CanFlyet: Habitat Zone and Diet Trait Dataset for Diptera Species of Canada and Greenland

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Abstract

Background

True flies (Diptera) are an ecologically important group that play a role in agriculture, public health and ecosystem functioning. As researchers continue to investigate this order, it is beneficial to link the growing occurrence data to biological traits. However, large-scale ecological trait data are not readily available for fly species. While some databases and datasets include fly data, many ecologically relevant traits for taxa of interest are not included. In this study we create a dataset containing ecological traits (habitat and diet) for fly species of Canada and Greenland having occurrence records on the Barcode of Life Data Systems (BOLD). We present a dataset containing trait information for 983 Diptera species.

New Information

Diptera were chosen for the dataset based on the occurrence records available for Diptera species from Canada and Greenland on the Barcode of Life Data Systems (BOLD). Trait data were then compiled based on literature searches conducted from April 2021 - January 2023 and assigned at the lowest taxonomic level possible. Three biological traits were included: habitat, larval diet, and adult diet. The dataset contains traits for 983 species across 380 genera, 25 subfamilies, and 61 families. This dataset allows for assignment of traits to occurrence data for Diptera species and can be used for further research into the ecology, evolution, and conservation of this order.

Keywords

Diptera, Canada, Greenland, dataset, habitat, diet, ecological traits

Introduction

True flies (Diptera) are a diverse, widespread taxonomic group, occurring across a wide range of ecological niches and geographic regions (Adler & Courtney, 2019, Marshall, 2012). This important group occupies various ecological roles, many of which have an impact on the environment and agricultural practices. Fly species can act as pests to crops, such as *Liriomyza bryoniae* on cabbages, lettuce, and tomatoes (Bragard et al., 2020); *Delia radicum* on broccoli and cauliflower (Mesmin et al., 2019); *Dasineura mali* on apples (Wearing et al., 2013); and *Bradysia ocellaris* and *Lycoriella ingenua* on mushrooms (Shamshad 2010). Diptera also includes pests of livestock such as the blood-feeding *Stomoxys calcitrans* (Olafson et al., 2021). Flies are also a group of interest with regard to public health, as some, like *Calliphora vomitoria*, are vectors of pathogenic microorganisms (Bedini et al., 2017). Despite these detrimental examples, flies also provide many important ecological benefits. Flies are an important pollinator group, especially in Arctic and Northern environments (Tiusanen et al., 2016). The

family Muscidae includes species that are pollinators of key plant species in this region and play an important role in the ecosystem (Tiusanen et al., 2016). Flies also fill various other ecological roles, such as parasitoids of other insects that act as vectors for pathogenic bacteria (Molinatto et al., 2020). Many species act as ecosystem engineers; changing environments through suspension-feeding, grazing, burrowing, and predation, as well as serving as an important food source for other organisms (Adler & Courtney, 2019). The saprophagous diet of many flies is also important for the breakdown of decaying organic material (Adler & Courtney, 2019). As biocontrol agents and bioindicators of water quality, flies act as a valuable resource for food production and research (Adler & Courtney, 2019).

This ecologically important group has been the focus of large DNA barcoding efforts, such as the Global Malaise Trap Program, which seeks to document Diptera diversity (which is likely under described) and open doors for ecological research and monitoring (deWaard et al., 2018, Geiger et al., 2016, Global Malaise Program, n.d.). DNA barcoding involves using a standardized gene region to identify and delineate species (Hebert et al., 2003), and there is a large amount of DNA barcoding data available on databases such as the Barcode of Life Data System (BOLD; Ratnasingham and Hebert, 2007), which contained 3 235 922 Diptera records representing 30 259 species as of Jan 18th, 2023. There is also a large amount of species occurrence data on databases such as the Global Biodiversity Information Facility (GBIF; GBIF.org, 2023), which contained 16 372 311 occurrences as of Feb 13th, 2023. As Diptera research continues, it is valuable to link such occurrence records with biological data.

