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Momordica charantia (Cucurbitaceae) as an alien weed in Ecuador: spatio-temporal distribution and invasion risk

KIMBERLY RIZZO[1], ILEANA HERRERA[1,2], ANAHÍ VARGAS[1], XAVIER CORNEJO[3] & EDUARD LÓPEZ-GUILLÉN[4]

[1] Escuela de Ciencias Ambientales, Universidad Espíritu Santo (UEES), Samborondón 091650, Ecuador
[2] Instituto Nacional de Biodiversidad (INABIO), Quito 170501, Ecuador
[3] Universidad de Guayaquil, Facultad de Ciencias Naturales, Departamento de Botánica, Herbario GUAY, P.O Box 09–01–10634 Guayaquil, Ecuador
[4] Institut Botànic de Barcelona (IBB), CSIC-Ajuntament de Barcelona, Barcelona 08038, Catalonia, Spain

ORCID iD. K. RIZZO: https://orcid.org/0000-0001-8696-9055, I. HERRERA: https://orcid.org/0000-0002-7201-7085, A. VARGAS: https://orcid.org/0000-0001-8324-5334, X. CORNEJO: https://orcid.org/0000-0002-4081-4047, E. LÓPEZ-GUILLÉN: https://orcid.org/0009-0007-7991-7151

Author for correspondence: I. Herrera (herrera.ita@gmail.com)

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Abstract

Momordica charantia (Cucurbitaceae) as an alien weed in Ecuador: Spatio-temporal distribution and invasion risk.— *Momordica charantia,* an alien vine weed native to tropical and subtropical Asia and Africa, is widely distributed in Ecuador. In this study, we examined the temporal and spatial distribution of *M. charantia* records and evaluated its invasion risk for Ecuador. Occurrences of the species were collected from various sources (databases and herbaria). The distribution of the species in Ecuador and priority conservation areas was analyzed, considering its climatic and ecosystem preferences. An invasion risk analysis was conducted for Continental Ecuador. Our results indicated that *M. charantia* was reported for the first time in the Coastal Region of Ecuador in 1846. The cause of its introduction remains unknown; however, one potential pathway for its expansion could be linked to its utilization as a medicinal plant in Ecuador. The species is now naturalized in Ecuador and recorded in all four regions, including the Galápagos Islands. The species was detected in 18 priority conservation areas, where its abundance appears incipient, and its eradication feasible. Citizen science (iNaturalist) provided the majority of species records, emphasizing its importance for monitoring alien species. Although *M. charantia* has a limited occurrence in natural environments (most of the records, 89%, are in disturbed areas), the species was categorized as "high risk" in Ecuador due to the country's climatically suitable regions for its establishment. Additionally, *M. charantia* has a high capacity for long-distance dispersal and considerable potential to become a weed in crops, posing a threat to agriculture. We highlight that the occurrence of *M. charantia* in disturbed areas could constitute a propagule source towards crop areas, where the species could behave as a weed. The management of *M. charantia* populations near crops could mitigate its potential agricultural impacts.

Key words: bitter melon; invasion drivers; invasive plants; medicinal plants; risk assessment.

Resumen

Momordica charantia (*Cucurbitaceae*) como maleza introducida en Ecuador: distribución espacio-temporal y riesgo de invasión.— *Momordica charantia*, una maleza trepadora introducida, es nativa del trópico y subtrópico de Asia y África y se encuentra ampliamente distribuida en Ecuador. En este estudio, examinamos la distribución espacio-temporal de los registros de *M. charantia* y evaluamos su riesgo de invasión para Ecuador. Se recolectaron ocurrencias de la especie de diversas fuentes (bases de datos y herbarios). Se analizó la distribución de la especie en Ecuador y en áreas prioritarias de conservación, considerando sus preferencias climáticas y ecosistémicas. Se realizó un análisis de riesgo de invasión para Ecuador Continental. Nuestros resultados indicaron que *M. charantia* fue reportada por primera vez en Ecuador en la región de la costa en 1846. La causa de su introducción es desconocida; sin embargo, una posible vía para su expansión podría estar relacionada con su uso como planta medicinal en Ecuador. Actualmente, la especie está naturalizada en Ecuador y se ha registrado en las cuatro regiones, incluyendo las Islas Galápagos. Se detectó la presencia de la especie en 18 áreas prioritarias de conservación, donde su abundancia parece incipiente y su erradicación factible. La ciencia ciudadana (*i.e.* iNaturalist) proporcionó la mayoría de los registros de la especie, resaltando su importancia para monitorear especies invasoras. Aunque *M. charantia* tiene una presencia limitada en ambientes naturales (el 89% de los registros se encuentran en áreas perturbadas), la especie fue categorizada como de "alto riesgo" debido a que en Ecuador hay regiones climáticamente adecuadas para su establecimiento. Además, *M. charantia* tiene una alta capacidad de dispersión a larga distancia y un considerable potencial para convertirse en maleza en cultivos, representando una amenaza para la agricultura. Destacamos que la presencia de *M. charantia* en áreas perturbadas podría constituir una fuente de propagación hacia áreas cultivadas, donde la especie podría comportarse como maleza. El manejo de las poblaciones de *M. charantia* cerca de los cultivos podría mitigar sus posibles impactos agrícolas.

Palabras clave: análisis de riesgo; conductores de invasión; pepino cimarrón; plantas invasoras; plantas medicinales.

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INTRODUCTION

Several species of the genus *Momordica* L. (family Cucurbitaceae) are cultivated worldwide for their edible fruits, leaves, buds, and seeds. Some species in this genus are often used as vegetables and as part of the traditional medicine. The top three most frequently cultivated species are *Momordica charantia* L. (bitter melon), *Momordica foetida* Schumach (bitter cucumber) and *Momordica balsamina* L. (African gourd) (Muronga *et al*., 2021).

Momordica charantia is a fast-growing monoecious vine commonly known in Ecuador as "achochilla", "pepino cimarrón" or "melón amargo". The species is considered native to tropical and subtropical Asia and Africa (Walters & Decker-Walters, 1988); however, it has been introduced to other tropical and subtropical regions (Girón *et al*., 1991; Lans & Brown, 1998; Alam *et al*., 2009; Deyto & Cervancia, 2009; Kumar *et al*., 2010). *Momordica charantia* has been categorized as naturalized or invasive across various regions of the world (Holm *et al*., 1997; PIER, 2013; Almeida *et al*., 2015). Several reproductive and ecological characteristics of the species may confer advantages in its ability to colonize both natural and disturbed ecosystems. These characteristics include asexual propagation (Holm *et al*., 1997; Vibrans, 2009), high reproductive efficiency (fruit-to-flower ratio >0.8) (Téllez Pérez, 2018), continuous fructification (Téllez Pérez, 2018), pollination by abundant and generalist pollinators (Téllez Pérez, 2018), and long-distance dispersal capabilities by animals, e.g. birds and reptiles (Ridley, 1930; Passos *et al*., 2013).

Momordica charantia has a wide variety of uses: except for the roots, the entire plant can be used for food and medicine (Duke & Ayensu, 1985; Virdi *et al*., 2003; Grover & Yadav, 2004; Marr *et al*., 2004). In Asia and India, the fruits, leaves, and flowers are harvested for human consumption (Reyes *et al*., 1993) and to treat various diseases, such as asthma, cancer, skin conditions, hypertension, and diabetes (Shubha *et al*., 2018; Banerjee *et al*., 2019; Gayathry & John, 2022). It is even known as "vegetable insulin" and it is used as a hypoglycemic agent in Asia, Africa and Latin America (for review, see Banerjee *et al*., 2019).

Momordica charantia is included in the list of useful plants in Ecuador (Torre *et al*., 2008), where the authors indicate that this species is used as food and medicine on the Ecuadorian coast, as the fruit is edible and the seeds are sucked, and the leaves are used for infusions to treat people with diabetes. In Ecuador, *M. charantia* invades natural and agricultural ecosystems (Amaya *et al*., 2018). In agricultural areas on the Ecuadorian coast, the species has been reported as one of the main weeds in crops of sugarcane (Correia & Zeitoum, 2010; Gómez, 2020), bananas (Amaya *et al*., 2018) and cacao

(Holm *et al*., 1997). However, little is known about the status of the species in natural ecosystems in Ecuador and the potential risk that it can generate when invading them.

Examining the occurrences of *M. charantia* will allow us to estimate the distribution of the species in wildlife and priority conservation areas, such as protected areas. On the other hand, one way to examine the risk of invasion by a species is through a Risk Analysis (RA). The RA makes it possible to assess and quantify the risk associated with the invasion of an alien species. These analyses are tools that estimate the probability and magnitude of potential adverse effects caused by the invasion, through the collection of information about the origin, reproductive biology, ecology, and invasion history. Specifically, RAs predict the invasive potential, possible impacts, and management difficulties (NRC, 1996; Groves *et al.*, 2001). This study aims to examine the temporal and spatial distribution of records of *M. charantia* and estimate the invasion risk of the species in Ecuador through a risk analysis.

MATERIALS AND METHODS

Study area

The study area covered the territory of the Republic of Ecuador (252,000 km^2), located in the northwest of South America. Ecuador has four bioregions: The Coastal Region, the Andean Region, the Amazonian Region, and the Insular Region (*i.e.* Galápagos Islands). Generally, the ecosystems that characterize the Coastal region are the humid forests, dry forests, xerophytic scrub, and mangroves (Espinoza-Amén *et al*., 2021); the Andean, dominated by the Andes Mountains, is characterized by montane forests and paramos (Cruzatty & Vollmann, 2012; Varela & Ron, 2018); and the Amazonian by humid forests and lowland floodplain forests. The Galápagos Islands, situated ~1000 km from the Ecuadorian coast, have an arid climate along the coastline and semi-humid to humid as altitude increases (Varela & Ron, 2018).

