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ORIGINAL ARTICLE

Understanding global patterns of insectivorous bat dietary research

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ABSTRACT

Studies focusing on the diet of insectivorous bats enhances our understanding of species foraging ecology, and the various ecosystem services provided by bats (especially regulating and suppressing pest populations). This service provides an important insight on their roles in ecosystems, and decreases crop damage as well as increasing productivity, reducing pesticide application, and as significant source of energy for cave ecosystems. This study aimed to understand patterns and provide an overview of how bat diet research has changed over seven decades, to enable more effective future research on conservation and bat pest-control related services. In this study, we reviewed and synthesized the insectivorous bat diet literature and the research which reported the dietary composition that published between 1950 and 2020 to evaluate trends and changes in research. We found studies on 374 species (33.3% of insectivorous species), and a progressive increase in research during over seven decades across all nine regions. The majority of publications were concentrated in North America (116 publications) with fewer studies in countries from the tropics. Most studies took place in natural areas (252 studies) with fewer in buildings and agroecosystems. All insectivorous-bats families were included in diet research, with Vespertilionidae having the greatest coverage (275 studies). Our synthesis highlights clear spatial and taxonomic biases in research. Future studies should focus on all and include more research in agroecosystems and urban areas to understand their roles in ecosystems as well as promote bat conservation.

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INTRODUCTION

As the second most diverse mammal group (following rodents) with over 1400 known species, bats contribute various ecosystem services that are an essential of both ecologically and economically (Boyles et al. 2013, Taylor et al. 2017, Kemp et al. 2019, Puig-Montserrat et al. 2020). Many bats are nocturnal predators with diets including arthropods such as insects, spiders, centipedes, millipedes, scorpions, and some small vertebrates such as rodents, birds, bats, fish, and frogs (Lee & McCracken 2005, Taylor et al. 2012, Maslo et al. 2017). A single bat can eat more than their body weight each night (Kolkert et al. 2020), and are hugely economically valuable through pest-control services (Cleveland et al. 2006, Brown et al. 2015, Aizpurua et al. 2018, Weier et al. 2018, Puig-Montserrat et al. 2020). Previous bat diet studies have been conducted in diverse taxa, habitat types, and regions (Agosta 2002, Maas et al. 2013, 2016, Adeyanju & Adeyanju 2018, Arrizabalaga-Escudero et al. 2018, Galan et al. 2018) which provides a better understanding of bat diets, foraging habits and strategies, the relationship between bat morphology and insects, habitat requirements for bat foraging, and facilitate management of landscapes to maintain the diversity (Clare et al. 2011, Burgar et al. 2014, Clare et al. 2014, Cohen et al. 2020).

The relationship between bats and pest insects is generally assessed through bat fecal analysis. Understanding the roles of bats in pest control can enable more effective pest regulation through integrated pest management (IPM) approaches (a key component of integrated farm management which aims to maximize sustainability through holistic planning), which includes reduced need for the pesticide, and using bat guano as fertilizer (Boyles et al. 2011, Gouge et al. 2015, Weier et al. 2018). For example, *Eptesicus fuscus* suppresses herbivorous arthropods that damage soybeans and apples in Canada and the United

States of America (USA) (Long & Kurta 2014, Put et al. 2018). *Chaerephon plicatus* and *Scotophilus kuhlii* in Thailand regulates various insect pest species (*Sogatella furcifera*) in paddy fields and increases rice production (Leelapaibul et al. 2005, Wanger et al. 2014, Srilopan et al. 2018, Nguyen et al. 2019). *Tadarida brasiliensis* is widely distributed and as an important pest controller in cotton, pecan, and walnuts in Mexico and the USA and in vineyards in Chile (Cleveland et al. 2006, McCracken et al. 2012, Braun de Torrez 2014, Brown et al. 2015, Rodríguez-San Pedro et al. 2018, Braun de Torrez et al. 2019). *Chaerephon pumilus* provides pest-control to the world's largest producer of macadamias in South Africa by suppressing a major insect pest species (*Nezara viridula*) (Taylor et al. 2012, 2013, 2017, 2018, Weier et al. 2018).

Insect pests reduce global crop production by varying degrees, with for example 50% in wheat to more than 80% in cotton production (in regional analysis, and similar losses are likely to be widely applicable; Oerke 2006, Thiéry et al. 2018, Puig-Montserrat et al. 2020). Farmers in some countries have combined biological control by bats using the integrated pest management approach in order to regulate pest populations in areas and improve crop yields, due to the evolution of pesticide resistance in pest insects (Gouge et al. 2015, Aizpurua et al. 2018, Puig-Montserrat et al. 2020). In addition, integrative farming management aims not only to enhance ecosystem function and species diversity in the area, but also to reduce chemical contamination in environment and water, reduce economic costs, effectively reduce crop damage, and indirectly benefit human health (Kunz et al. 2011; https://leaf.eco/farming/integrated-farm-management). Bat diet studies enhance our understanding of bat foraging ecology and facilitate conservation, maintenance of ecosystem, agricultural management, and ecosystem services concept (Taylor et al. 2013, Weier et al. 2018, Cohen et al. 2020).

