Revising primary data for conservation status assessments of Brazilian threatened butterflies

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Abstract

Primary data, such as geographical records of species, are base-line for conservation status assessments. For many years, data on Brazil's threatened butterflies (58 taxa) have been in need of improvement and the present paper provides a careful review of their geographical distribution data as well as an update of extent of occurrence (EOO) and area of occupancy (AOO). In total, ~ 6,700 records were compiled from several sources; 1,053 records are non duplicated geographical data. Of these 1,053 records, 566 (69%) come from surveyed literature (published records), 258 (31%) are unpublished records, and 229 (22%) were found to contain errors after data curation. Comparing "previous" to "current" estimates of both, EOO and AOO, changes in geographical range were reported for 48 taxa (83%). Based on current data (applying the thresholds of criterion B), there is a potential for changes in conservation status categories for 51 taxa (88%). Importantly, approximately half of unpublished records are from scientific collections and the remainder were provided by civil society (via personal communication), showing the importance of both data sources. The present updates of geographical records (and consequently, EOO and AOO) of Brazilian threatened butterflies may aid future conservation status assessments and also reinforce the importance of data curation.

Implications For Insect Conservation

The present study represents the most up-to-date effort to estimate EOO and AOO of Brazilian threatened butterflies. The new data presented here can be used for a more acurate conservation status assessments for these taxa, revealing a more realistic scenario for several species included in the national and global Red lists.

Introduction

Knowledge on the natural history and ecology of living organisms, including the conservation status of putative threatened species, is vital for successful management and conservation (Rodrigues et al. 2006; Mace et al. 2008; Parr et al. 2009). Several nations use the International Union for Conservation of Nature (IUCN) guidelines for assessing the risk of species extinction, thus providing support for Red List production all around the world (Rodrigues et al. 2006; Miller et al. 2007; Mace et al. 2008; IUCN 2012; National Red List 2016).

In extinction risk assessments, a large amount of information is taken into account, but basic data on population size and geographic distribution are the most used (IUCN 2012; Collen et al. 2016; IUCN Standards and Petitions Committee 2019). However, in Brazil population data is generally applied for vertebrates, since this kind of information is rarely available for invertebrates, and conservation status of the last are usually assessed on geographical data alone (the "B criterion" of IUCN, including extent of occurrence and area of occupancy) (ICMBio 2018).

Simple species inventories provide the necessary information for the application of the geographical "B criterion", and these are especially easy to get when published in "data papers" format (eg. Bovendorp et al. 2017 and Souza et al. 2019, for mammals; Hasui et al. 2018 for birds; Vancine et al. 2018, for amphibians; Queiroz-Santos et al. 2016, Santos et al. 2018 and Shirai et al. 2019 for butterflies). In addition to these, general studies containing new records of endangered species provide support for new assessments (some few examples of Brazilian species can be found in Dolibaina et al. 2010; Neto et al. 2018; Rosa et al. 2019; Freitas et al. 2020). Another valuable source of information useful for conservation science are provided from personal communication and/or citizen photographs from internet, then these people are recognized as 'citizen scientists' supporting the scientific research (Dickinson et al. 2012; Pocock et al. 2017; Suzuki-Ohno et al. 2017; Callaghan et al. 2019; Crawford et al. 2020; Marcenò et al. 2020; Cano and Pimienta 2021). Despite the increase in published distribution data for several biological groups, a wealth of lost information remains obscure in one of the best sources of geographical data: scientific collections (Suarez and Tsutshi 2004; Rocha et al. 2014; Meineke et al. 2018; Bakker et al. 2020). Numerous records of specimens in collections have not yet been compiled or digitized and remain unavailable for research, mainly due to the lack of human and financial resources (Dalton 2003; Paknia et al. 2015; Schilthuizen et al. 2015). For example, considering the three largest public collections of Lepidoptera (butterflies and moths) in Brazil, 1) the Museum of Zoology of São Paulo, with 400,000 specimens (Duarte pers. comm. 2021), 2) the Collection of Department of Zoology of Paraná Federal University with 400,000 specimens (Casagrande and Mielke pers. comm. 2021), and 3) the Museum of Biological Diversity of University of Campinas with above 200,000 specimens (AVLF unpublished data 2021), less than 6% of the data of any of them are available online (SIBBr 2020; speciesLink 2020a; speciesLink 2020b).

The purpose of this paper is to demonstrate how data curation can provide a different perspective from estimates of extent of occurrence and area of occupancy and thus aid future reassessments of conservation status for the Brazilian threatened butterflies.