However, finding biological trait data for fly species can be a challenge. There are various databases or datasets currently available for Diptera and other insect groups, covering a varying number of traits and taxa (Table 1). There are few databases that focus solely on Diptera, and while flies are included in some databases, not all species and traits of interest are included. A larger focus also appears to be on morphological traits, such as body size, with information on ecological traits, such as habitat and diet, being less readily available. Finally, few databases focus on Diptera from Canada or Greenland. Overall, traits for many Diptera species are very difficult to find and, when known, are typically present in taxon-specific studies rather than compiled datasets. The goal of this study was to create a dataset containing ecological traits (habitat and diet) for selected Diptera species found in Canada and Greenland. Species were selected that have multiple occurrence records and high-quality DNA barcode sequences on BOLD (following criteria outlined in Majoros et al. (2023)), which likely includes many of the most common species in the study region. This dataset can be used in future research to further our knowledge and understanding of this important taxonomic group.

General Description

This study provides a dataset containing the habitat and adult and larval diet for Diptera species of Canada and Greenland having occurrence records on BOLD. The traits were assigned to taxa using the currently available literature. This dataset will aid in further research that involves the ecological traits of Diptera species.

Project Description

Title: CanFlyet: Habitat Zone and Diet Trait Dataset for Diptera Species of Canada and Greenland

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Design Description: The dataset provides habitat, larval diet, and adult diet for Diptera species found in Canada and Greenland. Traits were determined based on a literature search.

Funding: Funding support for this project comes from the Natural Sciences and Engineering Research Council of Canada; the Government of Canada through Genome Canada and Ontario Genomics; the Ontario Ministry of Economic Development, Job Creation and Trade; and Food from Thought: Agricultural Systems for a Healthy Planet Initiative program funded by the Government of Canada through the Canada First Research Excellence Fund.

Sampling Methods

Description: The fly species were chosen for inclusion in this dataset by first downloading data for Diptera from Canada and Greenland from BOLD directly into R using BOLD's application programming interface (API) on June 24th, 2021. The records were filtered based on the requirements outlined in Majoros et al. (2023), and the remaining species were chosen for analysis and inclusion in this dataset. In Majoros et al. (2023), species were represented by Barcode Index Numbers (BINS), which are operational taxonomic units (OTUs) used by BOLD that are clusters of barcode sequences similar to species (Ratnasingham & Hebert, 2013). For other portions of the analysis, records were clustered by a 4% clustering threshold, and this was used in the place of BINs. Records needed to possess high quality DNA sequence data to be included in the analysis. BINs and clusters were included in the analysis if they possessed at least 20 records and were found in at least two geographic regions meeting the requirements of Majoros et al. (2023). They also needed to be represented by at least 10 records in each region they were found in. The species represented by these BINs and clusters were chosen and trait data was obtained. Additional species from Greenland were chosen based on occurrence records from GBIF (GBIF.org (June 24th, 2021)) GBIF Occurrence Download (https://doi.org/10.15468/dl.mk52hp) and included in the dataset. The traits were assigned to taxa using a series of literature searches conducted between April 2021 and January 2023.

Sampling Description: The biological traits for each species were determined and assigned through literature searches conducted from April 2021 - January 2023. Through the Omni Academic search tool available through the University of Guelph and Google Scholar, traits were found using the following search terms: trait AND "Taxonomic name", habitat AND "Taxonomic name", diet AND "Taxonomic name", and "Feeding mode" AND "Taxonomic name". The title and DOI of each reference are included in the dataset, and the full references are available in Appendix A. Traits were assigned to the lowest taxonomic level possible; however, not all traits could be assigned at the species level. For these species, traits were assigned using data from the next lowest level available, whether genus, subfamily or family. For example, if the authors of a given study mentioned that a particular genus has a specific trait, then species belonging to that genus were assigned that trait. The taxonomic level of the trait data is included in the dataset.

