Building a Terrestrial Biodiversity Inventory for Guam

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[1]

[1] https://github.com/aubreymoore/McIntire-Stennis/raw/master/final-report-2022/McIntire-Stennis-final-report-2022.pdf

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1 Introduction

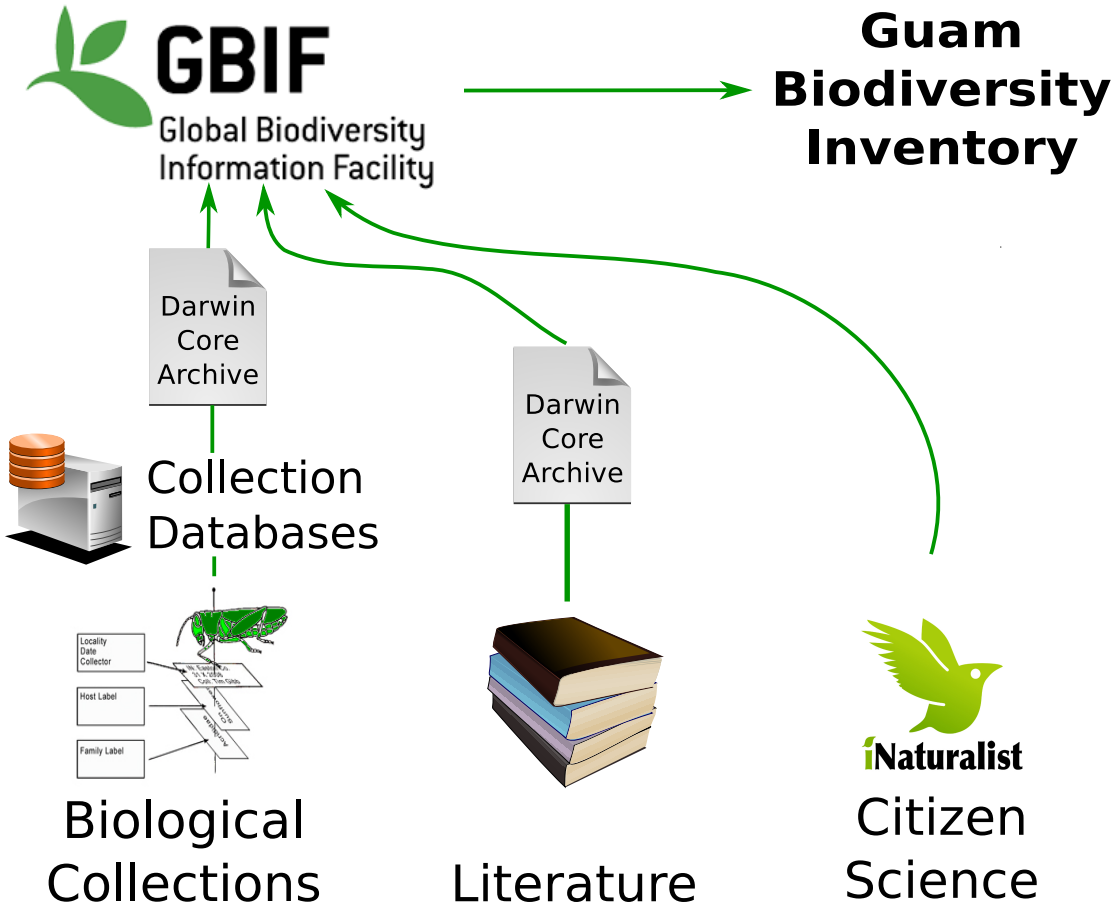

Figure 1: Conceptual design for the Guam Terrestrial Biodiversity Inventory

This project was proposed in 2018 [6] and plans were presented at the Guam Island Sustainability Conference [1] and the Second Annual Digital Data in Biodiversity Research Conference [2] during the same year.