Description of the species

The description of the species was based on seven collections of *M. charantia* deposited at the Herbarium of the Faculty of Natural Sciences of the University of Guayaquil (GUAY) and from at least ten living specimens observed in the field. This description helped us to avoid misidentification. The terminology used follows Jackson (1991). The habit is described, and also the organs of the vegetative and reproductive parts. Details under magnification have been observed in an Olympus SZ 61 0.67–4.5X stereoscope.

Occurrence data

The occurrences of *Momordica charantia* in Ecuador were obtained from two online databases: Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/country/EC/summary) and iNaturalist (https://www.inaturalist.org/). At the same time, an exhaustive search was carried out in several virtual herbaria, finding the scanned sheets not available in GBIF. Also, we included the information in the samples of *M. charantia* deposited at the Herbarium of the Faculty of Natural Sciences of the University of Guayaquil (GUAY). Due to the fact that GBIF has human observations from iNaturalist (photos taken from citizens), we used the RStudio (Racine, 2012) program to delete the duplicate occurrences (repeated information in GBIF and iNaturalist), thus getting a database with the following information: (1) occurrence ID, (2) geographic coordinates, (3) province, (4) locality, (5) year of collection or observation, and (6) occurrence type. All the occurrences were verified one by one, keeping only those with a clear image, for example, a photo of the living individuals or scanned herbaria sheets.

Spatio-temporal analysis of records

The information associated with the oldest record of *M. charantia* was used as an estimate of the year and place of its first introduction in Ecuador. This information allows to build the introduction and expansion history of the species through the different regions and provinces of Ecuador. Also, to analyze the spatial distribution and temporal change of the *M. charantia* records by bioregion in Ecuador, we made accumulative maps of the records organized by 45 years approximately. Also, the year reported for each record was used to elaborate a temporal accumulation curve. Additionally, to detect if *M. charantia* is present in protected areas, all the records of the species were overlapped on a layer of the National System of Protected Areas (available at http://ide.ambiente.gob.ec/mapainteractivo/), using QGIS software (v3.28.0).

Climatic and ecosystem preferences

To describe the climatic conditions associated with the *M. charantia* occurrences in Ecuador, we compiled for each record the values of six bioclimatic variables obtained from WorldClim v2.1 at the resolution of 2.5 minutes (Fick & Hijmans, 2017; available in http://www.worldclim.org/). These variables were: annual mean temperature (bio1), maximum temperature of warmest month (bio5), minimum temperature of coldest month (bio6), annual precipitation (bio12), precipitation of wettest month (bio13) and precipitation of driest month (bio14). Then a frequency histogram for each climatic variable was performed in RStudio v4.2.2 (Racine, 2012) considering the continental, insular (*i.e.* Galápagos), and the total records of *M. charantia*. To evaluate the differences in the climatic conditions where *M. charantia* is present among the regions of Ecuador (*i.e.* Andean, Coastal, Amazonian, and Insular), we ran a Principal Component Analysis (PCA) on 19 centered and scaled bioclimatic variables obtained from WorldClim v2.1 at the resolution of 2.5 minutes (Fick & Hijmans, 2017; available in http://www.worldclim.org/). Furthermore, to detect the type of natural ecosystems in which *M. charantia* occurs according to the records, we overlapped the layer of Ecosystems of Ecuador from the National Forest Monitoring System (MAE, 2013; http://ide.ambiente.gob.ec/mapainteractivo/), using QGIS software (v3.28.0). Also, we used the intersect tool of QGIS to obtain the number of occurrences in each ecosystem.

Risk analysis

We performed a risk analysis (RA) for *M. charantia* using the protocol developed for Brazil and requested from the Instituto Hórus de Desenvolvimento e Conservação Ambiental – Risk Analysis adapted for Latin America (IHDCA, 2022; available at https://institutohorus.org.br/en/analise-de-risco-para-especies-exoticas-eng/), which is an adaptation of the Australian system (Pheloung *et al*., 1999; Pheloung, 2001). The main modifications in this RA were on the climatic questions and those focused on the oceanic islands (Ziller *et al*., 2018). As this RA excluded features specifically for islands, the protocol was applied only to continental Ecuador records. Also, considering that the climate questions were adapted for Brazil's conditions, we adapted the climatic questions focusing on the bioregions of continental Ecuador. The RA protocol comprises three sections: (A) historical-biogeography, (B) undesired characteristics, and (C) biology and ecology characteristics, covering 45 questions, each one with a value assigned. The answer to each question must be supported by registering at least three references (scientific papers and technical reports). Not less than 30% of the questions per section should be answered to validate the RA. According to the score the level of risk is assigned with a recommendation from the system: (1) Very low risk (≤ 0), (2) Low risk (up to eight points), (3) Moderate risk (nine to 15 points), (4) High risk (16 to 30 points), and (5) Very high risk (>30 points). As recommendation, if the risk is very low or low, the species can be accepted; if the risk is moderate, the species might become invasive so more studies are required; if the risk is high or very high, the species should be rejected (Ziller *et al*., 2018). The institute mentions on its online page that the level of accuracy is approximately 90%. For Galápagos Islands, we did not find any available risk analysis protocol that could be applied to categorize *M. charantia* risk.

RESULTS

Description of the species *Momordica charantia* L.

Trailing vine, to 6 m, branched; stem slender, costate, pubescent. Leaves alternate (Fig. 1A), blade 4–11 × 4–10 cm, suborbicular, 5(–7)–deeply lobed, foliaceous to chartaceous, pilose, deeply cordate, dentate, mucronate, veins pinnate, sulcate adaxially, prominent abaxially; petioles 1.5–5 cm (Fig. 1B). Tendrils simple. Flowers solitary (Figs. 1A, C), suberect; pedicels 4–10 cm; bracts reniform (Fig. 1C). Staminate flowers with hypanthium pilose, cylindric-campanulate; calyx lobes 2.5–4 mm, lanceolate; corolla 5–lobed, yellow, short-pilose; filaments 1–1.5 mm; anthers 2–2.5 mm. Pistillate flowers with ovary fusiform, tomentulose, tuberculate; style 2–3.5 mm; stigma 3, 2–lobed. Fruit fleshy capsules, fusiform, 3–5 cm, dehiscent in 3 recurved valves, pericarp muricate, rostrate, orange (Fig. 1D–F); seeds many, 8–10 × 4–6 mm, oblong, slightly compressed, aril sticky, bright-red (Fig. 1G).

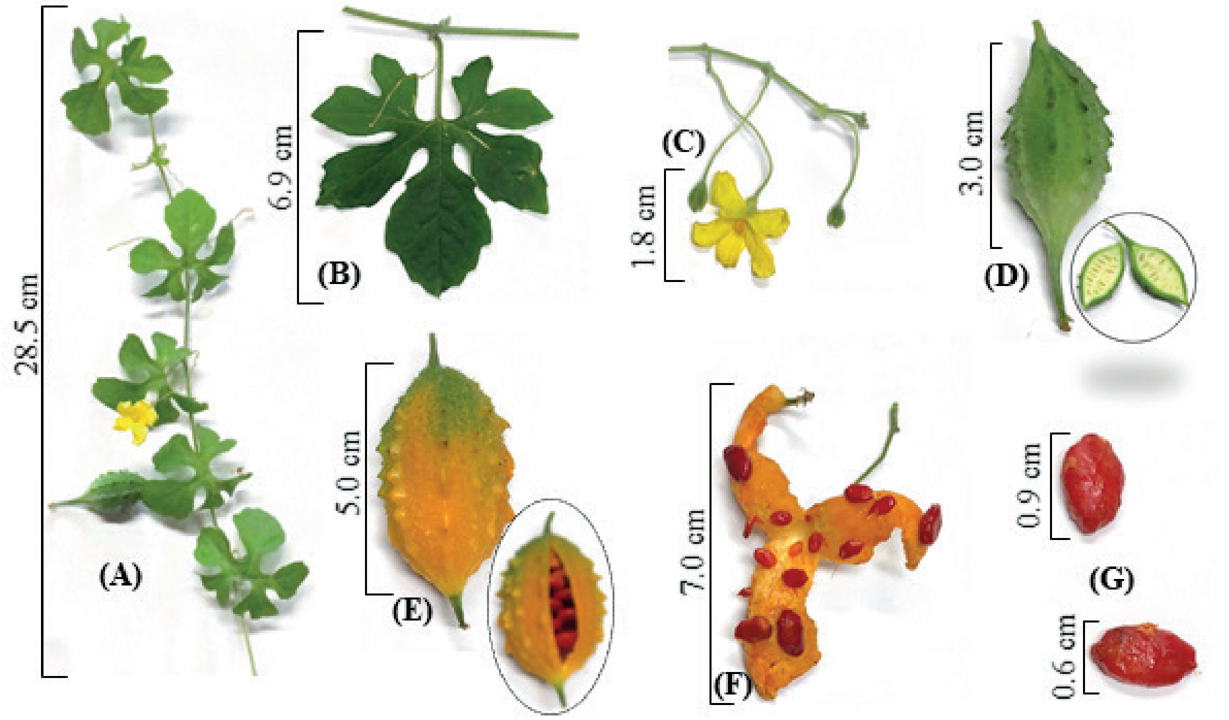

Figure 1. Plant (A) and organs (B–G) of *Momordica charantia*: (A), general view of the species; (B), leaf blade; (C), flower and flower buds; (D), unripe fruit; (E), ripe fruit (bright red arils inside); (F), dehiscent open fruit exhibiting arillate seeds; (G), arillate seeds.