For habitat, species were classified as terrestrial (defined as taxa that live primarily in land habitats), aquatic (defined as taxa that live primarily in water bodies or associated habitats), or semi-aquatic (defined as species that require both aquatic and terrestrial habitats). These assignments were

made based on the larval habitat requirements. For adult and larval diet, species could be classified as predaceous (defined as taxa who prey on insects or other animals), phytophagous (defined as taxa who feed on plant material), fungivores (defined as those who feed on fungi), saprophagous (defined as those who feed on decaying organic matter), omnivores (defined as those who consume material of both plant and animal origin), parasites (defined as those who live and feed in or on an organism of another species), parasitoid (defined as organism whose young develop within a host, eventually resulting in host death), or nectivore (defined as taxa that primarily feed on nectar). Taxa can also be assigned a combination of the diet categories.

Geographic Coverage

Description: This dataset includes Diptera species found in Canada and Greenland that also have multiple occurrence records and DNA barcode sequences publicly available on BOLD.

Taxonomic Coverage

Description: The dataset contains traits for 983 species across 380 genera, and 61 families. Traits are also provided for 25 subfamilies. The families are represented by varying numbers of species within the dataset (Fig. 1). For several families, the dataset only contains information for one species. The most species-rich family in this dataset is Chironomidae, which is represented by 182 species.

Trait Coverage

Description: The dataset contains information for three biological traits: habitat, adult diet, and larval diet. For habitat, 656 species were terrestrial, 235 were aquatic, and 92 were semi-aquatic (Fig 2a). For adult diet, 101 were saprophagous, 42 were phytophagous, 247 were nectivores, 138 were predaceous, 4 were fungivores, 1 was an omnivore, 36 were both nectivores and predaceous, 1 was both phytophagous and a fungivore, 4 were both fungivores and nectivores, 24 were both nectivores and saprophagous, and 385 were non-feeding (Fig. 2b). For larval diet, 296 were saprophagous, 164 were phytophagous, 209 were predaceous, 62 were fungivores, 2 were parasitic, 21 were omnivores, 36 were parasitoids, 30 were both phytophagous and fungivores, and 163 were both phytophagous and saprophagous (Fig. 2c).

Temporal Coverage

Notes: The literature searches were conducted from April 2021 to January 2023. The papers referenced were published from 1955 – 2022.

Usage licence

Usage licence: Creative Commons Public Domain Wavier (CC-Zero)

Data Resources

Data package title: CanFlyet: Habitat Zone and Diet Trait Dataset for Diptera Species of Canada and Greenland

Number of data sets: 1

Data set name: CanFlyet: Habitat Zone and Diet Trait Dataset for Diptera Species of Canada and Greenland

Data format: csv, xlsx, tsv

Data format version: xlsx is version 2302. Csv and tsv are UTF-8.

Description: The dataset presents habitat, adult diet, and larval diet for 983 species across 380 genera, 25 subfamilies, and 61 families. A table showing the column labels and descriptions is provided in Table 2. The Diptera species included are from Canada and Greenland and have multiple occurrence records and DNA sequence data on BOLD. The traits were assigned to taxa using a series of literature searches conducted between April 2021 and January 2023. This dataset can be used by researchers to determine biological traits for Diptera species and conduct research that involves ecological trait data.

Additional Information

For this study, we created a dataset containing habitat and adult and larval diet for 983 Diptera species across 61 families found in Canada and Greenland. This dataset allows for assignment of traits to a large variety of species. This is a valuable resource for bioinformatics work, as well as for ecological studies. This dataset was originally used to determine the relationship between biological traits and population genetic structure (Majoros et al., 2023) and can be applied to a wide range of other studies and research. These traits can also be linked to other types of data, such as species occurrence or community composition data.

The species included in this dataset possessed a wide variety of different habitat and dietary requirements. Most species were terrestrial, non-feeding at the adult life stage or saprophagous at the larval stage. Other diets were far less represented, such as those with a parasitic larval stage and those with a fungivore adult diet.