1.1 Why Guam Needs a Terrestrial Biodiversity Inventory

In its simplest form, a biodiversity inventory is essentially a database containing a comprehensive check list of all taxa known occur within a defined geographic area. Data are keyed to a taxonomic hierarchy commonly referred to as the *tree of life*.

The numbers and identities of terrestrial species on Guam are largely unknown. For example, the Global Biodiversity Information Facility (GBIF) currently lists only 1,095 insect species for Guam, whereas it is estimated that there are about 5,000 species.

A biodiversity inventory for Guam is needed:

- To document rapid changes to Guam's ecosystems including arrival of invasive species
- To provide free, open access to information on Guam's flora and fauna
- To share Guam biodiversity information with the global scientific community, policy makers and the public

The inventory will facilitate automatic generation and updates to lists such as:

- A list of all invasive species on Guam with year first recorded
- A list of new species described from specimens collected on Guam
- A list of observations for Guam's endangered species
- A list of Guam's native plants with associated herbivores and pathogens
- A list of crops grown on Guam and pests and pathogens which attack them
- A list of pests and associated biological control agents
- For any taxon, a literature reference list and links to images
- Taxonomic checklists and field guides with images

I used the methods described in this report to access biodiversity information for insects on Guam. These same methods can be used for other taxonomic groups and locations.

1.2 Design Considerations

Data for biodiversity inventories are commonly extracted from labels attached to specimens in biological collections and occurrence records in the scientific literature. In recent years, biodiversity data have become available via online sources such as iNaturalist, a citizen science social networking site where users record images and data from biological observations, and the Barcode of Life Data System (BOLD), a repository for DNA barcoding sequences.

Instead of building, maintaining and hosting a custom online database for the Guam Terrestrial Biodiversity Inventory, I decided to use GBIF as the online database and then build a set of custom tools to access Guam specific data. This design simplified the work tremendously. The major task for this project was to automate importation of Guam data into GBIF (Fig. 1). Development of taxonomic data standards, especially the Darwin Core Archive data format, have made it relatively easy to develop automated workflows for sharing biodiversity data among different systems. In the following sections I will describe methods used to push Guam data from biological collections, scientific literature and iNaturalist to GBIF.

I used free, open source software (FOSS) for this project. All code and documentation is stored in public GitHub repositories [5, 3, 4].

1.3 References

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2 Extracting Data from the University of Guam Insect Collection

The University of Guam Insect Collection maintains an online catalog of label data for all 35,000 pinned specimens. This catalog is part of the Symbiota Collections of Arthropods Network (SCAN). SCAN has been configured to automatically push data from the UOG insect collection to GBIF.

Note that biodiversity data extracted from the UOG insect collection database is extremely biased because soft bodied and minute insects preserved in liquid or on microscope slides are not included in the catalog. In many cases, occurrence records for these insects are currently available only from the scientific literature. In addition, only 21% of specimens in this collection are identified to species.

Acknowledgment Thanks to Peggy Denney and Laura Barnes for digitizing label data and to Neil S. Cobb, Northern Arizona University, for help with SCAN and for setting up automatic publishing of data to GBIF.

3 Extracting Data from Insects of Guam Publications

As a first attempt to extract biodiversity data from the scientific literature, we chose to datamine 38 chapters included in Insects of Guam I and II published by the Bishop Museum [1, 2]. These volumes document insects collected on Guam during a comprehensive entomological survey done in 1936 by O. H.Swezey from the Hawaii Sugar Planters' Association. Chapters from both books are available online as PDFs.

For this part of the project, we collaborated with Plazi, a Swiss-based international nonprofit association supporting and promoting the development of persistent and openly accessible digital bio-taxonomic literature. We work closely with data scientists at the Plazi office in Brazil: Marcus Guidoti, Carolina Sokolowicz, and Tatiana Ruschel. They provided online training, specialized software, server access, and technical support.