Here, we review and synthesize insectivorous bat diet research, exploring research trends over seven decades (1950-2020) and discuss four important components of insectivorous bats diet research: geographical distribution of research, study habitat, taxonomic group, and IUCN red list threat categories). We hope this will provide a useful baseline to understand trends in research, identify gaps, and direct priorities for future research on bat diet research and bat pest-control related service management.

MATERIAL AND METHODS

We reviewed published literature on insectivorous bat diets, to understand research trends. Literature publications were searched until the 31st of May 2021 using a standard website using the Web of Science (www.webofknowledge.com), Google Scholar (www.scholar.google.com), Academia.edu (www.academia.edu), and ResearchGate (www.researchgate.net). We searched the publications on "insectivorous bat" AND "diet" OR "dietary composition" OR "dietary analysis" OR "food habit" OR "ecosystem services" OR "pest regulation" and screened literature that reported the insectivorous-bats diet information based on feces analysis and some bat exclusion experiments. Additionally, our search results were supplemented with the Bat Eco-Interactions database (www.batbase.org) as certain publications may be missing from our searches. Our database was created by reviewing published literature and extracting key information (i.e., bat species, dietary composition, habitat type, and country). We then removed duplicated publications and verified the scientific names, geographical distribution, and IUCN threatened categories of bats using the IUCN Red List of Threatened Species (www.iucnredlist.org) (IUCN 2021).

Categorizing research

Nine regions were independently analysed based on the IUCN Red List listed regions, including Africa (North Africa and Sub-Saharan Africa countries), Europe, North America, Latin America (combination of the country among Caribbean Islands, Mesoamerica, and South America), East Asia, North Asia, South and Southeast Asia, West and Central Asia, and Oceania (based on regions designated in thematic mapper: https://thematicmapping.org/). We used ArcGIS 10.3 software to develop the global distribution map of insectivorous-bats species studied and dietary research based on the number of publications and species. To assess the trends of research over-time (1950-2020) and at regional level, we used Kendall's Tau B correlation coefficient and nonlinear regressions to express the relationship between time (year) and number of publications.

This synthesis includes seven decades, which were classified into seven periods of ten years each. The study habitats were classified into three categories: (1) natural areas (forests, caves, protected areas, islands, mountains, deserts, etc.), (2) agroecosystems and industrial areas (apple, cacao, cereals, chestnut, coffee, cotton, macadamia, maize, rice, soybean, sugarcane, mines, plantation, etc.), and (3) buildings (house, church, garage, office, street lights, under bridges, villages, etc.). Certain publications did not record study habitats in research, therefore, we separated them into "unspecified" to reduce bias on the number of publications for other habitat types. These were to encompass the three primary types of habitat structure often referred to in landscape zoning as "natural areas", "shared lands" (agriculture) and human dominated areas (urban areas) (Locke et al. 2019).

We tested the difference in the proportions of publications across geographical regions using the Pearson's Chi-squared (χ^2) to assess research patterns based on year, the study habitat, bat taxonomic group, and the IUCN threat status. We used JAMOVI statistical software (The JAMOVI project 2020) for all calculations and statistical analyses, and constructed graphs by using GraphPad Prism version 8.02 for Windows, GraphPad Software, La Jolla California USA (www.graphpad.com). The significance level was set at $p = 0.05$.

RESULTS

Overview of insectivorous bat dietary research trends

We found 408 publications on insectivorous-bat diets, the first of these was in 1917, but 405 publications were published between 1950 and 2020 (Fig. 1). The number of publications increased in each decadal period between 1950 to 2020 (Kendall's Tau B = 0.750; $p < 0.001$; $R^2 = 0.817$) (Fig.

1) and changed over time more than expected by chance using Chi squared ($\chi^2 = 395$; df = 6; $p < 0.001$). We found very few publications from 1950 to 1970 (n = 6 for each decade; 1.44% of all publications), however between 1971 and 2000 the number of publications increased to more than 20 publications per decade, and between 1991 and 2000 there were over 65 publications averaging 6.5 publications per year (15.55% of total). The majority of publications were from the last two decades (2001-2020) (290 publications: 69.38%), 124 publications (29.67%) and an average of 12.4 publications per year, from 2001 to 2010; and 166 (39.71%) and an average of 16.6 publications per year between 2011 and 2020.