Trait data has been used to investigate various ecological and evolutionary patterns and topics, such as community assembly (Kraft & Ackerly, 2010, Zhang et al., 2020), molecular evolution (May et al., 2020), phylogenetic assemblage structure (Barnagaud et al., 2014), and how populations change over time or in response to ecological change (Coulthard et al., 2019, De Palma et al., 2015). Similarly, this dataset can be used to answer a variety of questions and is a useful tool for future research. It can be used for various studies that relate to ecology, evolution, biogeography, and conservation of fly species and include the habitat and diet of flies. The dataset can be used to investigate the relationship between traits and population genetic structure or phylogenetic community structure. The dataset could also be used to find relationships between traits, such as in studies like Freire et al. (2021). A visualization is provided in Figure 3 of the phylogenetic relationships between species possessing different traits. This could be built upon to look at the relationship between traits and evolutionary history and to investigate

the phylogenetic relationships, such as in studies like Rainford & Mayhew (2015). The trait dataset can also be used to investigate the diversity of different fly traits in an area of interest, to determine how these traits impact occurrence patterns, how traits may relate to responses to environmental change, or to determine which species may be most likely to colonize these areas in the future. Trait data could also prove useful for biomonitoring of insect diversity in agricultural areas, such as research into which farming practices are associated with a balance of ecological functions in associated insect communities.

In this paper we presented a trait dataset containing habitat and diet information for a large number of Diptera taxa from Canada and Greenland that also have occurrence records and DNA barcoding sequences available on BOLD. This dataset will be made publicly available on Data Dryad but is currently available at https://github.com/S-Majoros/Diptera_Dataset_Phylogenetic_Tree. The file is available in csv, xlsx, and tsv format in order to make it as accessible as possible for future users. This dataset is publicly available so that other researchers can use it to conduct further studies, answer more questions, and improve our knowledge of this ecologically important group.

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

Author Contributions

Samantha E. Majoros – project design, dataset construction, manuscript writing and editing.

Sarah J. Adamowicz – project design, manuscript editing.

Figures & Tables

Table 1: Overview of some of the databases and datasets that include insects currently publicly available. Number of records are as of Feb 2nd, 2023.

Database Name	Taxonomic Focus	Geographic Focus	Types of Traits	Number of Traits	Number of Records	Data Availability	References
DISPERSE[1]	Annelida, Mollusca, Platyhelminthes & Arthropoda	Europe	Dispersal	9	480	Download as xlsx file	Sarremejane et al. (2020)
Freshwater Biological Traits[2]	Freshwater macroinvertebrate taxa	North America	Morphology, life history, mobility, environmental tolerance, resource acquisition/ preference	26	11912	Select taxa, region and traits on website. Download as an xlsx file	United States Environmental Protection Agency (2012)
Animal Traits[3]	Arthropoda, Chordata, Mollusca and Annelida	Global	Body mass, metabolic rate, brain size	3	3580	Download xlsx or csv file	Herberstein et al. (2022)
CONUS[4]	Arthropoda	United States of America	Life history, dispersal, morphology, ecology	11	2.05 million	Download csv file	Twardochleb et al. (2021)
Lotic Invertebrate Traits for	Invertebrates	North America	Ecology, morphology, behaviour, physiology	62	14127	Download as a txt file	Vieira et al. (2006)

[1]https://figshare.com/articles/dataset/DISPERSE_a_trait_database_to_assess_the_dispersal_potential_of_European_aquatic_macroinvertebrates/12417251/1
[2] https://cfpub.epa.gov/ncea/global/traits/search.cfm
[3] https://animaltraits.org/
[4] https://portal.edirepository.org/nis/mapbrowse?packageid=edi.481.5

