Artículo Original

An updated checklist of the butterflies (Lepidoptera: Papilionoidea) of Guayaquil, Ecuador

Lista actualizada de las mariposas (Lepidoptera: Papilionoidea) de Guayaquil, Ecuador

Pablo Sebastián Padrón[1*], Gabriel A. Brito-Vera[2], Mishelle Palomeque-Briones[3], Estefanía Dueñas-Galvis[3] and Shinichi Nakahara[4]

[1]*Laboratorio de Entomología, Museo de Zoología de la Universidad del Azuay, Cuenca, Ecuador.* [2]*Department of Ecology, Pontificia Universidad Católica de Chile, Santiago, Chile.* [3]*Department of Biology, Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador.* [4]*Department of Organismic and Evolutionary Biology, Museum of Comparative Zoology, Harvard University, Cambridge, MA, USA.* [*]*sebastianpadronm@yahoo.com*

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Abstract. Recent years saw an increased interest in biodiversity research regarding green spaces in urban areas around the globe. Wildlife studies of butterflies (Lepidoptera: Papilionoidea) in urban semi-natural habitats provide key information towards developing conservation strategies for such areas. This is especially true considering the charismatic aspect of these insects, as well as their ability to serve as bioindicators. The growing appreciation and interest of the general population towards biodiversity adds special importance to such studies. However, a firm understanding of the species-level diversity of butterflies is crucial to achieve this goal and such work is still lacking in many parts of the Neotropics. In the present study, we present an updated species checklist of butterflies for Guayaquil, Ecuador. Information of the species reported here was obtained from fieldwork, an intensive bibliographic review, and visits to entomological collections, along with information from the iNaturalist citizen science platform. A total of 557 valid records of butterflies are reported, which belong to 166 species that are represented in six families. A total of 48 species are reported for the first time for Guayaquil. Some areas, especially in parks and near protected areas are where more species can be found. This indicates that green areas in general should be preserved, managed appropriately, and increased to maintain this extraordinary urban butterfly biodiversity. We hope this new information will be utilized to increase the interest in the study of butterflies that inhabit Guayaquil. The purpose of this study is to improve our knowledge of the butterfly community, their interactions, and to design and implement adequate strategies for the conservation of the city's biodiversity.

Key words: Biodiversity; conservation; Neotropics; urban.

Resumen. En los últimos años se ha visto un mayor interés en la investigación de la biodiversidad en relación con los espacios verdes en las zonas urbanas. Los estudios faunísticos de mariposas (Lepidoptera: Papilionoidea) en hábitats seminaturales urbanos son clave para desarrollar estrategias de conservación para estas áreas, considerando que son insectos carismáticos, así como su capacidad para servir como bioindicadores. El creciente aprecio e interés de los ciudadanos por la biodiversidad añade especial importancia a este tipo de estudios. Sin embargo, una comprensión firme de la diversidad de mariposas a nivel de especie es crucial para lograr este objetivo, y esta clase de trabajos, son escasos en muchas partes del Neotrópico. En el presente estudio se entrega una lista actualizada

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de las especies de mariposas de Guayaquil, Ecuador. El listado se elaboró basados en información obtenida producto del trabajo de campo, revisión bibliográfica, visitas a colecciones entomológicas e información extraída de la plataforma de ciencia ciudadana iNaturalist. Se reporta un total de 557 registros válidos de mariposas diurnas, pertenecientes a 166 especies reunidas en seis familias, 48 de las cuales se reportan por primera vez para Guayaquil. Algunos lugares, especialmente los parques y los espacios cercanos a áreas protegidas, es donde se pueden encontrar más especies, esto indica que las áreas verdes en general deben preservarse, administrarse adecuadamente e incrementarse para mantener esta extraordinaria biodiversidad de mariposas. Se espera que esta nueva información sea utilizada para aumentar el interés en el estudio de las mariposas que habitan en Guayaquil y en otras regiones del país, ayudando a mejorar nuestro conocimiento sobre las comunidades de mariposas, sus interacciones y, finalmente, sea utilizada para el diseño e implementación de estrategias adecuadas que permitan la conservación de la biodiversidad de la ciudad.

Palabras clave: Biodiversidad; conservación; neotrópico; urbano.

Introduction

With accelerating urbanization worldwide, green spaces in urban settings have received increased attention in biodiversity research over the past decade (Ferenc *et al*. 2014; Aguilera *et al*. 2019; Chowdhury *et al.* 2021). Studies of urban green habitats not only focused on the urbanization impacts on biological communities, but research may range from testing island biogeography models based on urban green spaces (Fattorini *et al*. 2018) to assessments of the influence of urban green areas on human emotions (Li *et al*. 2022). Accumulation of data across various spatial and temporal scales, focal organisms, as well as geographic regions is essential to develop meaningful conservation strategies to prevent biodiversity losses resulting from rapid urbanization. Furthermore, preserving and protecting urban biodiversity produces positive aftereffects concerning public health, education, general human welfare as well as informing citizens of the urgency to conserve biodiversity (Dearborn and Kark 2010; Goddard *et al.* 2010; Dean *et al.* 2011).