Plazi did the initial annotation of each chapter using their open source software, GoldenGATE-Imagine (GGI). Final annotation, using GGI to parse material citations, was performed by myself and Annette Kang, a PhD student from Guam studying entomology at Cornell University.

For each chapter we annotated, the Plazi workflow created a journal article published in Zenodo. This is essentially a republished copy of the original chapter with links to files containing extracted data. Links are provided for a GBIF checklist dataset which may be downloaded in several formats including Darwin core archive (DwCA). In addition, a dataset for each taxon within the chapter is created and stored in the Plazi Treatment Bank. For example, here are the publicly accessible online data products which automatically appeared on the web after we annotated the Bees of Guam chapter and uploaded it back to the GoldenGATE server:

Zenodo article Cockerell, T. D. A. (1942). Bees of Guam. In Insects of Guam I (pp. 188–190). Bernice P. Bishop Museum. https://doi.org/10.5281/zenodo.5160372

GBIF dataset Cockerell T D A, carolina (1942). Bees of Guam. Plazi.org taxonomic treatments database. Checklist dataset https://www.gbif.org/dataset/356a98ac-1526-4045-ae7f-52d08e

This dataset can be downloaded in several formats including Darwin core archive.

Taxon treatments A page is available for each of the 7 taxa which appear in the chapter:

Cockerell, T. D. A. (1942). *Apis mellifera* Linnaeus. In Bees of Guam, pp. 188-190 in Insects of Guam I (p. 188). Bernice P. Bishop Museum. https://doi.org/10.5281/zenodo.5211876

Cockerell, T. D. A. (1942). *Megachile laticeps* Smith. In Bees of Guam, pp. 188-190 in Insects of Guam I (p. 188). Bernice P. Bishop Museum. https://doi.org/10.5281/zenodo.5164364

And so on for the 5 other species in this chapter.

Acknowledgments Thanks to Neal Evenhuis at the Bernice P. Bishop Museum for putting PDFs of *Insects of Guam I and II* on the web, to Plazi for collaboration, especially Donat Agosti in Switzerland and Marcus Guidoti, Carolina Sokolowicz, and Tatiana Ruschel in Brazil, and to Annette Kang, Cornell University, who did most of the final annotation.

3.1 References

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4 Extracting Data from iNaturalist

iNaturalist observations classified as *Research Grade* are automatically added to a iNaturalist Research-grade Observations GBIF dataset. This dataset currently includes 57 million occurrence records.

iNaturalist observations become candidates for *Research Grade* when they have a photo, date, and coordinates. They become *Research Grade* when the community agrees on an identification. If the community has multiple opinions on what taxon has been observed, iNaturalist chooses a taxon from all the proposed taxa (a higher-level taxon containing the proposed taxa) that more than two-thirds of the voters agree with.

I have been using iNaturalist for years as a tool to document observations made during my work as an extension entomologist. Several of my observations document the first observations of invasive species on Guam. I also use iNaturalist as a teaching tool. Students in my entomology courses are encouraged to use iNaturalist to catalog their insect collections. Many iNaturalist observations of insects on Guam are added to the iNaturalist Insects of Micronesia Project. This project currently includes 3605 observations of 438 species made by 154 people.

Acknowledgments Thanks to Ken Puliafico and others for observations and identifications contributed to the *Insects of Micronesia iNaturalist Project*.

5 Accessing Guam Biodiversity Information Stored in GBIF

Much of the time, Guam biodiversity data on GBIF can be accessed directly using the online search interface. For instance, to see a list of all insect occurrences for Guam, one simple opens the clicks on **Occurrences**, selects **Scientific name: Insecta** and **Country or Area: Guam**. The result of this search will be displayed in a large table containing a limited set of fields (currently about 23,000 records). For detailed analysis one can download the data specified for the current search by simply pressing the **Download** button. GBIF builds a custom dataset in one of three formats: **Simple**, **Darwin Core Archive**, and **Species List**. The custom dataset is stored on the GBIF server, is given a citable digital object identifier (DOI), and can be downloaded by anyone who visits the dataset download page [1] (Fig. 2).