Database Name	Taxonomic Focus	Geographic Focus	Types of Traits	Number of Traits	Number of Records	Data Availability	References
North America[5]							
European & Maghreb Butterfly Trait Database[6]	Lepidoptera	Europe and North Africa	Life history, morphology, resource-based, behaviour	25	542	Download as xlsx file	Middleton-Welling et al. (2020)
GlobalAnts[7]	Formicidae	Global	Morphology, ecology, life history	23	82910	Need to make an account to access. Can search for desired traits and download as a csv file	Parr et al. (2016)
The Odonate Phenotypic Database[8]	Odonata	Global	Morphology, life history, behaviour	35	3978	Download as a xlsx file	Waller et al. (2019)
Morphological trait database of saproxylic beetles[9]	Saproxylic Coleoptera	Europe	Morphology	13	1376	Download as a csv file	Hagge et al. (2021)
Data from: Sensitivity of functional diversity metrics to	Carabidae	The Netherlands	Morphology	7	73	Download as txt file	van der Plas et al. (2017)

[5] https://pubs.er.usgs.gov/publication/ds187
[6] https://butterflytraits.github.io/European-Butterfly-Traits/index.html
[7] http://globalants.org/
[8] http://www.odonatephenotypicdatabase.org/shiny/odonates/?_inputs_&choose_species=%22%22
[9] https://datadryad.org/stash/dataset/doi:10.5061/dryad.2fqz612p3

Database Name	Taxonomic Focus	Geographic Focus	Types of Traits	Number of Traits	Number of Records	Data Availability	References
sampling intensity[10]							
Data from: A summary of eight traits of Coleoptera, Hemiptera, Orthoptera and Araneae, occurring in Grasslands in Germany[11]	Arthropoda	Germany	Morphology, ecology	8	1230	Download as txt file	Gossner et al. (2015)

[10] https://datadryad.org/stash/dataset/doi:10.5061/dryad.1fn46
[11] https://datadryad.org/stash/dataset/doi:10.5061/dryad.53ds2

Table 2: The column labels and descriptions included within the dataset.

Column Label	Description
order	The order level taxonomic classification
family	The family level taxonomic classification
subfamily	The subfamily level taxonomic classification
genus	The genus level taxonomic classification
specificEpithet	The species level taxonomic classification
scientificName	The scientific name of the species
habitat	The habitat in which the taxon is found. Taxa can be assigned terrestrial (taxa that live primarily in land habitats), aquatic (taxa that live primarily in water bodies or associated habitats) or semi-aquatic (species that require both aquatic and terrestrial habitats).
traitName	The name of the biological trait. The traits included are adultDiet and larvalDiet.
traitValue	The trait category assigned to the species. Taxa can be assigned predaceous (taxa who prey on insects or other animals), phytophagous (taxa who feed on plant material), fungivores (those who feed on fungi), saprophagous (those who feed on decaying organic matter), omnivores (those who consume material of both plant and animal origin), nectivore (taxa that primarily feed on nectar), parasites (those who live and feed in or on an organism of another species) or parasitoid (organism whose young develop within a host, eventually resulting in host death). The taxa can also be assigned a combination of these categories. In this case, the categories are separated by "_and_". For example, "nectivore_and_predaceous".
traitAssignmentLevel	The taxonomic level mentioned in the publication from which the traits were obtained and assigned.
basisOfRecord	Where the trait data was obtained from.
referenceNumber	The number of sources referenced when obtaining the trait information for each taxon.
referenceTitle	The title of the reference used for the trait assignment. Full references are included in the manuscript. The number after referenceTitle refers to the number of each reference. For example, if there was a 3 in the referenceNumber column, and this was the 3rd reference, the column would be called referenceTitle3.
referenceDOI	The DOI of the reference used for the trait assignment. Full references are included in the manuscript. The number after referenceDOI refers to the number of each reference. For example, if

Column Label	Description
	there was a 3 in the referenceNumber column, and this was the 3rd reference, the column would be called referenceDOI3

