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## CHAPTER ONE

# NEARCTIC DIPTERA: TWENTY YEARS LATER

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## INTRODUCTION

Flies are found abundantly almost everywhere; they are only rare in oceanic and extreme arctic and antarctic areas. More than 150,000 extant species are now documented (Evenhuis *et al.* 2008). So, given this great diversity, understanding is aided by dividing the whole into pieces. Sclater (1858) proposed a series of regions for the better understanding of biotic diversity. Those areas were based on common shared distribution of bird species and now are understood to reflect the evolution and dispersal/vicariance of species since the mid-Mesozoic era. While the biotic regions defined by Sclater (1858) have been accepted by most zoologists, the precise definition used here follows the standards of the *BioSystematic Database of World Diptera* [BDWD] (Thompson 1999a). Biotic regions are statistical concepts that try to maximize the common (unique to one area only) elements and minimize the shared elements (Darlington 1957, Thompson 1972). For pragmatic reasons, the BDWD has taken the traditional definitions of the biotic regions and normalized them so that they follow political boundaries, which make the assignment of data easier (Thompson 1999a). Earlier authors (Osten Sacken 1858, 1878; Aldrich 1905) divided the New World into a northern and southern component. So their catalogs covered all the species of North America, that is, the Americas north of Colombia. Unfortunately, most subsequent authors decided to re-define both North America and the Nearctic Region as the area north of Mexico (most recently, Poole 1996 & Adler *et al.* 2004). Griffiths (1980) for his *Flies of the Nearctic Region* has adopted the classic definition of



Map 1.1. Nearctic Region  
(as illustrated by Wallace 1876).

Wallace (1876). So, users must always be aware of the definition of the words, Nearctic and North America.

The Nearctic Region was defined as essentially the non-tropical areas of North America (Wallace 1876, Map 1.1), a definition now modified slightly to follow the political boundaries of various Mexican states (Map 1.2). While Wallace divided the Nearctic into four subregions and subsequent workers more finely divided these subdivisions, current workers (Heywood 1995, Groombridge 1992) have abandoned this effort and view subdivision of the biogeographic regions as a series of ecological divisions or biomes. The Nearctic has six biomes: Arctic tundra, northern coniferous forest, temperate forest, temperate grassland, Mediterranean vegetation/chaparral and desert (Map 1.3).



Map 1.2. Biomes of the Nearctic Region  
(from Cox & Moore 2005).



Map 1.3. Mexico and boundary of Nearctic Region  
(from Thompson 1999a).

The Nearctic insect fauna was reviewed in the late 1980s (Kosztarab & Schaefer 1990; Diptera by Thompson 1990; also see Ross 1953). Then some 19,500 species of flies were described out of an estimated total of 30,000 species, but less than one per cent of them had been treated comprehensively in monographs and less than a quarter had been thoroughly revised. In the past twenty years, little has changed except that there are fewer workers today (some 250 authors published new species in the last twenty years versus 330 in the preceding 20 years, a 25% decrease). Only some 1,350 new species have been added (some 3,000 added from 1968–1987), and few new monographic works and revisions have been published. All this suggests that the prospects for comprehensive biodiversity inventories of little known groups, such as flies, are abysmal. Promises of new technologies to increase the rate of progress remain only that, as the necessary support for the people to use them is not available. Also, there is a reluctance of workers to abandon the ancient techniques they have used for centuries.

The data for this report are derived from the *BioSystematic Database of World Diptera* that we are building in Washington (Evenhuis *et al.* 2008).

This database has been built from the earlier regional Diptera catalogs, augmented from the *Zoological Record*, and checked against World-family-level catalogs as they have appeared. Full documentation on the status and sources of the BDWD can be found online (Evenhuis *et al.* 2008). Currently we have nomenclatural and distributional data on all the flies of the world. Also, a data file is maintained on people who work on Diptera. While preparing this summary, we queried several specialists about various questions. However, this report is largely an update of the previous one (Thompson 1990). As a historical footnote, mention needs to be made here of an important but formally unpublished dataset on Nearctic flies. During the late 1980s an effort was started to develop a revised catalog of Nearctic Diptera to up-date the classification and taxonomy in the then current Diptera catalog (Stone *et al.* 1965). This effort was lead by myself and was computerized. All the specialists on Nearctic Diptera contributed and the dataset was completed. Unfortunately, no support was found to publish a revised catalog. The dataset (except Tachinidae), however, was available and used subsequently by some. The dataset was the basis of the figures in my 1990 review. They were made available to the National Oceanographic Data Center (NODC) and appeared in their Taxonomic Code (Hardy 1993). From there, these data records were passed onto the Integrated Taxonomic Information System (ITIS) and eventually to the Species2000 and Global Biodiversity Information Facility (GBIF). Many online sources have copied these data. While this dataset was of the highest quality, there were errors in it. One error, originally made by a data entry clerk in 1987, for example, was discovered recently, and was found to have been duplicated on about a dozen different Internet sites (Animal-Diversity web, ZipCodeZoo, Wikipedia, etc.)!

## 1. Past

Our knowledge of the taxonomy of Nearctic Diptera began with Linnaeus in 1758, the designated starting date for zoological nomenclature. What needs to be stressed here is not how little Linnaeus knew of Nearctic Diptera, but that we began with a comprehensive summation of all that was known then. *Systema Naturae* (Linnaeus 1758) includes keys and diagnoses, current and correct nomenclature, and synopses of the literature and biology for all taxa. *Systema Naturae* was the last fully comprehensive work published. Works since that time have become ever more restricted

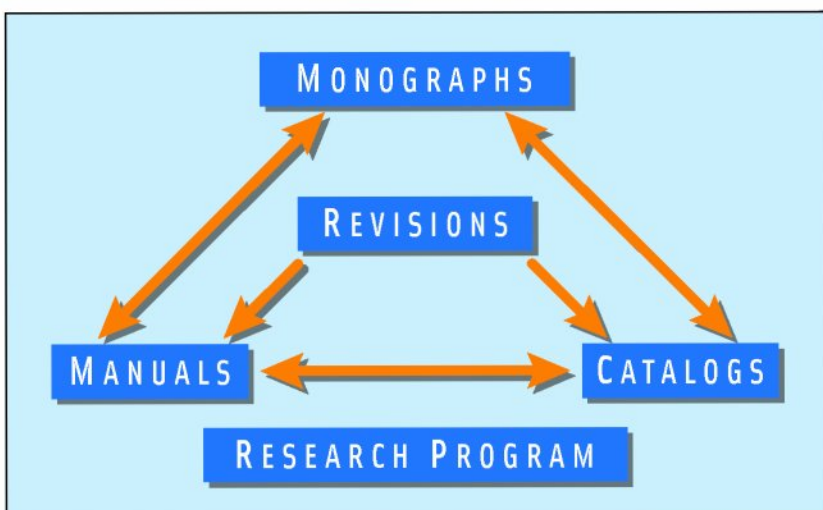


Figure 1.1. Research Program for North American Dipterology, see text for discussion.