Butterflies (Lepidoptera: Papilionoidea) are an enthralling and striking group of insects that have not only captured the attention of scientists and naturalists for centuries but also children and adults of all ages owing largely to their inherent beauty. Butterflies provide indispensable services within cities such as pollination and maintenance of trophic structures through ecological interactions such as herbivory, parasitism and competition, among others (Potter and LeBuhn 2015; Ramirez-Restrepo and MacGregor-Fors 2017). These activities allow for the interchange of energy and nutrients, and provide ecosystem stability (Kellert 1993). Moreover, butterflies are good indicators of change in the environment acting as bioindicators due to their high sensitivity towards local climate changes, food resources, light levels and human disturbances (Blair 1999; Taron and Ries 2015; Dylewski *et al.* 2019), allowing them to monitor the state of urban ecosystems (Longcore *et al.* 2010; Lizée *et al.* 2011). Also, in the last decades, the anatomy, physiology, beauty and environmental impacts of butterflies have been incorporated into educational programs for children and adult science programs to involve them in conservation awareness (Ramírez-Restrepo *et al.* 2015; Wang Wei *et al.* 2016). Therefore, comprehending the significance of butterflies in urban ecosystems is key from both a social and conservation perspectives. Despite the importance of studying butterflies in urban settings, coupled with the fact that the Neotropics contain the highest diversity of butterflies, relatively limited studies on urban butterflies originate from this geographical region 36/166; *ca.* 20% based urban butterfly articles surveyed in Ramírez-Restrepo and MacGregor-Fors (2017). In particular, 30 out of these 36 studies in South America are surveys conducted in Brazil. Research in other "megadiverse" countries, such as Ecuador, is lacking.

Guayaquil is the second most populated city in Ecuador and one of the most densely populated cities in the nation with more than three million inhabitants living in an area of 344.5 km² (INEC 2020). Also, Guayaquil is the main seaport for the country, and one of the most important for exporting and importing products during the last decades. Guayaquil has great biological relevance due to its tropical climate and location close to the equator. The city is in a transition zone between the Chocó region and the Tumbes region; both of which are hotspots of diversity (Myers *et al.* 2000). The climate and environment of Guayaquil is influenced both by marine currents and by the Andes mountain range which create marked seasonality. All these factors contribute towards generating and maintaining high endemicity and diversity (Sierra *et al*. 1999), especially in the dry forests and coastal humid forests (Gentry 1986; Ministerio del Ambiente 2013). Nevertheless, despite the importance of this region, the biodiversity of insects and especially butterflies in the Guayaquil area has been poorly studied. Starting from 1876, only a handful of articles focusing on butterflies was published (Crüger 1876; Weymer and Maassen 1890; Campos 1921) where Crüger (1876), published the first species lists for the city. In the last decade, some studies on community ecology, distributional behavior, and seasonal inventory of butterflies (Brito and Buestán 2014; Dueñas and Palomeque 2021) have significantly increased our knowledge on the species of Papilionoidea in this area.

However, in the same period, especially from 1985 to 1990, several green areas in Guayaquil were eliminated (Delgado 2013), a phenomenon resulting from population increase. Therefore, urbanization has created substantial environmental disturbances in Guayaquil (Aspiazu and Espinoza 2017; Perez de Murzi 2019), which pose one of the greatest threats to biodiversity and to butterflies especially, since they mirror plant distribution due to their association with host plant and nectar sources (New 2015; Baldock 2020).

Based on information acquired through fieldwork from multiple years, intensive bibliographic reviews, collection examinations, as well as data drawn from an online science platform, we generated a preliminary species checklist of the butterflies of Guayaquil. Our main goals are to aid and encourage the development of conservation programs, to motivate public interest towards biodiversity, and to stimulate further research regarding preservation and the impacts of urbanization on butterflies.

Materials and Methods

Study area

Since Guayaquil has undergone intensive periods of territorial contraction and expansion in the past few decades, we defined the city limits with the aid of the 2021 geoinformation available on the municipality website (Geoportal del GAD Municipal de Guayaquil 2022) (Fig. 1). For field sampling within Guayaquil, we chose some green areas which possess potentially favorable conditions and characteristics for butterflies such as the presence of vegetation, flowers, size of the green area, and for some of the areas, the state of conservation or protection. Under these criteria, the selected areas were: Bosque Protector La Prosperina (BPP) (-2.152778°S -79.961227° W, 120 masl), campus of Gustavo Galindo Escuela Superior Politécnica del Litoral (ESPOL) (-2.145796°S -79.967801°W, 80 masl) and Bosque Protector Cerro Blanco (BPCB) (-2.183568°S -80.016447°W, 30 masl). These areas are in the tropical dry forest in the equatorial ecoregion. The type of vegetation varies according to the height of the mountains and precipitation, with notable plant transitions between the higher altitudes and the lower plains (Dodson and Gentry 1991; Gentry 1995). There is a high diversity of epiphytes and a predominance of plant climbers; greater richness of the Piperaceae, Moraceae, Cucurbitaceae families and low richness

values for Bignoniaceae and Fabaceae (Cerón *et al*. 1999; Bonifaz and Cornejo 2004). Also, there are hills in Guayaquil that vary in height such as San Eduardo, Cerro Blanco, Cerro Prosperina, Cerro Santa Ana, Cerro Azul and Cerro del Carmen; all of them belonging to the coastal mountain system called Cordillera Chongón Colonche.

