya purchasi* and *Philornis downsi* as "invasive species with significant impacts on Galapagos ecosystems" (2007). We found relevant information for all except for *Brachygastra lecheguana* which was classified as Data Deficient (DD). *Solenopsis geminata* and *Polistes versicolor* were not classified as "harmful". In addition, *Camponotus conspicuus zonatus* had not been previously reported as a potential invader, although we found information that it is replacing the native species *Camponotus macilentus* (Herrera et al., 2020), which is why it was classified as "MR" but with a low level of confidence.

Rodolia cardinalis, a species introduced as a biological control of *Icerya purchasi*, was also included in the classification but the information compiled indicateda low probability that it could affect native species on the island (Lincango et al., 2011), which is why it was classified as "MC". Although the probability that a high impact could be generated with the introduction of this species is low, this possibility should not be ignored. At the other extreme, we have *Philornis downsi*, the parasitic fly classified by EICAT as "MO" due to several reports indicating mortality of numerous native/endemic birds due to parasitism by the fly larvae that consume tissues and leave several malformations (Cimadom et al., 2014; Fessl et al., 2006; Kleindorfer & Dudaniec, 2016; P. Lincango et al., 2015; O'Connor et al., 2010).

Introduced insects are one of the most widespread species but also the most underestimated (Venette & Hutchison, 2021). Although few species presented reported impacts, these can be devastating, considering the environment as well as in the socioeconomic aspect (Venette & Hutchison, 2021). For this reason, it is important to monitor what happens to these species and report the observed impacts or conduct research that simulates situations where impacts of non-native species present on the islands can be shown. Although it is difficult to predict how a species will behave when it reaches an environment with selective pressures different from that of its natural distribution center, generating this information allows for management plans that tend more towards prevention strategies, much less expensive than eradication programs for introduce invertebrates, such as vertebrates and plants.

CONCLUSIONS

This study encountered over 3000 published sources on ecological impacts of alien species on the native biodiversity of the Galapagos Islands, but the information in many articles overlapped with each other, since they referenced the same primary source of information. As the literature review was conducting in accordance with the internationally recognized EICAT standard, secondary references were discarded. The systematic review showed a bias towards information generated for invertebrates and vertebrates, which was significantly greater than that generated for plants. In addition, within invertebrates, spiders were the group with the most missing information, since there were species where it was not possible to ensure their native or introduced origin.

On the other hand, only 90 of the 184 articles that originally reported impacts were formally considered within the EICAT assessment. This means that the information on impacts that is being published is based on opinions or predictions of impact. Very few articles followed a methodology specifically designed to measure how an introduced taxon is affecting species belonging to the native Galapagos biodiversity.

In addition, it was possible to determine the magnitude of impacts of 27 introduced plant species, 8 introduced vertebrates and 11 introduced invertebrates. Following Lockwood et al. (2013) definition of introduced invasive species, species that were assigned the categories Minimal Concern (MC), Minor (MN), Moderate (MO), Major (MR) and Massive (MV), also represented species that could be formally considered invasive.

This analysis sought to stimulate the research of impacts on groups catalogued by our analysis as Data Deficient (DD) such as spiders or Galapagos reptiles. Both taxa have native organisms on the islands, but no previously published information on their ecological impacts. In addition, the same methodology can be followed to analyze the available impact information for groups that were not considered in this study, such as marine species or even viruses and microorganisms.

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ANNEX A: EICAT RELEVANT TERMS

a. **Minimal Concern (MC):** negible impacts but no reduction in native taxa performance
b. **Minor (MN):** reduction on individual performance but no population declines
c. **Moderate (MO):** clearly population declines in at least one native taxon
d. **Major (MR):** local or subpopulation extinction of at least one taxon (richness lost) but it is naturally reversible
e. **Massive (MV):** local extinction of at least one taxon naturally irreversible
f. **Data Deficient:** reports that evidence that alien populations exist (in that case in Galapagos) but current information is insufficient to assess their impact classification
g. **No alien population (NA):** native taxa or suspected of not being introduced
h. **Not Evaluated:** taxa that have not been evaluated by EICAT

ANNEX B: TABLES

Table 2. Search strings used in general bibliographic review by each search engine

<table>
<tr><th>Databases and catalogues</th><th>General search string</th></tr>
<tr><td>Web of Science</td><td>Galapagos and impact* and invas*
Galapagos and impact* and no native*
Ecuador and impact* and alien
Ecuador and impact* and invasive*
Ecuador and impact* and "invasive species"
Ecuador and impact* and "exotic species"</td></tr>
<tr><td>Google Scholar</td><td rowspan="3">galapagos AND nonnative species
galapagos AND nonnative species OR alien taxa OR introduced OR invasive OR introduction OR invasive
galapagos AND nonnative species OR alien taxa OR introduced OR introduction OR invasive AND plants OR flora AND impact
galapagos AND nonnative species OR alien taxa OR introduced OR introduction OR invader AND plants OR flora AND impact AND fabaceae
galapagos AND "non-native species" AND invasive* OR impact* ; galapagos AND "non-native species" AND invas* OR impact* AND flora OR plan*</td></tr>
<tr><td>Scopus</td></tr>
<tr><td>Scielo</td></tr>
</table>

Table 3. Search strings used in vertebrate and invertebrate bibliographic review by each search engine used

Databases and catalogues	General search string
Google Scholar	“Galapagos“ “-taxon-“ “-term-“ [-term- was replaced with: invasive, alien, non-native, nonnative, exotic, ecological invasion, biological invasion, invasion biology, invasion ecology, invasive species, introduced species, nonindigenous, allochthonous, exotic] [-taxon- was replaced with the respective group: Hymenoptera, Hemiptera, Coleoptera, Diptera, Araneae, birds, reptiles, amphibian, mammals]
Scopus	(invasive OR alien OR non-native OR nonnative OR exotic OR ecological invasión OR biological invasión OR invasión biology OR invasión ecology OR invasive species OR introduced species OR nonindigenous OR allochthonous OR exotic) AND (-taxon-) AND Galapagos [-taxon- was replaced with: Hymenoptera, Hemiptera, Coleoptera, Diptera, Araneae, birds, reptiles, amphibian, mammals]
Scielo	Galapagos AND -term- [-term- was replaced with: invasive, alien, non-native, nonnative, exotic, ecological invasion,

	biological invasion, invasion biology, invasion ecology, invasive species, introduced species, nonindigenous, allochthonous, exotic]