either taxonomically or geographically or both. After Linnaeus, Fabricius continued to try to produce comprehensive works on Insecta (*sensu lato*) (Fabricius 1775). The task, however, became more difficult as others began to adopt the Linnaean method, and more geographic areas were discovered and explored. Fabricius spent his life traveling widely in Europe to maintain contact with all insect systematists and to synthesize their work with his own. Near the end of his life, Fabricius did complete *Systema Antliatorum* (Fabricius 1805), his statement of what was then known about flies. Unfortunately, whereas Linnaeus' work was comprehensive by definition, such status cannot be ascribed to the Fabrician *Systema*, which did not include all the discoveries made about flies since 1758.

After Fabricius, systematists specialized more, working either on a single order or particular region. For North America, some Europeans (Macquart, Wiedemann, Walker, *et al.*) specialized on 'exotic' flies, that is, those that did not occur in Europe. During this period there was only one American, Thomas Say, who worked on all insects. Thus, by the middle of the 19<sup>th</sup> century our knowledge of Nearctic Diptera was in chaos: no comprehensive works, just descriptions scattered through the literature. Fortunately for us, there was a new development in Washington: the Smithsonian Institution. This new organization saw the need for a biotic survey and began sponsoring inventories of our biota. For Diptera, fortunately,

| Period             | Dates    | Species | Rate  | Years | Total Species | Total Names | names | %valid |
|--------------------|----------|---------|-------|-------|---------------|-------------|-------|--------|
| Linnaean           | to 1775  | 87      | 6,2   | 14    | 87            | 92          | 92    | 94,6%  |
| Fabrician          | to 1805  | 163     | 5,4   | 30    | 250           | 300         | 208   | 78,4%  |
| Wiedemann          | to 1858  | 1778    | 33,5  | 53    | 2028          | 2909        | 2609  | 68,1%  |
| Osten Sacken       | to 1879  | 1697    | 80,8  | 21    | 3725          | 5071        | 2162  | 78,5%  |
| Williston          | to 1908  | 3010    | 100,3 | 30    | 6735          | 9075        | 4004  | 75,2%  |
| Alexander, Curran  | to 1965  | 10370   | 220,6 | 47    | 17105         | 22222       | 13147 | 78,9%  |
| McAlpine, Sabrosky | to 1989  | 3646    | 145,8 | 25    | 20751         | 26170       | 3948  | 92,4%  |
| 'US'               | to today | 1214    | 71,4  | 17    | 21965         | 27405       | 1235  | 98,3%  |

Figure 1.2. History of Nearctic Diptera Fauna. The columns are: **Period**, named after a prominent dipterist characterizing the period; **Dates**, give the inclusive year; **Species**, gives the total species described within the period; **Rate**, is the total species described divided by the number of years within the period for an average rate of description.

there was a leader to take up the task. Carl Robert Romanovich, Baron von der Osten Sacken (Smith 1977), a Russian diplomat, by example and with the support of the Smithsonian, defined and started the current research program for North American Dipterology. First, Osten Sacken (1858) produced a list of the species already described from North America. Next, he organized people to collect flies, arranged to have the accumulated material studied by the best available specialist (Herman Loew), and arranged eventually to have material deposited in a public museum. Finally, he started a series of monographs (Loew 1862, 1864, 1873; Osten Sacken 1869). Osten Sacken concluded his work on the North American Diptera with a comprehensive synoptic catalog (1878). Samuel Wendell Williston, apparently seeing a weakness in the Osten Sacken program, introduced manuals (Williston 1888) that included keys to the families and genera. This improvement facilitated revisionary work, as the size of the taxonomic unit to be studied could then be as small as a genus. With the master research plan set (Fig. 1.1), the next hundred or so years (1888–1988) saw an alternation between descriptions (and revisions), catalogs (Aldrich 1905, Stone *et al.* 1965, 1983; Thompson 1988, Poole 1996, also see Arnett 2000), and manuals (Williston 1896, 1908; Curran 1934, 1965; McAlpine 1981, 1987, 1989), with a few monographs being done (Carpenter & La-Casse 1955; Hardy 1943, 1945; Webb 1984, Hogue 1987). This century saw

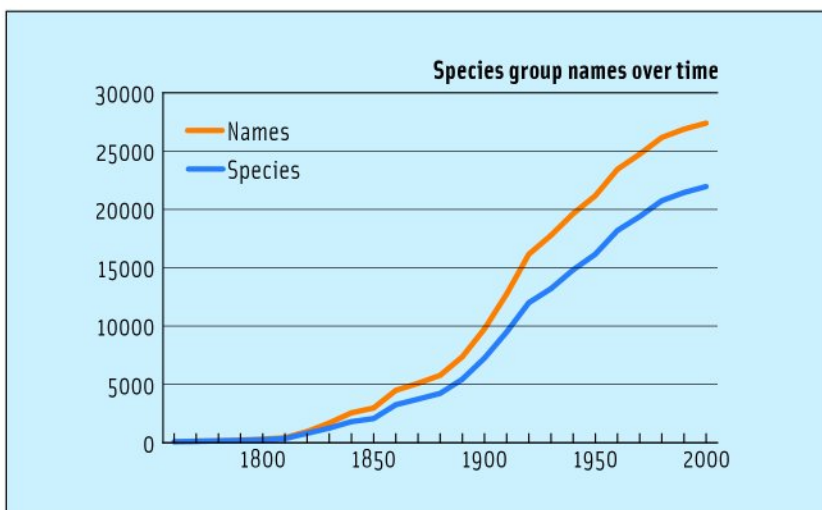


Figure 1.3. Growth of knowledge for Nearctic Diptera, based on increase of species and species-group names over time.