Trends and distribution of dietary research at a regional scale

Based on the papers reviewed we found insectivorous-bats diet research in 84 countries from nine regions. Out of 84 countries, 31 countries had at least one publication, and the greatest number of publications was in United States of America (99 publications, 20.37% of all publications) (Fig. 2A). The majority of publications were from North America (n = 116; 26.79% of all publications, 2 countries), followed by Europe (n = 97; 22.40%; 25 countries), with tropical regions showing fewer, despite having higher bat species diversity. The pattern of insectivorous bat diet research in the nine regions was significantly different but showed the positive trend in research in each region.

The proportion of publications in each of the nine regions was significantly different ($\chi^2 = 231$; df = 8; $p < 0.001$). The highest number of species studied were in Brazil (60 species), followed by Australia (45 species), three countries (South Africa, United States of America, and Costa Rica) had over 30 species each, while more than 50 countries had less than 10 species, and 18 countries focused on a single species (Fig. 2B). The highest number of species studied were in Latin America (101 species; 9 families; 25.50% of all species in IUCN RedList for the region) (Fig. 3B). Africa had the second highest number of species studied (92 species; 11 families; 34.85%), followed by South and Southeast Asia (61 species; 9 families; 20.54%), Oceania (52 species; 8 families; 42.98%), North America (37 species; 4 families; 77.08%), West and Central Asia (36 species; 8 families; 35.29%), Europe (34 species; 4 families; 73.91%), East Asia (27 species; 5 families; 18.75%), and North Asia (15 species; 1 family; 30.61%) (Fig. 3A).

Out of nine regions, only three regions (Latin America, North America, and South and Southeast Asia) had publications in all decades, and the majority of publications were found after 2000 (n = 31, 82, and 26 publications respectively). The other regions (Africa, East Asia, and Europe) had a majority of their publications (n > 20) after 2000. North Asia, Oceania, and West and Central Asia had few publications (n < 20) after 2000. However, the research trends of all regions between 1950 to 2020 were significantly positive (Table 1), and the proportion of publications from 1950 to 2020 was significantly different between regions ($\chi^2 = 117$; df = 48; $p < 0.001$) (Fig. 1 and Fig. 4A).