Material And Methods

Data compilation

The target butterflies here studied (see some examples from amateur photographers in Fig. 1) are those indicated as threatened in the Brazilian Red List (MMA 2014). All taxonomic changes published after 2014 were followed here for the sake of taxonomic stability. The current names of taxa and their synonyms were used for searches of the following data sources: 1) literature search: on two online platforms (Google Scholar and Web of Science) and printed material (documents not digitized). Literature data was compiled from a total of 384 documents (full list is shown in Appendix S1); 2) online databases, such as the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/), the speciesLink (https://specieslink.net/), 'Portal da Biodiverside' – ICMBio (https://portaldabiodiversidade.icmbio.gov.br/portal/) and the Brazilian Biodiversity Information System (SiBBr) (https://www.sibbr.gov.br/); 3) compiled data from 71 scientific collections (the full list is shown in Appendix S1).

In addition, 4) images (photographs) of threatened butterflies were searched in the world wide web, on Google images online platform and other specific websites (Flickr (https://www.flickr.com/), Biofaces (https://www.biofaces.com/), iNaturalist https://www.inaturalist.org/)), and also in specific groups of butterfly and animal related photographers of the social media Facebook (https://www.facebook.com/). Finally, 5) reliable specialists / researchers in the field

of lepidopterology (with emphasis on butterflies) were also consulted for unpublished data. Both photographic records and data from researchers and specialists were considered as “Field observation / Personal communication” (Appendix S1).

Data Curation

Each geographical site was carefully revised searching for “non duplicated geographic sites” (avoiding multiple data of the same site). Then, records were divided in three categories: 1) “published records”, which includes all geographical data available from the literature (*e.g.* scientific papers, books); and 2) “unpublished records”, i.e. all those from any source (see Appendix S1), not previously published in literature, and also outside of a grid of 4 km^2 where any of the “published records” was present (to avoid multiple “new” records overlapping in the same locality). The grid size (4 km^2) follows the IUCN recommendations for the area of occupancy (see further information in next section). Data from “published records” that includes obvious errors (*e.g. Euptychia boulleti* Le Cerf, 1919, a montane Atlantic Forest species, listed for a lowland forest in the Amazon basin), doubtful sites, data of untraceable origin and general distribution data, such as a continent (“South America”), country (“Brazil”), state (“Bahia”) or dubious sites (“Cachimbo”) and / or sites where the natural habitat was highly modified or destroyed (observed using Google Earth Pro software) were considered as “untrustworthy records”, (all listed under “Error / uncertainty / doubtful / unknown origin / only country or state-province / or no specific site” in Appendix S1).

Finally, since all records refer to threatened taxa that have potential commercial trade interest, specific geographic coordinates and geographical site were deliberately omitted for those unpublished data.

After data compilation (from 2016 to August 2021), each geographical site was mapped in the Google Earth Pro software. At this point, redundant geographical sites or those whose precision is low (e.g. referring to a country or state) were not mapped / analyzed. When the geographical site contained only the name of the municipality (without a specific site), it was plotted within the political limits of the municipality in a site where the habitat is similar to that already known for the taxon (based on previous knowledge of the species), all other record with specific site were included.

Estimates Of Geographical Range (Extent Of Occurrence And Area Of Occupancy)

Two metrics related to the restricted geographic distribution (IUCN criterion B) were used to assess the conservation status of each taxon: 1) the extent of occurrence (hereafter EOO) and 2) the area of occupancy (hereafter AOO) (IUCN 2012; IUCN Standards and Petitions Committee 2019). The EOO is defined as the area (in km^2) contained in the shortest continuous imaginary limit that can be drawn to cover all known, inferred, or projected sites of the current occurrence of a taxon, excluding cases of vagrancy. The AOO is a metric (in km^2) on a scale representing the area of suitable habitat currently occupied by a given taxon, within the limits of the EOO (IUCN 2012; IUCN Standards and Petitions Committee 2019). The EOO can be estimated as the area of the minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and that embraces all locations of occurrence), while the AOO is estimated by the sum of all grid cells (usually with the size of 4 km^2) containing at least one record of the target taxon (IUCN 2012; IUCN Standards and Petitions Committee 2019). The extinction risk categories based on the thresholds of criterion B for EOO are: Critically Endangered (CR) = 100 km^2, Endangered (EN) = 5,000 km^2 and Vulnerable (VU) = 20,000 km^2. For the AOO, the thresholds are: CR = 10 km^2, EN = 500 km^2 and VU = 2,000 km^2 (IUCN, 2012; IUCN Standards and Petitions Committee, 2019). Estimates were made as regional (using only information inside territorial limits of Brazil) and global (use of records inside and / or outside Brazil).

For the present study, values for both, EOO and AOO, were estimated based on two scenarios, here named the “previous” estimates and the “current” estimates. The “previous” estimate is an attempt to present the AOO and EOO values based on previous data, that is, those available to any researcher prior to the present study and it was based exclusively on the previously published records (i.e. from literature), including the imprecise geographical sites “untrustworthy records” (those not recognized as errors in the literature before the present study). Basically, the “previous estimates” were those used as basis to the butterfly assessments that resulted in the Brazilian Red List (MMA 2014). The “current” estimate is based on both, published records (from literature) plus all newly obtained “unpublished records” (not published in literature), in this case excluding all locality data considered as untrustworthy in data curation (errors / doubtful data / general site data, see above).