Fieldwork and specimen identification

Field work was performed throughout different months in different years in the selected collecting areas (BPP and ESPOL 2020; BPCB 2011, 2013, 2015) (Fig. 1). This work included the use of Van Someren-Rydon traps (VSR) baited with rotting meat and fruits, and the use of entomological nets with extension tubes (Brito and Buestán 2014; Dueñas and Palomeque 2021), both of these methods are essential for the study of tropical diurnal butterflies, and they have proven to be very efficient (Freitas *et al.* 2021). Sampled specimens were kept in paper envelopes, upon which information related to collection and locality were written. Specimens from BPCB were spread, labeled and deposited at the Zoology Museum of the Faculty of Natural Sciences of the University of Guayaquil, Ecuador. Taxonomic identification at subspecies levels in most cases were carried out by comparison with type photos available on the Butterflies of America website (Warren *et al.* 2016). In some cases, they were identified by experts or through the review of taxonomic publications. Taxonomic nomenclature follows that proposed on the Butterflies of America web page (Warren *et al*. 2016).

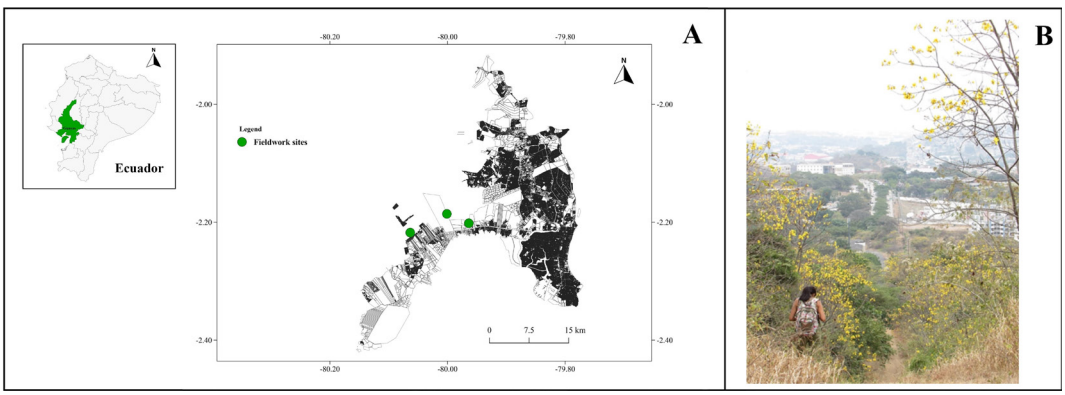

Figure 1. Study area. **A)** Fieldwork sites in Guayaquil city, Ecuador. **B)** Sampling at Bosque Protector La Prosperina. Área de estudio. / **A)** Sitios de trabajo de campo en la ciudad de Guayaquil. **B)** Muestreo en Bosque Protector La Prosperina.

Citizen science data

iNaturalist is a citizen-led science project and online platform used by scientists, citizens, and naturalists where the core concept is focused around mapping and sharing observations of biodiversity on a global scale, freely accessible by the community (Nugent 2018). An information search was conducted to look for butterfly observations in Guayaquil, Ecuador. The data was downloaded and saved in an occurrence data spreadsheet on Excel, which was later curated. To accomplish this task, we first projected each observation on the Guayaquil city map shapefile (see study area) in QGIS. Observation points projected outside the map of Guayaquil, as defined for this study, were removed. Subsequently, the remaining records were individually reviewed to correct potential identification errors. After this process, several observations were removed because they could not be identified mainly due to technical deficiencies of the photographs such as out of focus photographs, or there were no useful areas for identification, etc. Also, if the identification was not at the species-group level, the

identification was narrowed down as far as possible. Finally, a database with the correctly identified points within the city of Guayaquil was generated and projected in a map (Fig. 2).