For detailed analysis and construction of custom data products, the Darwin core archive (DwCA) can be downloaded and used locally. For example, I used a Jupyter notebook [2] to generate an interactive taxonomic tree containing scientific names for all insect taxa with GBIF occurrence records from Guam (Fig. 3). This taxonomic tree is publicly available as a static web page hosted on GitHub [3]. It can be used on any devices with a web browser, including smart phones.

5.1 References

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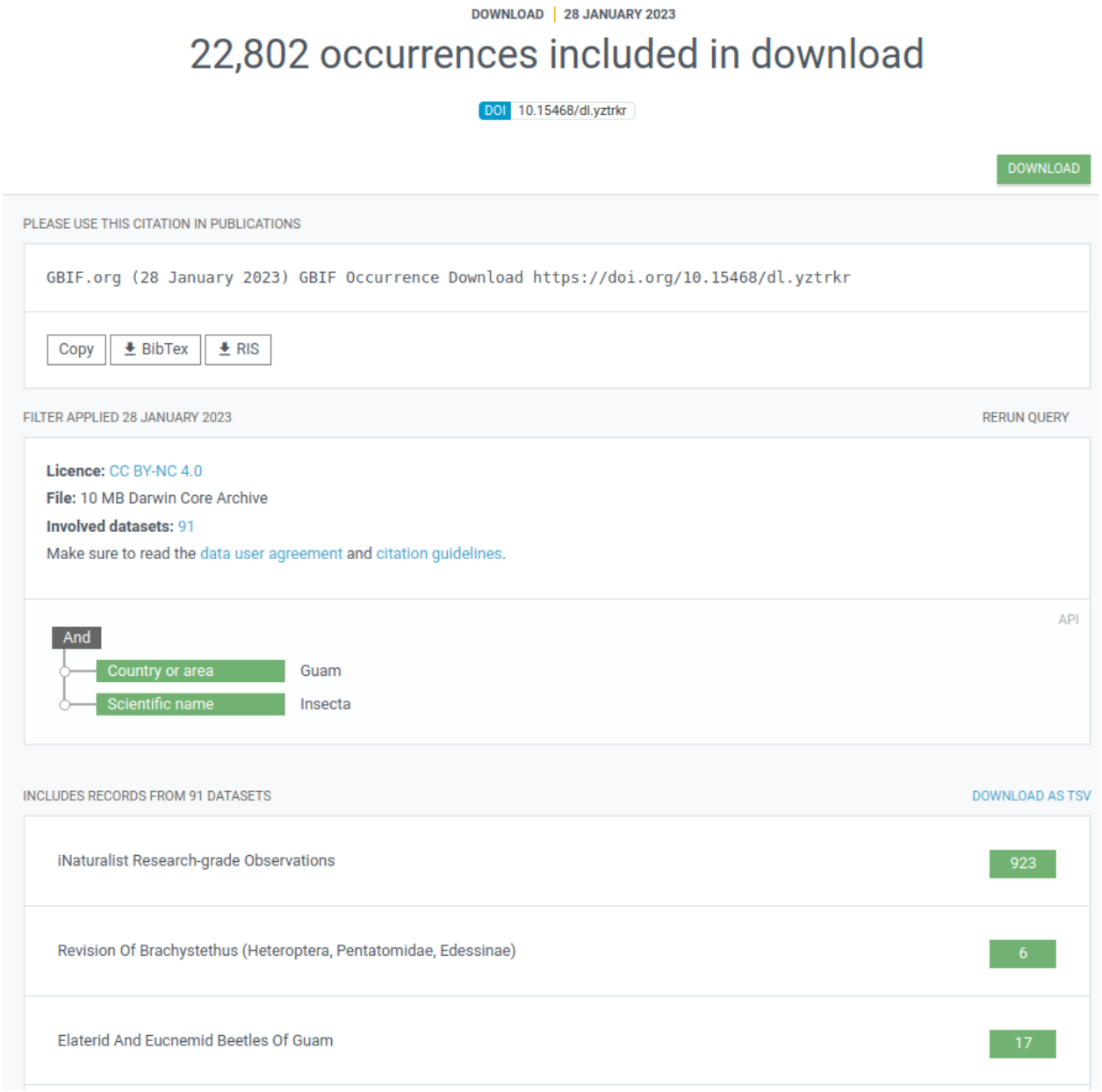