Spatio-temporal analysis of records

A total of 311 verified records were obtained for *M. charantia* in Ecuador; 83% of the records ($N = 259$) were based on human observation and come from citizen science conducted through the iNaturalist platform (where 70% of these records are available only in iNaturalist due to their quality grade as "Needs ID"); and 17% ($N = 52$) are preserved specimens supported in herbaria (Appendix 1). Half of all records were in the Coastal Region (52%; $N = 158$), representing the highest number of occurrences per region, followed by the Insular Region (26%; $N = 83$). The Amazonian and the Andean regions had the lowest number of records (12%; $N = 38$ and 10%; $N = 32$, respectively). Although the Coastal Region had the greatest number of records, at a province level, Galápagos (Insular Region) had the greatest number of records per province (27%; $N = 83$), followed by Guayas and Manabí provinces (both from the Coastal Region) (22%; $N = 69$; 12%; $N = 37$ respectively) (Table 1).

According to the data obtained for Ecuador, the oldest record of *M. charantia* in Ecuador was in Guayaquil City (Ecuadorian Coast) in March 1846 (Fig. 2A). This first record corresponds to a preserved specimen at the Smithsonian National Museum of Natural History (available in http://n2t.net/ark:/65665/33571c7bc-53c6-462e-be5f-857650920ea4). The second oldest record was reported seven years later (1853) on Santa Cruz Island (Galápagos, Insular Region, Fig. 2A), which is available in the botanical collection database of the Swedish Museum of Natural History (S) (available in https://herbarium.nrm.se/specimens/S10-14834). Until 1923, records increased up to four (Fig. 2B). The third (available in http://n2t.net/ark:/65665/3d4410b96-038b-4209-b2dc-253fcf06889d) and fourth (available in http://n2t.net/ark:/65665/309cd28c6-7a61-4298-b4d7-ee1eb6495940) records were 70 years later (1923) on the Ecuadorian Coast again (Guayaquil and Milagro cities, respectively); both come from preserved specimens at the Smithsonian National Museum of Natural History. In 1977, ten records were added, making a total of 14 records (Fig. 2C). Two of these records were for the first time in the Amazonian Region (Napo), in 1966 and 1968. In less

Table 1. Records of *Momordica charantia* at region and province (% values are specified only for the total of regions and provinces records).

Provinces	Regions of Ecuador				Total per provinces
	Insular	Coastal	Andean	Amazonian	
Galápagos	83	–	–	–	83 (27%)
Guayas	–	69	–	–	69 (22%)
Manabí	–	37	–	–	37 (12%)
Napo	–	–	–	22	22 (7%)
El Oro	–	17	–	–	17 (5%)
Esmeraldas	–	16	–	–	16 (5%)
Los Ríos	–	15	–	–	15 (5%)
Santo Domingo de los Tsáchilas	–	–	13	–	13 (4%)
Sucumbíos	–	–	–	10	10 (3%)
Pichincha	–	–	6	–	6 (2%)
Loja	–	–	5	–	5 (2%)
Santa Elena	–	4	–	–	4 (1%)
Bolívar	–	–	3	–	3 (1%)
Pastaza	–	–	–	3	3 (1%)
Cañar	–	–	3	–	3 (1%)
Orellana	–	–	–	3	3 (1%)
Ibarra	–	–	2	–	2 (1%)
Total per region	83 (26%)	158 (52%)	32 (10%)	38 (12%)	311 (100%)

than 45 years, 297 records were added, with an occurrence for the first time in the Andean Region in 1990 (Santo Domingo de los Tsáchilas) (Fig. 2D). Figure 2E shows the temporal accumulation of *M. charantia* records in Ecuador from March 1846 to November 2022. Until the 20th century, there were no more than 51 records. In fact, since 2019, there has been an abrupt increase in the records (Fig. 2E).

Momordica charantia was detected in some priority areas of conservation in Ecuador. Data showed that 36% (N = 112) of the records of the species were distributed in five Biosphere Reserves (Bosque Seco, Chocó Andino de Pichincha, Galápagos, Podocarpus El Cóndor, Sumaco; Fig. 3A). Nine percent (N = 28) of the records were in nine Protected Areas (Cayambe Coca National Park, Galápagos National Park, Samanes National Recreation Area, Machalilla National Park, Mache Chindul Ecological Reserve, Manglares Churute Ecological Reserve, Manglar del Estuario del Río Muisne Wildlife Refuge, Parque El Lago National Recreation Area, Puerto Cabuyal-Punta San Clemente Marine Reserve; Fig. 3B). Three records were in Protective Forests (Daule-Pereira, Loma de Guayabillas, La Ceiba; Fig. 3C) and three in Ramsar Wetlands (Churute Wetland, Segua Wetland; Fig. 3D). The protected area with the highest number of records (N = 83) was the Galápagos Biosphere Reserve.

Climatic and ecosystem preferences

Momordica charantia records in Ecuador are frequently in areas with an annual mean temperature between 21°C to 26°C (Fig. 4A), this interval being larger for the continent (22–26°C; Fig. 4B) than for Galápagos (21–23°C; Fig. 4C). A similar pattern was observed for the maximum temperature of the warmest month and the minimum temperature of the coldest month (Fig. 4D–I). In the continent, the records of *M. charantia* were located in areas with a maximum temperature of the warmest month from 28–32°C and a minimum temperature of the coldest month from 14–20°C (Fig. 4E, H). While, in Galápagos, *M. charantia* records were in areas with maximum temperature of the warmest month from 28–31°C and minimum temperature of the coldest month from 15–19°C (Fig. 4F, I).

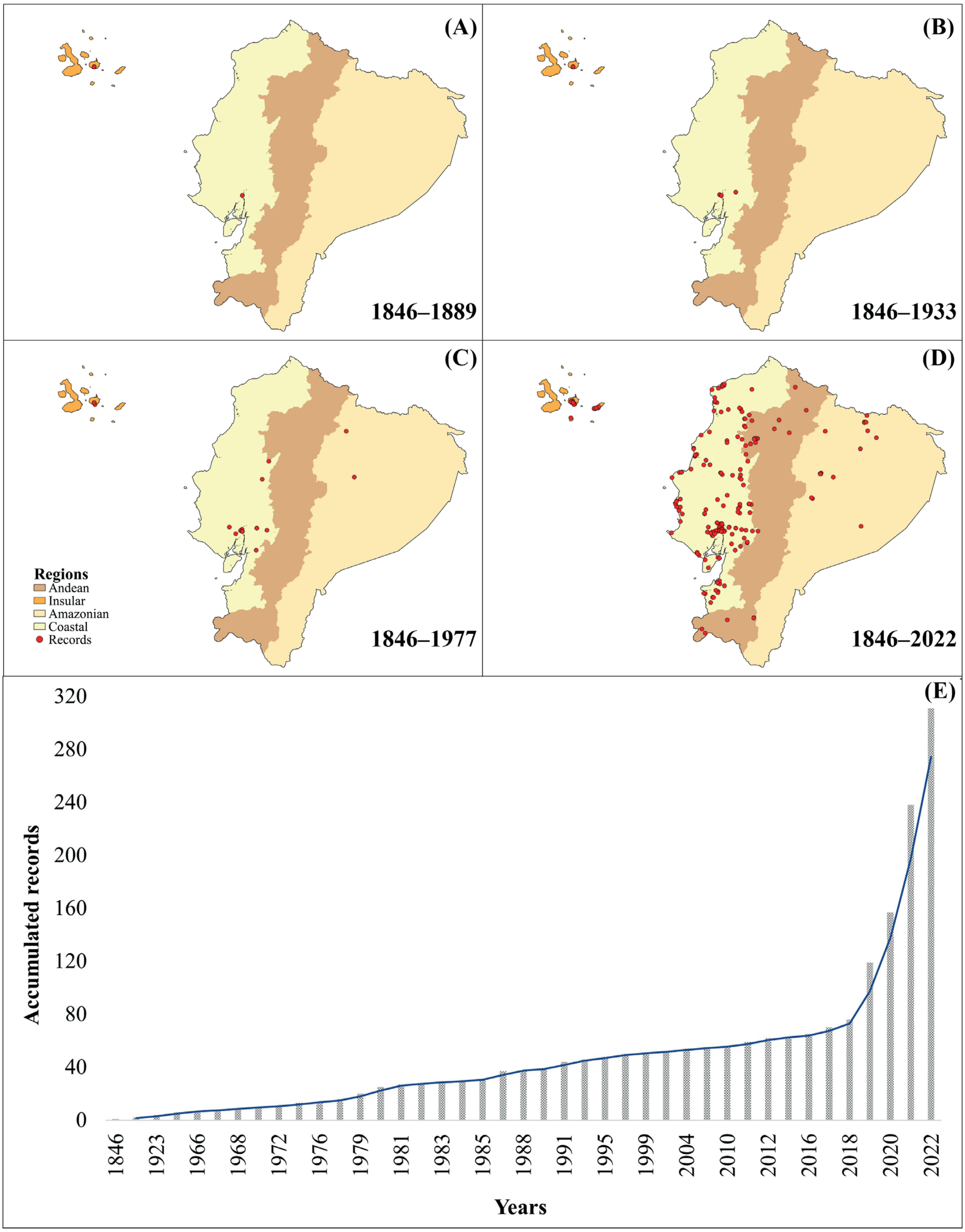

Figure 2. Spatial and temporal records accumulation of *Momordica charantia* records in Ecuador every 40 years approximately (records from: (A), 1846–1889; (B), 1846–1933; (C), 1846–1977; (D), 1846–2022; (E), temporal records accumulation (from March, 1846 to November, 2022).