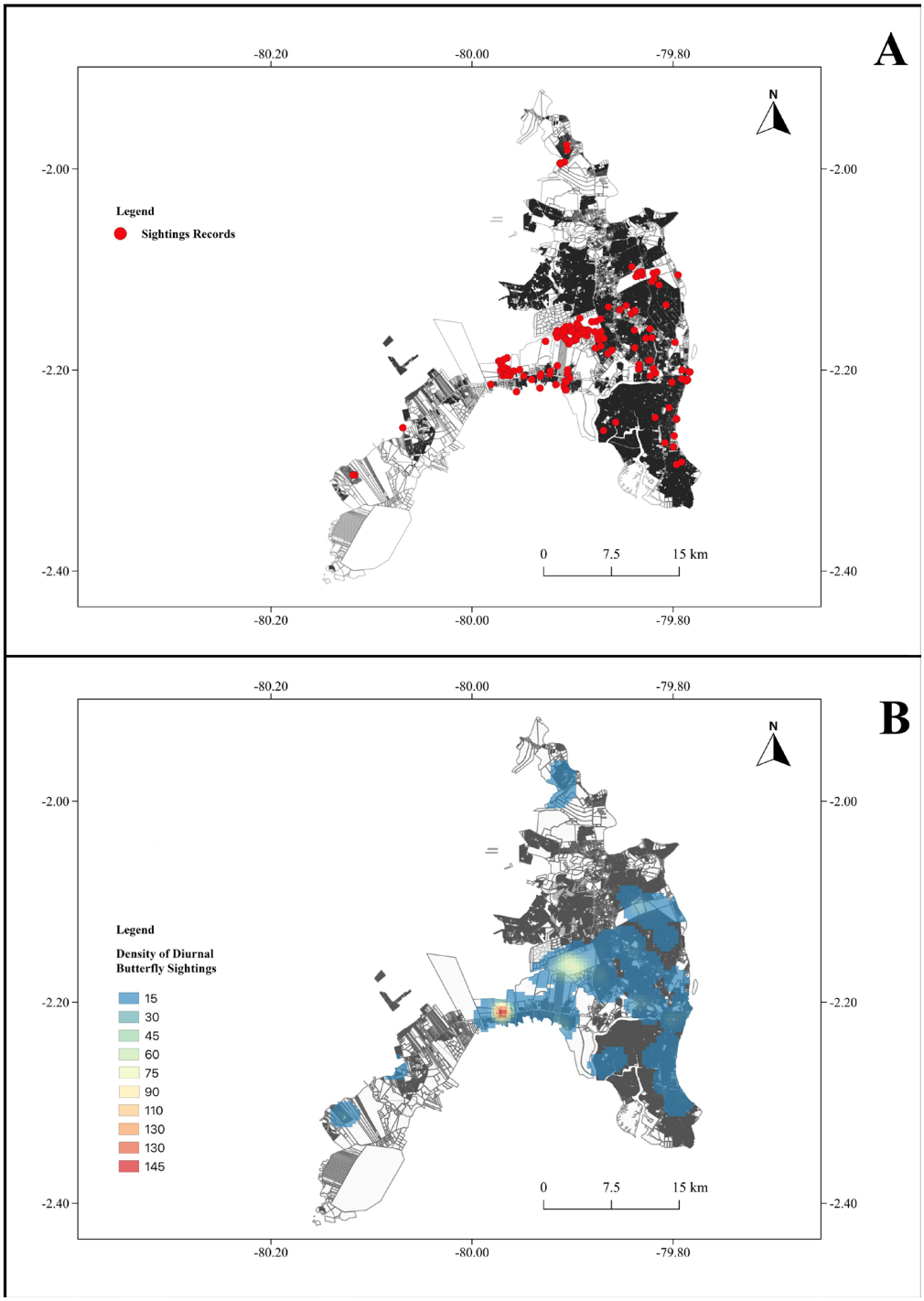

Figure 2. Sightings records of diurnal butterflies in Guayaquil, Ecuador. **A)** Sighting records. **B)** Heat map of diurnal butterfly sightings compiled in this research. /Registros de avistamientos de mariposas diurnas en Guayaquil, Ecuador. **A)** Registros de vistas. **B)** Mapa de calor de avistamientos de mariposas diurnas compilado en esta investigación.

Museum work and bibliographic review

Two entomological collections with specimens collected in Guayaquil were examined; Museum of Natural Sciences of the University of Guayaquil (Guayaquil, Ecuador) (MCNG) and the Municipal Museum of Guayaquil (Guayaquil, Ecuador) (MMG). The latter museum holds the Hermano Agustín collection.

Data analysis

Locality records obtained from three different sources (fieldwork, publications and from iNaturalist) were concatenated in the main database for analysis. Subsequently, the list of species was divided into two categories according to their taxonomic importance (T: Type) (NT: No Type); then the errors were corrected and the dubious or unverified species records were eliminated. With the final curated database, a point density raster was created using the Heatmap Tool from the Raster analysis menu in QGIS. This allows for the visualization of the concentration of records projected on the map of Guayaquil.

Results

A total of 767 records of butterflies were collected for the city of Guayaquil between observations (iNaturalist), specimens collected in the field, identification from two museum collections and in twenty-six publications where Guayaquil was registered as a place where specimens were collected (Doubleday 1844, 1846; Gray 1852; Hewitson 1856, 1862, 1867; Seitz 1860-1938; Butler 1868, 1869; Kirby 1871; Crüger 1876; Oberthür 1883; Weymer and Maassen 1890; Rothschild and Jordan 1906; Campos 1921; Brown 1933; Emsley 1963; Fox 1965, 1967; Ackery and Smiles 1976; Jenkins 1983; Racheli 1996; Willmott 2003; Abadjiev 2005; Brito and Buestán 2014; Dueñas and Palomeque 2021). It must be noted that some of these works, especially those made in the 19th century and the beginning of the 20th century, may have applied the term "Guayaquil" in a broad sense, and this may not be in accordance with our study. After the curation of the data, a total of 557 valid records for modern day Guayaquil were obtained. These records represent 166 species of butterflies distributed in six families (Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae and Riodinidae and 19 subfamilies (Tab. 1). The species composition and richness of each family was as follows: Nymphalidae 68 species, Hesperiidae 45 species, Pieridae 18 species, Lycaenidae 16 species, Papilionidae 9 species, and Riodinidae 10 species. Most of the species reported here are representatives of the dry forests. In relation to the importance of 166 species reported here, 8 taxa have Guayaquil as their type locality (Tab. 1).

Regarding the contribution of data for each of the sources of information used, citizen science through the iNaturalist application was the one that contributed the most to the number of data records with 332, followed by specimens collected in the field with 174 records. Museum collections and publications were the smallest contributors with 17 and 34 data points respectively. In data from publications, we detected several inconsistent records of butterflies originally reported for Guayaquil. Most of these errors were in records published in the 1800s and early 1900s where the accuracy of collection data was not a priority for butterfly collectors and taxonomy identification was not always accurate. It is also important to note that although citizen science (iNaturalist) contributed the largest number of records, it was the field collections that contributed the largest number of species with a total of 121 species representing 73% of all species listed here, followed by iNaturalist with 74 species (45%), and collections along with publications contributed 50 species (30%).