Figure 2: Screenshot of a GBIF dataset download page (https://doi.org/10.15468/dl.yztrkr).

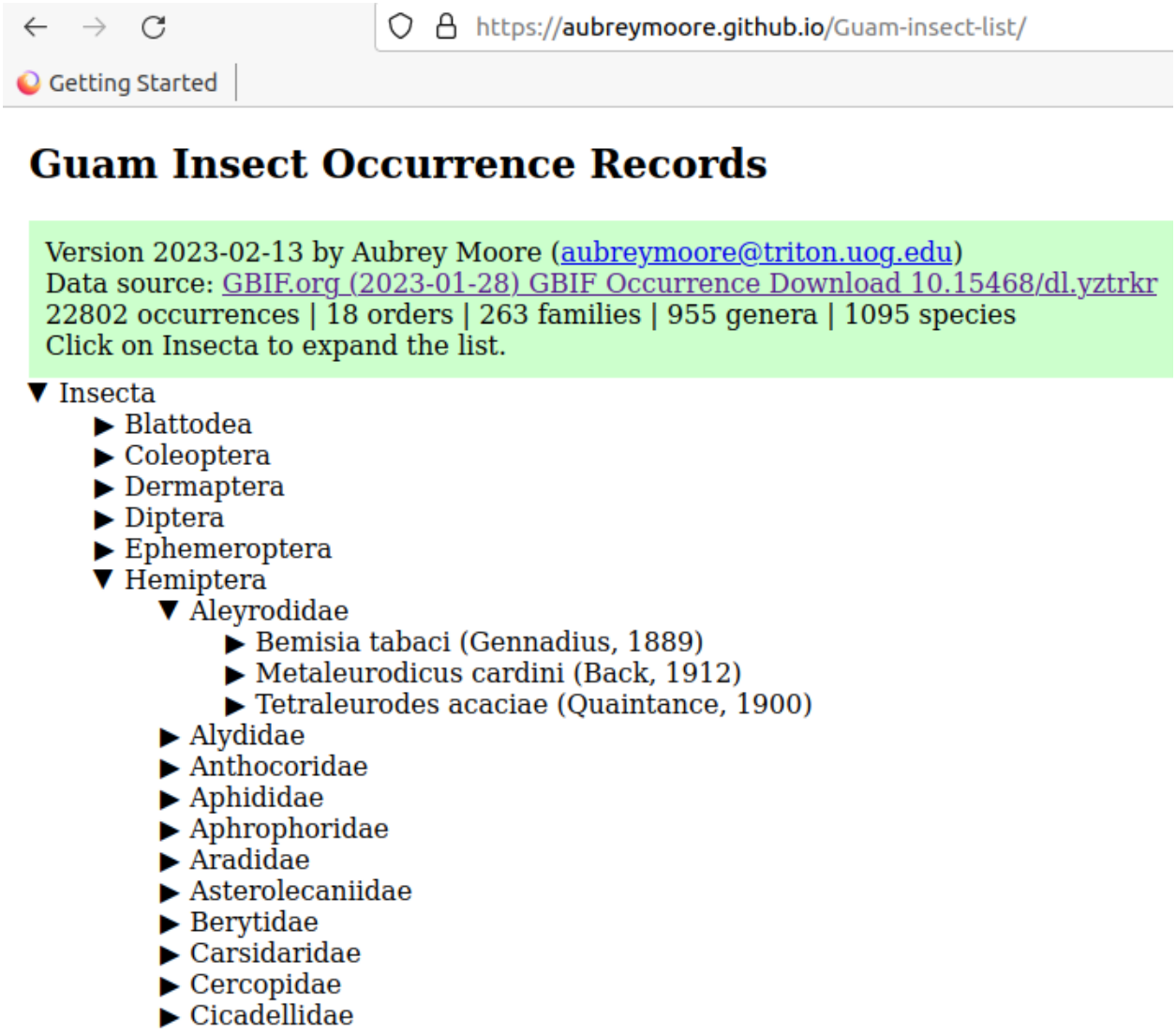

Figure 3: Screenshot of an interactive list of scientific names for insects included in GBIF occurrence records for Guam.

Table 1: GBIF datasets containing Guam insect occurrence records. * indicates datasets which were contain data contributed by McIntire-Stennis project GU0930. These datasets contain 85 percent (19481 of 22802) of Guam occurrence records for insects.

	ms	dataset	Guam records
1	*	University of Guam Insect Collection	15300
2		Stuart M. Fullerton Collection of Arthropods (UCFC), University of Central Florida	1466
3	*	iNaturalist Research-grade Observations	923
4		NMNH Extant Specimen Records (USNM, US)	700
5	*	Miscellaneous Families of Guam Coleoptera	491
6	*	Lepidoptera, Geometridae, Arctiidae, Agrotidae, and Pyralidae of Guam	436
7		Natural History Museum (London) Collection Specimens	410
8	*	Hemiptera Heteroptera of Guam	396
9	*	Curculionidae of Guam	246
10	*	Hymenoptera Formicidae of Guam	189
11	*	Notes On Some Guam Chalcidoidea	135