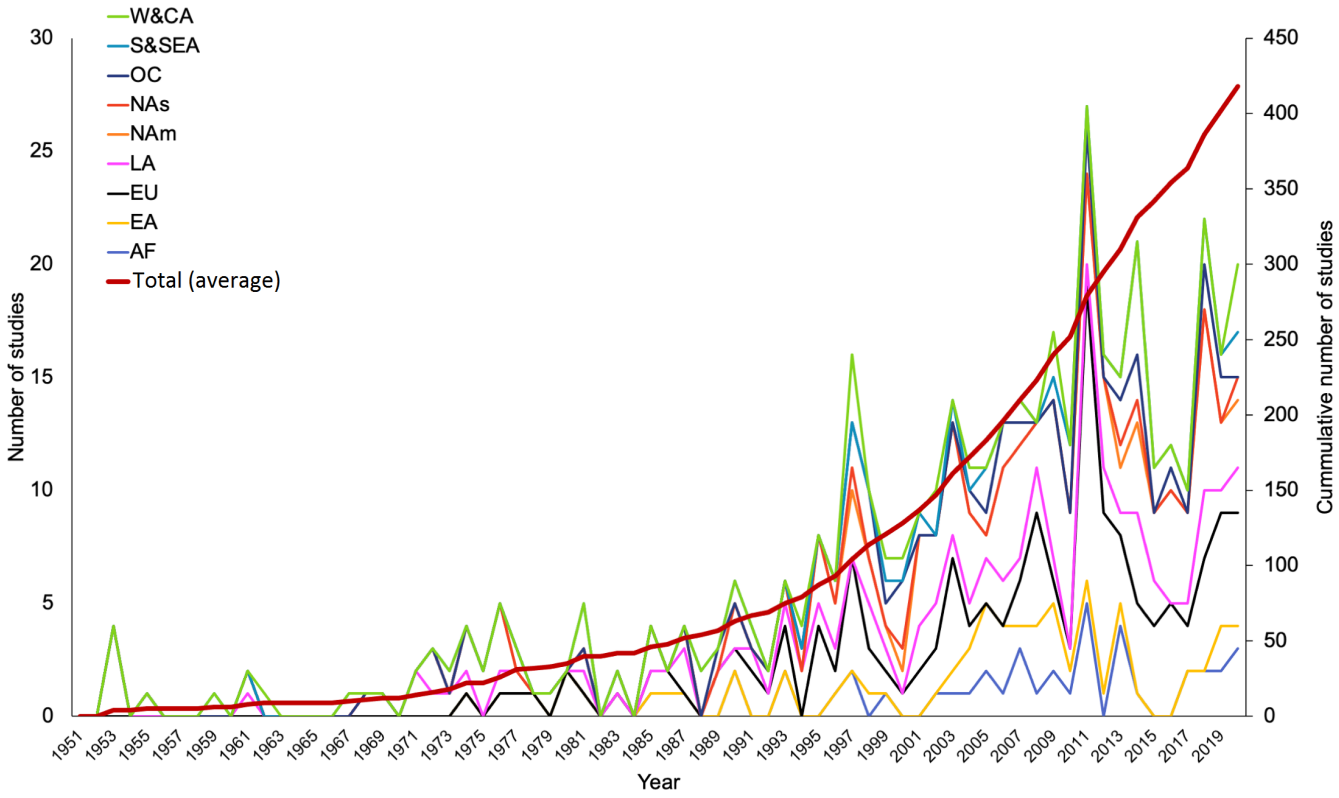

Fig. 1 - Number of insectivorous bat diet publications between 1950 to 2020. The average trend of insectivorous bat diet publications based on the number of publications from 1950 to 2020. W&CA: West and Central Asia, S&SEA: South and Southeast Asia, OC: Oceania, NAs: North Asia, NAm: North America, LA: Latin America, EU: European Union, EA: East Asia, AF: Africa.

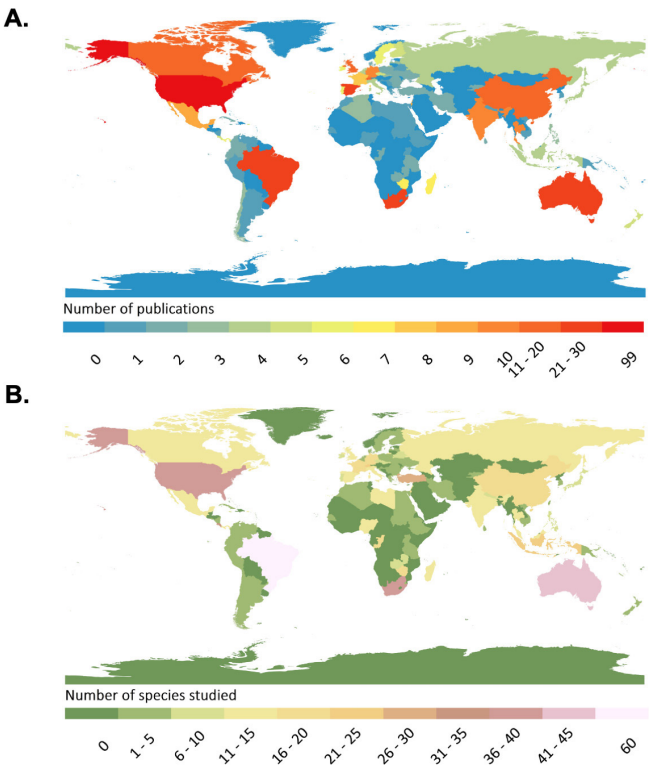

Fig. 2 - A) Number of insectivorous bat diet publications between 1950 to 2020. **B)** Number of insectivorous bat species with diet studies per country.

Study areas and bat diversity of research

Published insectivorous-bat diet studies occurred in a number of types of natural habitats, agroecosystems and buildings. The majority of studies occurred in natural areas (n = 252; 57.80%), followed by buildings (n = 85; 19.50%), agroecosystems (n = 81; 18.58%), and the proportion of publications among three habitats was significantly different (χ^2= 137; df = 2; p < 0.001). All regions had studies in all three habitat types, with the exception of North Asia which had no studies in agro-ecosystems (Fig. 4B).

Natural areas were divided into five categories, the majority of publications were in forests (n = 134; 53.17%) and caves (n = 87; 34.52%), while the other categories included mountains (n = 16; 6.35%), islands (n = 11; 4.37%), and deserts (n = 4; 1.59%) (Table 2). For dietary research in agroecosystems, which included 22 categories, the majority of publications were in agricultural areas (n = 25; 29.07%) including rice fields (n = 11; 12.79%), and there were 11 crop types (cereals, chestnut, coffee, maize, olive, palm, papaya, pasture, soybean, sugarcane, and walnut) which with only a single publication (n = 1; 1.16%) (Table 3 and Fig. 5).

Spatial and taxonomic patterns

Diet research has been conducted on 374 bat species from 19 families, the proportion of publications for different bat families was significantly different (χ^2= 2,156; df = 18; p < 0.001) (Table 4). In total at least 749 insectivorous-bats species (66.70% of all insectivorous bat species) had inadequate information on foraging and diet. Only families comprising few species (e.g., Cistugidae,

Table 1 - Correlation coefficients and nonlinear regression on the trends of research based on the number of publications over time in each geographical region.