To estimate the EOO when only two geographical sites were available, a polygon was drawn around the AOO grid (4 km^2) joining the two grid cells with the polygon tool in Google Earth Pro software. Sites where the original habitat of a given taxon was modified, replaced or destroyed (based on recent visits or direct observation of Google Earth Pro images) were not used for AOO-EOO estimates (these are possible cases of local extintion). The EOO and AOO were estimated using all the non-duplicated geographic sites compiled in the study. These data were analyzed using the online open source program GeoCAT (Geospatial Conservation Assessment Tool, available at http://geocat.kew.org/) (Bachman et al. 2011). Grid cells of 4 km^2 were used following the recommendation of the IUCN for AOO analyzes (IUCN 2012; IUCN Standards and Petitions Committee 2019).

For the percentages of changes in the values of EOO-AOO, taxa with national and global values (n = 58 global taxa, 3 national taxa only) were included, however for the percentages of changes of values between the conservation status categories only national data were compared (n = 58).

Results

About 6,700 records for the 58 taxa of Brazilian threatened butterflies were compiled from several sources, 1,053 of which correspond to non duplicated geographical sites. After data curating, 229 records (21%) were removed from the analysis because they were identified as containing errors, were of untraceable origin or had only general distribution data (Appendix S1). Thus, a total of 824 valid locality records (without errors) were used, comprising 566 (69%) from the literature (corresponding to 212 municipalities, 209 in Brazil; and 323 geographical sites, 319 in Brazil) and 258 (31%) unpublished records

(from 134 unpublished municipalities in Brazil) (Appendix S1). These valid records are distributed in 4 countries, 20 states / provinces (17 in Brazil), 285 municipalities (281 in Brazil) and 457 different localities (455 in Brazil) (Fig. 2).

For the unpublished records, 125 records (48.5%) come from specimens in scientific collections, and 133 (51.5%) come from field observations. Data from field observation correspond to personal communications (n = 82 records; 61.6%), from the Facebook social network (n = 38; 28.5%), from the iNaturalist website (n = 11; 8.3%), from Flickr website (n = 1; 0.8%) and from Biofaces website (n = 1; 0.8%) (Appendix S1).

In General, comparing “previous” to “current” estimates, changes in geographical range (EOO-AOO) were reported for 48 taxa (83%). Comparing “previous” to “current” estimates for EOO only, changes were reported for 43 taxa (74.1%), 27 of which (46.5%) presented an increase and 16 (27.6%) presented a decrease in the EOO. Concerning the AOO, changes were reported for 45 taxa (77.6%), with an increase reported for 37 taxa (63.8%) and a decrease for 8 taxa (13.8%) (Table 1, Table 2, Fig. 3).

Table 1
Estimates of extent of occurrence (EOO) and area occupancy (AOO)., percentage of changes and threatened category for the 58 taxa of threatened Brazilian butterflies