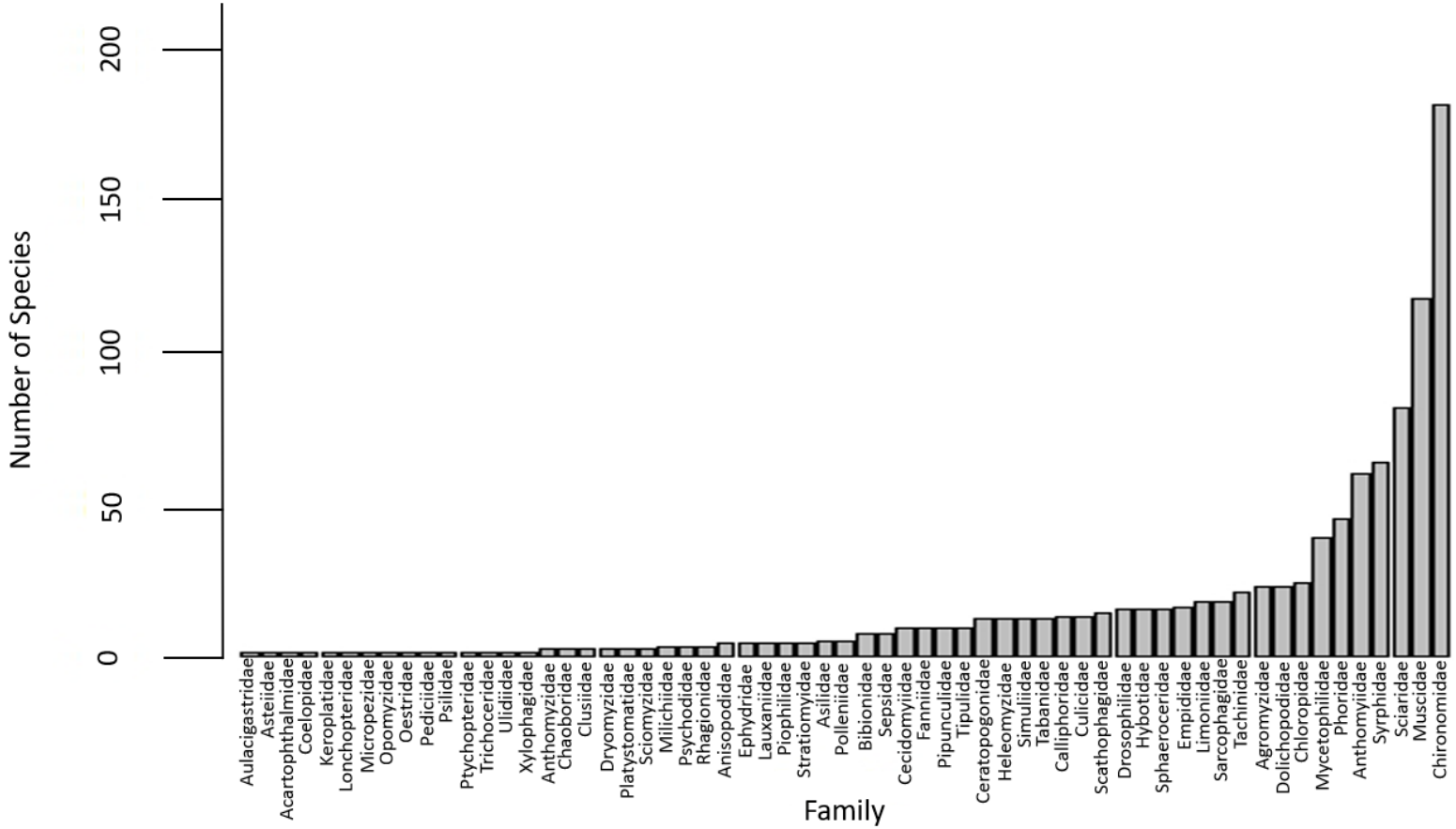

Figure 1: The number of Diptera species from Canada and Greenland of each family that is present in the dataset. The selected species included here also have multiple occurrence records and DNA barcode sequences publicly available on BOLD. For several small families, only one species is included. Chironomidae is the largest family within the dataset, with 182 species present.