12	*	Notes On Some Fulgoroidea Of Guam	131
13	*	Orthoptera And Related Orders Orthoptera And Related Orders Of Guam	128
14	*	Homoptera, Fulgoroidea and Jassoidea of Guam	119
15		International Barcode of Life project (iBOL)	109
16		INSDC Sequences	107
17	*	Lepidoptera, Butterflies of Guam	105
18		Australian National Insect Collection	102
19		CAS Entomology (ENT)	90
20	*	Coccidae of Guam	77
21	*	Wasps of Guam	72
22	*	Ichneumonidae, Evaniidae, And Braconidae Of Guam	71
23	*	ODONATA, DRAGONFLIES OF GUAM	70
24	*	SOME MISCELLANEOUS DIPTERA OF GUAM	66
25	*	New Longicorn Beetles From Guam (Cerambycidae)	60
26	*	Neuropteroid Insects from Guam	58
27		AntWeb	49
28		Wichita State University Collection	48
29	*	Coleoptera Heteromera From Guam	46
30		Essig Museum of Entomology	42
31	*	Psyllidae from Guam	38

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Table 1: GBIF datasets containing Guam insect occurrence records. * indicates datasets which contain data contributed by McIntire-Stennis project GUA0930. These datasets contain 85 percent (19481 of 22802) of Guam occurrence records for insects.