There was a pattern between the number of observations and the presence of green areas, such as parks, gardens, protected areas, university grounds or remnants of vegetation. Areas with less vegetation yielded lower numbers of observations and, therefore, a lower diversity of butterflies (Fig. 2).

Table 1. Species list of butterflies recorded in Guayaquil, Ecuador. Source Code 1: iNaturalist, 2: collected in the field, 3: from publications or museum's collections. Species name in bold means new species record for Guayaquil reported in this publication. *Denotes species with available host plant records based on Beccaloni *et al*. (2008) and/or Janzen and Hallwachs (2018). / Lista de especies de mariposas registradas en Guayaquil, Ecuador. Código fuente 1: iNaturalist, 2: colectado en campo, 3: de publicaciones o colecciones de museos. El nombre de la especie en negrita significa nuevo registro de especie para Guayaquil reportado en esta publicación. * Indica especies con registros de plantas hospedantes disponibles según Beccaloni *et al.* (2008) y/o Janzen y Hallwachs (2018).

Family	Subfamily	Species	Importance	Source
Hesperiidae	Eudaminae	***Telegonus anaphus* (Cramer, 1777)***		1, 2
		Telegonus fulgerator (Walch, 1775)*		1, 2, 3
		Telegonus talus* (Cramer, 1777)		1
		***Bungalotis aureus* Austin, 2008**		1
		Chioides catillus (Cramer, 1779)*		1, 2, 3
		Chioides zilpa* (Butler, 1872)		1
		Codatractus alcaeus apulia* Evans, 1952		1
		Nascus phocus* (Cramer, 1777)		3
		Polygonus leo (Gmelin, [1790])*		1, 2, 3
		Cecropterus dorantes (Stoll, 1790)*		1, 2, 3
		Cecropterus doryssus (Swainson, 1831)*		2, 3
		Urbanus esmeraldus (Butler, 1877)*		1, 2
		Cecropterus procne* (Plötz, 1881)		1
		Urbanus proteus (Linnaeus, 1758)*		2, 3
		Urbanus simplicius (Stoll, 1790)*		2, 3
	Hesperiinae	***Artines aepitus* (Geyer, 1832)**		2
		Calpodes ethlius* (Stoll, 1782)		1, 2
		Hylephila phyleus* (Drury, 1773)		1, 2
		Niconiades nikko* Hayward, 1948		2
		***Panoquina* sp.**		2
		Parphorus decora (Herrich-Schäffer, 1869)*		2, 3
		Perichares adela* (Hewitson, 1867)		2
		Hedone vibex* (Geyer, 1832)		2
		Pompeius pompeius* (Latreille, [1824])		2
		Calpodes esperi* (Evans, 1955)		1
		Vettius sp.		2
		Vehilius sp.		1, 2
	Pyrginae	***Achlyodes* sp.**		2

Family	Subfamily	Species	Importance	Source
Hesperiidae	Pyrginae	***Antigonus* sp.**		1
		Celaenorrhinus songoensis Draudt, 1922		1, 2
		Eantis thraso* (Hübner, [1807])		1, 2
		***Erynnis* sp.**		1
		Gorgythion begga* (Prittwitz, 1868)		1
		Heliopetes alana* (Reakirt, 1868)		1
		Heliopetes laviana (Hewitson, 1868)*		2
		***Heliopetes marginata* Hayward, 1940**		1
		Heliopetes sp.		2
		Mylon sp.		2
		Myscelus sp.		2
		Myscelus amystis distinctus Röber, 1925*		2
		Ouleus panna Evans, 1953		1, 2
		Paches loxus (Westwood, 1852)*		1, 2, 3
		***Polyctor* sp.**		2
		Timochares sp.		2
		Burnsius orcus (Stoll, 1780)		1, 2
Lycaenidae	Lycaeninae	***Tmolus* sp.**		1
	Polyommatinae	***Hemiargus ramon* (Dognin, 1887)***		1, 2, 3
		Leptotes marina (Reakirt, 1868)*		1, 2, 3
		Leptotes sp.		1, 2
		***Zizula cyna* (Edwards, 1881)**		2
	Theclinae	*Arawacus lincoides* (Draudt, 1917)*		2, 3
		***Calycopis origo* (Godman & Salvin, 1887)**		1
		Calycopis sp.		2
		***Chlorostrymon* sp.**		2
		Cyanophrys herodotus (Fabricius, 1793)*		2, 3
		Oenomaus ortygnus* (Cramer, 1779)		1
		Panthiades phaleros* (Linnaeus, 1767)		1, 2
		Pseudolycaena marsyas (Linnaeus, 1758)*		2, 3
		Pseudolycaena damo (Druce, 1875)*		1, 2
		Strymon daraba (Hewitson, 1867)*		2, 3
		Strymon mulucha* (Hewitson, 1867)		2
Nymphalidae	Apaturinae	***Doxocopa pavon* (Latreille, [1809])***		2
	Biblidinae	*Dynamine haenschi* Hall, 1917		2, 3
		Dynamine postverta (Cramer, 1779)*		1, 2
		Hamadryas amphichloe (Boisduval, 1870)*	Syntype	1, 2 ,3