ANNEX C: FIGURES

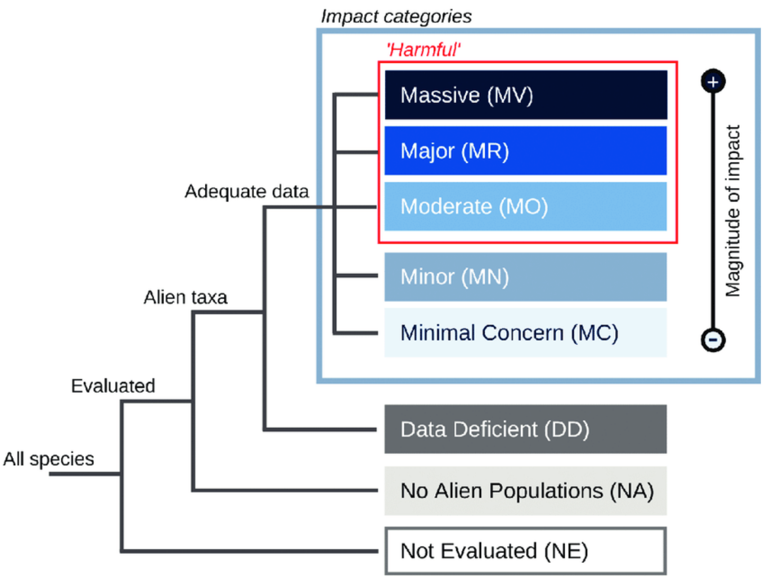
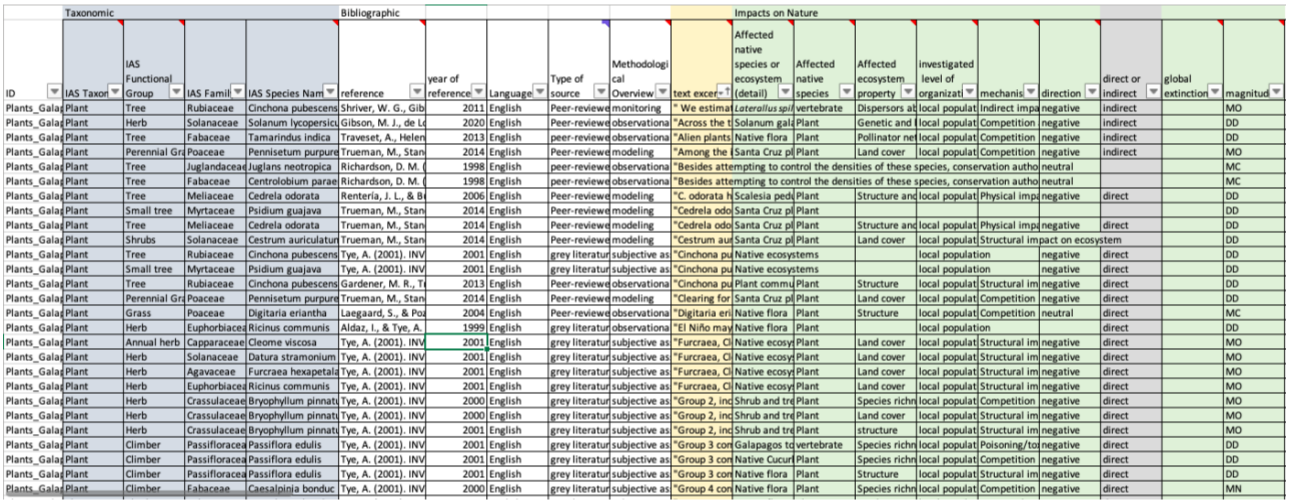


Figure 2. Categories used for EICAT assessment based on methodology proposed by Hawkins et al., 2015.