the introduction of regional monographic series (such as *Insects of Connecticut*, *Ohio*, *Illinois*, *California*, *Virginia*, *Florida*, *Canada & Alaska*), but the coverage of Diptera in them has been limited. With the passing of Williston and the 19<sup>th</sup> century, a number of highly productive dipterists (Alexander, Felt, Malloch, Melander, Curran and Van Duzee) arrived to build on the foundation of Williston's last manual and Aldrich's catalog. In a short 40 years or so, more flies were described than in the first 150 years and at a rate never since exceeded (Fig. 1.3). The late 20<sup>th</sup> Century (1960s onward) saw a resurgence starting with a new catalog (Stone *et al.* 1965, 1983) followed by a new manual (McAlpine 1981, 1987, 1989) and then the start of a monographic series, the *Flies of the Nearctic Region* (Griffiths [1980] and others). Unfortunately, the century ended in a decline that continues due to the loss of support and resources. Also, the diminished ranks of specialists on the Nearctic Diptera fauna were distracted by the new and exciting efforts to understand the Neotropics, especially Costa Rica (Brown 2005). In the last 20 years, some 4,500 new species have been described from the Neotropics (almost 700 from Costa Rica alone) compared to only 1,350 for the Nearctic. Also, other exotic survey projects have likewise been distractions (see Evenhuis 2007). So, in summary, the history of Nearctic Dipterology can be viewed as a series of

eight periods (Fig. 1.2); a more detailed history of Nearctic dipterology has been written by Stone (1980) (also see Aldrich 1930, Coquillett 1904).

In my prior treatment of the Nearctic Diptera fauna (Thompson 1990), the history was divided into eight periods with dates rounded off to the nearest decade. For this work, the exact year of major defining events have been used. These events are as follows: the Linnaean period runs until the first publication of Fabricius (1775); the Fabrician period runs until his last Diptera publication (1805); the Wiedemann period runs until the first publication of Osten Sacken on North American flies (Osten Sacken 1858); the Osten Sacken period runs to the first publication of Williston (1879) (Osten Sacken's last major North American work was his catalog [1878]); the Williston period runs until his last publication (1908); the Alexander-Curran period runs until publication of the new Diptera catalog (Stone *et al.* 1965, 1983); the McAlpine period runs from the date of that catalog until the publication of the last volume of the Nearctic Diptera Manual (McAlpine 1989).

Given how our knowledge of Nearctic Diptera has developed, the next questions are: 'what do we know and what do we not know?' In considering these questions, we can divide the answers into the description of the problem (fauna), the resources (literature, collections, and human) available or needed to solve the problems, and the approach to solving the problem (research program).

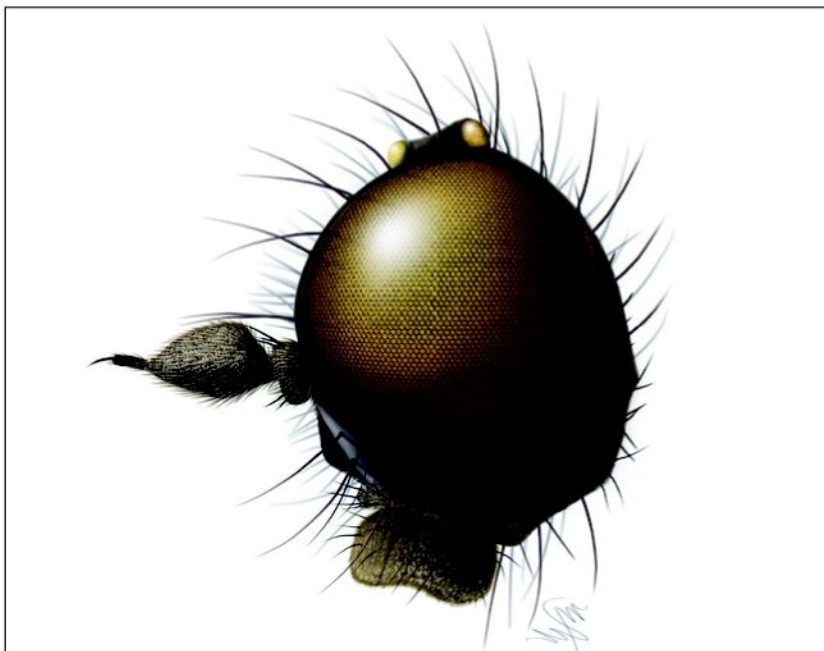
## 2. Fauna

The Nearctic Diptera fauna is largely a transitional one. The northern two-thirds of the Nearctic region have a Diptera fauna that is largely shared with the Palearctic region, and the southern third has many elements shared with the Neotropics. There is only one really distinctive clade endemic to the Nearctic area, the Apystomyiidae (Plate 1.1). This group is restricted to California and is probably the sister-group to all higher Diptera (Nagatomi & Liu 1994; Wiegmann, unpubl.). The Oreoleptidae (Zloty *et al.* 2005) are also endemic and restricted to the Rocky Mountains, although this group is probably nothing more than an athericid that has lost a synapomorphy.

The Nearctic Region essentially consists of three major countries, Canada, Mexico and the United States, which now form an economic unit, The North American Free Trade Alliance (NAFTA). Unfortunately, these



Plate 1.1. *Apystomyia elinguis* Melander. Dorsal habitus (above) and head in profile (below) of adult female.  
(Illustration: Marie Metz.)



countries have taken different approaches to their biodiversity. The Convention on Biological Diversity (CBD 1994) defines a standard for the nations of the World, but the USA has not ratified the convention. Hence, there is little official concern about biodiversity within the USA. Canada and Mexico, on the other hand, have joined the convention. Canada established a 'Biological Survey for Terrestrial Arthropods' even before the formation of the CBD. This effort has produced a number of major works on the origin of the North American fauna (Downes & Kavanaugh 1988), the Canadian insect fauna (Danks 1979, 1993), the Diptera fauna (McAlpine 1979) and the changes in it (Downes 1981), the arctic arthropods (Danks 1981a, b), the Yukon insects (Danks & Downes 1997), and arthropods of special habitats, such as springs (Williams & Danks 1991), peatland (Finnamore & Marshall 1994) and marshes (Rosenberg & Danks 1987). Most recently, the Survey has started a new online *Canadian Journal of Arthropod Identification* (CJAI, see Kits *et al.* 2008, for example). Mexico has also established a biodiversity program, the Comisión Nacional Para el Conocimiento y uso de la Biodiversidad (CONABIO), and a couple of works have resulted from the program that cover some groups of flies (Llorente-Bousquets *et al.* 1996). The countries with minor possessions in the Nearctic, Denmark and the United Kingdom, also have had or have recent programs to assess their Diptera or broader, their arthropod fauna. For Bermuda, Woodley & Hilburn (1994) have produced a modern review; for Greenland, a 'Greenart' project is working on an identification handbook of the insects and arachnids of the island (Böcher & Kristensen in prep.).