Family	Subfamily	Species	Importance	Source
Nymphalidae	Biblidinae	*Hamadryas amphinome* (Linnaeus, 1767*)		1, 2, 3
		Hamadryas feronia (Linnaeus, 1758)*		1, 2, 3
		Hamadryas fornax (Hübner, [1823])		3
		***Mestra hersilia* (Fabricius, 1776)**		2
		Myscelia cyaniris Doubleday, 1848*		2, 3
		Temenis laothoe (Cramer, 1777)*		2, 3
	Cyrestinae	*Marpesia chiron* (Fabricius, 1775)*		2, 3
		Marpesia petreus petreus* (Cramer, 1776)		2
		***Marpesia crethon* (Fabricius, 1776)**		2, 3
	Charaxinae	*Archaeoprepona demophon* (Linnaeus, 1758)*		2, 3
		Consul fabius* (Cramer, 1776)		1
		Fountainea eurypyle (C. Felder & R. Felder, 1862)*		2, 3
		Memphis moruus (Fabricius, 1775)*		2
		Prepona laertes (Hübner, [1811])*		2
	Danainae	*Danaus plexippus* (Linnaeus, 1758)*		1, 2, 3
		Danaus erippus (Cramer, 1775)*		2, 3
		Elzunia pavonii (Butler, 1873)*		1, 2, 3
		Hypoleria lavinia* (Hewitson, [1855])		1
		Ithomia hyala hyala Hewitson, [1856]	Syntype	2, 3
		Ithomia cleora Hewitson, 1855	Syntype	3
		Lycorea halia fasciata Haensch, 1909*		3
		Mechanitis menapis mantineus Hewitson, 1869*		2, 3
		Mechanitis polymnia chimborazona H. Bates, 1864*		2, 3
		Oleria zelica zelica (Hewitson, 1856)*		3
		Pteronymia aletta lilla (Hewitson, 1856)*		2,3
		Scada zemira (Hewitson, 1856)	Syntype	2, 3
		Mechanitis lysimnia macrinus Hewitson, 1856*		2, 3
	Heliconiinae	*Agraulis vanillae* (Linnaeus, 1758)*		1, 2, 3
		Dione juno andicola (Bates, 1864)		2, 3
		Dryadula phaetusa* (Linnaeus, 1758)		1
		Dryas iulia (Fabricius, 1775)*		1, 2, 3
		Eueides isabella* (Stoll, 1781)		2
		Euptoieta hegesia (Cramer, 1779)*		1, 2, 3
		Heliconius erato* (Linnaeus, 1758)		1, 3
		Heliconius atthis (Doubleday, 1847)*		2, 3

Family	Subfamily	Species	Importance	Source
Nymphalidae	Heliconiinae	*Heliconius eleuchia primularis* Butler, 1869*	Syntype	2, 3
		Heliconius ismenius Latreille, [1817]*		1
		Heliconius melpomene cythera (Hewitson, 1869)*		2, 3
		Heliconius charitonia (Linnaeus, 1767)*		2, 3
		Heliconius peruvianus (C. Felder & R. Felder, 1859)		2, 3
	Limenitidinae	*Adelpha serpa* (Boisduval, 1836)*		2,3
	Nymphalinae	*Anartia amathea* (Linnaeus, 1758)*		1, 2, 3
		Anartia jatrophae (Linnaeus, 1763)*		1, 2, 3
		Anthanassa hermas (Hewitson, 1864)		1, 2, 3
		Colobura dirce (Linnaeus, 1758)*		1, 2, 3
		Historis odius odius (Fabricius, 1775)*		1, 2, 3
		Junonia genoveva (Cramer, 1780)*		1, 2, 3
		Siproeta stelenes (Linnaeus, 1758)*		2, 3
		Siproeta epaphus (Latreille, [1813])*		2, 3
		Smyrna blomfildia (Fabricius, 1781)*		2, 3
		Tegosa flavida (Hewitson, 1868)		2, 3
		Tegosa sp.		1
		Vanessa annabella* (Field, 1971)		2
		Vanessa braziliensis* (Moore, 1883)		2
	Satyrinae	*Caligo* sp. 1?		1, 2, 3
		Caligo sp. 2		1
		Cissia labe (Butler, 1870)*		2,3
		Cissia pseudoconfusa Singer, DeVries & Ehrlich, 1983*		1
		Eryphanis automedon (Cramer, 1775)*		1, 2, 3
		Hermeuptychia sp.		2, 3
		Magneuptychia libye (Linnaeus, 1767)*		1, 2
		Morpho helenor (Cramer, 1776)*		1, 2, 3
		Opsiphanes cassina C. Felder & R. Felder, 1862*		1, 2, 3
		Taygetis virgilia (Cramer, 1776)*		2, 3
Papilionidae	Papilioniinae	*Battus polydamas* (Linnaeus, 1758)*		1, 2, 3
		Heraclides anchisiades (Esper, 1788)*		2, 3
		Heraclides epenetus (Hewitson, 1861)*		2,3
		Heraclides paeon (Boisduval, 1836)*		1, 2, 3
		Heraclides thoas nealces (Rothschild & Jordan, 1906)*		2, 3