Taxon	Threatened category (2014)[1]	Previous EOO (km^2)	Current EOO (km^2)	EOO Change (%)	Previous AOO (km^2)	Current AOO (km^2)	AOO Change (%)	Category based on EOO[2]	Category based on AOO[2]
Hesperiidae									
Drephalys (*Drephalys*) *miersi*	EN[6]	219	219	0	8	8	0	EN	CR
Drephalys (*Drephalys*) *mourei*	CR[5]	166,137.97	166,137.97	0	12	12	0	LC	EN
Oxynetra (*Olafia*) *roscius iphimedia*	VU[5]	27,049.99	80,524.68	198	32	48	50	LC	EN
Parelbella (*Parelbella*) *polyzona*	EN[5]	47,860.08	47,860.08	0	12	16	33	LC	EN
Parelbella (*Pseudocroniades*) *machaon seabrai*	CR[5]	4	4	0	4	4	0	CR	CR
Turmosa camposa	EN[6]	8,805.48	132	-99	16	8	-50	EN	CR
Zonia zonia diabo	EN[5]	8,439.21	279,135.98	3208	12	24	100	LC	EN
Lycaenidae									
Arawacus aethesa	EN[5]	62,069.15	3,144.094	-95	20	20	0	EN	EN
Magnastigma julia	EN[5]	164,115.25	189,642.24	16	64	80	25	LC	EN
Strymon ohausi	EN[5]	519,940.84	475,242.96	-9	40	64	60	LC	EN
Nymphalidae									
Actinote quadra	VU[5]	73,751.675	74,049.23	0	68	92	35	LC	EN
Actinote zikani	CR[6]	28.62	28.62	0	8	8	0	CR	CR
Dasyophthalma geraensis	CR[6]	5,996.55	2,336.36	-61	28	40	43	EN	EN
Dasyophthalma rusina delanira	CR[6]	67.7	75.74	12	8	12	50	CR	EN
Dasyophthalma vertebralis	CR-PEX[5]	20.227.71	30,556.44	51	20	24	20	LC	EN
Doxocopa zalmunna	CR-PEX[5]	30,586.86	30,586.86	0	20	20	0	LC	EN
Ceratinia vitrea	EN[6]	15,601.19	17,018.15	9	24	28	17	VU	EN
Eresia erysice erysice	CR[4]	5,073.72	1,932.30	-62	16	20	25	EN	EN
Euptychia boulleti	CR[5]	29,551.94	29,551.94	0	32	40	25	LC	EN
Hamadryas velutina browni	EN[4]	19,480.67	19,480.67	0	24	28	17	VU	EN
Heliconius nattereri	EN[5]	120,507.70	29,721.65	-75	44	32	-27	LC	EN
Hyalyris fiammetta	CR-PEX[5]	51,177.18	51,881.51	1	36	32	-11*	LC	EN
Hyalyris leptalina	CR[5]	69,542.62	68,672.52	-1	64	64	0	LC	EN
Mcclungia cymo fallens	CR[5]	87,047.38	87,047.38	0	44	48	9	LC	EN
Melinaea mnasias thera	CR[6]	1,623.37	7,264.35	347	12	16	33	VU	EN
Morpho epistrophus nikolajewna	CR[5]	5,386.10	6,901.55	28	12	24	100	VU	EN
Morpho menelaus eberti	CR[5]	193,331.97	229,791.69	19	64	104	53	LC	EN
Napeogenes rhezia rhezia	CR[5]	15,686.37	4,932.05	-69	28	20	-29	EN	EN

Taxon	Threatened category (2014)[1]	Previous EOO (km^2)	Current EOO (km^2)	EOO Change (%)	Previous AOO (km^2)	Current AOO (km^2)	AOO Change (%)	Category based on EOO[2]	Category based on AOO[2]
Orobrassolis ornamentalis	CR[6]	258.00	70.17	-73	16	24	50	CR	EN
Pampasatyrus glaucope boenninghauseni	EN[6]	2,444.94	2,458.09	1	44	68	55	EN	EN
Pampasatyrus glaucope glaucope	EN[6]	57,996.959	48,563.03	-16	48	44	-8	LC	EN
Pampasatyrus gyrtone biezankoi	EN[5]	114,273.19	51,008.24	-55	52	68	31	LC	EN
Catagramma hydarnis	EN[6]	30.226,148	34.323,09	14	32	56	27	LC	EN
Anaea suprema	EN[6]	1,282.05	4,260.66	232	32	104	189	EN	EN
Prepona deiphile	VU[5]	179,257.68	204,124.29	14	56	84	50	LC	EN
Scada karschina delicata	EN[4]	5,638.60	5,638.60	0	16	24	0	VU	EN
Tithorea harmonia caissara	VU[5]	82,644.104	83,780.053	1	60	104	73	LC	EN
Papilionidae									
Heraclides himeros baia	EN[5]	620,847.15	328,982.75	-47	24	20	-17	LC	EN
Heraclides himeros himeros	EN[5]	25,081.70	41,304.76	65	32	68	113	LC	EN
Eurytides (*Mimoides*) *lysithous harrisianus*	CR[6]	26,067.51	32,033.00	23	52	96	85	LC	EN
Eurytides (*Mimoides*) *lysithous sebastianus*	VU[5]	654.00	161,319.40	24,567	8	20	150	LC	EN
Parides ascanius	EN[5]	28,614.436	25,898.87	-9	252	288	14	LC	EN
Parides bunichus chamissonia	CR[6]	147.11	1,260.97	757	16	52	225	EN	EN
Parides burchellanus	CR[7]	262,202.69	183,733.00	-30	188	184	-2	LC	EN
Parides klagesi	CR[5]	104,105.78	104,105.78	0	16	16	0	LC	EN
Parides klagesi [3]	CR[5]	37.465	37.465	0	8	8	0	LC	CR
Parides panthonus castilhoi	CR[6]	342.10	981.22	187	12	16	33	EN	EN
Parides tros danunciae	EN[4]	333.36	3,437.91	931	12	24	100	EN	EN
Pieridae									
Charonias theano	EN[5]	330,970.19	352,361.18	6	120	192	60	LC	EN
Hesperocharis hirlanda fulvinota	VU[8]	27.90	27.9	0	8	8	0	CR	CR
Hesperocharis hirlanda planasia	VU[8]	457,730.34	1,023,668.32	124	56	128	129	LC	EN
Glennia pylotis	EN[6]	761,488.97	1,170,441.04	54	40	160	300	LC	EN
Glennia pylotis [3]	EN[6]	758,169.00	1,166,509.00	54	36	156	333	LC	EN
Moschoneura pinthous methymna	VU[5]	127,166.58	80,468.76	-37	44	40	-9	LC	EN
Perrhybris pamela flava	EN[5]	190.82	2,514.87	1218	12	16	33	EN	EN
Riodinidae									
Joiceya praeclarus	CR[6]	3,151.73	1,350,749.59	42,757	12	16	33	LC	EN
Joiceya praeclarus [3]	CR[6]	3,151.73	200,376.00	6258	12	12	0	LC	EN