Geographical region	Kendall's Tau B	R^2	p - value
Africa	0.498	0.348	0.252
East Asia	0.454	0.274	0.098
Europe	0.666	0.514	0.002
Latin America	0.407	0.224	0.089
North America	0.613	0.620	0.001
North Asia	0.263	0.128	0.163
Oceania	0.432	0.260	0.415
South and Southeast Asia	0.465	0.355	0.006
West and Central Asia	0.210	0.081	0.653
Total	0.750	0.817	< 0.001

Table 2 - Number and percentage of insectivorous bat diet publications in natural areas

Natural areas category	Number of publications	Percentage of publications (%)
Forests	134	53.17
Caves	87	34.52
Mountains	16	6.35
Islands	11	4.37
Deserts	4	1.59

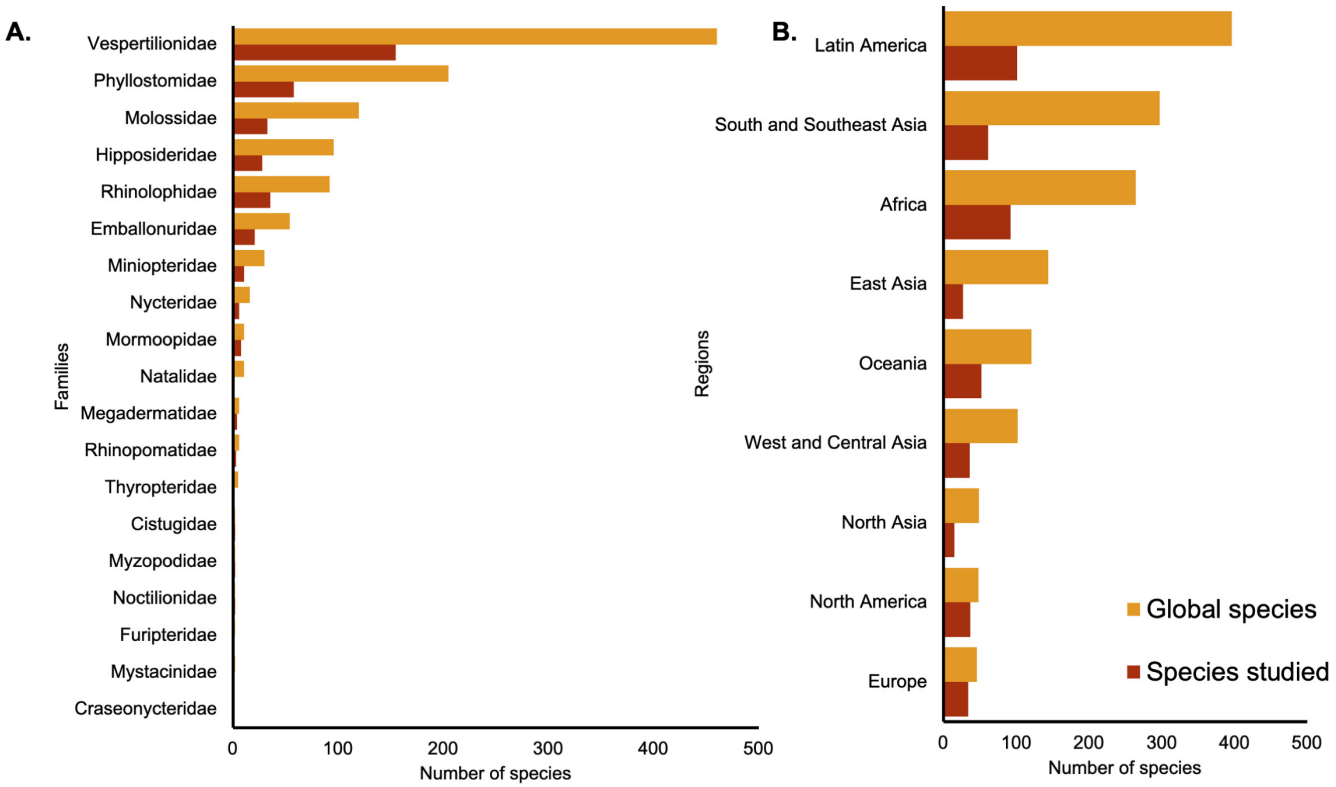

Fig. 3 - A) Number of insectivorous bat species studied for each family. **B)** Number of insectivorous bat species studied for each region.