### 2.1 Faunal statistics

Where we are today is best summarized by statistics on the fauna (Table 1.1), as well as some statistics on the human, collection, and literature resources. Trend curves plotted for species-group names (Fig. 1.4) show no leveling off; hence, the curves are of little predictive value, merely indicating clearly that the fauna is not fully described (Steyskal 1965, but see also White 1975, 1979, Frank & Curtis 1979, and O'Brien & Wibmer 1979). The percentage of the fauna estimated to be known (49%, Thompson 1990) is probably too low, as Gagné estimates that there are some 14,000 undescribed species of gall midges in the Nearctic Region (1,247 species currently described), an estimate based on the assumption that gall midges are host specific (monophagous) (see Gagné 1983: 9–11, 1989: 2, 34–37).

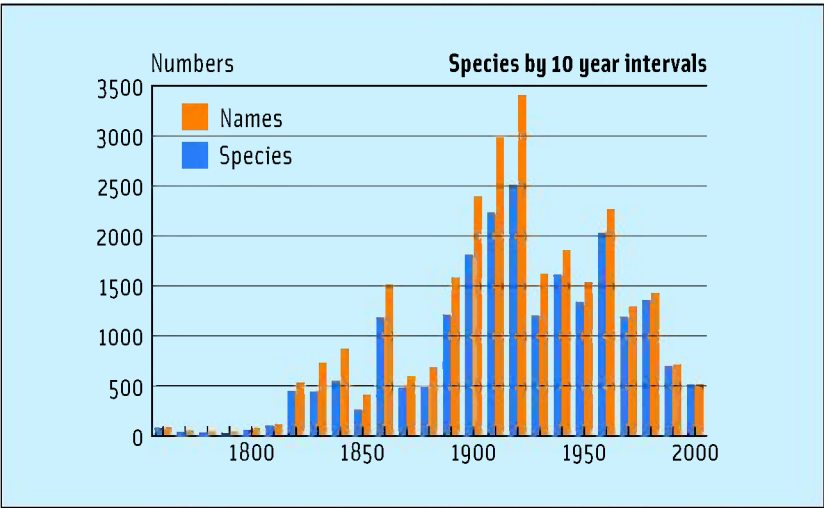


Figure 1.4. Growth of knowledge for Nearctic Diptera, based on increase of species and species-group names by 10 year intervals.

If the gall midge estimate is reduced on the assumption of broader host specificity (polyphagous, using 50% known, instead of 8% known), then the estimate of percentage-fauna-known increases to about 70%. The percentage of species known from only one sex is not estimated, as the statistic is trivial. For many taxa species recognition is based on charac-

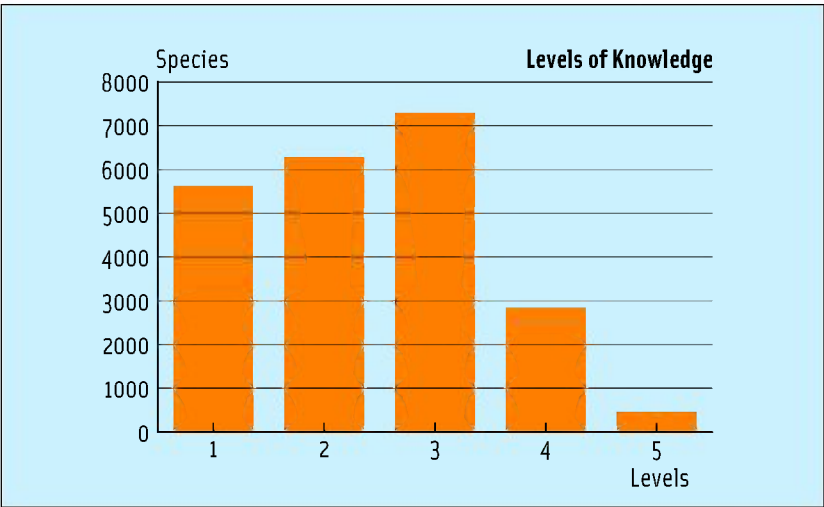


Figure 1.5. Levels of knowledge of Nearctic Diptera, see text for explanation.

ters of the male genitalia or secondary sexual characters. Hence, in these situations the percentage known from only one sex is by definition 100%. However, females are not unknown, as female specimens are recognized as belonging to higher taxa such as species groups, and these females do provide characters for our classifications. The taxonomy of flies is based on the holomorph. When material has been available, characters have been found in all stages (eggs, larvae, pupae, adult male, and female). Our knowledge of immature stages of Diptera was last reviewed by Hennig (1948, 1950, 1952), and for those of Cyclorrhapha by Ferrar (1987). About 98% of all families need revision. Only five families have been treated in comprehensive monographs. To produce a more meaningful measure of the status of our knowledge of Diptera of America north of Mexico, I have defined five levels of taxonomic knowledge based on comprehensiveness and quality of publications.

Level 0 — Species descriptions only. Recent examples: Byers & Rossmann (2008), Grogan & Philips (2008), Robinson & Knowles (2008).

Level 1 — Keys to few (about 25% or less) species. Keys usually unreliable as they are based on characters subsequently shown to be variable (such as color) and they are not supported by illustrations. Fortunately, there are no recent examples of poor quality keys, but in many taxa the only keys available are older ones, such as Camras (1945) or Telford (1970).

Level 2 — Keys to some (about 50%) species. Keys reliable, based on non-variable characters (such as male genitalia) and usually illustrated. Examples: Spencer & Stegmaier (1973), Spencer (1981), Spencer & Steyskal (1986).

Level 3 — Keys to most (about 75% or more) species. Keys of high quality, supported by illustrations of essential characters. Usually only adults are treated, and only some species described. Nomenclature and types frequently revised. Examples: Kits *et al.* (2008; regional), Pratt & Pratt (1980), Thompson (1981), Vockeroth (1986).

Level 4 — Revisions. Taxon revised, with keys to most or all adults; all species redescribed; nomenclature, types and literature revised. Examples: Brown (1987), Griffiths (1982–2004), Hall & Evenhuis (1980–2004), Lonsdale & Marshall (2007), Mathis (1982), Michelsen (1988), Thompson (1980).

Level 5 — Monographs. Same as revisions, but immature stages also covered. Examples: Adler *et al.* (2004), Courtney (1990, 1994), Feijen (1989), Hogue (1973, 1987).