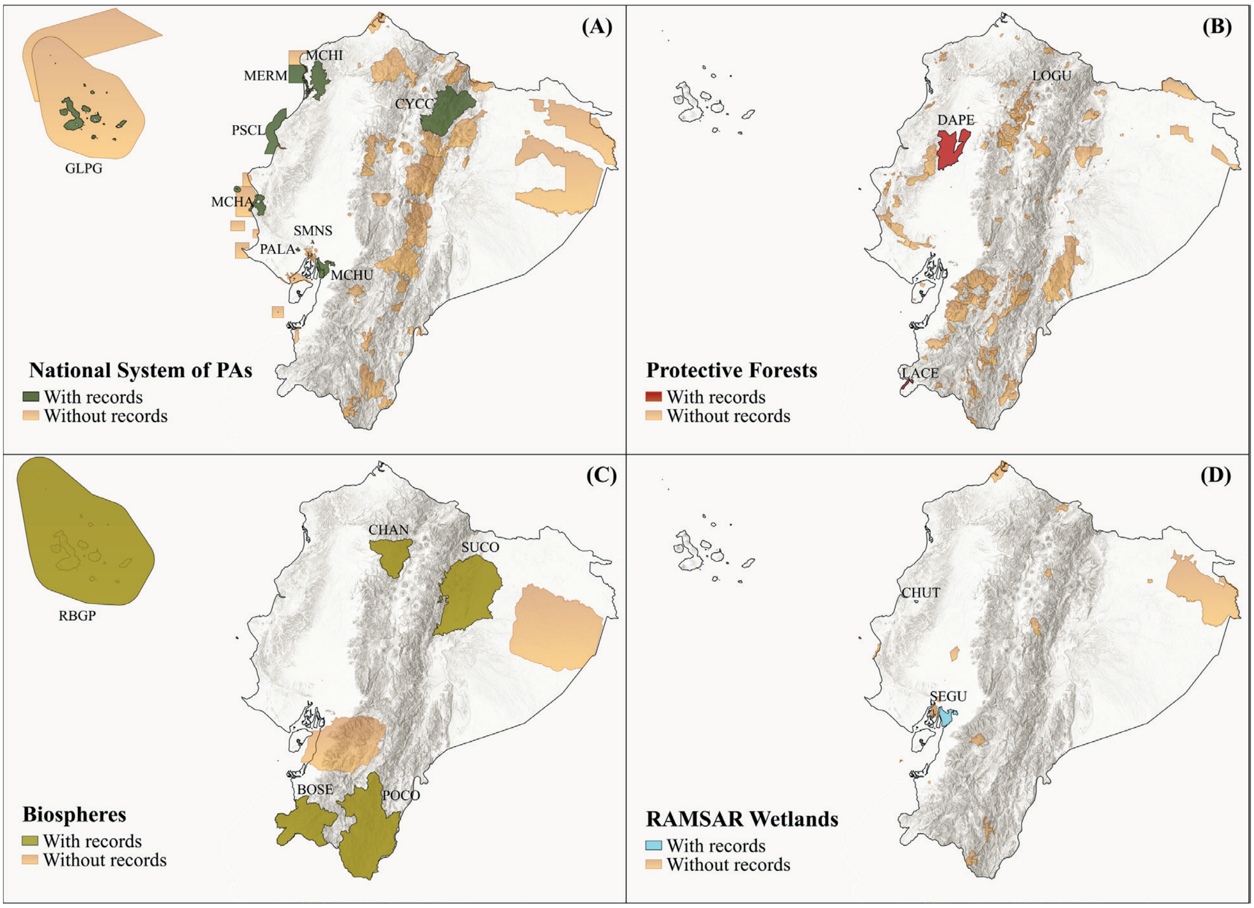

Figure 3. Presence of *Momordica charantia* records in the priority areas of conservation in Ecuador. (A), National System of Protected Areas (CYCC: Cayambe Coca National Park, *N* = 1; GLPG: Galápagos National Park, *N* = 15; SMNS: Samanes National Recreation Area, *N* = 2; MCHA: Machalilla National Park, *N* = 1; MCHI: Mache Chindul Ecological Reserve, *N* = 2; MCHU: Manglares Churute Ecological Reserve, *N* = 1; MERM: Manglar del Estuario del Río Muisne Wildlife Refuge, *N* = 1; PALA: Parque El Lago National Recreation Area, *N* = 4; PSCL: Puerto Cabuyal-Punta San Clemente Marine Reserve, *N* = 1). (B), Protective Forests (DAPE: Daule-Pereira, *N* = 1; LOGU: Loma de Guayabillas, *N* = 1; LACE: La Ceiba, *N* = 1). (C), Biosphere Reserves (BOSE: Bosque Seco, *N* = 3; CHAN: Chocó Andino, *N* = 2; RBGP: Galápagos, *N* = 83; POCO: Podocarpus El Cóndor, *N* = 2; SUCO: Sumaco, *N* = 24). (D), RAMSAR Wetlands (CHUT: Churute Wetland, *N* = 1; SEGU: Segua Wetland, *N* = 2).

The records of this species in Ecuador are in areas with an interval of annual precipitation (196–4374 mm; Fig. 4J). In the continent, the species occupied more humid areas (196–4374 mm; Fig. 4K) compared to Galápagos (252–2676 mm; Fig. 4L). The same pattern occurred for the variables precipitation of the wettest month (Figs. 4M–O) and precipitation of the driest month (Fig. 4P–R). Values of bio13 and bio14 were significantly lower for Galápagos than the Continent (Fig. 4M–N; Q–R). For example, for the continent, the bio14 values were lower than 150 mm (Fig. 4O), while for Galápagos, the values of this variable were below 50 mm (Fig. 4R).

The first and second PCA axes (Fig. 5) explained 80% of the total variance. Positive values on principal component 1 (PC1, x-axis, 44.6% of variance) corresponded to areas with higher annual precipitation (bio12), while negative values corresponded to areas fluctuating in the seasonal and annual temperatures (bio4 and bio7, respectively; Fig. 5). Along principal component 2 (PC2, y-axis, 35.4% of variance), the positive values corresponded to areas with higher temperatures (e.g. bio1) (Fig. 5). Globally, the PCA showed that the records in Andean region occupy a broader range of climatic conditions, in contrast to the narrower climatic conditions of the records in Galápagos (Fig. 5).

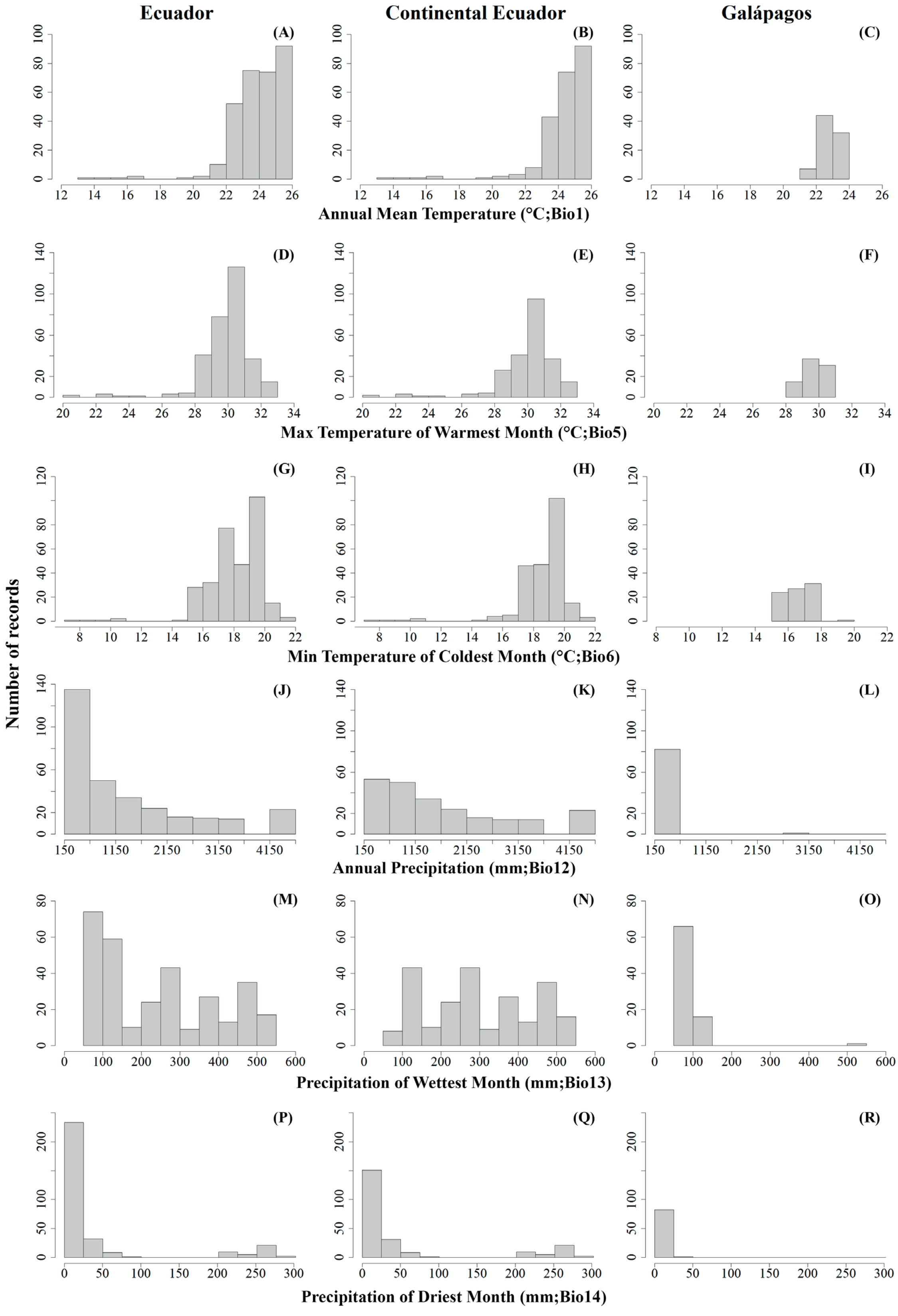

Figure 4. Frequency histogram for six bioclimatic variables selected considering the total records, the continental records, and the insular records (Galápagos) of *Momordica charantia*.