Taxon	Threatened category (2014)[1]	Previous EOO (km^2)	Current EOO (km^2)	EOO Change (%)	Previous AOO (km^2)	Current AOO (km^2)	AOO Change (%)	Category based on EOO[2]	Category based on AOO[2]
Panara ovifera	VU[8]	983.60	804.62	-18	16	32	100	EN	EN
Petrocerus catiena	CR[5]	187.00	187.00	0	8	8	0	EN	CR
Rhetus belphegor	CR[6]	11,416.86	11,416.86	0	72	72	0	VU	EN
Eucorna sanarita	EN[5]	7,600.72	7,968.56	5	36	48	33	VU	EN

[1] Brazilian Red list 2014 (only national level);

[2] Based on EOO-AOO thresholds limites of criterion B (geographical range) of IUCN. Only using current data;

[3]AOO-EOO estimatad (only national level);

[4] Threatened category based on IUCN B criterion (only EOO);

[5] Threatened category based on IUCN B criterion (only AOO);

[6] Threatened category based on IUCN B criterion (EOO and AOO);

[7] Threatened category based on IUCN C criterion;

[8] Threatened category based on IUCN D criterion;

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Consern.

Table 2
Number of taxa and percentage of changes in extent of occurence (EOO) and area of ocupancy (AOO)

Change (%)	EOO (n)	AOO (n)
-51 to -100	8	-
-11 to -50	5	5
-1 to -10	3	3
0	15	13
1–10	6	1
11–50	7	18
51–100	3	20
101 to 1000	7	6
> 1000	4	-

All butterflies present in the current National Brazilian Red List fauna (MMA, 2014) are assessed as belonging to the following threat status categories: Vulnerable (VU) 15.5% (n = 9 taxa), Endangered (EN) 43.2% (n = 25) and Critically Endangered (CR) / Critically Endangered possibly extinct (CR-PEX) 41.3% (n = 24) (Table 1). Based on the IUCN criteria, Brazilian threatened butterflies (MMA, 2014), were included in the Red List by the following criteria and or sub-criteria: 54 taxa (93.1%) based on criterion B, 6 taxa (10,3%) from B1 (only EOO), 31 taxa (53.4%) from B2 (AOO only) and 17 taxa (29.3%) from both B1 + B2 (EOO + AOO). The remaining (4 taxa, 7%) were included based on criteria C (n = 1) and D (n = 3) (Table 1).

Based on current data (applying the thresholds of IUCN criterion B), there is a potential for changes in conservation status categories for 51 taxa (88%) (Table 1). Based only on EOO (B1) thresholds of criterion B, there is a potential for changes for 46 taxa (79.3%), 27 of which (46.5%) will remain in some extinction risk category: 8 taxa (13.8%) as VU, 14 (24.1%) as EN and 5 (8.6%) as CR (Table 1). The remaining 31 taxa (53.5%) should chage status to be categorized as Least Concern (LC) category (Table 1).

Based on AOO (B2) thresholds, there is a potential for changes in conservation status categories for 34 taxa (58.6%) taxa (Table 1). However, all 58 taxa should remain in some extinction risk category, as follows: 51 taxa (87.9%) in EN and 7 taxa (12.1%) in CR (Table 1).

Discussion

Our results point to a potential change in the conservation status of approximately 90% of Brazilian threatened butterflies, exclusively by applying the IUCN B criterion of geographic range with the use of compiled and properly curated records. Moreover, with the new data presented here, changes in the extent of

occurrence (EOO) and area of occupancy (AOO) were reported for most taxa: changes in EOO were reported for 74.1% taxa (with an increase for 46.5% and reduction for 27.6%) and changes in AOO for 77.6% (with an increase for 63.8% and a decrease for 13.8% taxa). Based only on EOO, there is the potential for a change in conservation status category of about 80% of the threatened taxa, with more than half (53.5%) possibly outside the threshold of any extinction risk category (VU, EN or CR). However, based on the AOO, changes were reported for 58.6% of the taxa, all of which will remain in a category of risk of extinction.