Level 4 and 5 are very similar, but differ only in comprehensiveness. The work of Griffiths (1982–2004) in his *Flies of the Nearctic Region* may be considered by some as being level 5, but is here considered level 4 as Griffiths has not treated the immature stages even though they are known for many of the taxa he has covered. Also, mosquitoes represent another special case. The last comprehensive treatment of them was by Carpenter & LaCasse (1955), but even this was not monographic in the sense that it lacks nomenclatural details such as information on types and synonyms. However, the work did present descriptions and keys to all stages. Since then there has been a series of identification guides with distribution data (latest, Darsie & Ward 2005), which keep our knowledge of mosquitoes up to date and make the group the best known Diptera taxon in the Nearctic Region.

When our knowledge of Diptera of America north of Mexico is viewed in terms of these levels (Fig. 1.5), the true magnitude of work remaining to be done is evident. While we may have described two-thirds of the species that exist, we have not properly synthesized these descriptions into comprehensive revisions or monographs. Only five families of North American flies have been effectively treated: black flies, mosquitoes and net-winged midges (Simuliidae, Culicidae, Blephariceridae, Deuterophlebiidae and Nymphomyiidae)!

The above assessment deals only with the extant fauna. While knowledge of the past is always limited, the Nearctic Region has a number of sites that provide exceptional information on the past Diptera faunas. These have been recently summarized: Virginia where there are late Triassic (220 Mya) fossil beds (Blagoderov *et al.* 2007); New Jersey where there are Cretaceous (90 Mya) amber deposits (Grimaldi 2000; Grimaldi & Cumming 1999) and the Rocky Mountains, mainly Florissant and others, where there are late Eocene (34 Mya) shale fossils (Meyer 2003). All together, some 74 families, 229 genera and 516 species are known from fossils in the Nearctic Region. Some represent clades that are unknown from the extant fauna but appear to be endemic elsewhere, such as the tsetse (*Glossina*, Glossinidae, now only known from subsaharan Africa).

Our knowledge of Diptera phylogeny is good: The sister group of Diptera is almost certainly a mecopteran, probably phenetically and cladistically related to Nannochoristidae (Wood & Borkent 1989, but see Whiting 2005 for review). The major monophyletic groups of flies have been blocked out; within the grade 'Nematocera,' the relationships among the

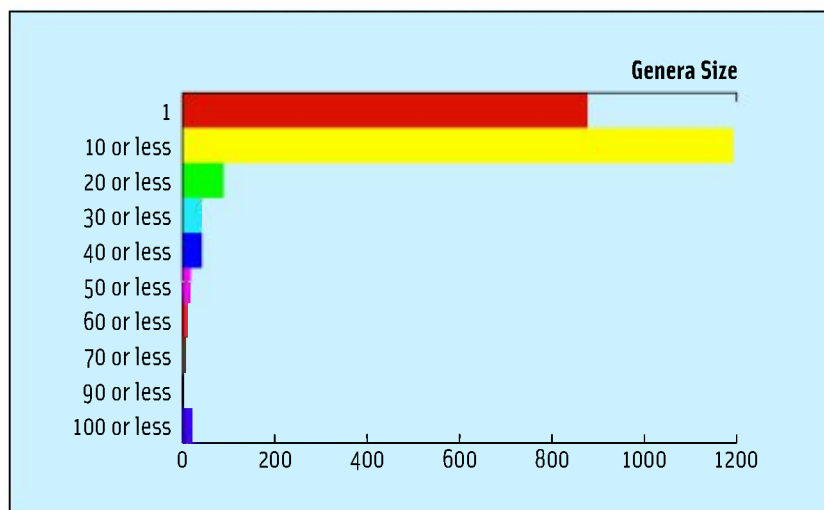


Figure 1.6. Size of Nearctic genera of Diptera.

There is a strong dominance of small genera with either one species (877 genera) or 2–10 species (1192 genera).

Only two genera have more than one hundred species:

*Dolichopus* Latreille with 316 spp. and

*Tipula* Linnaeus with 525 spp.

family group taxa have been largely deciphered (although the contents and position of the Tipulomorpha remain uncertain), and within the grade ‘Brachycera,’ the major monophyletic clusters have been identified (See Yeates & Wiegmann 2005 for overall review). Much, however, needs to be done to define and objectively rank families; among the cyclorrhaphous flies, monophyletic families have been defined by greatly restricting the scope of these taxa, and much still needs to be discovered to cluster these ‘microfamilies’. While the classification of the Nearctic Diptera has been fairly stable in recent times due to the conservative nature of dipterists, this classification does not reflect our progress in the knowledge of Diptera. The current families of Diptera neither conform to cladistic, nor phenetic or ‘evolutionary’ [*sensu* Mayr] classification conventions. Consider the contradictory treatment of the Phoridae and pupiparous Diptera (Maa & Peterson 1987, Peterson 1987, Peterson & Wenzel 1987, Wenzel & Peterson 1987). Under phenetic or ‘evolutionary’ conventions, the Phoridae should be treated as a cluster of families equivalent to the present con-

cept of the pupiparous Diptera. Under a cladistic approach as used here<sup>1</sup> the pupiparous Diptera are considered to be one family (Griffiths 1972). Similarly at the generic level, no consistent standard has been applied. For example, the genus *Tipula*, in relation to diversity, age of origin, and size, is more than equivalent to most families of Schizophora (Fig. 1.6)!

On morphology and terminology, North American dipterists have accepted the treatment given in the *Manual of Nearctic Diptera* (McAlpine 1981) as the standard, with one major exception. Terminology for the male genitalia of cyclorrhaphous flies is, unfortunately, theory-laden. Hence, there are different sets of terms depending on the interpretation of genital evolution one accepts (Griffiths 1981, 1984).

### 3. Resources

#### 3.1 Literature

The current literature resources for Diptera are excellent. Our research program has been and is based on three interrelated core publications (Fig. 1.1): catalogs, manuals, and monographs. Catalogs are the indexes to the diffuse literature of keys, descriptions, and biological data (Thompson & Knutson 1987; but see Steyskal 1988); manuals are the keys to the smallest operational taxonomic group (that is, the genus); and monographs are the ultimate species-level syntheses of all that is known about a taxonomic group, usually a family or subfamily. Today, these categories of publications are represented by the Catalog of the Diptera of America north of Mexico (Stone *et al.* 1965), the *Manual of Nearctic Diptera* (McAlpine 1981, 1987, 1989), and the *Flies of the Nearctic Region* series. The black fly monograph (Adler *et al.* 2004) and the fascicle on Blephariceridae (Hogue 1987) in the *Flies of the Nearctic Region* series, are without doubt the best examples of a monographic treatment of Nearctic insect groups. Similarly, the *Manual of Nearctic Diptera* represents the best ordinal treatment