	Taxonomic				Bibliographic						Impacts on Nature								
ID	IAS Taxon	IAS Functional Group	IAS Famil	IAS Species Nam	reference	year of reference	Language	Type of source	Methodological Overview	text excer	Affected native species or ecosystem (detail)	Affected native species	Affected ecosystem property	investigated level of organizati	mechanis	direction	direct or indirect	global extinction	magnitud
Plants_Gala	Plant	Tree	Rubiaceae	Cinchona pubescens	Shriver, W. G., Gib	2011	English	Peer-reviewe	monitoring	" We estimat	*Laterallus spil*	vertebrate	Dispersors ab	local populat	Indirect impa	negative	indirect		MO
Plants_Gala	Plant	Herb	Solanaceae	Solanum lycopersicu	Gibson, M. J., de L	2020	English	Peer-reviewe	observationa	"Across the t	Solanum gala	Plant	Genetic and	local populat	Competition	negative	indirect		DD
Plants_Gala	Plant	Tree	Fabaceae	Tamarindus indica	Traveset, A., Helen	2013	English	peer-reviewe	observationa	"Alien plants	Native flora	Plant	Pollinator net	local populat	Competition	negative	indirect		DD
Plants_Gala	Plant	Perennial Gra	Poaceae	Pennisetum purpure	Trueman, M., Stan	2014	English	Peer-reviewe	modeling	"Among the i	Santa Cruz pl	Plant	Land cover	local populat	Competition	negative	indirect		MO
Plants_Gala	Plant	Tree	Juglandaceae	Juglans neotropica	Richardson, D. M. (	1998	English	peer-reviewe	observationa	"Besides attempting to control the densities of these species, conservation autho						neutral			MC
Plants_Gala	Plant	Tree	Fabaceae	Centrolobium parae	Richardson, D. M. (	1998	English	peer-reviewe	observationa	"Besides attempting to control the densities of these species, conservation autho						neutral			MC
Plants_Gala	Plant	Tree	Meliaceae	Cedrela odorata	Rentería, J. L., & B	2006	English	Peer-reviewe	modeling	"C. odorata h	Scalesia pedu	Plant	Structure and	local populat	Physical impa	negative	direct		DD
Plants_Gala	Plant	Small tree	Myrtaceae	Psidium guajava	Trueman, M., Stan	2014	English	Peer-reviewe	modeling	"Cedrela odo	Santa Cruz pl	Plant							DD
Plants_Gala	Plant	Tree	Meliaceae	Cedrela odorata	Trueman, M., Stan	2014	English	Peer-reviewe	modeling	"Cedrela odo	Santa Cruz pl	Plant	Structure and	local populat	Physical impa	negative	direct		DD
Plants_Gala	Plant	Shrubs	Solanaceae	Cestrum auriculatun	Trueman, M., Stan	2014	English	Peer-reviewe	modeling	"Cestrum aur	Santa Cruz pl	Plant	Land cover	local populat	Structural impact on ecosystem				DD
Plants_Gala	Plant	Tree	Rubiaceae	Cinchona pubescens	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Cinchona pu	Native ecosystems			local population		negative	direct		DD
Plants_Gala	Plant	Small tree	Myrtaceae	Psidium guajava	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Cinchona pu	Native ecosystems			local population		negative	direct		DD
Plants_Gala	Plant	Tree	Rubiaceae	Cinchona pubescens	Gardener, M. R., T	2013	English	Peer-reviewe	observationa	"Cinchona pu	Plant commu	Plant	Structure	local populat	Structural im	negative	direct		DD
Plants_Gala	Plant	Perennial Gra	Poaceae	Pennisetum purpure	Trueman, M., Stan	2014	English	Peer-reviewe	modeling	"Clearing for	Santa Cruz pl	Plant	Land cover	local populat	Competition	negative	direct		DD
Plants_Gala	Plant	Grass	Poaceae	Digitaria eriantha	Laegaard, S., & Po	2004	English	Peer-reviewe	observationa	"Digitaria eri	Native flora	Plant	Structure	local populat	Competition	neutral	direct		MC
Plants_Gala	Plant	Herb	Euphorbiacea	Ricinus communis	Aldaz, I., & Tye, A.	1999	English	grey literatur	observationa	"El Niño may	Native flora	Plant		local population			direct		DD
Plants_Gala	Plant	Annual herb	Capparaceae	Cleome viscosa	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Furcraea, Cl	Native ecosy	Plant	Land cover	local populat	Structural im	negative	direct		MO
Plants_Gala	Plant	Herb	Solanaceae	Datura stramonium	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Furcraea, Cl	Native ecosy	Plant	Land cover	local populat	Structural im	negative	direct		MO
Plants_Gala	Plant	Herb	Agavaceae	Furcraea hexapetala	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Furcraea, Cl	Native ecosy	Plant	Land cover	local populat	Structural im	negative	direct		MO
Plants_Gala	Plant	Herb	Euphorbiacea	Ricinus communis	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Furcraea, Cl	Native ecosy	Plant	Land cover	local populat	Structural im	negative	direct		MO
Plants_Gala	Plant	Herb	Crassulaceae	Bryophyllum pinnatu	Tye, A. (2001). INV	2000	English	grey literatur	subjective as	"Group 2, inc	Shrub and tre	Plant	Species richn	local populat	Competition	negative	direct		MO
Plants_Gala	Plant	Herb	Crassulaceae	Bryophyllum pinnatu	Tye, A. (2001). INV	2000	English	grey literatur	subjective as	"Group 2, inc	Shrub and tre	Plant	Land cover	local populat	Structural im	negative	direct		MO
Plants_Gala	Plant	Herb	Crassulaceae	Bryophyllum pinnatu	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Group 2, inc	Shrub and tre	Plant	structure	local populat	Structural im	negative	direct		MO
Plants_Gala	Plant	Climber	Passifloracea	Passiflora edulis	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Group 3 con	Galapagos to	vertebrate	Species richn	local populat	Poisoning/to	negative	direct		DD
Plants_Gala	Plant	Climber	Passifloracea	Passiflora edulis	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Group 3 con	Native Cucur	Plant	Species richn	local populat	Competition	negative	direct		DD
Plants_Gala	Plant	Climber	Passifloracea	Passiflora edulis	Tye, A. (2001). INV	2001	English	grey literatur	subjective as	"Group 3 con	Native flora	Plant	Structure	local populat	Structural im	negative	direct		DD
Plants_Gala	Plant	Climber	Fabaceae	Caesalpinia bonduc	Tye, A. (2001). INV	2000	English	grey literatur	subjective as	"Group 4 con	Native flora	Plant	Species richn	local populat	Competition	negative	direct		MN

Figure 3. Database used for preliminary analysis where we report the information of introduce species report by each article, and EICAT preliminary assessment