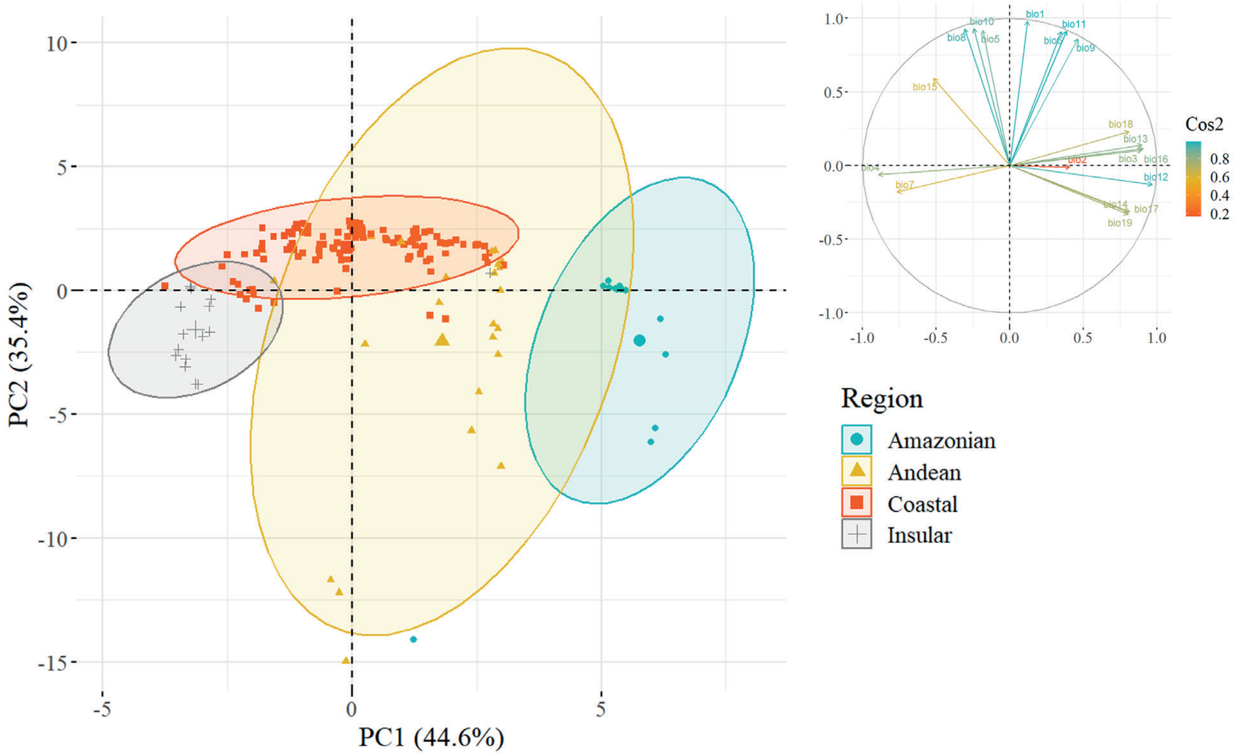

Figure 5. Principal Component Analysis (PCA) performed with the bioclimatic variables of *Momordica charantia* occurrences in Ecuador grouped by regions. bio1: annual mean temperature; bio2: mean diurnal range; bio3: isothermality; bio4: temperature seasonality; bio5: max temperature of warmest month; bio6: min temperature of coldest month; bio7: temperature annual range; bio8: mean temperature of wettest quarter; bio9: mean temperature of driest quarter; bio10: mean temperature of warmest quarter; bio11: mean temperature of coldest quarter; bio12: annual precipitation; bio13: precipitation of wettest month; bio14: precipitation of driest month; bio15: precipitation seasonality; bio16: precipitation of wettest quarter; bio17: precipitation of driest quarter; bio18: precipitation of warmest quarter; bio19: precipitation of coldest quarter.

Momordica charantia occupied areas with higher rainfall in the continent, particularly in the Amazonian region, compared to Galápagos, where the species occupied drier climates. The areas inhabited by the species in Galápagos also had lower temperatures and greater annual and seasonal variation of this climatic variable (Fig. 5).

Momordica charantia was present in 15 types of natural ecosystems with 34 occurrences; 12 of the 15 ecosystems belonged to the Coastal Region (N = 31), two to the Andean Region (N = 2), and one to the Amazonian Region (N = 1) (Table 2). The ecosystems with the highest number of occurrences were the deciduous and semi-deciduous forests of the Jama-Zapotillo lowland, with seven records each and both with a high threat level (Table 2). The rest of the occurrences (N = 277, 89.1%) were in disturbed areas, being most of them urban or agricultural-industrial zones.

Risk analysis

Momordica charantia was assessed as "High risk" (total score: 27) (Table 3). Forty of the 45 questions of RA were answered (Appendix 2). Enough information was available to answer the minimum number of questions per section. We answered 100% (N = 12) of the questions in the A section (biogeographical history), 92% (N = 12) of the questions in the B section (undesirable traits), and 80% (N = 16) of the questions in the C section (biological and ecological traits), with a total of 40 (89%) questions answered, with three references as minimum per question (Table 3; Appendix 3).

The A, B, and C sections contributed 52% (score: 14), 26% (score: 7), and 22% (score: 6) of the total score (total score: 27), respectively (Table 3). The A section obtained a score of 14 out of 17, representing 82% of the score. Climatic similarity

Table 2. Number of *Momordica charantia* occurrences per Ecosystems in Continental Ecuador.

Region	Threat	Code	Forest Ecosystems	Occurrences
Amazonian	Low	BsTa03	Evergreen forest of the Tigre-Pastaza lowland	1
Andes	Medium	BdPn01	Piedmont deciduous forest of the Catamayo-Alamor	1
		BsMn01	Montane evergreen forest of the north-eastern Andean range	1
Coast	Low	BdPc01	Deciduous forest of the Equatorial Pacific coastal range	1
		BePc02	Piedmont seasonal evergreen forest of the Equatorial Pacific coastal range	3
		BsBc01	Low montane evergreen forest of Chocó coastal range	1
		BsTc04	Equatorial Chocó mangrove	1
	Medium	BeTc02	Seasonal evergreen forest of the Jama-Zapotillo lowland	3
		BmPc01	Semideciduous forest of the Equatorial Pacific coastal range	1
		BsTc01	Evergreen forest of the Equatorial Chocó lowland	2
		BsTc05	Jama-Zapotillo mangrove	2
	High	BdTc01	Deciduous forest of the Jama-Zapotillo lowland	7
		BdTc02	Low forest and deciduous shrubland of the Jama-Zapotillo lowland	2
		BeTc01	Seasonal evergreen forest of Equatorial Chocó lowlands	1
		BmTc01	Semideciduous forest of the Jama-Zapotillo lowland	7

Table 3. Final scores per section (A, B, C) and subsections (A1–A3, B1–B2, C1–C3) of the risk assessment protocol used for *Momordica charantia* in Continental Ecuador. Levels of risk: Very low (≤ 0); Low (1–8); Moderate (9–15); High (16–30); Very High (>30).

		Questions per group	Questions answered	Score
A – Biogeographical history				
	A1 – Cultivation/ Domestication	3	3	1
	A2 – Climate	3	3	6
	A3 – Records of occurrence and invasion	6	6	7
	Total section A	12	12	14
B – Undesirable traits				
	B1 – Undesirable traits	7	7	4
	B2 – Habit and potential competition for resources in natural areas	6	5	3
	Total section B	13	12	7
C – Biological and ecological traits				
	C1 – Reproductive mechanisms	8	6	4
	C2 – Dispersal mechanisms	8	7	3
	C3 – Persistence attributes	4	3	-1
	Total section C	20	16	6
Total		45	40	27
Level of risk				**High**

and introduction history contributed significantly to the total score (Appendix 2). In section B, the score obtained was seven out of 14. The species had undesirable traits that contributed to this score, such as the possibility of being a weed in crops and toxic to animals or humans (Appendix 2). In section C, the score obtained was six out of 19. Seed dispersal by animals and short juvenile period were examples of reproductive traits that contributed to the score achieved in the C section (Appendix 2).