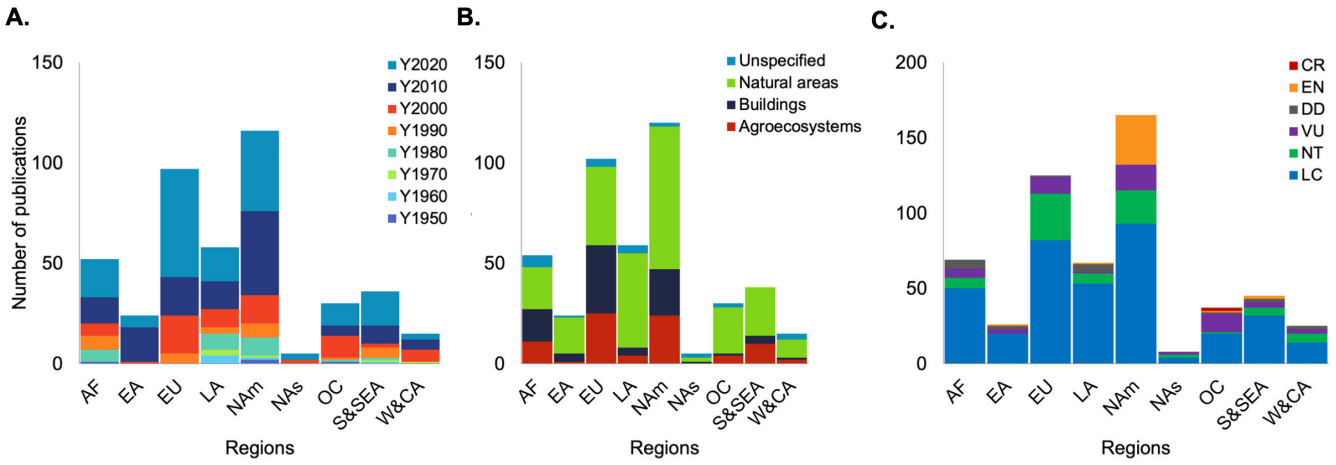

Fig. 4 - Number of insectivorous bat diet publications A. in terms of year between 1950 to 2020. B. in terms of habitat type. C. in terms of IUCN Red List categories.

Craseonycteridae, Myzopodidae, Noctilionidae) included research on all species, and only six of the species studied (*Eptesicus fuscus*, *Myotis lucifugus*, *Lasiurus borealis*, *Pipistrellus pipistrellus*, *Rhinolophus ferrumequinum*, and *Lasiurus cinereus*) had above 20 publications between 1950 and 2020. Vespertilionids were the best studied (n = 275 publications, 33.7%). Conversely four families (Cistugidae, Craseonycteridae, Furipteridae, and Natalidae) only showed a single publication. However, for diverse families (Vespertilionidae, Phyllostomidae, Molossidae, Hipposideridae, Rhinolophidae, Emballonuridae, and Miniopteridae), more research efforts are needed as only a small percentage of species have diet studies (40% of all insectivorous bat species).

Insectivorous bats had the highest species diversity in Latin America (396 species; 35.26% of all species), of which 205 species belong to Phyllostomidae (>50% of species distributed in the region), yet only 101 bat species (25.50%) in Latin America had diet research. South and Southeast Asia had the second highest species diversity (297 species; 26.45% of all species), with Vespertilionidae being the most diverse group in the region (140 species; 47.14% of species distributed in region), with a total of 61 species (20.54%) with diet research.

North America and Europe had the highest level of species coverage (77.08% and 73.91% respectively), whereas all other regions had under 50% of species covered. Three regions (North America, Europe, and North Asia) hosted low species diversity but had high coverage of species. In both North America and Europe the majority of species (> 70% of species) are Vespertilionidae. For North Asia, more research effort is needed for all families in the region, as all the species studied are from Vespertilionidae despite only including 35.71% of the species of this family. All other

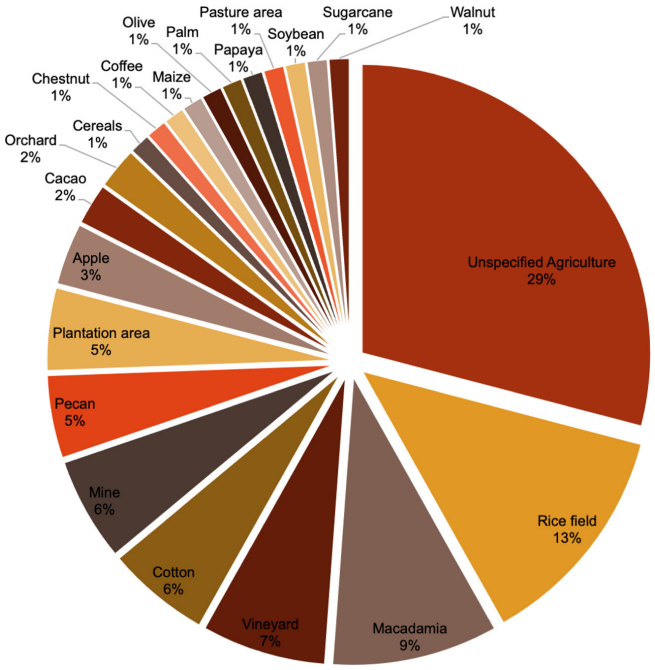

Fig. 5 - Percentage of insectivorous bat diet publications in agroecosystems

regions lacked sufficient diet data on all groups, meaning that species predominantly in these regions (Hipposideridae, Rhinolophidae) had particularly little data.