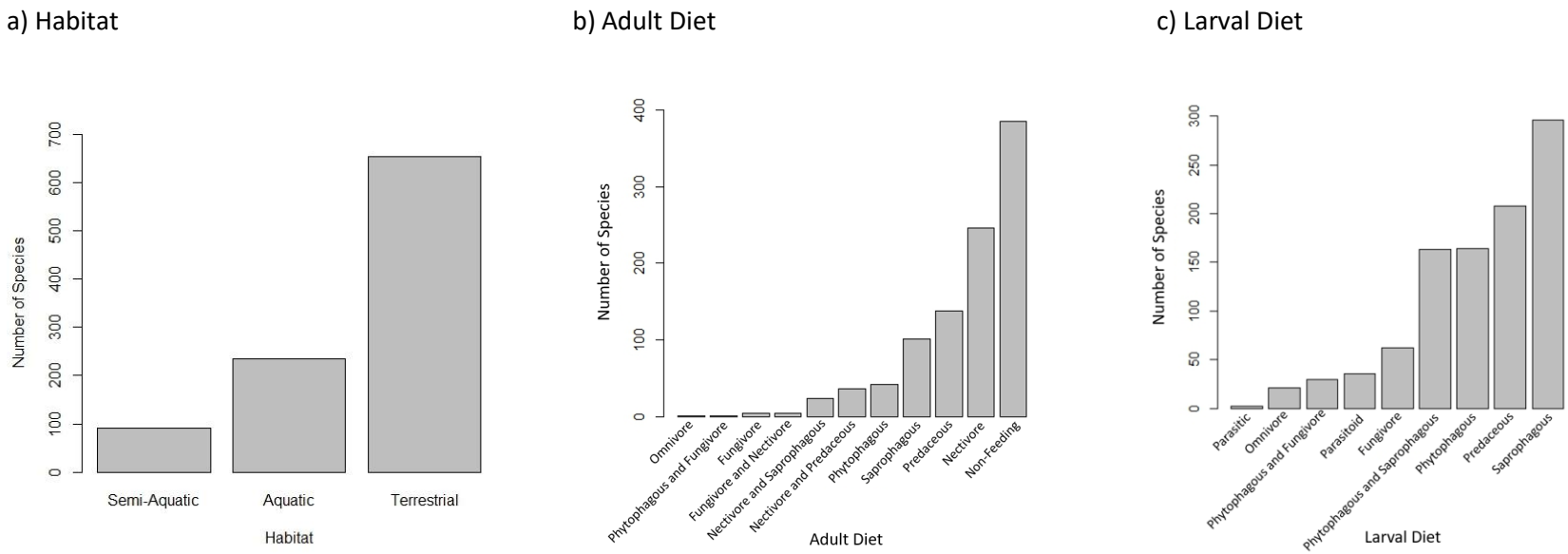

Figure 2: The number of Diptera species from Canada and Greenland in this dataset having each trait category for: a) habitat, b) adult diet, and c) larval diet. The majority of species included in the dataset are terrestrial. Most species are non-feeding at the adult life stage, and few are omnivores or phytophagous and fungivores as adults. The majority of species included in the dataset are saprophagous as larva, and few are parasitic.