Data cleaning has identified 229 records considered to be erroneous or without traceable origin: these data were excluded and should be omitted in future conservation status assessments. Unpublished municipality records increased by 38.5% in relation to the records previously available in the literature, encompassing 212 municipalities. Many other studies containing records of Brazilian threatened butterflies have already provided significant advances on previous assessments (e.g. Dolibaina et al. 2010; Greve et al. 2013; Freitas et al. 2014; Gomes et al. 2014; Kerpel et al. 2014; Bedê et al. 2015; Kaminski et al. 2015).

It is important to mention that, for unpublished records, approximately half come from scientific collections, with the remainder from field observations / personal communications. This reinforces the importance of scientific collections as important data sources for studies related to species conservation, as well as in conservation status assessments (Shaffer et al. 1998; Miller et al. 2007; Dolibaina et al. 2010; Drew, 2011; Meineke et al. 2018; Muniz et al. 2020). Data digitization is extremely important for facilitating access to researchers; however, this kind of action takes time and demands human and financial resources (Dalton 2003; Paknia et al. 2015; Schilthuizen et al. 2015; Meineke et al. 2018; Cobb et al. 2019). In collections where the data is not yet digitized, the information on voucher specimens can be lost forever. In a recent tragic example, the fire at the National Museum of Rio de Janeiro in 2018 resulted in the permanent loss of at least 200,000 specimens of Lepidoptera (Freitas and Marini-Filho 2011; Zamudio et al. 2018), with mere 16.5% of these available online (Hoffmann and Mello-Patiu 2018).

Records from field observations and correspondence with researchers and civil society also brought several new records, mainly through personal communication followed by photographic records from the social network Facebook and citizen science repositories such as iNaturalist. In addition to contributing beautiful images of organisms in nature, amateur photographers also contribute to scientific research related to species conservation (Rosa et al. 2017; Giovos et al. 2019; Wilson et al. 2020).

Each type of data source contributes differently, with the source with the highest number of geographical sites records being found from literature, followed by field observations (personal communication and photos from websites, such as Facebook social network, iNaturalist, Flickr and Biofaces) and finally, specimens in scientific collections. It is important to emphasize that both, literature data and scientific collections will inevitably be exhausted and few or no new records from these sources may be added in future. Clearly, field observation data (with or without image records) obtained from researchers, citizen scientists and data mined from websites, all have extraordinary potential for use in data assessment for conservation.

For some taxa reported in the present study, “current” estimates of EOO and AOO were higher than “previous” estimates, with increases of more than 100% in the EOO and AOO for 11 and six taxa, respectively. Also, based on new records, the EOO has been widely expanded for several species. For example, based on the new records, the EOO of the papilionid *Parides bunichus chamissonia* (Eschscholtz, 1821), a butterfly known from few restinga sites in southern Brazil, increased from 147.11 km^2 to 1,260.97 km^2 (757% in increase). Similarly, the EOO for the skipper *Zonia zonia diabo* Mielke & Casagrande, 1998 (Fig. 1e) increased from 8,439.21 km^2 to 279,135.98 km^2 (increase of 3208%) and the EOO of the metalmark *Joiceya praeclarus* Talbot, 1928, increased from 3,151.73 km^2 to 1,350,749.59 km^2 (an increase of 42,757%) after the inclusion of a new site from Peru. For these and other butterfly taxa, the increase in the EOO brings us new perspectives on a more realistic distribution of these organisms inside and outside Brazil.

Another notable case was observed for the nymphalid *Morpho menelaus eberti* Fischer, 1962, which was known from only five localities in northeastern Brazil. After checking dozens of specimens, it was found that the populations of this species are not restricted to the northeast of Brazil, but extend from the state of Paraíba to the middle part of Espírito Santo state (southeastern Brazil), expanding to a total of 26 localities (Patrick Blandin pers. comm. 2019; Freitas et al. 2018). In this study, we must make it clear that increases and decreases in EOO-AOO estimates come from the current knowledge of data quality (e.g. unpublished records can increase EOO-AOO, whereas “errors” records were removed and can decrease EOO-AOO) and are not the result of conservation interventions in their natural range areas (for increases of EOO-AOO).

Based on present results, increases in the EOO could result in the exclusion of more than half of the butterfly taxa from the Brazilian Red List, with some possibly falling into low or no risk categories such as “Near Threatened” (NT) and “Least Concern” (LC). However, it is worth noting that the polygons defined by the EOO are unrealistic in terms of the availability of suitable habitats inside them and, ideally, the AOO is a better way to assess the conservation status of butterflies. However, for the application of AOO, it is necessary to have a good biological knowledge of the organism, especially concerning its habitat restrictions (ICMBio 2013; IUCN Standards and Petitions Committee 2019). The lack of biological knowledge added to a few geographic distribution records and the use of 4 km^2 grids (as recommended by IUCN) may not reflect the actual area occupied by the taxon and lead to an “inflated” Red List using the criterion B2. Accordingly, based on the estimates of AOO, even with the increases, all taxa present in current Brazilian Red List would fall under some threat category.