	ms	dataset	Guam records
32	*	Anthribidae Of Guam	34
33	*	Thysanoptera: Thrips of Guam	31
34	*	Bees of Guam	31
35	*	Trypetidae, Otitidae, Helomyzidae, And Clusiidae of Guam (Diptera)	28
36	*	Barkbeetles of Guam	28
37		Museum of Comparative Zoology, Harvard University	26
38	*	Hymenoptera, New Species Of Guam Chalcidoidea	22
39	*	Diptera, Tipulidae of Guam	20
40		C.A. Triplehorn Insect Collection (OSUC), Ohio State University	20
41	*	Homoptera, Cercopidae of Guam	19
42		San Diego Natural History Museum Entomology Department	18
43	*	Elaterid And Eucnemid Beetles Of Guam	17
44	*	Some New Species Of Nemocerous Diptera From Guam	17
45		Gunma Museum of Natural History, Insect Specimen	17
46	*	Membracidae of Guam	15
47	*	Coleoptera, Staphylinidae Of Guam	14
48	*	Sphingidae Of Guam	11
49		Mississippi Entomological Museum	10
50	*	Culicidae of Guam	10
51	*	Rhipiceridae Of Guam	9
52		University of Hawaii Insect Museum	8
53		University of Alberta E. H. Strickland Entomological Museum (UASM)	8
54		Field Museum of Natural History (Zoology) Insect, Arachnid and Myriapod Collection	8
55		Entomological Collections (NHRS), Swedish Museum of Natural History (NRM)	8
56		UTEP Insects (Arctos)	7
57	*	Isoptera of Guam	6
58		Texas A&M University Insect Collection	6
59		Revision Of Brachystethus (Heteroptera, Pentatomidae, Edessinae)	6
60	*	Ciidae of Guam	5
61	*	Aphididae and Aleurodidae Of Guam	5
62		Australian Museum provider for OZCAM	5
63		Queensland Museum provider for OZCAM	4

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Table 1: GBIF datasets containing Guam insect occurrence records. * indicates datasets which contain data contributed by McIntire-Stennis project GUA0930. These datasets contain 85 percent (19481 of 22802) of Guam occurrence records for insects.

	ms	dataset	Guam records
64		C.P. Gillette Museum of Arthropod Diversity	4
65		Entomology Division, Yale Peabody Museum	4
66		LACM Entomology Collection	4
67		Revision of the black fungus gnat species (Diptera: Sciaridae) described by W. A. Steffan from Micronesia	4
68		Synonymy of Reikosiella Yoshimoto under Merostenus Walker (Hymenoptera: Chalcidoidea: Eupelmidae), with a checklist of world species and a revision of those species with brachypterous females	3
69		Swiss Psyllid (Hemiptera) Collections - Geneva	3
70		New ants (Hymenoptera: Formicidae) from Micronesia.	2
71		Dryinidae of the Oriental region (Hymenoptera: Chrysidoidea)	2
72		Naturalis Biodiversity Center (NL) - Diptera	2
73		Lyman Entomological Museum (LEMQ)	2
74	*	Strepsiptera of Guam	2
75		Comparative morphology of the endophallic structures of the genus Laius (Coleoptera, Melyridae), with the descriptions of three new species	1
76		Global compendium of Aedes albopictus occurrence	1
77		Cleveland Museum of Natural History	1
78		A taxonomic revision of the Cardiocondyla nuda group (Hymenoptera: Formicidae)	1
79		Bee Biology and Systematics Laboratory	1
80		Lund University Biological Museum - Insect collections Inventory	1
81		North Carolina State University Insect Collection	1
82		Guadeloupe_Insectes	1
83		On the origin of Anagyrus callidus (Hymenoptera: Encyrtidae), a parasitoid of pink hibiscus mealybug Maconellicoccus hirsutus (Hemiptera: Pseudococcidae)	1
84		Invertebrata varia (Luomus)	1
85		Coleoptera World (Luomus) (EC)	1
86		Entomological Specimens of Museum of Nature and Human Activities, Hyogo Pref., Japan	1
87		First record of Eggplant Mealybug, Coccidohystrix insolita (Hemiptera: Pseudococcidae), on Guam: Potentially a major pest	1

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Table 1: GBIF datasets containing Guam insect occurrence records. * indicates datasets which contain data contributed by McIntire-Stennis project GUA0930. These datasets contain 85 percent (19481 of 22802) of Guam occurrence records for insects.

ms	dataset	Guam records
88	hymenoptera	1
89	New Zealand Arthropod Collection (NZAC)	1
90	NMNH Material Samples (USNM)	1
91	New ants (Hymenoptera: Formicidae) from Micronesia	1