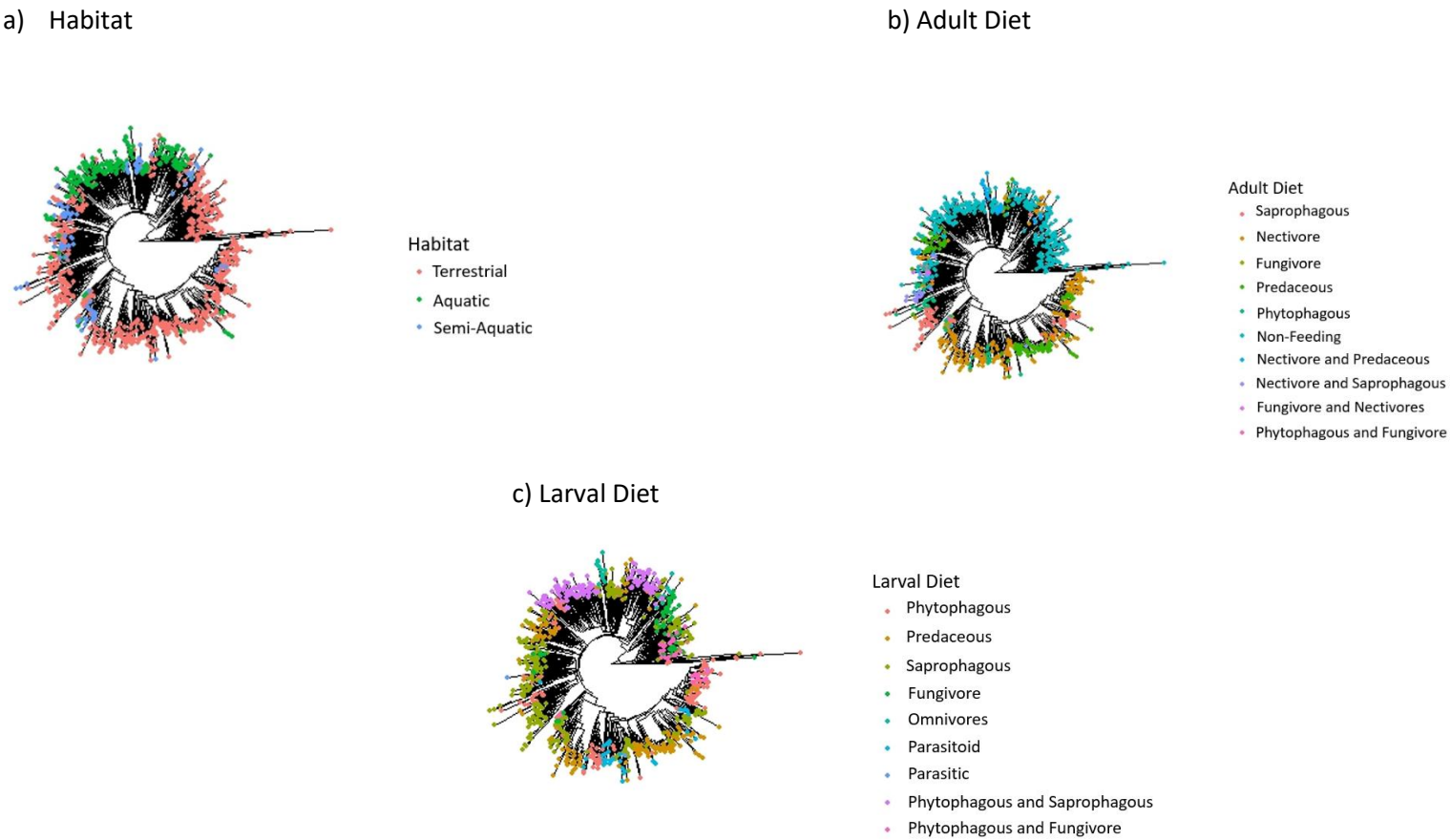

Figure 3: Phylogenetic trees of Diptera species from Canada and Greenland included in this dataset; these species also have multiple occurrence records and DNA barcode sequences publicly available on BOLD. The different colours of the tips represent species with different: a) habitat categories, b) adult diet categories, and c) larval diet categories. The traits provided in the dataset could be used to investigate the relationship between traits and evolutionary history. These maximum likelihood trees were created using cytochrome c oxidase subunit 1 (CO1) sequences from BOLD and functions from the package phangorn version 2.11.1(Schliep, 2011) in the R programming language (R Core Team, 2023). The tips were coloured using the package ggtree version 3.6.2 (Yu et al., 2017). The code for how to create this tree is provided at https://github.com/S-Majoros/Diptera_Dataset_Phylogenetic_Tree

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APPENDICES

Appendix A: References for Diptera habitat and diet traits

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