Recently, one of the proposed solutions to solve problems related to EOO and AOO estimates for threatened species has been the application of species distribution modelling (see: Jiménez-Alfaro et al. 2012; Marcer et al. 2013; Pena et al. 2014; Syfert et al. 2014; Silva et al. 2020), an approach that may provide more accurate predictive maps and still has the advantage of being low-costwhen compared to genetic and or demographic studies (Araújo et al. 2002; Guisan and Thuiller 2005; Cayuela et al. 2009). Thus, a promising approach is the use of species distribution modeling combined with the EOO polygons. By combining these two methods, besides obtaining new predicted areas of occurrence for each evaluated taxon, relevant information of habitat suitability inside the EOO polygons will be available for a more realistic application of the IUCN criterion of geographic scope (Rosa et al. in prep.).

These updates in the EOO and AOO of Brazilian threatened butterflies have the potential to change the conservation status of most of the currently threatened taxa. However, in some cases these changes could be a result of the current quantity and quality of information and downlistening these butterfly taxa could be premature. Accordingly, the objectives of the present study are to present new acurate data for future conservation status assessments. Also, the results reinforce the importance of compiling and curating data, in addition to field work and demographic studies, for achieving more realistic information about threatened taxa, especially for insects and other invertebrates.

Declarations

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This article does not contain any studies with human participants or animals performed by any of the authors.

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Figures

Figure 1

Photos of some Brazilian threatened butterflies (all collaborations from amateur photographers). **A.** *Eurytides*(*Mimoides*) *lysithous harrisianus* (Swainson, 1822) (courtesy of Luiz Freire); **B.** *Panara ovifera* Seitz, 1913 (courtesy of Luan Felipe Andrade); **C.** *Glennia pylotis* (Godart, 1819) (courtesy of Rodrigo Conte); **D.** *Charonias theano* (Boisduval, 1836) (courtesy of Edson Roberto); **E.** *Zonia zonia diabo* O. Mielke & Casagrande, 1998 (courtesy of Tiago Babosa); **F.** *Strymon ohausi*(Spitz, 1933) (courtesy of Rodrigo Conte);**G.** *Catagramma hydarnis* (Godart, [1824]) (courtesy of Luan Felipe Andrade);**H.** *Actinote quadra* (Schaus, 1902) (courtesy of Antonio Carlos Fiorito Junior).

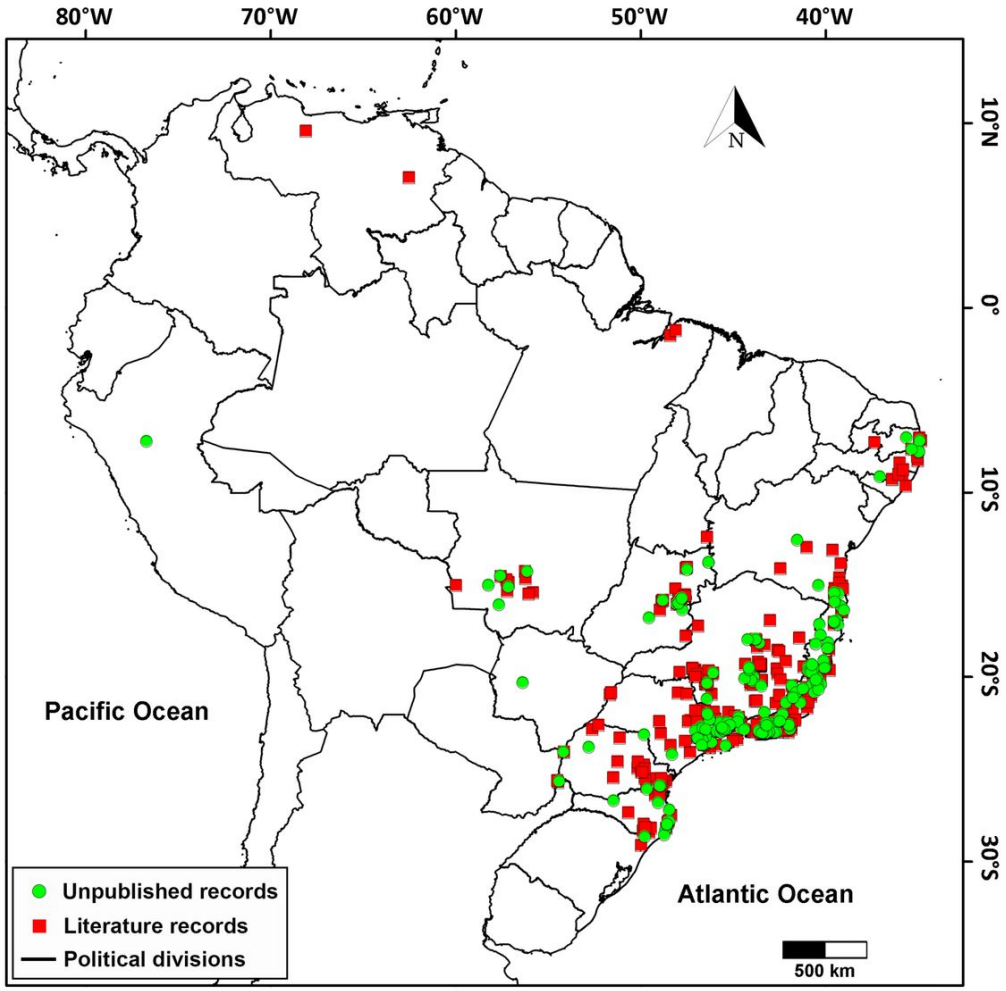

Figure 2

All known records of Brazilian threatened butterflies (only curated data). Circle: unpublished records; Square: literature records.

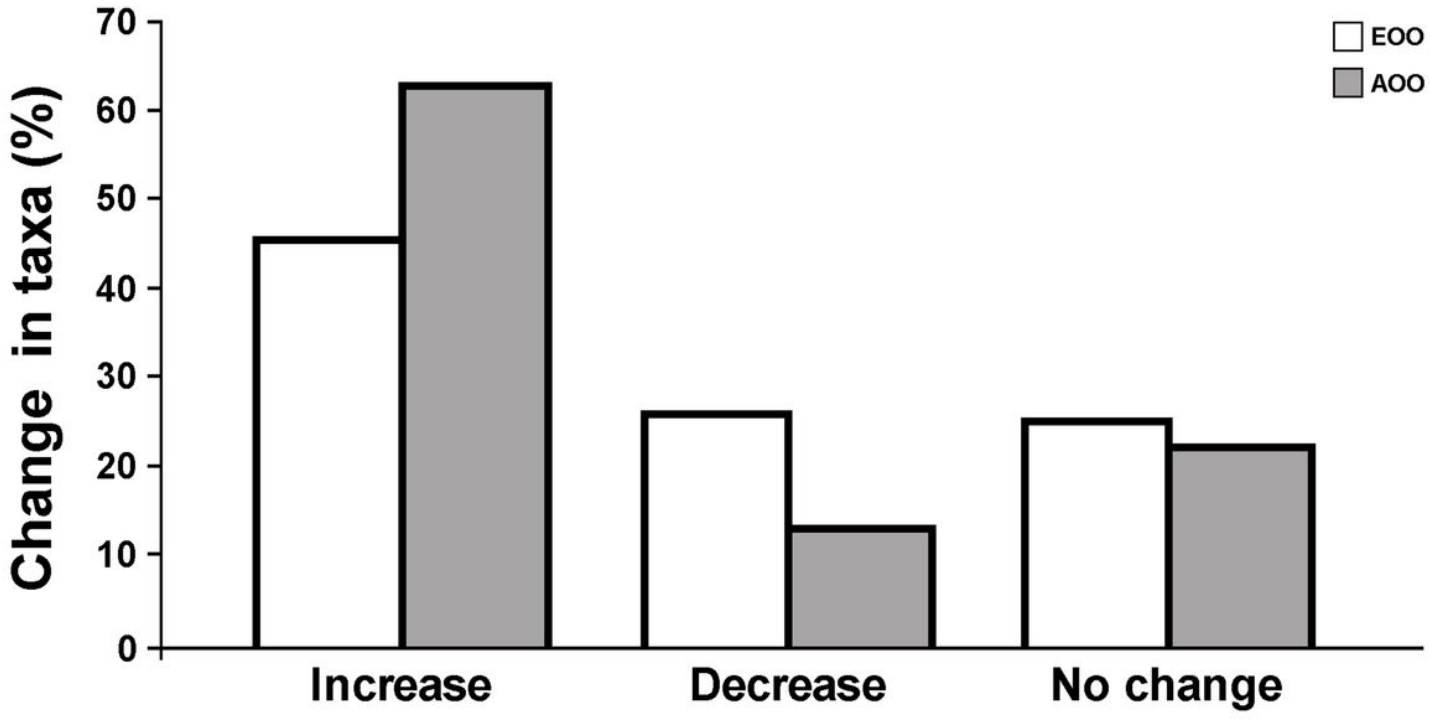

Figure 3

Percentage of change in extent of occurrence (EOO) and area occupancy (AOO) of Brazilian threatened butterflies. Open bars = EOO; Solid bars = AOO.