DISCUSSION

Our study reveals that *M. charantia* is naturalized in Ecuador. We found that the species is present in all regions of Ecuador, being more common on the Ecuadorian Coast, where it was first reported in 1846. Although *M. charantia* can establish itself in natural ecosystems, it is more frequent in perimeters of urban and agricultural areas. Despite its low presence in natural ecosystems, the risk analysis categorized *M. charantia* as a high-risk invasive species in Ecuador due to its toxicity to animals and humans and its potential to become a weed in crops. Additionally, the species can be dispersed over long distances by animals, and Ecuador's suitable climatic conditions make it vulnerable to invasion.

In addition to being naturalized in Ecuador, *M. charantia* has been reported as invasive in other Neotropical countries such as Brazil (Santana Júnior *et al*., 2018; Alves & Fabricante, 2019; Fabricante *et al*., 2021), Cuba (Oviedo & González-Oliva, 2015; Pagad *et al.*, 2022), México (Vibrans, 2009), Guyana, Bolivia, Nicaragua, Paraguay, Costa Rica, Panama, and Belize (Pagad *et al.*, 2022). The climatic conditions in the Neotropics appear to be suitable for the species' establishment. Some authors suggest that *M. charantia* prefers humid areas with annual rainfall between 480 to 4100 mm, temperatures ranging from 12.5 to 25°C, altitudes up to 1000 m, and does not tolerate drought and water stress (Duke, 1979; Holm *et al.*, 1997; Behera *et al.*, 2011). In Ecuador, most records are within a temperature range (21° to 26°C) that falls within the thermal preferences suggested for *M. charantia* by these authors. However, these records are associated with annual precipitation values that span a much wider range (196–4374 mm). In fact, 25% of the records in Ecuador are in areas with annual precipitation values <480 mm. In Ecuador, *M. charantia* tends to establish in drier areas compared to those occupied in other regions (Duke, 1979; Holm *et al.*, 1997; Behera *et al.*, 2011). Furthermore, almost all records of *M. charantia* in natural ecosystems are located in tropical dry forests (not floodable semi-deciduous or deciduous forests with a maximum elevation of 400 m).

The number of occurrences of *M. charantia* in natural ecosystems and protected areas is relatively low. Only 34 out of 311 records are in natural ecosystems; of these, only ten are in priority conservation areas, suggesting that *M. charantia* maintains a small population size in these areas. When an invasion is detected early, few individuals are present, and measures to eradicate the individuals are made quickly, the success probability is high because the low population density (Simberloff, 2009). According to this, eradication of *M. charantia* in these priority conservation areas is feasible. A previous study reported the presence of *M. charantia* in three protected areas on the Ecuadorian Coast: Machalilla National Park, Manglares Churute, and Mache Chindul Ecological Reserves (Espinoza-Amén *et al.*, 2021). As well as these three protected areas, our study reports the presence of the species in six additional protected areas, three forest reserves, five biosphere reserves, and two Ramsar wetlands. The addition of *M. charantia* to the flora of several priority conservation areas highlights the lack of studies for protected areas, particularly on the status of alien plant species in continental Ecuador (Speziale *et al.*, 2012; Yánez, 2016; Zenni *et al.*, 2022).

Although the introduction pathways of *M. charantia* in Ecuador are unknown, it is possible to infer that the value of the species as a medicinal plant could expand its distribution in Ecuador. In Manabí, Coastal Region province, leaf infusions are made to treat diabetes (Torre *et al.*, 2008). We did not find any report of *Momordica charantia* cultivated for commercial use in Ecuador; however, other studies encourage the use of the species as a medicinal plant and its cultivation in the country, emphasizing that the cultivation of the species would reduce the extraction rates of the wild population (Aragundi & Pérez, 2003; Manzano, 2011). The latter highlights the lack of knowledge about the status of the species as an alien plant in Ecuador. On the other hand, there are reports of *M. charantia* causing effect on human health. Studies determined that the dry extracts of the species exhibit cytotoxicity and low maternal toxicity on *Allium cepa* (onion) and *Rattus norvegicus* (wistar rats) (Trautenmuller *et al.*, 2022), while ethanol seed extract has contraceptive and androgenic properties on male albino individuals of *Mus musculus* (mice) (Patil & Patil, 2011); also, their action as abortifacients in women has been verified (see for review Verissimo *et al.*, 2011) suggesting that indiscriminate ethnopharmacological use should be avoided (Trautenmuller *et al.*, 2022).

Momordica c*harantia* has a high growth and reproductive rate. Seeds dispersed to a new location germinate rapidly, flowering can begin a month (36–43 days) after germination, pollination occurs by generalist pollinators, approximately 80% of the flowers produce fruits, and fruits mature 15 days after anthesis (Holm *et al*., 1997; Deyto & Cervancia, 2009; Tellez Perez, 2018). Once established, *M. charantia* can expand locally and long-distance through vegetative propagation and seed dispersal by animals, respectively (Holm *et al.*, 1997; Vibrans, 2009). Several previous studies suggest that when the fruits of *M. charantia* are ripe and open, their exposed red and sticky seeds are highly attractive and can be dispersed by birds, reptiles, and mammals, either through consumption or adherence to the animals' bodies (Ridley, 1930; Holm *et al*., 1997; Villaseñor & Espinosa, 1998; Agosto, 2007; Passos *et al.*, 2013). Nevertheless, we did not find studies that identify the dispersers of *M. charantia* in Ecuador. These studies are necessary to detect the risk of species expansion and characterize its interaction with the local fauna.

The presence of *M. charantia* as a weed increases its risk of invasion. This species is known as a weed in at least 22 types of crops (such as cacao, African oil palm, sesame, hibiscus, banana, sugarcane, etc.) (Sosa & Medrano, 1996; Holm *et al.*, 1997; Arangundi & Pérez, 2003; Correia & Zeitoum, 2010; Amaya *et al.*, 2018; Ortega-Acosta *et al.*, 2020). Additionally, *M. charantia* is a significant host of the whitefly (*Bemisia tabaci* and *B. argentifolli*), a pest that can affect tomato crops (Bastidas *et al.*, 2008). In Jamaica, it was found that *M. charantia* is a weed host reservoir for the Papaya ringspot virus, a virus transmitted by aphids that reduces papaya production (Chin *et al.*, 2007). In Ecuador, the species is classified as a weed in crops such as rice, corn, soybeans, plantain, and cacao (Venegas & Muñoz, 1984; Amaya *et al.*, 2018). It has also been reported that the species is toxic to livestock in Ecuador (Venegas & Muñoz, 1984). The majority of the records in Ecuador are in disturbed areas on the perimeters of cities and agroecosystems. Some studies suggest that the management of the weeds in field margins is important to reduce population size and prevent seed production (e.g. Blumenthal & Jordan, 2001; Ihara & Kobayashi, 2022). The presence of *M. charantia* in disturbed areas on the perimeters of cities and agroecosystems could represent a constant source of propagules towards crops favoring the abundance of this species as a weed. Controlling *M. charantia* populations in disturbed areas near agricultural zones is necessary to reduce the harmful effects caused by this weed on crops and livestock in Ecuador. Chemical control has been effective in the management of *M. charantia* in some cases. For instance, in sugarcane crops in Brazil, the application of herbicides mesotrione and amicarbazone (either in combination or separately) is effective for the control of *M. charantia* (Correia & Zeitoum, 2010).

Our risk analysis categorized *M. charantia* as a high-risk invasive species for Continental Ecuador. Similar to the RA adapted by the Instituto Horus, this species has been categorized as a high-risk invasive species in Hawaii (PIER, 2013) and as a moderate-risk species in Colombia (Baptiste *et al.*, 2010). Using a different methodology, Espinoza-Amén *et al*. (2021) classified *M. charantia* as a moderately risky alien species for eight protected areas on the Ecuadorian coast. The risk analysis previously mentioned agrees that *M. charantia* is a species with a moderate to high risk of invasion. In Ecuador, the species has a high probability of invasion due to suitable climatic conditions and to the reproductive and propagule dispersal attributes that facilitate its expansion. On the other hand, *M. charantia* could affect human and animal health, and in several crops is established as a weed. Mitigating these impacts requires controlling the species in natural and disturbed ecosystems as well as in agricultural areas. We did not find evidence that proves that the species could affect conservation areas since its occurrence in undisturbed ecosystems is low.

Additionally, our study highlights the relevant role of citizen science in monitoring alien species. The number of *M. charantia* records has sharply increased since 2018, and almost all species records (77%, *N* = 241) were reported through iNaturalist. Several studies acknowledge that the use of alien species records generated by citizen science significantly contributes to their monitoring (e.g. Hiller & Haelewaters, 2019; Herrando-Moraira *et al*., 2020; Werenkraut *et al*., 2020) and even allows the detection of alien species that have gone unnoticed by scientists (e.g. Kleitou *et al*., 2019). Thus, the verified biodiversity data generated by citizen science should be included in protocols for monitoring alien species.

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REFERENCES

Agosto, V. A. 2007. *Evaluación de dos sistemas de tutoreo en dos variedades de cundeamor (*Momordica charantia *L.) en los llanos de la La Fragua, Zacapa*. Bachelor's Thesis. Universidad de San Carlos de Guatemala, Ciudad de Guatemala.