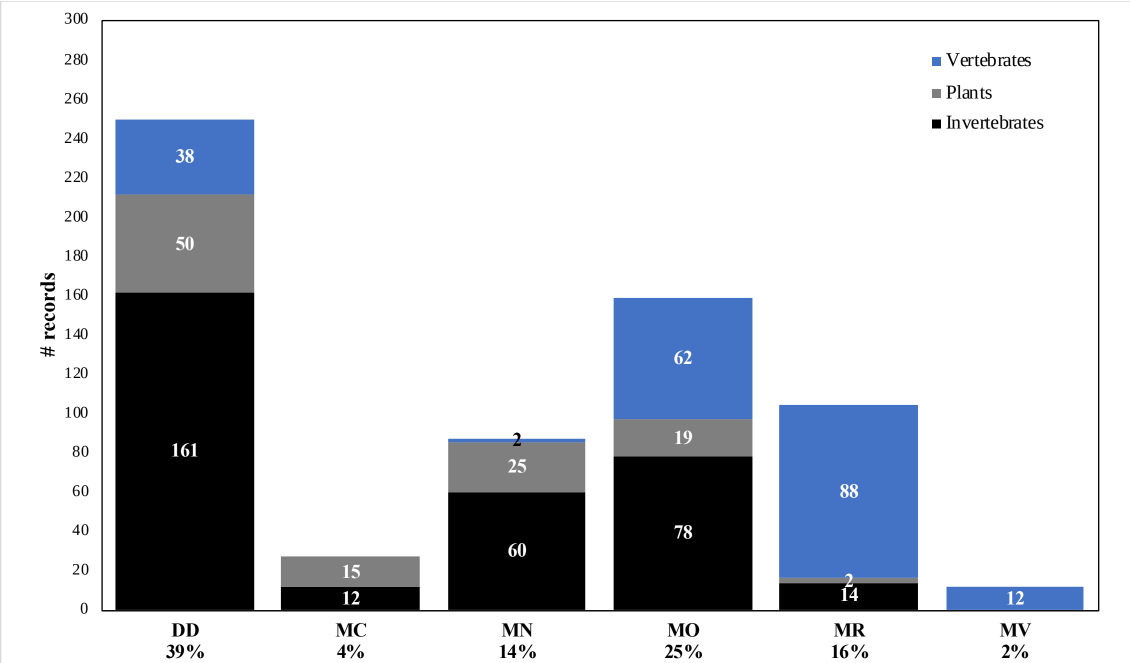


Figure 4. Impacts reported on preliminary EICAT assessment for vertebrates, plants, and invertebrates in the Galapagos. Data Deficient (DD), Minimal Concern (MC), Minor (MN), Moderate (MO), Major (MR) and Massive (MV) EICAT categories are represent on the x-axis.

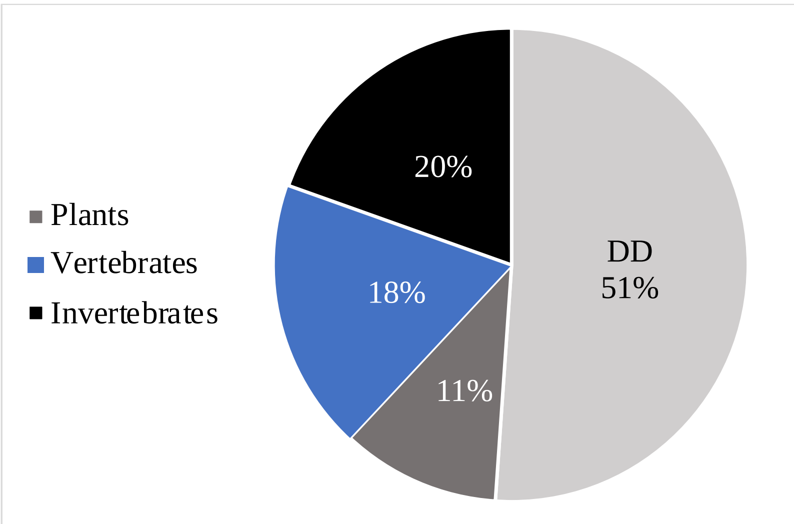


Figure 5. Percentage of articles classify as "Data deficient (DD)" and useful for EICAT assessment for plants (dark grey), vertebrates (blue) and invertebrates (black).

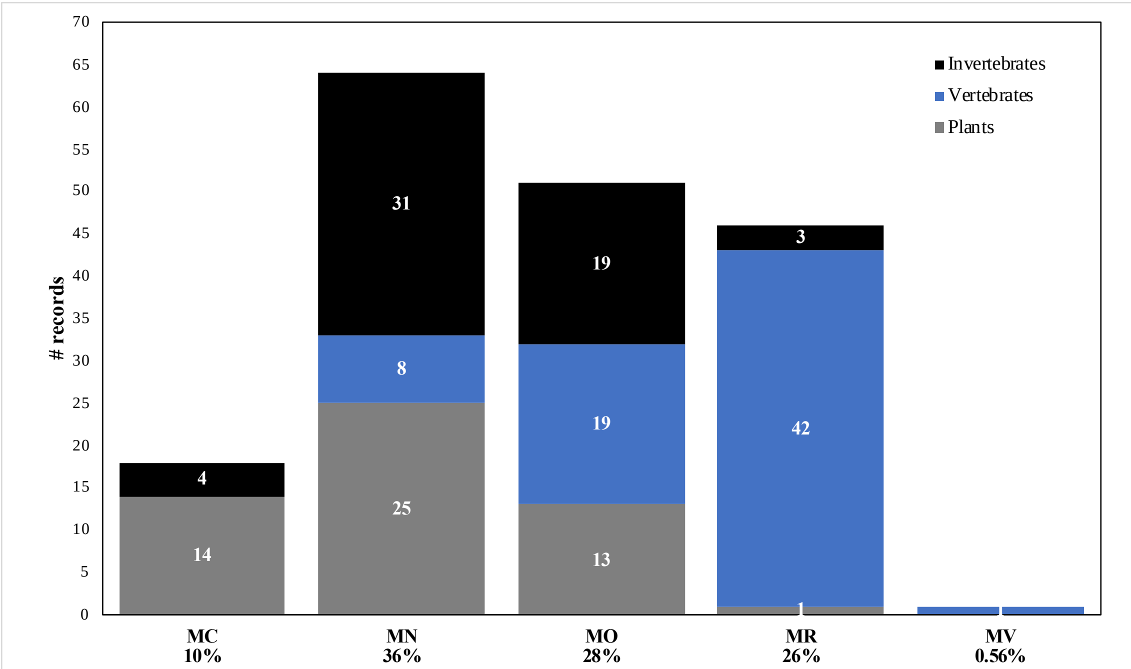


Figure 6. Impacts reported to forty-six introduced vertebrates (blue), plants (grey) and invertebrates (black) classify on each EICAT categories: Minimal Concern (MC), Minor (MN), Moderate (MO), Major (MR) and Massive (MV).