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1. The cladistic approach of Hennig and here implemented requires that all families be monophyletic and at least Cretaceous in the age of origin. Age is documented by fossils or inferred by phylogenetic sequence of subordination. Cladistic data are derived principally from Wood & Borkent (1989), Woodley (1989), Griffiths (1972, 1987) and Yeates & Wiegmann (2005); other sources are Hennig (1972), Oosterbroek (1986), Krivosheina (1969, 1978, 1986, 1988), Matile (1990), Chvála (1981, 1983), D.K. McAlpine (1985), and Rotheray & Gilbert (2008). The conventions used follow Wiley (1981) and Griffiths (1972).

of any insect group for any region of the world. However, the *BioSystematic Database of World Diptera* is not as comprehensive as the *Catalog of Hymenoptera in America North of Mexico* (Krombein *et al.* 1979), which is the best example of any systematic catalog ever done. Other types of literature resources are: 1) Handbooks for general users, such as Gagné (1989); 2) comprehensive character surveys (Ferrar 1987); 3) identification aids (Darsie & Ward 2005); 4) regional treatments (Wood *et al.* 1979); 5) type collection listings (Arnaud 1979); 6) annotated bibliographies (West & Peters 1973); 7) parasite and host indexes (Arnaud 1978); and 8) biographies (Shor 1971) with technical summaries (Arnaud & Owen 1981). These examples are the best of their genre; comprehensive listings of literature resources for Nearctic Diptera are found in the Manual and the Catalog and online in the BDWD.

The Internet provides access to digital material for all who have computers and network access. Now some groups have begun to scan and digitize copies of the critical literature and to make those copies accessible via the Internet. For example, more than 80% of the taxonomic literature on mosquitoes is now available online (<http://www.wrbu.org/mosqlit.html>), and a group of museums and herbaria have joined together to make all the literature on biosystematics of organisms available online (see the *Biodiversity Heritage Library* program at <http://www.biodiversitylibrary.org>).

The area where dipterists lag behind their colleagues is in ordinal societies and journals. We do not have as many national and international societies as the coleopterists or lepidopterists do, and hence, there are few special journals devoted exclusively to Diptera. For flies, we have *Studia Dipterologica* and its *Supplements*, and there are some specialized journals which deal with groups of flies, such as mosquitoes (*Mosquito News*, *Mosquito Systematics*) and flower flies (*Volucella*). Unfortunately, the Diptera community is also plagued by personal journals produced by individuals who cannot get their work published in regular, peer-reviewed scientific journals (*Fragmenta Dipterologica*, *Dipteron*, *Journal of Dipterological Research*). We also have very few international newsletters as compared to, e.g., the hymenopterists (Bullock 1988). However, we are improving. Since 1988, every four years dipterists hold an International Congress of Dipterology to share our developing knowledge of flies.

What of the future? Literature has always been one of the major stumbling blocks for taxonomy, as the *International Code of Zoological Nomenclature* (ICZN 1999) has enshrined priority and usage as its basic operating

principles based on printed publications. Early attempts at modernization of the Code failed (ICZN 1989, IUBS 1989, Ride & Yones 1986), but the future is bright as this stumbling block will be removed forever by advances in technology and changes in our code. Already *ZooBank* has been proposed as a universal registration system for names of animals (Polaszek *et al.* 2005a,b, 2008). Technology and projects such as the *Biodiversity Heritage Library* now allows anyone to have an exact copy of any original publication. In building our various regional Diptera catalogs, we have also built our working libraries. So, the sponsors of the various Diptera catalogs may be able to provide copies if one cannot obtain them locally. Technologies that allow rapid computer access to large volumes of information (Internet) as well as archival storage, such as compact disks (CD-ROM, DVD), mean that future publications will be inexpensive and easy to use. For example, *Die Fliegen der Palaearktischen Region* (Lindner 1924–1993), which runs to over 16,000 pages, would cost approximately a million dollars to be printed at today's publication costs, and sells for about \$4,000 for a complete set. For the selling price alone, we could produce 1,000 copies on CD-ROM reducing four shelf-feet of books to a single 5 inch disk!! The *Diptera Data Dissemination Disk* is one publication that used CD-ROM technology. Already new publication ventures, such as *Zootaxa* (<http://www.mapress.com/zootaxa/>) and *ZooKeys* (<http://pensoftonline.net/ZooKeys/index.php/journal>) provide immediate publication and dissemination via Internet as well as paper copies distributed to libraries. The digital version (Adobe pdf file format) can be readily downloaded and stored on disks. The only hope for completing an inventory of our biota is to use new technologies!

### 3.2 Collections

Detailed statistics are not available for the holdings of Nearctic Diptera in various collections. This information, however, is part of the *BioSystematic Database of World Diptera* (Evenhuis *et al.* 2008). Preliminary analysis [based on a sample of 15,686 species-group names out of a total of 26,789 names] suggests that, for types, the major depositories [acronyms follow those of *Flies of Nearctic Region* series (Griffiths 1980: viii–xiii)] are: 1) the United States National Collection (USNM: 8,081); 2) the Natural History Museum, London (BMNH: 1,264); 3) the Canadian National Collection (CNC: 1,228; Cooper 1991; Cooper & Cumming 1993, 2000; Cooper & O'Hara 1996); 4) the Museum of Comparative Zoology (MCZ: 810), and 5) the California Academy of Sciences (CAS: 710; Arnaud 1979). After

these collections, the following have large holdings of types: American Museum of Natural History (AMNH: 363); Academy of Natural Sciences (ANSP: 341); Illinois Natural History Survey (INHS: 123), University of Kansas (UKaL: 267) and Cornell University (CU: 69). Many foreign museums, especially those in Paris (MNHN: 211), Copenhagen (UZMC: 92), Vienna (NMW: 160), Berlin (ZMHU: 150), Stockholm (NRS: 112) and Lund (ZIL: 291), have a large number of types of American flies. Finally, and surprisingly, virtually all North American collections have at least a few types of Diptera. Only a few collections have adopted a policy of not retaining primary type material and of depositing such material in major collections. For general Diptera material, the Canadian National Collection at the Biosystematics Research Centre clearly has the largest and most diverse holdings of flies from Nearctic America. Once the Museum of Comparative Zoology (MCZ) had the honor. One hundred years ago, the MCZ had the best fly collections, but today it retains status only as a major museum because of the types it has. Some 80 years ago the collection at Washington surpassed that of Cambridge due to the strong programs of the U.S. Department of Agriculture (USDA) and later the Smithsonian Institution (SI), but the building phase of the USNM Diptera Collection petered out some fifty years ago as interests shifted to exotic areas (SI) or programs became more applied in emphasis (USDA). Some forty years ago the Canadian National Collection began its collection building phase, but, at least for flies, that phase has now peaked as there are few dipterists on the staff today. Excellent accumulations of regional material are available in the California Academy of Sciences, Bishop Museum, University of California (Berkeley, Davis and Riverside), University of Guelph, University of Kansas, Kansas State University, University of Minnesota, Florida State Collection of Arthropods, etc. A number of dipterists were queried as to the comprehensiveness of the existing collection resources. The responses to date suggest that the collections provide an adequate sample of adults for most groups of flies. That is, there is now far more material waiting to be studied than there are specialists available to study it! However, in some groups, those with specialized habits or whose taxonomy is based on special characters, such as gall midges, there is a paucity of appropriately collected material.

Today many collections have made lists of their holdings, especially their types, available online, and there is a growing trend to making digital images also available online. The Museum of Comparative Zoology

| Specialist   | Valid | Names | % Valid |
|--------------|-------|-------|---------|
| Alexander    | 1210  | 1311  | 92%     |
| Loew         | 1048  | 1310  | 80%     |
| Coquillett   | 918   | 1090  | 84%     |
| Felt         | 791   | 1086  | 73%     |
| Malloch      | 629   | 885   | 71%     |
| Melander     | 784   | 866   | 91%     |
| Walker       | 437   | 733   | 60%     |
| Curran       | 438   | 684   | 64%     |
| Van Duzee    | 527   | 649   | 81%     |
| Osten Sacken | 446   | 517   | 86%     |

Figure 1.7. Leading specialists on Nearctic Diptera measured as taxonomic output.

has started this trend (see <http://mcz-28168.oeb.harvard.edu/mcztypedb.htm>) and other museums are following suit.

While the resources available in collections are adequate to begin the revisionary work which needs to be done, more material will be needed to finish the job. Material is needed of immatures and from certain geographic areas, such as Alaska (Nome Peninsula and Aleutian Islands), the Ozarks, the Red Hills in Alabama, and Nearctic Mexico. Unfortunately, given the history of declining support for surveys and museum programs, the prospects of obtaining the necessary material seem dim.

### 3.3 Human

Some 1,028 people have contributed to our knowledge of the taxonomy of Nearctic Diptera. The major contributors are listed in Figs. 1.7–1.8. Today, we know some 281 people working on Nearctic Diptera during the past twenty years (out of a data file on some 1,536 workers world-wide for the same period). To characterize these people better, we have grouped them on the basis of their primary occupation, as this gives an indication of the amount of time available for research.

Volunteers or amateurs, whose occupations are not related to entomology and who do systematics in their leisure time (8) or who are retired (46).

Entomologists, who are not employed to do systematic work (12) or are consultants (3).

| Specialist | Valid | Names | % Valid |
|------------|-------|-------|---------|
| Hall       | 230   | 246   | 93%     |
| Griffiths  | 210   | 215   | 98%     |
| Sæther     | 164   | 186   | 88%     |
| Evenhuis   | 166   | 181   | 92%     |
| Gagné      | 160   | 164   | 98%     |
| Marshall   | 134   | 135   | 99%     |
| Sublette   | 102   | 119   | 86%     |
| McAlpine   | 111   | 111   | 100%    |
| Robinson   | 106   | 111   | 95%     |
| Grogan     | 69    | 69    | 100%    |

Figure 1.8. Top ten living specialist on Nearctic Diptera measured as taxonomic output.

University-based systematists, who may also be required to teach, do extensive research work, and/or curate (19).

Museum-based systematists, who also may be required to curate and do identifications (30).

Then there were others (14) who are now deceased, and students (8) who have left the field after publishing their work.

For the remainder (111), insufficient data were available to classify them in one of the above groups.

What is interesting about these numbers is that the number of university-based systematists has dropped by half (19 now, 37 previously), but the number working in museums has increased slightly (30 now, 24 previously), and previously I did not tally those who were retired as there were so few of them. Retired workers now make up the largest component.

Unfortunately, no data are available on the amount of time spent on (taxonomic) research. An estimate has not been made as there are too many variables involved, and the statistic is not really relevant. Time relates to productivity, that is, the amount of research done per unit time. Productivity varies widely among systematists (Figs 1.7, 1.8); for example, how many ‘Alexanders’ have there been? While Alexander managed to describe more than 10,000 species in a life-time (Byers 1982), most workers have described only one or two! So, the measure of man-years will not translate to what we really want to know, which is how much research is being done. The amount of research being done is best measured by quan-

tity of research results: the number of genera, species, and names published (Figs 1.3, 1.4, 1.7, 1.8). These data clearly show that while there are still many species to be described, our rate of description has significantly declined. The decline is probably directly attributable to the decrease in number of active systematists, but see Evenhuis (2007) for other reasons. However, while quantity of taxa described has decreased, the quality of the work has increased, that is, the percentage of taxa that are valid. Obviously both number of taxa described and the validity of them are only surrogate measures selected as they are easily obtained from databases. One only needs to compare the descriptions of Fabricius to one of today's specialists to see the great improvement in quality, from numerous illustrations to increased number of characters used.

The future for human resources in Diptera remains poor. When this review was last done, we bemoaned the retirement of those key teachers, such as Alexander of Massachusetts, Berg of Cornell, Byers of Kansas, Cook of Minnesota, Schlinger of California, and Hardy of Hawai'i, who had trained this generation of dipterists, and noted that only Steve Marshall of the University of Guelph, Monty Wood of the Biosystematics Research Centre in Ottawa, and the Maryland Center for Systematics (MCSE) utilizing the dipterists in Washington, had active programs for training dipterists. Today, Guelph and Ottawa retain active programs, as the Maryland program has become inactive. Fortunately, a couple of programs are filling this void: new cooperative programs between the American Museum of Natural History and Cornell (Grimaldi), a new molecular phylogenetic program at North Carolina State University (Wiegmann), and a revived program at Iowa State University (Courtney). And in between the first report and this, there was an active program at the University of Illinois that trained 7 students (Gaimari, Hauser, Hill, Holston, Metz, Winterton and Yang).

No short courses are offered in Diptera systematics as, for example, those provided by the North American hymenopterists (Bee Course, Parasitic Hymenoptera).

## 4. Research Program

### 4.1 Approach

The research program established by Osten Sacken and Williston is sufficient for the task. What is needed is the adoption of new technologies

to improve research productivity and distribution of results. We should be using more automated tools in our research: for example, simple word processing to sophisticated data analysis (MacClade, PAUP, TNT, etc.) and presentation (DELTA, Fact Sheet Fusion, Linnaeus II, Lucid, etc.) software (see Thompson *in* Knutson *et al.* 1987; Winterton 2009). We should also not forget who supports our research and should therefore provide our results in user-friendly, interactive expert systems so all can obtain biosystematic information directly. At the Systematic Entomology Laboratory, a prototype Biosystematic Information Database and Expert System for fruit flies (Thompson 1999b) was developed to demonstrate the increased productivity for scientists and greater accessibility for users that the integration of these new technologies will bring. Unfortunately, while the message of the need to recognize user-needs and to increase productivity is accepted, systematists continue to waste resources either by re-inventing proven technologies (as for example, EDIT [Lane 2008; Scoble 2008]) or simply sprucing-up the old (HTML keys as in CJAI).

#### 4.2 Priorities

What taxa should be studied first and what taxa should be left for later? Most families of flies require urgent priority work, as only a few aquatic groups (Culicidae, Blephariceridae, Deuterophlebiidae, Nymphomyiidae, Simuliidae) are truly well known! Why? Because complete knowledge of our biota is, as Aristotle (see Osten Sacken 1869: iii) and E. O. Wilson (1985a,b, 1986, 1987a, b, 1988) stated, an essential humanistic goal, and the time remaining to complete this task is short due to the rapid deterioration of the environment. To set priorities, one needs criteria. Given that the only appropriate goal is a comprehensive knowledge of our entire biota, the criterion for deciding which taxon deserves the highest priority for revision is which is most threatened by extinction. Unfortunately, we do not know enough to apply such a criterion, nor could such a criterion work at a higher taxonomic level as a family group taxon, the usual level of revisionary work. Obviously, given different priority criteria other answers are possible. For example, I work for USDA, and our priorities rank Tephritidae, Cecidomyiidae, and Agromyzidae high for the plant-feeding pests they include, and Tachinidae, Syrphidae, Pipunculidae, *et cetera*, high for the potential biological control agents they include. Obviously, the Department of Defense considers mosquitoes (Culicidae), of the highest priority due to the numerous human disease vectors found among

them. The Environmental Protection Agency should rank midges (Chironomidae) of high priority, because of their value as indicators of water quality. Other funding agencies will have different criteria, hence, different priority groups. And, our evaluation of the criteria will vary depending on our knowledge of the taxon. So, I believe the time for 'triage' on the basis of taxon is never: we need to know about all flies!

#### 4.3 *Environmental effects*

Is there any evidence that flies are affected by acid rain or other air pollutants? Will climate-change/global warming affect fly diversity? Are there endangered habitats that if eliminated would cause the extinction of one or more species of flies? Are there endangered species of flies? These questions cannot be answered readily and in sufficient detail because our knowledge of Diptera is so poor. The general answer is clearly yes, as we do know that Diptera are a major component of all non-marine ecosystems. So, given that some ecosystems are affected by acid rain and aerial pollutants or climate-change, then Diptera are affected. A recent study of pollinators in England and the Netherlands documented that climate-change has affected the ranges of flower flies (Biesmeijer *et al.* 2006). So flies with restricted ranges, such as alpine endemics, will surely disappear along with the polar bears. Given that some specialized habitats are eliminated, then some flies will be too. Many phytophagous flies have narrow host ranges, with most gall midges and leaf miners apparently being species specific (Gagné 1989). So, given endangered plants, there must be endangered phytophages. Evolution is an on-going process; numerous flies have evolved and gone to extinction in the 200 million years that flies have existed on Earth. Obviously, the process is continuing today, so there must be some endangered species of flies somewhere! The problem is the difficulty of separating the real examples of declining and endangered populations from those that appear to be because of a lack of knowledge. For example, there is only one US federally listed endangered species of fly, the Delhi Sands flower-loving fly (*Rhaphiomidas terminatus abdominalis* Cazier). This species was placed on the list as its habitat has been greatly reduced and its nominate subspecies was believed to be extinct. However, further research has revealed that the nominate subspecies is alive and well elsewhere (George & Mattoni 2006). California has a number of other species with very restricted habitats, such as Wilbur Springs Shore Fly (*Paracoenia calida* Mathis), found only at the spring but very abundant

there (Mathis 1975), or a couple of robber flies associated with Antioch Dunes (*Efferia antiochi* Wilcox (Wilcox 1966), *Cophura hurdi* Hull (Hull 1960), and *Metapogon hurdi* Wilcox (Wilcox 1964)). These species are endangered in the sense that their habitat is, but as long as the habitat is preserved these species will also be preserved. One recent species of Nearctic fly has been officially listed by the International Union for Conservation of Nature (IUCN 2007) as now extinct, *Stonemyia velutina* (Bigot), and that species was also a narrow California endemic, known from central California (Madera & Mariposa counties (Middlekauff & Lane 1980)) but this status is questioned by the local specialist (J. Burger, pers. comm.) as no scientific survey has been undertaken to access the true status.

### SUMMARY

Today, the study of Nearctic Diptera remains stagnant, as in the past twenty years little taxonomic progress was made despite the great promise of technology. An assessment and basic synthesis of our knowledge of flies has been completed. What we know about flies is embodied in the *BioSystematic Database of World Diptera* and the *Manual of Nearctic Diptera*. About two-thirds of all the flies estimated to occur in the Nearctic Region have now been named. Unfortunately, less than one percent of these flies are treated comprehensively in monographs and less than a quarter have been thoroughly revised. To complete the task, a full and comprehensive inventory of the flies of America north of Mexico will require the utilization of new technologies, the training of new dipterists, and the securing of permanent positions for them. Given better tools, which are being developed, we need 30 full-time 'Wirths' (1,200 scientific years) or eight 'Alexanders' (560 SYS) to finish the job of just naming the flies of Nearctic America!

### ACKNOWLEDGEMENTS

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| Table 1.1.1. Nearctic Diptera Fauna — statistics by families. |        |       |         |       |         |           |              |          |                     |                   |
|---|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
| Taxon   | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|   | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| NEMATOCERA  |        |       |         |       |         |           |              |          |                     |                   |
| Tipulomorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Cylindrotomidae   | 4      | 4     | 8       | 15    | 90      | 50        | 4            | 1        | 4                   | 9                 |
| Limoniidae  | 105    | 133   | 927     | 1034  | 80      | 5         | 4            | 1        | 2                   | 1159              |
| