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Article

An Annotated Checklist of Invasive Species of the Phylum Arthropods and Chordates in Panama

Digna Rodríguez-Gavilanes ¹, Humberto A. Garcés B. ², Rogemif Fuentes ³, Louise Rodriguez ⁴, Yostin Añino ⁵, Oscar G. López-Chong ⁶ and Enrique Medianero ^{7,8,*}

¹ Universidad de Panamá, Escuela de Biología, Campus Octavio Méndez Pereira

² Universidad de Panamá, Departamento de Biología Marina y Limnología. Campus Octavio Méndez Pereira, Avenida Simón Bolívar, Panamá, Panamá

³ Fundación Los Naturalistas, P.O. Box 0426-01459, David, Chiriquí, Panama; rogemifdaniel@gmail.com

⁴ Programa de Maestría en Ciencias Biológicas, Facultad de Ciencias, Naturales, Exactas y Tecnología, Universidad de Panamá, Panamá; louise.rodriguez001@outlook.com

⁵ Museo de Invertebrado G.B.Fairchild, Universidad de Panamá, Panama; yostin0660@gmail.com

⁶ Colección de aves, Instituto Smithsonian de Investigaciones Tropicales

⁷ Universidad de Panamá, Departamento de Ciencias Ambientales y Programa de Maestría en Entomología, Campus Octavio Méndez Pereira, Avenida Simón Bolívar, Panamá, Panamá

⁸ Miembro del Sistema Nacional de Investigación (SNI-SENACYT)

* Correspondence: enrique.medianero@up.ac.pa

Simple Summary: Invasive species are considered a threat to the conservation of different environments. Annotating the amount and species of these invasive organisms is critical in developing conservation strategies. This research gives background information on the types and possible origins of invasive species from arthropod and chordate groups in Panama. The results indicated that approximately 133 exotic arthropod and chordates species have been reported as invasive species in Panama. Most of these species are believed to have been introduced via the Panama Canal Zone or accidentally. With the information compiled, this research will serve as preliminary data on the sources of income and will provide information for future research and plans to prevent the impact of those species.

Abstract: Invasive species are one of the five main causes of biodiversity loss, along with habitat destruction, overexploitation, pollution, and climate change. Represent one of the first barriers to overcome in ecological conservation programs, since are difficult to control and eradicate. Due to the lack of records of invasive exotic species in Panama, this research is necessary to identify and register the documented groups of invasive species of the Chordates and Arthropod groups in Panama. This exhaustive search of invasive species was carried out in different bibliographic databases, electronic portals and scientific journals which addressed the topic at a global level. The results indicate that approximately 133 invasive exotic species of the Arthropoda and Chordata Phylum have been reported in Panama. Of the 133 species, 49 species belong to the Arthropoda Phylum and 84 species belong to the Chordate Phylum. The Panamanian economic activity could promote the introduction of alien species in this country. The study provides the first list of invasive exotic chordate and arthropod species reported for the Republic of Panama.

Keywords: invasive species; introduced species; biodiversity; Central America; tropical forest; pest

1. Introduction

Invasive species are one of the five main causes of biodiversity loss, along with habitat destruction, overexploitation, pollution, and climate change. An invasive species is understood to be an exotic species that establishes itself in a natural, semi-natural ecosystem or habitat, is an agent that induces changes and affects native biodiversity [1]. The process of invasion is a progressive phenomenon that doesn't have to be unidirectional [2]. It means, not all introduced species (exotic)

will become naturalized, nor all naturalized ones will become invasive. Neither exist a constant proportion of species that go from one phase to another [2].

The problems associated with invasive species are summarized in three main aspects [3]: (1) the big economic costs and ecological impacts caused by many invasive species; (2) the increase in the number of introduced species that become invasive and in consequence the problems associated with these species; and (3) the needs to include the invasive species in any ecological study, taking in mind that the current nature dynamics are governed by many invasive species [3].

Globally, 90% of vertebrate and plant introductions are intentional and the remaining 10% are accidental [4]. Invasive species are one of the first barriers to overcome in ecological conservation programs, since are difficult to control and eradicate, mainly due to their reproductive strategies combined with their dispersal, establishment, and persistence [3].

Invasive alien species can be found in all groups of organisms [5]. After plants, arthropods and chordates include the largest number of invasive exotic species reported for Latin America and the Caribbean [4].

The animal groups which pertain to the Phylum Arthropoda contain the largest number of species known today [6]. Some species transmit diseases or are vectors of them, and some can affect crops and many serve as natural indicators and pollinators. In addition, a few of these species play the role of primary, secondary consumers or decomposers [7].

Most morphologically and physiologically complex organisms are found in the Chordate Phylum, they have a high diversity of ecological niches, with notable terrestrial and aquatic environment adaptations [7]. In terms of ecosystemic level, the introduction of mammals can affect the food chain function, generating a cascade effect in the composition and abundance of invasive predator, herbivore, and plant species, as well as nutrient cycles [8].

Panama is the twenty-eighth country in the world with the greatest biological diversity [9]. However, in proportion to its size it ranks tenth. Panama has a higher number of known vertebrate animals than any other country in Central America or the Caribbean and more bird species than the United States and Canada together [9]. In addition, it has 3.5% of the plants with flowers and 7.3% of the fern and related species in the world [10]. Due to its geographical position, high land, and maritime connectivity, as well as the existence of the Panama Canal, Panama has helped biological invasions [10]. According to [11], the new locks used in the expansion of the Panama Canal allow passage of ships that are 71 meters longer and 16 meters wider, allowing more mobilization of exotic species within its ballast waters or attached to the ship hull [10].

According to the IV Panama National Biodiversity Report, an estimate of approximately 324 exotic species were introduced in Panama, the majority are plants. In addition, the introduction of exotic species as pets has increased. Among the exotic species used as pets are birds, reptiles, and mammals [10]; however, it is not known how many of these exotic species have become invasive species. Due to the lack of records of invasive exotic species in Panama, this research is necessary to help answer how many invasive species of the group of chordates and arthropods have been registered in Panama.

This research will provide the first list of invasive species in the Panamanian territory of two important groups of organisms: arthropods and chordates. This research will serve as preliminary data on the sources of income and will provide information for future research and plans to prevent the impact of those species.

2. Materials and Methods

2.1. Study Area

Panama is geographically located at 7° 12' 07" and 9° 38'46" north latitude and 77° 09' 24" and 83° 03' 07" west Neotropical Region longitude. Panama is in the central part of the American continent, in the most eastern and south part of Central America. It limits to the north with the Caribbean Sea, to the south with the Pacific Ocean, to the east with Colombia and to the west with Costa Rica [9].

With a land area of 75,416.6 km², administratively composed of ten provinces, three indigenous regions (Kuna Yala, Emberá, Ngäbe Buglé) with province status, two regions (Kuna de Madungandí and Kuna de Wargandí) with the level of municipal government, and 623 townships throughout the country [12].

Panama bases its economy on four activities, one of them being the logistics industry, which is fundamentally based on the movement of cargo from all over the world [13]. This movement that develops through ports, airports, railways, and the Panama Canal is one of the activities recognized as a means of introducing invasive species [14], in addition to the already known Zona del Canal that during that time allowed the intentional introduction of several species [10].

2.2. Study Selection

The study was carried out through an exhaustive information review, in the following sources; Global Invasive Species Database: <http://www.iucngisd.org/gisd/species.php?sc=965>, Invasive Species Specialist Group IUCN/SSC, Invasive Species Specialist Group (ISSG), Invasive Species Compendium (CABI) <https://www.cabi.org/isc/datasheet/108530#toListOfSpecies>. In bibliographic databases such as Web of Science (WOS), Science Direct, Scielo, PubMed, Redalyc, Dimensions and Google Scholar. Using the Publish or Perish software, the URLs resulting from the searches were downloaded in csv format, which was worked in Excel to filter those records that contained the mixture of words (invasive species, Panama alien species, invasive species in Panama, invasive exotic species in Panama, Panama invasive species). Additionally, thorough search was carried out in specialized journals on the subject, such as: BioInvasions Records (Reabic), Biological Invasions (Springer), Revista Bioinvasiones, Check List the Journal of biodiversity data (PENSOFT), as well as the journals published in Panama that are found on the ABC Platforms (SENACYT) such as National Resources and SIBIUP of the University of Panama.

The search was done under the keywords of: invasive species, exotic species, invasive species in Panama, invasive exotic species in Central America, invasive species of insects in Panama, invasive species in America, New records + Panamá, Pest + Panama, introduced species + Panamá, "Alien species", and filtered by the word Panama, New records + Panama, Pest + Panama, Introduced species + Panama.

Due to the limited literature published on the subject for Panama, the country's specialists from the different groups under study were asked for a list of the species considered invasive in the country. We visited Environment Ministry bibliography and reviewed the subject related, the Aquatic Resources Authority of Panama, the Panama Canal Authority, the Herbarium of the Panama University and the Directorate of Plant Health of the Ministry of Agricultural Development.

Other sources of information used were: Fifth National Report of Panama to the Convention on Biological Diversity [15]; Invasives in Mesoamerica and the Caribbean (International Union for nature and natural resources conservation 2002); National Biodiversity Strategy and Action Plan 2018-2050 [12], Ministerio de Desarrollo Agropecuario database of invasive species 2019.

The information obtained was organized in tables for easier understanding. A database of the species was created (in cases where the information was obtained) with the following variables: report date (year), province, altitude, place of origin. This allowed us to answer the research question and meet one of the objectives. Also to make easy the access to information on invasive species of the Phylum Arthropoda and Chordata, another two tables were created, one that included the taxonomic identification of the groups and the reference according to the article or database that was obtained for the species, and the last one that contained pets limited distribution under official control in Panama Republic.

3. Results

Through the collection of information, the results indicate that approximately 134 invasive exotic species of the Arthropoda and Chordata Phylum have been reported in Panama. Of the 133 species, 49 species belong to the Arthropoda Phylum and 84 species belong to the Chordata Phylum, indicated in taxonomy table 1.

Of the 49 species belonging to the Arthropoda Phylum, 36 species belonged to the Insecta class, three to the Arachnida class, nine to the Malacostraca class and one to the Maxillopoda class. Of the 84 species of the Chordate Phylum, 42 belonged to the Actinopterygii class, 20 to the Ascidiacea class, eight species to the Reptilia class, six to the bird class, and four to the Amphibia and Mammalia class.

In the Arthropoda Phylum, 18 species belong to the Coleoptera order, being the most abundant of the groups in this Phylum followed by Decapoda with nine species, Hymenoptera with six species, Diptera, Hemiptera with five each group. Acarida with two species, and one species in the Lepidoptera, Blattodea, Mesostigmata and Cephalobaenida orders.

In the Chordate Phylum, 11 belong to the Stolidobranchia order, 10 to Cichliformes, eight to the Cypriniformes order, seven species belong to Squamata order, six species belong to the Perciformes, Cyprinodontiformes, and Aplousobranchia orders, four to the Passeriformes and Anura orders, three to the Characiformes and Phlebobranchia orders, two in the Rodentia, Carnivora, Salmoniformes and Gobiiformes orders, and one species for the Columbiformes, Pelecaniformes, Carangiformes, Bleniformes, Acanthuriformes, Scorpaeniformes, Siluriformes and Testudines orders.

The three most abundant families of the Arthropoda Phylum are: Curculionidae (14 spp.), Formicidae (4 spp.), Tephritidae (3 spp.). For the Chordata Phylum the three most abundant families are: Cichlidae (10 spp.), Styelidae (8 spp.) and Cyprinidae (7 spp.).

There's one case we called "Eye Attention" for *Rachycentron canadum* (Linnaeus, 1766), were the data located it in the Pacific zone of the Panama Republic, but have never seem again in other Panama aquatic ecosystem.

Table 1. Exotic invasive species taxonomy list from the Panama Republic.

Species	Family	Order	Class	Phylum	Reference
<i>Hypothenemus hampei</i> Ferrari, 1867	Curculionidea	Coleoptera	Insecta	Arthropoda	[26]
<i>Coccotrypes advena</i> Blandford 1894	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Ambrosiodmus obliquus</i> LeConte, 1878	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Coptoborus ricini</i> Eggers, 1932	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Xyleborus bispinatus</i> Eichhoff, 1864	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Xylosandrus morigerus</i> Blandford, 1894	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Xylosandrus compactus</i> Eichhinoff, 1876	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Cryptocarenum seriatus</i> Eggers, 1933	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Coccotrypes vulgaris</i> Eggers, 1923	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Dendrocranulus tardus</i> Blandford, 1896	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Scolytopsis puncticollis</i> Blandford, 1896	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Xylosandrus crassiusculus</i> Motschulsky, 1866	Curculionidae	Coleoptera	Insecta	Arthropoda	[28]
<i>Xyleborinus exiguus</i> Walker, 1859	Curculionidae	Coleoptera	Insecta	Arthropoda	[27]
<i>Rhynchophorus palmarum</i> Linneus, 1758	Curculionidae	Coleoptera	Insecta	Arthropoda	[29]
<i>Euonitellus intermedius</i> Reiche, 1849	Scarabaeidae	Coleoptera	Insecta	Arthropoda	[30]
<i>Harmonia axyridis</i> Pallas, 1773	Coccinellidae	Coleoptera	Insecta	Arthropoda	[31]
<i>Callosobruchus phaseoli</i> Gyllenhal, 1833	Chrysomelidae	Coleoptera	Insecta	Arthropoda	[32]
<i>Saperda candida</i> Fabricius, 1787	Cerambycidae	Coleoptera	Insecta	Arthropoda	[33]
<i>Brachyplatys subaeneus</i> Westwood, 1837	Plastaspidae	Hemiptera	Insecta	Arthropoda	[34]
<i>Diaphorina citri</i> Kuwayama, 1908	Psyllidae	Hemiptera	Insecta	Arthropoda	[35]
<i>Pseudacysta perseae</i> Heideman, 1908	Tingidae	Hemiptera	Insecta	Arthropoda	[36]
<i>Aulacaspis yasumatsui</i> Takagi, 1977	Diaspididae	Hemiptera	Insecta	Arthropoda	[37]
<i>Aphis spiraeicola</i> Patch, 1914	Aphididae	Hemiptera	Insecta	Arthropoda	[38]
<i>Apis mellifera</i> Linneus, 1758	Apidae	Hymenoptera	Insecta	Arthropoda	[39]
<i>Tapinoma melanocephalum</i> Fabricius, 1793	Formicidae	Hymenoptera	Insecta	Arthropoda	[33]
<i>Paratrechina longicornis</i> Motshulsky, 1863	Formicidae	Hymenoptera	Insecta	Arthropoda	[33]
<i>Monomorium floricola</i> Jerdon, 1851	Formicidae	Hymenoptera	Insecta	Arthropoda	[33]
<i>Quadrastichus erythrinae</i> Kim, 2004	Eulophidae	Hymenoptera	Insecta	Arthropoda	[40]
<i>Nylanderia fulva</i> Mayr, 1862	Formicidae	Hymenoptera	Insecta	Arthropoda	[41]
<i>Ceratitis capitata</i> Weidemann, 1824	Tephritidae	Diptera	Insecta	Arthropoda	[42]
<i>Anastrepha obliqua</i> Macquart, 1835	Tephritidae	Diptera	Insecta	Arthropoda	[43]
<i>Anastrepha grandis</i> Macquart, 1846	Tephritidae	Diptera	Insecta	Arthropoda	[44]
<i>Aedes aegypti</i> Linnaeus, 1762	Culicidae	Diptera	Insecta	Arthropoda	[45]
<i>Aedes albopictus</i> Skuse, 1895	Culicidae	Diptera	Insecta	Arthropoda	[45]
<i>Tuta absoluta</i> Meyrick, 1917	Gelechiidae	Lepidoptera	Insecta	Arthropoda	[46]
<i>Blattella germanica</i> Linnaeus, 1767	Ectobiidae	Blattodea	Insecta	Arthropoda	[47]

<i>Brevipalpus phoenicis</i> Geijskes, 1936	Tenuipalpidae	Acarida	Arachnida	Arthropoda	[48]
<i>Brevipalpus californicus</i> Banks, 1904	Tenuipalpidae	Acarida	Arachnida	Arthropoda	[49]
<i>Dermanyssus gallinae</i> De Geer, 1778	Dermanyssidae	Mesostigmata	Arachnida	Arthropoda	[50]
<i>Rhithropanopeus harrisi</i> Gould, 1841	Panopeidae	Decapoda	Malacostraca	Arthropoda	[51]
<i>Elamenopsis kemp</i> i Chopra y Das, 1930	Hymenosomatidae	Decapoda	Malacostraca	Arthropoda	[52]
<i>Procambarus clarkia</i> Girard, 1852	Cambaridae	Decapoda	Malacostraca	Arthropoda	[44]
<i>Penaeus monodon</i> Fabriciud, 1798	Penaeidae	Decapoda	Malacostraca	Arthropoda	[44]
<i>Cherax tenuimanus</i> Smith, 1912	Parastacidae	Decapoda	Malacostraca	Arthropoda	[44]
<i>Macrobrachium amazonicum</i> Heller, 1862	Palemonidae	Decapoda	Malacostraca	Arthropoda	[53]
<i>Macrobrachium rosenbergii</i> De Man, 1879	Palemonidae	Decapoda	Malacostraca	Arthropoda	[62]
<i>Goniopsis cruentata</i> Latrelle, 1803	Grapsidae	Decapoda	Malacostraca	Arthropoda	[53]
<i>Pachygrapsyus gracilis</i> de Saussure, 1857	Grapsidae	Decapoda	Malacostraca	Arthropoda	[53]
<i>Raillietiella frenatus</i> Riley & Self, 1981	Cephalobaenidae	Cephalobaenida	Maxillopoda	Arthropoda	[54]
<i>Mus musculus</i> Linnaeus, 1758	Muridae	Rodentia	Mammalia	Chordata	[55]
<i>Rattus norvegicus</i> Berkenhout, 1769	Muridae	Rodentia	Mammalia	Chordata	[55]
<i>Herpestes auropunctatus</i> Hodgson, 1836	Herpestidae	Carnivora	Mammalia	Chordata	[33]
<i>Herpestes javanicus</i> Hilaire, 1818	Herpestidae	Carnivora	Mammalia	Chordata	[33]
<i>Columba livia</i> Gmelin, 1789	Columbidae	Columbiformes	Aves	Chordata	[33]
<i>Bubulcus ibis</i> Linnaeus, 1758	Ardeidae	Pelecaniformes	Aves	Chordata	[33]
<i>Mimus gilvus</i> Viellot, 1808	Mimidae	Passeriformes	Aves	Chordata	[33]
<i>Passer domesticus</i> Linnaeus, 1758	Passeridae	Passeriformes	Aves	Chordata	[56]
<i>Quiscalus mexicanus</i> Gmelin, 1788	Icteridae	Passeriformes	Aves	Chordata	[55]
<i>Sicalis flaveola</i> Linnaeus, 1766	Thraupidae	Passeriformes	Aves	Chordata	[56]
<i>Rachycentron canadum</i> Linnaeus, 1766	Rachycentridae	Carangiformes	Actinopterygii	Chordata	[57]
<i>Oreochromis niloticus</i> Linnaeus, 1758	Cichlidae	Cichliformes	Actinopterygii	Chordata	[58] , [59]
<i>Oreochromis aureus</i> Steindachner, 1864	Cichlidae	Cichliformes	Actinopterygii	Chordata	[58]
<i>Oreochromis mossambicus</i> Peters, 1852	Cichlidae	Cichliformes	Actinopterygii	Chordata	[58]
<i>Oreochromis urolepis</i> Norman, 1912	Cichlidae	Cichliformes	Actinopterygii	Chordata	[58]
<i>Coptodon rendalli</i> Boulenger, 1897	Cichlidae	Cichliformes	Actinopterygii	Chordata	[58]
<i>Cichla ocellaris</i> Bloch & Schneider, 1801	Cichlidae	Cichliformes	Actinopterygii	Chordata	[33]
<i>Cichla monoculus</i> Agassiz, 1831	Cichlidae	Cichliformes	Actinopterygii	Chordata	[58] , [59]
<i>Parachromis managuensis</i> Günther, 1867	Cichlidae	Cichliformes	Actinopterygii	Chordata	[60] , [59]
<i>Astronotus ocellatus</i> Agassiz, 1881	Cichlidae	Cichliformes	Actinopterygii	Chordata	[59]
<i>Mesonauta festivus</i> Heckel, 1840	Cichlidae	Cichliformes	Actinopterygii	Chordata	[59]
<i>Eleotris melanosoma</i> Bleeker, 18531859	Eleotridae	Gobiiformes	Actinopterygii	Chordata	[61]
<i>Butis koilomatodon</i> Bleeker, 1849	Butidae	Gobiiformes	Actinopterygii	Chordata	[61]
<i>Lepomis macrochirus</i> Rafinesque, 1819	Centrarchidae	Perciformes	Actinopterygii	Chordata	[62]
<i>Lepomis microlophus</i> Günther, 1859	Centrarchidae	Perciformes	Actinopterygii	Chordata	[63]
<i>Micropterus salmoides</i> Lacepede, 1802	Centrarchidae	Perciformes	Actinopterygii	Chordata	[63] , [59]
<i>Pomoxis annularis</i> Rafinesque, 1818	Centrarchidae	Perciformes	Actinopterygii	Chordata	[61]
<i>Pomoxis nigromaculatus</i> Lesueur, 1829	Centrarchidae	Perciformes	Actinopterygii	Chordata	[61] , [59]
<i>Lepomis humilis</i> Girard, 1858	Centrarchidae	Perciformes	Actinopterygii	Chordata	[59]
<i>Omobranchus punctatus</i> Valenncienes, 1836	Blenniidae	Blenniiformes	Actinopterygii	Chordata	[61]
<i>Sciaenops ocellatus</i> Linnaeus, 1766	Sciaenidae	Acanthuriformes	Actinopterygii	Chordata	[44]

<i>Oncorhynchus mykiss</i> Walbaum, 1792	Salmonidae	Salmoniformes	Actinopterygi i	Chordata	[33] , [59]
<i>Salmo trutta</i> Linnaeus, 1758	Salmonidae	Salmoniformes	Actinopterygi i	Chordata	[63]
<i>Pterois volitans</i> Linnaeus, 1758	Scorpaenidae	Scorpaeniformes	Actinopterygi i	Chordata	[64]
<i>Cirrhinus chinensis</i> Günther, 1868 sin <i>C. molitorella</i>	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[44]
<i>Cirrhinus molitorella</i> Valenciennes, 1844	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[44]
<i>Ctenopharyngodon Idella</i> Valenciennes, 1844	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[61]
<i>Cyprinus carpio</i> Linnaeus, 1758	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[33] , [59]
<i>Hypophthalmichthys molitrix</i> Valenciennes, 1844	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[61]
<i>Hypophthalmichthys nobilis</i> Richardson, 1845	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[33]
<i>Mylopharyngodon piceus</i> Richardson, 1846	Cyprinidae	Cypriniformes	Actinopterygi i	Chordata	[44]
<i>Ictiobus cyprinellus</i> Valenciennes, 1844	Catostomidae	Cypriniformes	Actinopterygi i	Chordata	[44]
<i>Gambusia holbrooki</i> Girard, 1859	Poeciliidae	Cyprinodontiformes	Actinopterygi i	Chordata	[59]
<i>Xiphophorus helleri</i> Heckel, 1848	Poeciliidae	Cyprinodontiformes	Actinopterygi i	Chordata	[59] , [65]
<i>Gambusia affinis</i> Baird & Girard, 1853	Poeciliidae	Cyprinodontiformes	Actinopterygi i	Chordata	[65]
<i>Gambusia nicaraguensis</i> Günther, 1866	Poeciliidae	Cyprinodontiformes	Actinopterygi i	Chordata	[65]
<i>Poecilia reticulata</i> Peters, 1859	Poeciliidae	Cyprinodontiformes	Actinopterygi i	Chordata	[65]
<i>Xiphophorus variatus</i> Meek, 1904	Poeciliidae	Cyprinodontiformes	Actinopterygi i	Chordata	[65]
<i>Ictalurus punctatus</i> Rafinesque, 1818	Ictaluridae	Siluriformes	Actinopterygi i	Chordata	[44]
<i>Colossoma macropomum</i> Cuvier, 1816	Serrasalminae	Characiformes	Actinopterygi i	Chordata	[61] , [59]
<i>Piaractus brachipomus</i> Cuvier, 1818	Serrasalminae	Characiformes	Actinopterygi i	Chordata	[44]
<i>Piaractus mesopotamicus</i> Holmberg, 1887	Serrasalminae	Characiformes	Actinopterygi i	Chordata	[44]
<i>Hemidactylus brookii</i> Gray, 1845	Gekkonidae	Squamata	Reptilia	Chordata	[66]
<i>Hemidactylus frenatus</i> Dumeril & Bibron, 1836	Gekkonidae	Squamata	Reptilia	Chordata	[66] , [33]
<i>Hemidactylus mabouia</i> Moreau de Jonnes, 1818	Gekkonidae	Squamata	Reptilia	Chordata	[66] , [33]
<i>Hemidactylus turcicus</i> Linnaeus, 1758	Gekkonidae	Squamata	Reptilia	Chordata	[66] , [67]
<i>Lepidodactylus lugubris</i> Dumeril & Bibron, 1836	Gekkonidae	Squamata	Reptilia	Chordata	[66] , [68]
<i>Anolis sagrei</i> Cocteau in Dumeril & Bibron, 1837	Polychrotidae	Squamata	Reptilia	Chordata	[69]
<i>Sphaerodactylus argus</i> Gosse, 1850	Sphaerodactylidae	Squamata	Reptilia	Chordata	[66] , [62]
<i>Trachemys scripta elegans</i> Wied, 1838	Emydidae	Testudines	Reptilia	Chordata	[33]
<i>Eleutherodactylus antillensis</i> Reinhardt & Lütken, 1863	Eleutherodactylidae	Anura	Amphibia	Chordata	[70] , [71]
<i>Eleutherodactylus johnstonei</i> Barbour, 1914	Eleutherodactylidae	Anura	Amphibia	Chordata	[70]
<i>Eleutherodactylus planirostris</i> Cope, 1862	Eleutherodactylidae	Anura	Amphibia	Chordata	[72]
<i>Rana catesbeiana</i> Shaw, 1802	Ranidae	Anura	Amphibia	Chordata	[44]
<i>Ascidia incrassata</i> Heller, 1878	Ascididae	Phlebobranchia	Ascidacea	Chordata	[73]
<i>Ascidia sydneyensis</i> Stimpson, 1855	Ascididae	Phlebobranchia	Ascidacea	Chordata	[73]
<i>Phallusia nigra</i> Savigny, 1816	Ascididae	Phlebobranchia	Ascidacea	Chordata	[73]
<i>Botrylloides nigrum</i> Herdman, 1886	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Botryllus planus</i> Van Name, 1902	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]

<i>Polyandrocarpa anguinea</i> Sluiter, 1898	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Polyandrocarpa sagamiensis</i> Tokioka, 1953	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Polyandrocarpa zorritensis</i> Van Name, 1931	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Styela canopus</i> Savigny, 1816	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Symplegma brakenhielmi</i> Michaelsen, 1904	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Symplegma rubra</i> Monniot, 1972	Styelidae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Herdmania pallida</i> Heller, 1878	Pyuridae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Microcosmus exasperatus</i> Heller, 1878	Pyuridae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Pyura vittata</i> Stimpson, 1852	Pyuridae	Stolidobranchia	Ascidacea	Chordata	[73]
<i>Didemnum perlucidum</i> Monniot F, 1983	Didemnidae	Aplousobranchia	Ascidacea	Chordata	[73]
<i>Didemnum psammatodes</i> Sluiter, 1895	Didemnidae	Aplousobranchia	Ascidacea	Chordata	[73]
<i>Diplosoma listerianum</i> Milne Edwards, 1841	Didemnidae	Aplousobranchia	Ascidacea	Chordata	[73]
<i>Lissoclinum fragile</i> Van Name, 1902	Didemnidae	Aplousobranchia	Ascidacea	Chordata	[73]
<i>Trididemnum orbiculatum</i> Van Name, 1902	Didemnidae	Aplousobranchia	Ascidacea	Chordata	[73]
<i>Polyclinum constellatum</i> Savigny, 1816	Polyclinidae	Aplousobranchia	Ascidacea	Chordata	[73]

Based on the information obtained, we can say that the province with the highest record of invasive species introduction in the Panama Republic is the Panama province (79 records), followed by the Colon (16 records), Chiriqui province (ten records), Veraguas (six records), Coclé province (four records), West Panama and Bocas del Toro (three records), Herrera (two records), Los Santos, San Blas and Darien province (one record), (Table 2).

The four continents with more record of invasive species origin that had been reported in Panama are: Asia (22 records), South America (21 records), Africa (15 records) and North America (14 records) (Table 2).

Table 2. Information about: invasive species, province, district, site, year, species altitude was found for the first time in Panama Republic, place of origin, affectation.

Species	Province	District	Site	Introduction Year	Site altitude	Belonging Continent
<i>Hypothenemus hampei</i>	Chiriqui	Chiriqui	Border with Costa Rica	2007		Africa
<i>Coccotrypes advena</i>	Panama, Colon	Panama, Colón	Panama Canal	2007		Asia
<i>Ambrosiodmus obliquus</i>	Panama					
<i>Coptoborus ricini</i>	Panama					
<i>Xyleborus bispinatus</i>	Panama					
<i>Xylosandrus morigerus</i>	Panama					
<i>Xylosandrus compactus</i>	Panama					
<i>Cryptocarenum seriatus</i>	Panama					
<i>Coccotrypes vulgaris</i>	Panama					
<i>Dendrocranulus tardus</i>	Panama					
<i>Scolytopsis puncticollis</i>	Panama					
<i>Xylosandrus crassiusculus</i>	Panama	Gatun	Barro Colorado	2004	10 m	Asia
<i>Xyleborinus exiguus</i>	Panama	Gatun	Barro Colorado	2019	10 m	Asia
<i>Rhynchophorus palmarum</i>	Panama	Panama, Colon	Panama			
<i>Euoniticellus intermedius</i>	Chiriqui	Renacimiento	Chiriqui	2015		Africa
<i>Harmonia axyridis</i>	Colon	Colon	Centro Regional Colon	2014		Europa
<i>Callosobruchus phaseoli</i>	Panama	Arraijan	Las villas de Arraijan	2022		Neotropic
<i>Saperda candida</i>						
<i>Brachyplatys subaeneus</i>	Herrera	Chitre	Costa Pacífica	2016		Asia
<i>Diaphorina citri</i>	Bocas del Toro	Bocas del Toro	Bocas del Toro	2016		Asia
<i>Pseudacysta perseae</i>	Los Santos	Santa Maria	Peninsula de Azuero	2017	28 a 49	Europe
<i>Aulacaspis yasumatsui</i>	Panama	Panama	Balboa	2011-2021	4m-50m	Asia

<i>Aphis spiraeicola</i>	Cocle	Penonome, Ola	Cocle	2002	180 a 440	South America
<i>Apis mellifera</i>	Panama	Panama	Panama Republic			Africa
<i>Tapinoma melanocephalum</i>						
<i>Paratrechina longicornis</i>						
<i>Monomorium floricola</i>						
<i>Nylanderia fulva</i>	Chiriqui	Chiriqui	Chiriqui			
<i>Ceratitis capitata</i>	Chiriqui	Chiriqui	Chiriqui	1963		South America
<i>Anastrepha obliqua</i>	Cocle	Cocle	Cocle	2011	14 a 1550	
<i>Anastrepha grandis</i>	Darien	La Palma	Darien	2009	20	South America
<i>Aedes aegypti</i>	Panama	Panama	Panama	1985		Africa
<i>Aedes albopictus</i>	Panama	Panama	Panama	2003		Asia
<i>Tuta absoluta</i>	Panama	Panama	Panama			
<i>Quadrastichus erythrinae</i>	Panama	Panama	Panama Canal	2018		South America
<i>Blattella germanica</i>	Panama	Panama	Panama			Africa
<i>Brevipalpus phoenicis</i>						
<i>Brevipalpus californicus</i>						
<i>Dermanyssus gallinae</i>	Herrera	Ocu	Las Guabas	2018		
<i>Rhithropanopeus harrisii</i>	Panama, Colon		Gatun Lake	1969		Noth America
<i>Elamenopsis kemp</i>	Panama, Colon		Gatun Lake	2007		Africa
<i>Procambarus clarkii</i>	Panama	Panama		1987		
<i>Penaeus monodon</i>	Panama	Panama	Panama			North America
<i>Cherax tenuimanus</i>	Panama	Panama	Panama			Oceania
<i>Macrobrachium amazonicum</i>	Panama, Colon		Gatun Lake			
<i>Macrobrachium rosenbergii</i>	Panama			1981		Asia
<i>Goniopsis cruentata</i>	Panama, Colon		Gatun Lake			
<i>Pachygrapsyus gracilis</i>	Panama, Colon		Gatun Lake			
<i>Raillietiella frenatus</i>	Panama					
<i>Mus musculus</i>	Panama	Panama	Panama	1973		Europe, Asia
<i>Rattus norvegicus</i>	Panama	Panama	Panama			Asia
<i>Herpestes auropunctatus</i>	Panama	Panama	Panama			Asia
<i>Herpestes javanicus</i>						
<i>Columba livia</i>	Panama	Panama	Panama	1608		Europe, Africa, Asia
<i>Quiscalus mexicanus</i>	Panama	Panama	Panama			North America
<i>Passer domesticus</i>	Panama	Panama	Panama	2019		Europe
<i>Sicalis flaveola</i>	Panama	Panama	Panama			South America
<i>Mimus gilvus</i>	Panama					
<i>Bubulcus ibis</i>	Panama					
<i>Rachycentron canadum</i>	Panama		Gulf of Panama	2015		South America
<i>Oreochromis niloticus</i>	Chiriqui, Veraguas, Panama, Colon		Fortuna, La Yeguada, Gatun, Alajuela, Bayano and rivers	1976		Africa
<i>Oreochromis aureus</i>	Panama	Panama	Panama Canal	1976		Northwest Africa
<i>Oreochromis mossambicus</i>	Panama	Gatún, Alajuela	Panama Canal	1940		Southeast Africa
<i>Oreochromis urolepis</i>	Panama	Panama	Panama Canal	1979		Southeast Africa
<i>Coptodon rendalli</i>	Panama	Panama	Panama Canal	1977		Africa, Middle east
<i>Cichla ocellaris</i>	Panama, Colon		Gatun Lake	1967		South America