ANNEX D: SUPLEMENTARY RESULTS

Table 4. Priority plant species lists with the number of articles and impacts valid for EICAT, impact mechanism, category, and confidence classification according to Hawkins et al. (2015).

#	Family	Plant species	# articles	# EICAT impacts	EICAT mechanism	EICAT	Confidence
1	Rosaceae	*Rubus niveus*	5	7	(1) (11) (12)	MR	Medium
2	Verbenaceae	*Lantana camara*	3	5	(1) (6) (11)	MO	Low
3	Rubiaceae	*Cinchona pubescens*	4	4	(9) (10) (11) (12)	MO	Medium
4	Myrtaceae	*Psidium guajava*	3	3	(1) (11) (12)	MO	Low
5	Crassulaceae	*Bryophyllum pinnatum*	1	3	(1) (11)	MO	Very low
6	Capparaceae	*Cleome viscosa*	1	1	(11).	MO	Very low
7	Solanaceae	*Datura stramonium*	1	1	(11).	MO	Very low
8	Agavaceae	*Furcraea hexapetala*	1	1	(11).	MO	Very low
9	Euphorbiaceae	*Ricinus communis*	1	1	(11).	MO	Very low
10	Fabaceae	*Caesalpinia bonduc*	2	5	(1) (11)	MN	Very low
11	Fabaceae	*Leucaena leucocephala*	1	3	(1) (11)	MN	Very low
12	Meliaceae	*Cedrela odorata*	2	2	(9) (10)	MN	High

13	Solanaceae	*Cestrum auriculatum*	1	2	(6) (11)	MN	Very low
14	Poaceae	*Pennisetum purpureum*	1	2	(11) (12)	MN	Low
15	Convolvulaceae	*Ipomoea alba*	1	1	(1).	MN	Low
16	Poaceae	*Melinis minutiflora*	1	1	(1).	MN	Very low
17	Passifloraceae	*Passiflora edulis*	1	1	(10).	MN	Very low
18	Solanaceae	*Solanum pimpinellifolium*	1	1	(3).	MN	Low
19	Commelinaceae	*Tradescantia fluminensis*	1	1	(1).	MN	Low
20	Poaceae	*Brachiaria decumbens*	1	1	(11).	MC	Low
21	Poaceae	*Brachiaria mutica*	1	1	(11).	MC	Low
22	Fabaceae	*Centrolobium paraense*	1	1	(1).	MC	Very low
23	Poaceae	*Cynodon nlemfuensis*	1	1	(1).	MC	Low
24	Poaceae	*Digitaria eriantha*	1	1	(1).	MC	Low
25	Juglandaceae	*Juglans neotropica*	1	1	(1).	MC	Very low
26	Fabaceae	*Lablab purpureus*	1	1	(10).	MC	Low
27	Cucurbitaceae	*Momordica charantia*	1	1	(11).	MC	Very low
28	Fabaceae	*Abrus precatorius*	0	0		DD	
29	Fabaceae	*Acacia caven*	0	0		DD	
30	Fabaceae	*Acacia nilotica*	0	0		DD	
31	Fabaceae	*Albizia guachapele*	0	0		DD	
32	Fabaceae	*Arachis hypogaea*	0	0		DD	
33	Fabaceae	*Arachis pintoi*	0	0		DD	
34	Poaceae	*Axonopus micay*	0	0		DD	
35	Fabaceae	*Bauhinia monandra*	0	0		DD	
36	Fabaceae	*Bauhinia variegata*	0	0		DD	
37	Fabaceae	*Caesalpinia gilliesii*	0	0		DD	
38	Fabaceae	*Caesalpinia pulcherrima*	0	0		DD	
39	Fabaceae	*Cajanus cajan*	0	0		DD	
40	Fabaceae	*Calliandra calothyrsus*	0	0		DD	
41	Fabaceae	*Canavalia dictyota*	0	0		DD	
42	Fabaceae	*Canavalia ensiformis*	0	0		DD	
43	Fabaceae	*Canavalia rosea*	0	0		DD	
44	Fabaceae	*Cassia fistula*	0	0		DD	
45	Fabaceae	*Cassia grandis*	0	0		DD	
46	Poaceae	*Chloris barbata*	0	0		DD	
47	Rutaceae	*Citrus medica*	0	0		DD	
48	Rutaceae	*Citrus x aurantifolia*	0	0		DD	
49	Rutaceae	*Citrus x limon*	0	0		DD	
50	Fabaceae	*Clitoria ternatea*	0	0		DD	
51	Boraginaceae	*Cordia alliodora*	0	0		DD	
52	Fabaceae	*Crotalaria retusa*	0	0		DD	
53	Cucurbitaceae	*Cucumis dipsaceus*	0	0		DD	
54	Fabaceae	*Delonix regia*	0	0		DD	
55	Fabaceae	*Desmodium incanum*	0	0		DD	