Alam, S., Asad, M., Asdaq, S. M. B. & Prasad, V. S. 2009. Antiulcer activity of methanolic extract of *Momordica charantia* L. in rats. *Journal of Ethnopharmacology* 123(3): 464–469. https://doi.org/10.1016/j.jep.2009.03.024

Almeida, W. R., Lopes, A. V., Tabarelli, M. & Leal, I. R. 2015. The alien flora of Brazilian Caatinga: deliberate introductions expand the contingent of potential invaders. *Biological Invasions* 17(1): 51–56. https://doi.org/10.1007/s10530-014-0738-6

Alves, J. da S. & Fabricante, J. R. 2019. Exotic invasive flora evaluation on different environments and preservation conditions from a caatinga area, Petrolina, PE. *Gaia Scientia* 13(1): 140–152. https://doi.org/10.22478/ufpb.1981-1268.2019v13n1.39803

Amaya, A., Santos, M., Morán, I., Vargas, P., Comboza, W. & Lara, E. 2018. Malezas presentes en cultivos del cantón Naranjal, Provincia Guayas, Ecuador. *Investigatio* 11: 1–16. https://doi.org/10.31095/investigatio.2018.11.1

Aragundi, P. F. & Pérez, V. C. 2003. *Proyecto de cultivo de plantas medicinales (*Momordica charantia*, achochilla), con mujeres microagriculturas, con especial atención a la viabilidad financiera.* Bachelor's Thesis, Escuela Superior Politécnica del Litoral, Guayaquil.

Banerjee, J., Chanda, R. & Samadder, A. 2019. Anti-diabetic activity of *Momordica charantia* or bitter melon: a review. *Acta Scientific Pharmaceutical Sciences* 3: 24–30.

Baptiste, M. P., Castaño, N., Cárdenas, D., Gutiérrez, F. de P., Gil, D. L. & Lasso, C. A. (Eds.) 2010. *Análisis de riesgo y propuesta de categorización de especies introducidas para Colombia.* Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá.

Bastidas, H., Pantoja, A., Lugo, M. de L. & Stansly, P. 2008. Malezas hospederas de la mosca blanca en siembras de tomate en el sur de Puerto Rico. *The Journal of Agriculture of the University of Puerto Rico* 92(3–4): 231–234. https://doi.org/10.46429/jaupr.v92i3-4.2640

Behera, T. K., Joseph, J. J., Bharathi, L. K. & Karuppaiyan, R. 2011. *Momordica.* In: Kole, C. (Ed.), *Wild Crop Relatives: Genomic and Breeding Resources*. Springer, Berlin & Heidelberg: 217–246. https://doi.org/10.1007/978-3-642-20450-0_10

Blumenthal, D. & Jordan, N. 2001. Weeds in field margins: a spatially explicit simulation analysis of Canada thistle population dynamics. *Weed Science* 49(4): 509–519. https://doi.org/10.1614/0043-1745(2001)049[0509:WIFMAS]2.0.CO;2

Chin, M., Ahmad, M. H. & Tennant, P. 2007. *Momordica charantia* is a weed host reservoir for *Papaya ringspot virus* type P in Jamaica. *Plant Disease* 91(11): 1518. https://doi.org/10.1094/PDIS-91-11-1518A

Correia, N. M. & Zeitoum, V. 2010. Controle químico de melão-de-são-caetano em área de cana-soca [Bitter gourd chemical control in sugarcane]. *Bragantia* 69: 329–337 [in Portuguese]. https://doi.org/10.1590/S0006-87052010000200010

Cruzatty, L. C. G. & Vollmann, J. E. S. 2012. Caracterización de suelos a lo largo de un gradiente altitudinal en Ecuador. *Revista Brasileira de Ciências Agrárias* 7(3): 456–464. https://doi.org/10.5039/agraria.v7i3a1736

Deyto, R. C. & Cervancia, C. R. 2009. Floral biology and pollination of ampalaya (*Momordica charantia* L.). *Philippine Agricultural Scientist* 92(1): 8–18.

Duke, J. A. 1979. Ecosystematic data on economic plants. *Quarterly Journal of Crude Drug Research* 17(3–4): 91–109. https://doi.org/10.3109/13880207909065158

Duke, J. A. & Ayensu, E. S. 1985. *Medicinal plants of China* (Medicinal plants of the world, 4). Reference Publications, Algonac.

Espinoza-Amén, B., Herrera, I., Cruz-Cordovez, C., Espinoza, F., Freire, E. & Bustamante, R. O. 2021. Checklist and prioritization for management of non-native species of phanerogam plants and terrestrial vertebrates in eight protected areas on the Ecuadorian coast. *Management of Biological Invasions* 12(2): 389–407. https://doi.org/10.3391/mbi.2021.12.2.12

Fabricante, J. R., Cruz, A. B. S., Reis, F. M. dos & Almeida, T. S. 2021. Invasão biológica em sítios de Restinga no Nordeste brasileiro [Biological invasion in Restinga sites in northeastern Brazil]. *Research, Society and Development* 10(6): e48410615942 [in Portuguese]. https://doi.org/10.33448/rsd-v10i6.15942

Fick, S. & Hijmans, R. 2017. WorldClim 2: new 1 km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37(12): 4302–4315. https://doi.org/10.1002/joc.5086

Gayathry, K. S. & John, J. A. 2022. A comprehensive review on bitter gourd (*Momordica charantia* L.) as a gold mine of functional bioactive components for therapeutic foods. *Food Production, Processing and Nutrition* 4: 10. https://doi.org/10.1186/s43014-022-00089-x

Girón, L. M., Freire, V., Alonzo, A. & Cáceres, A. 1991. Ethnobotanical survey of the medicinal flora used by the Caribs of Guatemala. *Journal of Ethnopharmacology* 34(2–3): 173–187. https://doi.org/10.1016/0378-8741(91)90035-C

Gómez, L. B. 2020. *Análisis geoespacial de las arvenses presentes en caña de azúcar (*Saccharum officinarum*), en el Ingenio Coazúcar del cantón La Troncal*. Bachelor's Thesis, Universidad Agraria del Ecuador, Milagro.

Grover, J. K. & Yadav, S. P. 2004. Pharmacological actions and potential uses of *Momordica charantia*: a review. *Journal of Ethnopharmacology* 93(1): 123–132. https://doi.org/10.1016/j.jep.2004.03.035

Groves, R. H., Panetta, F. D. & Virtue, J. G. (Eds.) 2001. *Weed risk assessment*. CSIRO Publishing, Collingwood.

Herrando-Moraira, S., Vitales, D., Nualart, N., Gómez-Bellver, C., Ibáñez, N., Massó, S., Cachón Ferrero, P., González-Gutiérrez, P. A., Guillot, D., Herrera, I., Shaw, D., Stinca, A., Wang, Z. & López-Pujol, J. 2020. Global distribution patterns and niche modelling of the invasive *Kalanchoe × houghtonii* (Crassulaceae). *Scientific Reports* 10: 3143. https://doi.org/10.1038/s41598-020-60079-2

Hiller, T. & Haelewaters, D. 2019. A case of silent invasion: Citizen science confirms the presence of *Harmonia axyridis* (Coleoptera, Coccinellidae) in Central America. *PLoS ONE* 14(7), e0220082. https://doi.org/10.1371/journal.pone.0220082

Holm, L., Doll, J., Holm, E., Pancho, J. V. & Herberger, J. P. 1997. *World weeds: natural histories and distribution*. John Wiley & Sons, New York.

Ihara, N. & Kobayashi, H. 2022. Populations of *Ipomoea hederacea* var. *integriuscula* in field margins are maintained by seed production of individuals from a specific cohort. *Agronomy* 12(10): 2392. https://doi.org/10.3390/agronomy12102392

IHDCA [Instituto Horus de Desenvolvimento e Conservação Ambiental] 2022. *Risk Analysis adapted for Latin America*. Retrieved November 22, 2022, from https://institutohorus.org.br/en/analise-de-risco-para-especies-exoticas-eng/

Jackson, B. D. 1991. *A glossary of botanic terms with their derivation and accent* (4th ed.). Duckworth, London.

Kleitou, P., Giovos, I., Wolf, W. & Crocetta, F. 2019. On the importance of citizen-science: the first record of *Goniobranchus obsoletus* (Rüppell & Leuckart, 1830) from Cyprus (Mollusca: Gastropoda: Nudibranchia). *BioInvasions Records* 8(2): 252–257. https://doi.org/10.3391/bir.2019.8.2.06

Kumar, D. S., Sharathnath, K. V., Yogeswaran, P., Harani, A., Sudhakar, K., Sudha, P. & Banji, D. 2010. A medicinal potency of *Momordica charantia*. *International Journal of Pharmaceutical Sciences Review and Research* 1(2): 95–100.

Lans, C. & Brown, G. 1998. Observations on ethnoveterinary medicines in Trinidad and Tobago. *Preventive Veterinary Medicine* 35(2): 125–142. https://doi.org/10.1016/S0167-5877(97)00055-X

MAE [Ministerio del Ambiente del Ecuador] 2013. *Sistema de Clasificación de los Ecosistemas del Ecuador Continental*. Subsecretaría de Patrimonio Natural, Quito.

Manzano, A. G. 2011. *Proyecto de factibilidad para el cultivo de* Momordica charantia*, achochilla, con mujeres microagricultoras de la parroquia san Jacinto del Búa, provincia de Santo Domingo de los Tsáchilas y su comercialización en la ciudad de Quito*. Bachelor's Thesis, Universidad Politécnica Salesiana, Quito.

Marr, K. L., Mei, X. Y. & Bhattarai, N. K. 2004. Allozyme, morphological and nutritional analysis bearing on the domestication of *Momordica charantia* L. (Cucurbitaceae). *Economic Botany* 58(3): 435–455. https://doi.org/10.1663/0013-0001(2004)058[0435:AMANAB]2.0.CO;2

Muronga, M., Quispe, C., Tshikhudo, P. P., Msagati, T. A. M., Mudau, F. N., Martorell, M., Salehi, B., Abdull, A. F., Sunusi, U., Kamal, R. M. & Sharifi-Rad, J. 2021. Three selected edible crops of the genus *Momordica* as potential sources of phytochemicals: biochemical, nutritional, and medicinal values. *Frontiers Pharmacology* 12: 625546. https://doi.org/10.3389/fphar.2021.625546

NRC [National Research Council] 1996. *Understanding risk: Informing decisions in a democratic society.* National Academies Press, Washington. https://doi.org/10.17226/5138

Ortega-Acosta, S. Á., Ochoa-Martínez, D. L., Hernández-Morales, J. & Palemón-Alberto, F. 2020. Caracterización morfológica y genética de aislados de *Corynespora cassiicola* obtenidos de jamaica y malezas asociadas. *Revista Mexicana de Fitopatología* 38(1): 62–78. https://doi.org/10.18781/r.mex.fit.1909-2

Oviedo, R. & González-Oliva, L. 2015. Lista nacional de especies de plantas invasoras y potencialmente invasoras en la República de Cuba - 2015. *Bissea* 9(NE2): 1–88. https://doi.org/10.13140/RG.2.1.3815.6004

Pagad, S., Bisset, S., Genovesi, P., Groom, Q., Hirsch, T., Jetz, W., Ranipeta, A., Schigel, D., Sica, Y. V. & McGeoch, M. A. 2022. Country compendium of the global register of introduced and invasive species. *Scientific Data* 9: 391. https://doi.org/10.1038/s41597-022-01514-z

Passos, D. C., Zanchi, D., Souza, I. H. B. de, Gallão, M. I. & Borges-Nojosa, D. M. 2013. Frugivory of *Momordica charantia* (Cucurbitaceae) by *Ameivula ocellifera* (Squamata: Teiidae) in a coastal area of northeastern Brazil. *Salamandra* 49(4): 234–236.

Patil, S. A. & Patil, S. B. 2011. Toxicological studies of *Momordica charantia* Linn. seed extracts in male mice. *International Journal of Morphology* 29(4): 1212–1218. https://doi.org/10.4067/S0717-95022011000400024

Pheloung, P. 2001. Weed risk assessments for plant introductions to Australia. In: Groves, P. H., Panetta, F. D. & Virtue, J. G. (Eds.), *Weed Risk Assessment*. CSIRO Publishing, Collingwood: 83–92.

Pheloung, P., Williams, P. & Halloy, S. 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57(4): 239–51. https://doi.org/10.1006/jema.1999.0297

PIER [Pacific Islands Ecosystems at Risk] 2013. *Momordica charantia* L.*, Cucurbitaceae*. Retrieved March 1, 2023, from http://www.hear.org/pier/wra/pacific/Momordica_charantia_CGC.pdf

Racine, J. S. 2012. RStudio: A platform-independent IDE for R and Sweave. *Journal of Applied Economics* 27: 167–172. https://doi.org/10.1002/jae.1278

Reyes, M., Gildemacher, B. & Jansen, G. 1993. *Momordica* L. In: Seimonsma, J. S. & Piluek, K. (Eds.), *Plant Resources of South-East Asia* 8*: Vegetable*s. Pudoc Scientific Publishers, Wageningen: 206–210.

Ridley, H. N. 1930. *The dispersal of plants throughout the world*. L. Reeve & Co., Ashford.

Santana Júnior, J. A. de, Silva, E. J. da, Silva Oliveira, E. V. da & Nascimento Prata, A. P. do 2018. Florística do entorno de cavernas em remanescentes de mata atlântica e caatinga de Sergipe [Floristic of surrounding caves in remnants of atlantic rainforest and caatinga of Sergipe State, Brazil]. *Revista Brasileira de Geografia Física* 11(1): 192–205 [in Portuguese]. https://doi.org/10.26848/rbgf.v10.6.p192-205

Shubha, A. S., Devaraju, Sharavati, M. B., Srinivasa, V., Kantharaj, Y., Ravi, C. S., Angadi, A., Yallesh, H. S. & Ahmed, S. 2018. Medicinal and nutritional importance of bitter melon (*Momordica charantia* L.): a review article. *Journal of Pharmacognosy and Phytochemistry* 7(3S): 297–300.

Simberloff, D. 2009. We can eliminate invasions or live with them. Successful management projects. *Biological Invasions* 11(1): 149–157. https://doi.org/10.1007/s10530-008-9317-z

Sosa, L. & Medrano, C. 1996. Efecto de la competencia de las malezas en platanales (*Musa* AAB) establecidos. *Revista de la Facultad de Agronomía de la Universidad del Zulia* 14(6): 591–602.

Speziale, K. L., Lambertucci, S. A., Carrete, M. & Tella, J. L. 2012. Dealing with non-native species: what makes the difference in South America? *Biological Invasions* 14: 1609–1621. https://doi.org/10.1007/s10530-011-0162-0

Téllez Pérez, L. J. 2018. *Biología reproductiva de* Momordica charantia (Cucurbitaceae) *en un bosque de galería en la Orinoquía colombiana*. Bacherlor's Thesis, Universidad de la Salle, Bogotá.

Torre, L. de la, Navarrete, H., Muriel, P., Macía, M. J. & Balslev, H. (Eds.) 2008. *Enciclopedia de las plantas útiles del Ecuador*. Herbario QCA & Herbario AAU, Quito & Aarhus.

Trautenmuller, A. L., Almeida Soares, J. de, Behm, K. C., Guimarães, L. M. M., Xavier-Silva, K. R., Monteiro de Melo, A., Batista, G. A., Paula, J. A. M. de, Bailão. E. F. L. C. & Amaral, V. C. S. 2022. Cytotoxicity and maternal toxicity attributed to exposure to *Momordica charantia* L. (Cucurbitaceae) dry leaf extract. *Journal of Toxicology and Environmental Health, Part A:* 1–15. https://doi.org/10.1080/15287394.2022.2157354

Varela, L. A. & Ron, S. R. 2018. *Geografía y clima del Ecuador*. BIOWEB. Pontificia Universidad Católica del Ecuador. Retrieved March 1, 2023, from https://bioweb.bio/fungiweb/GeografiaClima/

Venegas, F. & Muñoz, R. 1984. *Malezas tropicales del litoral ecuatoriano*. Estación Experimental Tropical Pichilingue, Instituto Nacional de Investigaciones Agropecuarias, Quito. Retrieved March 1, 2023, from http://repositorio.iniap.gob.ec/handle/41000/1599

Verissimo, L. F., Bacchi, A. D., Zaminelli, T., Paula, G. H. O. de & Moreira, E. G. 2011. Herbs of interest to the Brazilian Federal Government: female reproductive and developmental toxicity studies. *Revista Brasileira de Farmacognosia* 21: 1163–1171. https://doi.org/10.1590/S0102-695X2011005000146

Vibrans, H. 2009. *Malezas de México, Ficha* - Momordica charantia. Comisión Nacional para el conocimiento y uso de la biodiversidad, México, D. F. Retrieved March 1, 2023, from http://www.conabio.gob.mx/malezasdemexico/cucurbitaceae/momordica-charantia/fichas/ficha.htm

Villaseñor, J. L. & Espinosa, F. J. 1998. *Catálogo de malezas de México*. Universidad Nacional Autónoma de México. Consejo Nacional Consultivo Fitosanitario. Fondo de Cultura Económica. México, D. F.

Virdi, J., Sivakami, S., Shahani, S., Suthar, A. C., Banavalikar, M. M. & Biyani, M. K. 2003. Antihyperglycemic effects of three extracts from *Momordica charantia. Journal of Ethnopharmacology* 88(1): 107–111. https://doi.org/10.1016/S0378-8741(03)00184-3

Walters, T. W. & Decker-Walters, D. S. 1988. Balsam-pear (*Momordica charantia*, Cucurbitaceae). *Economic Botany* 42(2): 286–288.

Werenkraut, V., Baudino, F. & Roy, H. E. 2020. Citizen science reveals the distribution of the invasive harlequin ladybird (*Harmonia axyridis* Pallas) in Argentina. *Biological Invasions* 22: 2915–2921. https://doi.org/10.1007/s10530-020-02312-7

Yánez, P. 2016. Las áreas naturales protegidas del Ecuador: características y problemática general. *Qualitas* 11: 41–55.

Zenni, R. D., Herrera, I., Sá Dechoum, M. de, Ziller, S. R., Matos, A. C. L. de, Núñez, C. I., Núñez, M. A. & Pauchard, A. 2022. Plant invasions in South America. In: Clements, D. R., Upadhyaya M. K., Joshi, S. & Shrestha, A. (Eds.), *Global Plant Invasions*. Springer, Cham: 187–208. https://doi.org/10.1007/978-3-030-89684-3_9

Ziller, S. R., Sá Dechoum, M. de & Zenni, R. D. 2018. Predicting invasion risk of 16 species of eucalypts using a risk assessment protocol developed for Brazil. *Austral Ecology* 44(1): 28–35. https://doi.org/10.1111/aec.12649

APPENDICES

Appendices 1 to 3, due to their size, are available for download online in the HTML version of the article.