<i>Cichla monoculus</i>	Panama, Colon, Veraguas		Gatun, Alajuela y La Yeguada	1969	South America
<i>Parachromis managuensis</i>	Chiriqui, Veraguas, Panama, Colon		Fortuna, La Yeguada, Gatun, Alajuela and rivers	1973	Central America (Atlantic Slope)
<i>Astronotus ocellatus</i>	Panama, Colon		Gatun Lake, Alajuela	1991	South America
<i>Mesonauta festivus</i>	Panama, Colon		Gatun Lake	1998-1999	South America
<i>Eleotris melanosoma</i>	Panama	Panama	Panama		Africa, Asia, Indo-Pacific
<i>Lepomis macrochirus</i>	Chiriqui, West Panama, Panama		Lagunas de Volcan y San Carlos, Las Cumbres	1955	North America
<i>Lepomis microlophus</i>	Panama	Panama	Panama		North America
<i>Micropterus salmoides</i>	Chiriqui		Lagunas de Volcan	1955	North America
<i>Pomoxis annularis</i>	Panama	Panama	Panama		North America
<i>Pomoxis nigromaculatus</i>	West Panama	La Laguna	Laguna de San Carlos	1925-1935	North America
<i>Omobranchus punctatus</i>	Panama	Panama	Panama Canal	2011	East Asia
<i>Lepomis humilis</i>	West Panama	La Laguna	Laguna de San Carlos	1925-1935	North America
<i>Sciaenops ocellatus</i>	Cocle	Aguadulce	El Salado	1987	North America
<i>Oncorhynchus mykiss</i>	Chiriqui		Chiriqui Viejo, Caldera, Boquete	1925	North America
<i>Salmo trutta</i>	Panama	Panama	Panama		Europe
<i>Pterois volitans</i>	Colon	Colon	Panamanian caribbean	2008	Pacific ocean, Asia
<i>Butis koilomatodon</i>	Panama	Panama	Miraflores locks	1973	Occidental Indo-Pacific
<i>Cirrhinus chinensis</i> Günther, 1868	Panama	Panama	Panama	1977	Asia
<i>Cirrhinus molitorella</i>	Panama	Panama	Panama	1980	Asia
<i>Ctenopharyngodon idella</i>	Panama	Panama	Panama	1978	Asia
<i>Cyprinus carpio</i>	Chiriqui, Veraguas		Fortuna, La Yeguada	1976	Europe, Asia
<i>Hypophthalmichthys molitrix</i>	Panama	Panama	Panama	1978	Asia
<i>Hypophthalmichthys nobilis</i>	Panama	Panama	Panama	1978	Asia
<i>Mylopharyngodon piceus</i>	Panama	Panama	Panama		East Asia
<i>Ictiobus cyprinellus</i>	Veraguas	Santiago	Santiago	1987	Cuba
<i>Ictalurus punctatus</i>	Panama	Panama	Panama	1981	North America
<i>Gambusia holbrooki</i>	Panama, Colon		Gatun Lake		North America
<i>Xiphophorus helleri</i>	Cocle, Panama		Las Cumbres, Anton Valley	1950's y 1970's	Central America (Atlantic Slope)
<i>Gambusia affinis</i>	Panama	Panama	Panama		
<i>Gambusia nicaraguensis</i>	Panama	Panama	Panama		
<i>Poecilia reticulata</i>	Veraguas, Panama		Santiago, Pacora, Chame, Las Cumbres, Cerro Azul	1910-1912	South America
<i>Xiphophorus variatus</i>	Panama	Panama	Panama		
<i>Colossoma macropomum</i>	Panama	Panama?	Panama? Es La Yeguada, río	1980	South America

			Sereno y Alajuela			
<i>Piaractus brachypomus</i>	Panama	Panama	Panama	1980		South America
<i>Piaractus mesopotamicus</i>	Panama	Panama	Panama	1986-1987		South America
<i>Hemidactylus brookii</i>	Panama	Panama	Tocumen			
<i>Hemidactylus frenatus</i>	Panama	Panama	Chepo, Tocumen	2019	36	Tropical region, Indo-Pacific
<i>Anolis sagrei</i>	Panama	Panama	Albrook	2018		Cuba
<i>Hemidactylus mabouia</i>	Panama	Panama	Canal zone	1994		sub-Saharan Africa
<i>Hemidactylus turcicus</i>	Panama	Panama	Canal Zone	1914		
<i>Lepidodactylus lugubris</i>	Not specific			2004		Siri Lanka-Africa
<i>Sphaerodactylus argus</i>	Bocas del Toro, San Blas	Bocas del Toro	Bocas del Toro, San Blas	2002		Jamaica, Caribbean island
<i>Trachemys scripta elegans</i>	Panama	Panama	Panama			United States
<i>Eleutherodactylus antillensis</i>	Panama	Panama	Panama city	1950-1960		Puerto Rico, Virgin Island
<i>Eleutherodactylus johnstonei</i>	Panama	Panama	Panama	1980		
<i>Eleutherodactylus planirostris</i>	Panama	Panama	Panama			Cuba, Bahamas
<i>Rana catesbeianus</i>	Panama	Panama	Panama			North America
<i>Ascidia incrassata</i>	Panama	Panama	Panama canal	2009		Indo Pacific
<i>Ascidia sydneyensis</i>	Panama	Panama	Panama			Australia-Oceania
<i>Phallusia nigra</i>	Panama	Panama	Panama			Indo Pacific
<i>Botrylloides nigrum</i>	Panama	Panama	Panama Canal	2002		South America
<i>Botryllus planus</i>	Panama	Panama	Panama			Indo Pacific
<i>Polyandrocarpa anguinea</i>	Panama	Panama	Panama			Africa
<i>Polyandrocarpa sagamiensis</i>	Panama	Panama	Panama			Suth America
<i>Polyandrocarpa zorritensis</i>	Panama	Panama	Panama			Suth America
<i>Styela canopus</i>	Colon	Colon	Panama canal			Indo Pacific
<i>Symplegma brakenhielmi</i>	Panama	Panama	Panama			
<i>Symplegma rubra</i>	Panama	Panama	Taboguilla			Indo- Pacific
<i>Herdmania pallida</i>	Bocas del Toro	Colon Island	Bocas del Toro			South America
<i>Microcosmus exasperatus</i>	Panama	Panama	Panama			Colombia-South America
<i>Pyura vittata</i>	Panama	Panama	Panama			
<i>Didemnum perlucidum</i>	Panama	Panama	Panama			South America
<i>Didemnum psammotodes</i>	Panama	Panama	Panama			
<i>Diplosoma listerianum</i>	Panama	Panama	Panama			
<i>Lissoclinum fragile</i>	Panama	Panama	Panama			
<i>Trididemnum orbiculatum</i>	Panama	Panama	Panama			South America
<i>Polyclinum constellatum</i>	Panama	Panama	Panama			

Among the species reported as invasive for the Panama Republic, nine species are under official control, all belonging to the insect class, causing damage to cucurbit crops, tomato, citrus, coffee, and species of the Arecaceae family (Table 3).

Table 3. Information about: invasive species, province, district, site, year, species altitude was found for the first time in Panama Republic, place of origin, affectation.

Pests	Class	Species	Host
South American cucurbit fly	insecta	<i>Anastrepha grandis</i> Macquart, 1846	Cucurbitaceae

Tomato moth	insecta	<i>Tuta absoluta</i> Meyrick, 1917	Tomato
Huanglongbing (HLB)	insecta	<i>Diaphorina citri</i> Kuwayama, 1908	Citrus
Mediterranean fly	Insecta	<i>Ceratitis capitata</i> Wiedemann, 1824	fruit plants (citrus, cucurbitaceae)
Oriental <i>Trips palmi</i>	Insecta	<i>Trips palmi</i> Karny, 1990	Cucurbitaceae
Coffe berry borer	Insecta	<i>Hypothenemus hampei</i> Ferrari, 1867	Coffe
Citrus leprosis virus	Insecta	<i>Brevipalpus californicus</i> Banks, 1904	Citrus
	Insecta	<i>Brevipalpus phoenicis</i> Geijskes, 1936	Citrus
Red Ring Disease	Insecta	<i>Rhynchophorus palmarum</i> Linnaeus, 1758	Arecaceae

4. Discussion

According to our results from the Arthropoda and Chordate Phylum, there are an estimated 133 invasive species for the Panama Republic. Comparing with the information from other Iberoamerican countries we found that for the countries that are part of the Andean Community (Colombia, Ecuador, Venezuela, Peru and Bolivia) 227 invasive exotic species have been identified, mostly plants (92 species), insect pests (61 species) and vertebrates (30 species) [16]. In Costa Rica 235 invasive species have been reported from all groups of organisms [17]. For the Dominican Republic, 192 invasive species have been reported, were 38 fish, 4 amphibians, 8 reptiles, 13 birds and 13 mammals [18]. While in other latitudes such as the Iberian Peninsula (Spain, Portugal and Andora) 100 invasive species have been recorded [19].

When comparing the number of invasive species based on the surface area of each country (Andean Community and Dominican Republic) in which this study is addressed, we found that for the Panama Republic the number is higher: Panama (134 species), compared to the Andean Community (166 species), Dominican Republic (138 species).

Panama has 75,416.6 km² area regard to the countries of the Andean community; Colombia (1,142 million km²), Ecuador (256,370 km²), Venezuela (916,445 km²), Peru (1,285 million km²), Bolivia (1,099 million km²) and the Dominican Republic with an area of 48,442 km², which indicates that the Panama Republic, even though it is a small country compared to those previously mentioned, it has quite a considerable number of invasive species in the territory.

Considering economic activity of the Dominican Republic based in beaches tourism [20], Colombia in the free market (exchange of goods and services between people and companies through monetary transactions) [21], Ecuador and Venezuela in oil revenues [22,23], Peru in the exploitation, processing and export of natural resources, mainly mining, agricultural and fishing [24], Bolivia in the natural gas [25], and since the Panama Republic is a country that bases its economy as a logistics and transportation center, commercial and financial center, we can assume that this is the reason why the constant influx of invasive species is reflected so high compared to the others countries.

5. Conclusions

The results indicate that approximately 133 invasive exotic species of the Arthropoda and Chordata Phylum have been reported in Panama. Of the 133 species, 49 species belong to the Arthropoda Phylum and 84 species belong to the Chordate Phylum. When comparing the number of invasive species based on the surface area of each country, in which this study is addressed, we found that for the Panama Republic the number is higher: This research can serve as a basis for future studies in the country that are of vital importance for pest control and recommendations for the complete collection of information. This research benefits the wealth of the country and therefore the care of our resources, and provides more information to entities seeking management plans to solve problems caused by the invasion of species.

Within the limitations of the work, it must also be considered that it is possible that some species are not included due to the dispersion of the information or that they have not been considered invasive for some researchers because they may correspond to natural dispersal patterns, like is the case of the Coyote.

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