56	Fabaceae	*Desmodium glabrum*	0	0	DD
57	Fabaceae	*Desmodium intortum*	0	0	DD
58	Fabaceae	*Desmodium limense*	0	0	DD
59	Fabaceae	*Dioclea reflexa*	0	0	DD
60	Fabaceae	*Dioclea virgata*	0	0	DD
61	Fabaceae	*Erythrina corallodendron*	0	0	DD
62	Fabaceae	*Erythrina edulis*	0	0	DD
63	Fabaceae	*Erythrina fusca*	0	0	DD
64	Fabaceae	*Erythrina poeppigiana*	0	0	DD
65	Fabaceae	*Erythrina smithiana*	0	0	DD
66	Fabaceae	*Galactia tenuiflora*	0	0	DD
67	Fabaceae	*Geoffroea spinosa*	0	0	DD
68	Fabaceae	*Gliricidia sepium*	0	0	DD
69	Fabaceae	*Glycine max*	0	0	DD
70	Lamiaceae	*Hyptis rhomboidea*	0	0	DD
71	Fabaceae	*Indigofera suffruticosa*	0	0	DD
72	Fabaceae	*Inga edulis*	0	0	DD
73	Fabaceae	*Inga insignis*	0	0	DD
74	Fabaceae	*Inga sapindoides*	0	0	DD
75	Fabaceae	*Inga spectabilis*	0	0	DD
76	Fabaceae	*Inga striata*	0	0	DD
77	Fabaceae	*Inga vera*	0	0	DD
78	Fabaceae	*Lens culinaris*	0	0	DD
79	Fabaceae	*Leucaena trichodes*	0	0	DD
80	Fabaceae	*Macroptilium lathyroides*	0	0	DD
81	Fabaceae	*Medicago sativa*	0	0	DD
82	Fabaceae	*Mimosa pudica*	0	0	DD
83	Fabaceae	*Mucuna rostrata*	0	0	DD
84	Bombacaceae	*Ochroma pyramidale*	0	0	DD
85	Poaceae	*Panicum maximum*	0	0	DD
86	Lauraceae	*Persea americana*	0	0	DD
87	Fabaceae	*Phaseolus coccineus*	0	0	DD
88	Fabaceae	*Phaseolus lunatus*	0	0	DD
89	Fabaceae	*Phaseolus vulgaris*	0	0	DD
90	Fabaceae	*Pisum sativum*	0	0	DD
91	Fabaceae	*Schizolobium parahyba*	0	0	DD
92	Fabaceae	*Senna alata*	0	0	DD
93	Fabaceae	*Senna bicapsularis*	0	0	DD
94	Fabaceae	*Senna hirsuta*	0	0	DD
95	Fabaceae	*Senna obtusifolia*	0	0	DD
96	Fabaceae	*Senna septemtrionalis*	0	0	DD
97	Fabaceae	*Senna siamea*	0	0	DD
98	Malvaceae	*Sida rhombifolia*	0	0	DD

99	Solanaceae	*Solanum lycopersicum*	0	0		DD	
100	Fabaceae	*Spartium junceum*	0	0		DD	
101	Myrtaceae	*Syzygium jambos*	0	0		DD	
102	Fabaceae	*Tamarindus indica*	0	0		DD	
103	Ulmaceae	*Trema micrantha*	0	0		DD	
104	Fabaceae	*Vicia faba*	0	0		DD	
105	Fabaceae	*Vigna unguiculata*	0	0		DD	
106	Fabaceae	*Zornia curvata*	0	0		DD	
107	Fabaceae	*Zornia piurensis*	0	0		DD	
108	Poaceae	*Zoysia tenuifolia*	0	0		DD	

Note: mechanism are (1) Competition, (2) Predation, (3) Hybridization, (4) Transmission of diseases, (5) Parasitism, (6) Poisoning/toxicity (7) Bio-fouling (8) Grazing/ herbivory/ browsing (9) Chemical impacts on ecosystems (10) Physical impacts on ecosystems (11) Structural impacts on ecosystems (12) Indirect impacts through interaction with other species (Hawkins et al., 2015)

Table 5. Priority vertebrate species lists with the number of articles and impacts valid for EICAT, impact mechanism, category, and confidence classification according to Hawkins et al. (2015).

#	Class	Vertebrate species	# articles	# EICAT impacts	EICAT mechanism	EICAT	Confidence
1	Mammal	*Capra hircus*	8	10	(2) (8)	MV	Low
2	Mammal	*Rattus rattus*	10	28	(1) (2) (8)	MR	Low
3	Mammal	*Canis familiaris*	3	10	(2).	MR	Low
4	Mammal	*Equus asinus*	4	6	(1) (8)	MR	Low
5	Mammal	*Felis catus*	5	6	(2) (4)	MR	Low
6	Mammal	*Sus scrofa*	3	6	(2) (8)	MR	Low
7	Mammal	*Bos taurus*	1	2	(8).	MR	Low
8	Bird	*Crotophaga ani*	1	2	(2).	MO	Low
9	Bird	*Gallus gallus*	0	0		DD	
10	Reptile	*Hemidactylus frenatus*	0	0		DD	
11	Mammal	*Mus musculus*	0	0		DD	
12	Reptile	*Phyllodactylus reissii*	0	0		DD	
13	Amphibian	*Scinax quinquefasciatus*	0	0		DD	

Note: mechanism are (1) Competition, (2) Predation, (3) Hybridization, (4) Transmission of diseases, (5) Parasitism, (6) Poisoning/toxicity (7) Bio-fouling (8) Grazing/ herbivory/ browsing (9) Chemical impacts on ecosystems (10) Physical impacts on ecosystems (11) Structural impacts on ecosystems (12) Indirect impacts through interaction with other species (Hawkins et al., 2015)

Table 6. Priority invertebrate species lists with the number of articles and impacts valid for EICAT, impact mechanism, category, and confidence classification according to Hawkins et al. (2015).

#	Funtional Group	Invertebrate species	# articles	# EICAT impacts	EICAT mechanism	EICAT	Confidence
1	Hymenoptera	*Camponotus conspicuus zonatus*	1	1	(1).	MR	Low
2	Hymenoptera	*Wasmannia auropunctata*	6	11	(1) (2)	MR	Medium
3	Coleoptera	*Cicindela trifasciata*	2	2	(1).	MO	Medium
4	Diptera	*Philornis downsi*	20	24	(2).	MO	Medium
5	Hemiptera	*Icerya purchasi*	2	2	(7).	MO	Low
6	Diptera	*Sarcodexia lambens*	1	1	(5).	MN	Low
7	Hymenoptera	*Monomorium destructor*	1	1	(1).	MN	Low
8	Hymenoptera	*Polistes versicolor*	1	2	(1) (2) (12)	MN	Low
9	Hymenoptera	*Solenopsis geminata*	5	11	(2) (5) (6)	MN	Low
10	Hymenoptera	*Tetramorium bicarinatum*	1	1	(1).	MN	Low
11	Coleoptera	*Rodolia cardinalis*	1	1	(7).	MC	Low
12	Arachnida	*Achaearanea dromedariformis*	0	0		DD	
13	Arachnida	*Achaearanea orana*	0	0		DD	
14	Arachnida	*Anyphaenoides octodentata*	0	0		DD	
15	Arachnida	*Coleosoma floridanum*	0	0		DD	
16	Arachnida	*Eidmannella pallida*	0	0		DD	
17	Arachnida	*Euophrys vestita*	0	0		DD	
18	Arachnida	*Heteropoda venatoria*	0	0		DD	
19	Arachnida	*Laminacauda baerti*	0	0		DD	
20	Arachnida	*Latrodectus geometricus*	0	0		DD	
21	Arachnida	*Loxosceles laeta*	0	0		DD	
22	Arachnida	*Menemerus bivittatus*	0	0		DD	
23	Arachnida	*Modisimus culicinus*	0	0		DD	
24	Arachnida	*Nesticodes rufipes*	0	0		DD	
25	Arachnida	*Physocyclus globosus*	0	0		DD	
26	Arachnida	*Plexippus paykulli*	0	0		DD	
27	Arachnida	*Scytodes fusca*	0	0		DD	
28	Arachnida	*Scytodes longipes*	0	0		DD	
29	Arachnida	*Selenops mexicanus*	0	0		DD	
30	Arachnida	*Theridion melanostictum*	0	0		DD	
31	Arachnida	*Triaeris stenaspis*	0	0		DD	
32	Coleoptera	*Acupalpus*	0	0		DD	
33	Coleoptera	*Anotylus*	0	0		DD	
34	Coleoptera	*Bradycellus*	0	0		DD	
35	Coleoptera	*Brentus*	0	0		DD	
36	Coleoptera	*Calleida migratoria*	0	0		DD	

37	Coleoptera	*Carcinops*	0	0	DD	
38	Coleoptera	*Chaetocnema confinis*	0	0	DD	
39	Coleoptera	*Coccidophilus*	0	0	DD	
40	Coleoptera	*Coccotrypes carpophagus*	0	0	DD	
41	Coleoptera	*Coccotrypes dactyliperda*	0	0	DD	
42	Coleoptera	*Coccotrypes rhizophorae*	0	0	DD	
43	Coleoptera	*Dalotia coriaria*	0	0	DD	
44	Coleoptera	*Galapaganus howdenae howdenae*	0	0	DD	
45	Coleoptera	*Hypothenemus brunneus*	0	0	DD	
46	Coleoptera	*Hypothenemus californicus*	0	0	DD	
47	Coleoptera	*Lathrobium*	0	0	DD	
48	Coleoptera	*Myrmecocephalus concinnus*	0	0	DD	
49	Coleoptera	*Oligota chrysopyga*	0	0	DD	
50	Coleoptera	*Oligotergus fasciatus*	0	0	DD	
51	Coleoptera	*Oxytelus incisus*	0	0	DD	
52	Coleoptera	*Paromalus*	0	0	DD	
53	Coleoptera	*Pentagonica flavipes*	0	0	DD	
54	Coleoptera	*Phanerota tridentata*	0	0	DD	
55	Coleoptera	*Philonthus discoideus*	0	0	DD	
56	Coleoptera	*Philonthus pauxillus*	0	0	DD	
57	Coleoptera	*Philonthus ventralis*	0	0	DD	
58	Coleoptera	*Platystethus spiculus*	0	0	DD	
59	Coleoptera	*Sunius debilicornis*	0	0	DD	
60	Coleoptera	*Tarsostenus univittatus*	0	0	DD	
61	Coleoptera	*Thalpius*	0	0	DD	
62	Coleoptera	*Xylosandrus morigerus*	0	0	DD	
63	Coleoptera	*Zabrotes subfaciatus*	0	0	DD	
64	Diptera	*Anastrepha fraterculus*	0	0	DD	
65	Diptera	*Culex quinquefasciatus*	0	0	DD	
66	Diptera	*Euxesta eluta*	0	0	DD	
67	Diptera	*Euxesta stigmatias*	0	0	DD	
68	Diptera	*Gitona braziliensis*	0	0	DD	
69	Diptera	*Lonchaea*	0	0	DD	
70	Diptera	*Simulium bipunctatum*	0	0	DD	
71	Hemiptera	*Acyrthosiphon bidenticola*	0	0	DD	
72	Hemiptera	*Agallia pecki*	0	0	DD	
73	Hemiptera	*Aleurothrixus floccosus*	0	0	DD	
74	Hemiptera	*Aleurotrachelus trachoides*	0	0	DD	
75	Hemiptera	*Aonidiella aurantii*	0	0	DD	
76	Hemiptera	*Aonidiella orientalis*	0	0	DD	
77	Hemiptera	*Aphis coreopsidis*	0	0	DD	
78	Hemiptera	*Aphis craccivora*	0	0	DD	
79	Hemiptera	*Aphis gossypii*	0	0	DD	

80	Hemiptera	*Aphis nerii*	0	0	DD
81	Hemiptera	*Aphis spiraecola*	0	0	DD
82	Hemiptera	*Aspidiotus excisus*	0	0	DD
83	Hemiptera	*Aspidiotus nr. Pacificus*	0	0	DD
84	Hemiptera	*Aulacorthum circumfleuxum*	0	0	DD
85	Hemiptera	*Aulacorthum solani*	0	0	DD
86	Hemiptera	*Balclutha aridula*	0	0	DD
87	Hemiptera	*Balclutha incisa*	0	0	DD
88	Hemiptera	*Balclutha lucida*	0	0	DD
89	Hemiptera	*Balclutha neglecta*	0	0	DD
90	Hemiptera	*Balclutha rosea*	0	0	DD
91	Hemiptera	*Barce fraterna*	0	0	DD
92	Hemiptera	*Bemisia*	0	0	DD
93	Hemiptera	*Brevicoryne brassicae*	0	0	DD
94	Hemiptera	*Cerataphis*	0	0	DD
95	Hemiptera	*Ceroplastes cirripediformis*	0	0	DD
96	Hemiptera	*Ceroplastes floridensis*	0	0	DD
97	Hemiptera	*Ceroplastes rusci*	0	0	DD
98	Hemiptera	*Ceroplastes sinensis*	0	0	DD
99	Hemiptera	*Cicadulina tortilla*	0	0	DD
100	Hemiptera	*Circulifer tenellus*	0	0	DD
101	Hemiptera	*Coelidiana krameri*	0	0	DD
102	Hemiptera	*Conchaspis angraeci*	0	0	DD
103	Hemiptera	*Dialeurodes citrifolii*	0	0	DD
104	Hemiptera	*Dysmicoccus boninsis*	0	0	DD
105	Hemiptera	*Dysmicoccus brevipes*	0	0	DD
106	Hemiptera	*Empoasca canavalia*	0	0	DD
107	Hemiptera	*Engytatus modestus*	0	0	DD
108	Hemiptera	*Exitanius fasciolatus*	0	0	DD
109	Hemiptera	*Ferrisia virgata*	0	0	DD
110	Hemiptera	*Halticus bractatus*	0	0	DD
111	Hemiptera	*Heteropsylla cubana*	0	0	DD
112	Hemiptera	*Heza ephippium*	0	0	DD
113	Hemiptera	*Hysteroneura setariae*	0	0	DD
114	Hemiptera	*Ischnaspis longirostris*	0	0	DD
115	Hemiptera	*Jikradia galapagoensis*	0	0	DD
116	Hemiptera	*Lepidosaphes beckii*	0	0	DD
117	Hemiptera	*Leptobyrsa decora*	0	0	DD
118	Hemiptera	*Loxa viridis*	0	0	DD
119	Hemiptera	*Macrosteles fascifrons*	0	0	DD
120	Hemiptera	*Mecidea minor*	0	0	DD
121	Hemiptera	*Myzus persicae*	0	0	DD
122	Hemiptera	*Neomegalotomus parvus*	0	0	DD

123	Hemiptera	*Nezara viridula*	0	0	DD
124	Hemiptera	*Niesthrea sidae*	0	0	DD
125	Hemiptera	*Orthezia insignis*	0	0	DD
126	Hemiptera	*Paracarsidara dugesii*	0	0	DD
127	Hemiptera	*Paracoccus solani*	0	0	DD
128	Hemiptera	*Pentalonia nigronervosa*	0	0	DD
129	Hemiptera	*Phenacoccus herreni*	0	0	DD
130	Hemiptera	*Phenacoccus solenopsis*	0	0	DD
131	Hemiptera	*Piezodorus guildinii*	0	0	DD
132	Hemiptera	*Pinnaspis strachani*	0	0	DD
133	Hemiptera	*Planococcus citri*	0	0	DD
134	Hemiptera	*Planococcus minor*	0	0	DD
135	Hemiptera	*Podisus distinctus*	0	0	DD
136	Hemiptera	*Protolebrella brasiliensis*	0	0	DD
137	Hemiptera	*Prytanes confusus*	0	0	DD
138	Hemiptera	*Pseudophacopteron*	0	0	DD
139	Hemiptera	*Pulvinaria psidii*	0	0	DD
140	Hemiptera	*Rasahus hamatus*	0	0	DD
141	Hemiptera	*Rhopalosiphum maidis*	0	0	DD
142	Hemiptera	*Rhopalosiphum rufiabdominale*	0	0	DD
143	Hemiptera	*Tagalis seminigra*	0	0	DD
144	Hemiptera	*Taylorilygus apicalis*	0	0	DD
145	Hemiptera	*Toxoptera citricida*	0	0	DD
146	Hemiptera	*Toya propinqua*	0	0	DD
147	Hemiptera	*Vazuezitocoris andinus*	0	0	DD
148	Hemiptera	*Xestocephalus desertorum*	0	0	DD
149	Hymenoptera	*Adelomyrmex myops*	0	0	DD
150	Hymenoptera	*Brachygastra lecheguana*	0	0	DD
151	Hymenoptera	*Brachymyrmex heeri*	0	0	DD
152	Hymenoptera	*Cardiocondyla emeryi*	0	0	DD
153	Hymenoptera	*Cardiocondyla minutior*	0	0	DD
154	Hymenoptera	*Crematogaster sp*	0	0	DD
155	Hymenoptera	*Cyphomyrmex rimosus*	0	0	DD
156	Hymenoptera	*Hypoponera punctatissima*	0	0	DD
157	Hymenoptera	*Monomorium floricola*	0	0	DD
158	Hymenoptera	*Monomorium pharaonis*	0	0	DD
159	Hymenoptera	*Nylanderia steinheili*	0	0	DD
160	Hymenoptera	*Odontomachus bauri*	0	0	DD
161	Hymenoptera	*Odontomachus ruginodis*	0	0	DD
162	Hymenoptera	*Paratrechina longicornis*	0	0	DD
163	Hymenoptera	*Pheidole megacephala*	0	0	DD
164	Hymenoptera	*Pyramica membranifera*	0	0	DD
165	Hymenoptera	*Rogeria curvipubens*	0	0	DD

166	Hymenoptera	*Sceliphron caementarium*	0	0	DD	
167	Hymenoptera	*Solenopis geminata*	0	0	DD	
168	Hymenoptera	*Solenopsis invicta*	0	0	DD	
169	Hymenoptera	*Solenopsis tenuis*	0	0	DD	
170	Hymenoptera	*Strumigenys emmae*	0	0	DD	
171	Hymenoptera	*Strumigenys membranifera*	0	0	DD	
172	Hymenoptera	*Tapinoma melanocephalum*	0	0	DD	
173	Hymenoptera	*Tetramorium caldarium*	0	0	DD	
174	Hymenoptera	*Trichomyrmex destructor*	0	0	DD	

Note: mechanism are (1) Competition, (2) Predation, (3) Hybridization, (4) Transmission of diseases, (5) Parasitism, (6) Poisoning/toxicity (7) Bio-fouling (8) Grazing/ herbivory/ browsing (9) Chemical impacts on ecosystems (10) Physical impacts on ecosystems (11) Structural impacts on ecosystems (12) Indirect impacts through interaction with other species (Hawkins et al., 2015)