Family	Subfamily	Species	Importance	Source
Papilionidae	Papilioniinae	*Parides panares paralius* (Rothschild & Jordan, 1906)*		2
		Parides eurimedes timias (Gray, [1853])*	Syntype	2, 3
		Parides iphidamas calogyna (Rothschild & Jordan, 1906)*		2, 3
		Protesilaus telesilaus* (C. Felder & R. Felder, 1864)		2
Pieridae	Coliadinae	*Anteos clorinde* (Godart, [1824])*		1, 2, 3
		Anteos maerula (Fabricius, 1775)*		1, 2, 3
		Eurema albula Cramer, 1775*		1, 2, 3
		Eurema arbela angulata (Wallengren, 1860)*		2, 3
		Eurema daira (Godart, 1819)*		1, 2,3
		Phoebis argante (Fabricius, 1775)*		2, 3
		Phoebis bourkei (Dixey, 1933) (record for Guayaquil based on *P. tatei* Brown, 1933, junior subjective synonym of *P. bourkei*)	Holotype	3
		Phoebis philea (Linnaeus, 1763)*		1, 2, 3
		Phoebis sennae (Linnaeus, 1758)*		1, 2, 3
		Pyrisitia leuce athalia (C. Felder & R. Felder, 1865)*		3
		Pyrisitia nise (Cramer, 1775)*		2, 3
		Pyrisitia proterpia (Fabricius, 1775)*		2, 3
		Zerene cesonia* (Stoll, 1790)		1
	Pierinae	*Ascia monuste* (Linnaeus, 1764)*		1, 2, 3
		Ganyra phaloe sincera (Weymer, 1890)*		2, 3
		Glutophrissa drusilla (Cramer, 1777)*		2, 3
		Itaballia marana (Doubleday, 1844)	Lectotype	1, 2, 3
		Perrhybris pamela (Stoll, 1780)*		1, 2, 3
Riodinidae	Riodininae	*Baeotis zonata* R. Felder, 1869		1
		Calephelis laverna* (Godman & Salvin, 1886)		2
		Emesis lucinda lucinda (Cramer, 1775)*		2, 3
		Emesis sp.		2
		Melanis leucophlegma (Stichel, 1910)*		1, 2, 3
		Perophthalma tullius (Fabricius, 1787)*		2, 3
		***Seco calagutis* (Hewitson, 1871)**		2
		***Synargis mycone* (Hewitson, 1865)**		2
		Theope basilea Bates, 1866		2
		Theope publius C. Felder & R. Felder, 1861*		2, 3

Discussion

Based on information obtained from fieldwork and literature reviews, along with reviews of museum collections and citizen science sights, an updated list of butterfly species is presented here for Guayaquil, the second most populated city. The present study is especially relevant because the information provided here can enhance the lives of its citizens by increasing urban biodiversity, which has a positive influence on people's overall welfare. This information can also be used by government authorities to manage the city in a more respectful and responsible way to protect the environment and conserve a higher degree of biodiversity.

In total, 166 species of butterflies were identified for Guayaquil, which significantly increased the number of species previously known for the city, namely Crüger's (1876) 13 species and Campos' (1921) 21 species for the city and Brito and Buestan's (2014) 77 species and Dueñas and Palomeque's (2021) 44 species for its surroundings. Is clear that more species may be recorded in the future, especially if new surveys are conducted in poorly studied areas such as the western side of the city, or if sampling is carried out throughout the year. This is due to the fact that this area registers strong seasonal changes associated with rainfall (Ilbay-Yupa *et al.* 2021), and every couple of years it is affected by El Niño–Southern Oscillation (ENSO) (De Guenni *et al.* 2016). These fluctuations in the amount and frequency of precipitation are reflected in the phenology of plants (Gentry 1986; Linares-Palomino *et al.* 2010; Vicente-Serrano *et al*. 2017), and due to the close link between plants and butterflies (host plants for immatures and nectar source for adults), ENSO creates a seasonality in the populations of butterflies (Castro and Espinosa 2015; Checa *et al.* 2019). Therefore, to accurately record both types and number of species, samples should be taken throughout the year and through several years (Luk *et al.* 2019). Nevertheless, we consider that the list presented here is a good representation and approximation of the butterfly fauna of Guayaquil.

Interestingly, host plant records are available for a remarkable 74% (123 out of 166) of butterfly species reported here based on Beccaloni *et al.*'s (2008) catalog and Janzen and Hallwachs' (2018) database. For example, host plant records in the study by Beccaloni *et al.* (2008) covered 26% of the total butterfly fauna in the Neotropics, suggesting that the percentage (74%) reported here is unusually high for a given butterfly community in the same region. One possible interpretation for this discrepancy in host plant records may be that butterfly fauna of Guayaquil reported here is composed mainly of common and/or widespread species. These species often have increased information available due to the large number of encounters in nature.

In relation to butterfly family composition, Nymphalidae is the largest family found in the city with 68 species recorded. These patterns have been found before in other study of urban butterflies in Ecuador (Nuñez-Penichet *et al*. 2021), followed by Hesperiidae with 45 species. The least species-rich families are Riodinidae with 10 species and Papilionidae with 9 species.

It is important to mention that several historical records of species for Guayaquil were ambiguous records, therefore they were not included in our species list. These inconsistent records are mainly because they were named in scientific articles as having been collected in Guayaquil, but their known habitats and distribution is outside the elevation range and region of Guayaquil. One example is the type specimen of *Parapedaliodes parepa parepa* (Hewitson, 1862) (Viloria *et al.* 2008). This species is found southwest of Loja and Zamora province, which is far from Guayaquil and at a higher elevation range. Other examples include *Scada kusa* (Hewitson, 1872) reported by Fox (1967), *Pterourus zagreus* (Doubleday, 1847) reported by Rothschild and Jordan (1906) and Oberthür (1883); *Parides erithalion* (Boisduval, 1836) reported by Kirby (1871); *Podotrichia judith mellosa* (Stichel,

1906) reported by Emsley (1963); *Eueides isabella dianasa* (Hübner, [1806]) and *Heliconius erato dignus* (Stichel, 1923) cited by Doubleday (1846). These species are considered as erroneously reported from Guayaquil in the current study for the following reasons: absence of accurate methods of recording localities, errors in labeling specimens, labeling ports of shipment of specimens such as Guayaquil as if this were the place where they were collected (Emsley 1963).