Dietary research on threatened species

LC species were included in over 60% of all publications (n = 357) and LC species represented the greatest number of publications in all regions, and a higher degree of completeness in these groups (likely as they are easier to capture). However, with increasingly high levels of threat, progressively fewer species were studied. The number of publications among all threatened categories was significantly different (Table 5). Out of 374 species studied, 306 species (>80% of all species studied) were categorized as LC, and 108 LC species had only a single dietary publication. Threatened species studied (i.e., Critically Endangered, Endangered, Vulnerable) included 29 species within 99 publications (< 20% of all publications). The majority of insectivorous bats were LC (60.27% of all species sorted by category) and DD category (20.09%) (Fig. 4C), yet coverage of these groups is also variable (45.33% of LC and 7.56% of DD). The proportion of publications for all threat categories across regions was significantly different ($\chi^2 = 165$; df = 40; $p < 0.001$), so threatened species in understudied regions had particularly little data.

Table 3 - Number and percentage of insectivorous bat diet publications at agroecosystems and other modified rural systems.

Agroecosystems category	Number of publications	Percentage of publications (%)
Unspecified Agriculture	25	29.07
Rice field	11	12.79
Macadamia	8	9.30
Vineyard	6	6.98
Cotton	5	5.81
Mine	5	5.81
Pecan	4	4.65
Plantation area	4	4.65
Apple	3	3.49
Cacao	2	2.33
Orchard	2	2.33
Cereals	1	1.16
Chestnut	1	1.16
Coffee	1	1.16
Maize	1	1.16
Olive	1	1.16
Palm	1	1.16
Papaya	1	1.16
Pasture area	1	1.16
Soybean	1	1.16
Sugarcane	1	1.16
Walnut	1	1.16

Table 4 - Number and percentage of insectivorous bat diet publications based on bat family, and number of insectivorous bat species with studies and globally based on the IUCN RedList.

Bat family	Number of publications	Percentage of publications (%)	Number of species studied	Number of species globally	Percentage of species studied (%)
Cistugidae	1	0.16	2	2	100
Craseonycteridae	1	0.16	1	1	100
Emballonuridae	24	3.84	21	54	38.89
Furipteridae	1	0.16	1	2	50.00
Hipposideridae	48	7.68	28	96	29.17
Megadermatidae	17	2.72	4	6	66.67
Miniopteridae	29	4.64	11	30	36.67
Molossidae	68	10.88	33	120	27.50
Mormoopidae	12	1.92	8	11	72.73
Mystacinidae	3	0.48	1	2	50.00
Myzopodidae	3	0.48	2	2	100
Natalidae	1	0.16	1	11	9.09
Noctilionidae	6	0.96	2	2	100
Nycteridae	19	3.04	6	16	37.50
Phyllostomidae	38	6.08	58	205	28.29
Rhinolophidae	72	11.52	36	92	39.13
Rhinopomatidae	5	0.80	3	6	50.00
Thyropteridae	2	0.32	1	5	20.00
Vespertilionidae	275	44.00	155	460	33.70

Table 5 - Number and percentage of insectivorous bat diet publications and insectivorous-bat species studied based on threat categories by IUCN Red List.

Threatened category	Number of publications	Percentage of publications (%)	Number of species studied	Number of species globally	Percentage of species studied (%)
DD	19	3.45	17	225	7.56
LC	357	64.79	306	675	45.33
NT	76	13.79	22	73	30.14
VU	59	10.71	18	76	23.68
EN	38	6.90	10	56	17.86
CR	2	0.36	1	15	6.67

DISCUSSION

Globally around 1,123 insectivorous bat species within 19 families have been described (IUCN 2021), with highest diversity in Vespertilionidae (460 species; 40.96% of all species), Phyllostomidae (205 species; 18.25%), and Molossidae (120 species; 10.69%). Yet of these only a small proportion had data on their diets, and 749 insectivorous bat species (66.70%) had insufficient information on foraging and diet, with under 35% of species studied in almost every group. The majority of bat species (143 species; 38.23% of all species studied) had a single publication on their diet.

Outside Europe and North America only a small proportion of species have been studied. North Asia and West and Central Asia (<5% of all publications) indicating large research gaps. For five regions, research was focused on a subset of common families (i.e., Vespertilionidae, Phyllostomidae, and Hipposideridae), but many small population and rare species still lack information and need more foraging ecological research. Similarly studies using species distribution modelling in bats were dominated by publications in Europe and Africa (Razgour et al. 2016), with an almost continuous increase between 2001 and 2016, however developed regions continue to dominate most studies.

Technological advancements in research processes, developing equipment, knowledge integration, these could contribute to increasing research effort (Berthinussen et al. 2014, Furey & Racey 2016). Insectivorous-bats diet research has increased continuously over seven decades, especially in the last 20 years (after 2000), but is growing at a slower rate in many diverse, tropical regions.

Study areas and bat diversity of research

Insectivorous-bats diet research has been conducted in three key categories of terrestrial ecosystem (1) natural areas, (2) agroecosystems and industrial, and (3) buildings. The majority of research took place in natural areas and the key habitat in natural areas were forests and caves. This highlights the need for more research in areas with crops to better understand economic dimensions, but majority of research was in general farm areas and rice paddies, but less exists in other crop types. Publications in natural areas were highest in North America, while publications focused on agroecosystems and built-up areas were predominantly in Europe. The number of publications between the three habitats were significantly different. Natural areas are essential for many species, as well as providing important ecosystem services (i.e., regulation of air quality and water, carbon sequestration, erosion, etc.), also important for bats due to using natural areas for roosting, foraging, breeding, and hibernating (Medellín et al. 2000). Agroecosystems cover to 40% of terrestrial ecosystems (FAOSTAT 2011, Williams-Guillén et al. 2016). However, insectivorous bat research in agricultural areas can provide new insights on roles of ecosystem services as pest regulators (Taylor et al. 2012, Kasso & Balakrishnan 2013) to suppress and control pest populations, which prevents crop damage and loss (Oerke 2006, Taylor et al. 2013, Maas et al. 2013, Williams-Guillén et al. 2016). Likewise, bat research around buildings has implications human disease management, by suppressing mosquitoes which are vectors of various diseases (Mickleburgh et al. 2002, Kasso & Balakrishnan 2013, Gouge et al. 2015). In agroecosystems and urban areas more research effort is needed to understand how species use these spaces, which can contribute new insights about the role of bats at agricultural area on the insect pest diversity suppressed by bats, as well as the bat benefits with farmer in agricultural pest management, reduce the costs for pesticide, and damage to crops. Reduction of pesticide would also benefit bats by enabling them to provide greater service provision.

Spatial and taxonomic patterns

High species diversity in tropical regions (Africa, East Asia, Latin America, Oceania, South and Southeast Asia, and West and Central Asia) and low research effort indicated a great inadequate foraging ecology research in several families (i.e., Molossidae, Rhinolophidae, and Hipposideridae).

Vespertilionidae make up the majority of species studied, except in Latin America (highest diversity in Phyllostomidae) and South and Southeast Asia (highest diversity in Rhinolophidae). Therefore, research gaps exist in each family, especially in the most diverse regions.

Regions with low species diversity (North America, Europe, and North Asia) show an adequate research effort on the diet of only Vespertilionidae (> 70.00%). However, diet studies on many other bat families are still lacking (i.e., Molossidae, Rhinolophidae, Phyllostomidae). For North Asia, the taxonomic patterns in the region indicated a lack of research in all families.

Dietary research on threatened species

Some species with dietary publications are not yet in the IUCN database (i.e., *Miniopterus fuliginosus*, *Rhinolophus cornutus*, and *Rhinolophus thailandensis*) (Mickleburgh et al. 2002). Our analysis highlights the lack of foraging ecology research for many insectivorous-bats species (66.70% of all insectivorous bat species listed by the IUCN).

Furthermore under 20% of the species classified as threatened according to the IUCN have been studied which indicates studies fail to include assessments of more vulnerable groups. Further research, especially for under-studied groups and in tropical regions will help target management and facilitate maintenance of crucial ecosystem service provision.

CONCLUSIONS

Ecosystem service provision is undoubtedly important, and when it comes to pest control, the services provided by bats have been estimated at millions of USD annually (Cleveland et al. 2006), yet where and how representative these studies are, has never been explored previously. Here we conduct a global synthesis, to understand the patterns of research on bat diets. Overall, North America and Europe have the best species coverage, where over 70% of species distributed in region have been included in studies, whereas fewer studies have been recorded in Asia (< 10%) and Oceania (7%). Natural areas are the key locations for insectivorous-bat diet research, though at least 22 crop systems have been studied for agroecosystems providing important insight on the value of bats by regulating pest populations and its impact on agricultural management and economics in farm areas (29%) and rice paddies (13%). However, 41% of species studied were Vespertilionids, and 38% of bat species only had a single study. Vespertilionid studies dominate in almost all regions, except in Latin America where Phyllostomidae dominate, and South and Southeast Asia with Hipposideridae. Least concern (LC) species are the best studied in all regions, with over 60% of publications and 80% of species studied, conversely the research on threatened species is scant (< 20%). Given the importance of insectivorous bat diet research to ecosystems services and economics through pest control services, and conservation this provides a useful baseline to direct future work on bat dietary research and address the various gaps in our current understanding.

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