Other historical records we considered as errors of identification include; for example, Crüger's (1876), mentions the presence of the genus *Callicore* Hübner, [1819] in Guayaquil, although without species-level identification. Having such a striking taxon makes it very unlikely that no one else has observed this genus after Crüger; therefore, we believe this record should be considered an identification error. Other species cited by Campos (1921), such as *Junonia coenia* (Hübner, 1822), *Morpho menelaus* (Linnaeus, 1758), *Tachyris ilaire* (Godt), *Pieris elodia* (Boisduval, 1836) those reported by Weymer and Maassen (1890) such as *Panara jarbas* (Drury, 1782) and *Myscelia orsis* (Drury, 1782) are also likely identification errors. However, identifying more errors was not possible due to the absence of the collected material, which prevented corroborating their identification. Hence, most of the records presented here come from the work done in recent years by the authors and by citizen science records from the iNaturalist application, even though some have not been identified at the species level to avoid errors.

Finally, other previously reported species for Guayaquil such as *Nascus phocus* (Cramer, 1777) (Hesperiidae), *Hamadryas fornax* (Hübner, 1823), and *Lycorea halia fasciata* (Haensch, 1909) (Nymphalidae) (Crüger 1876; Weymer and Maassen 1890; Rothschild and Jordan 1906; Campos 1921; Ackery 1976) might have become locally extinct since these species were not recorded again despite being common elsewhere. This could be due to the expansion of the city that drastically reduced green areas where they might find host plants or food sources. Also, rapid urban expansion has formed isolated patches of vegetation, isolating butterflies' populations. The remnants of vegetation in the city allow the survival of species groups with high anthropic tolerance. These effects on conservation of urban butterflies have been identified as one of the main factors of local extinction of species in cities (Clark *et al.* 2007; Aguilera *et al.* 2019).

Regarding the importance of the specific species collected, some of them are considered common species, which are widely distributed in Ecuador as is the case for *Urbanus dorantes* (Stoll, 1790), *Hamadryas amphinome* (Linnaeus, 1767), *Danaus plexippus* (Linnaeus, 1758), *Dione juno* (Cramer, 1779), *Anartia amathea* (Linnaeus, 1758), *Anartia jatrophae* (Linnaeus, 1763), *Junonia genoveva* (Cramer, 1780) and *Siproeta epaphus* (Latreille, 1813). These can be found in different ecosystems in Ecuador, including developed areas or forest edges. Crüger (1876) already classified *Anthanassa hermas* (Hewitson, 1864), *Argaulis vanillae* (Linnaeus, 1758), *Euptoieta hegesia* (Cramer, 1779), *A. amathea* (Linnaeus, 1758), *A. jatrophae* (Linnaeus, 1763), *J. genoveva* (Cramer, 1780) and *Heliconius charitonia* (Linnaeus, 1767) as "*common species*". Other records correspond to rarer species such as: *Archaeoprepona demophon* (Linnaeus, 1758), *Memphis moruus* (Fabricius, 1775) and *Prepona laertes* (Hübner, [1811]), which are generally associated with forests in a better state of conservation. Nevertheless, a deeper analysis of the rarity of species requires a long-term study of the area and a deeper knowledge of the butterfly fauna of Ecuador in general.

One key aspect of our research was the incorporation of data obtained from citizen science, although this is a common practice in the study of insect biodiversity in urban areas (Wang Wei *et al.* 2016). However, to our knowledge, the present study is one of the few projects in Ecuador that have incorporated this kind of information in a research project focused on insects (Cisneros-Heredia and Peñaherrera-Romero 2020). The potential of this kind of data collected by thousands of users is valuable, but the quality of the results it generates is determined by the reliability of the data itself (Bonter and Cooper 2012;

Hochmair *et al.* 2020). It is very important to first curate and validate this information, eliminating possible misidentifications or incorporating missing taxonomic information. In this way, this information is consolidated into an important data source as we demonstrate in this publication.

Human disturbances in urban areas, as a result of human population growth and migration towards cities, affect urban biodiversity (Yamamoto 1977; Ramirez-Restrepo *et al*. 2017). Migration to urban areas has been identified as one of the most alarming sources of biodiversity endangerment attributable to the great environmental disturbances it generates (Shochat *et al.* 2010; Kowarik 2011). In our results, it is clear that the distribution of butterfly records in the city shows a pattern, where the largest number of observations are in or near green areas, be they parks, university campuses, remnants of vegetation or protected vegetation areas. This shows the importance of these spaces for the maintenance, conservation, and hopefully, the increase of butterfly populations in the city of Guayaquil.

Finally, the information on the butterfly species reported here for the city of Guayaquil can serve as a baseline for more research on these charismatic insects, allowing for the study of their interactions with plants and other organisms along with their current use of the green areas of the city. It is important in evaluating the connectivity between populations and to analyze the overall conservation status of butterflies. The information presented here is also vital to study the effect of urbanization. All of these aspects are key to any conservation program that would not only protect the butterflies but also the city's biodiversity in general.

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Declarations

Conflict of Interest - the authors declare no competing interests.

Author contributions

All authors made intellectual contributions.

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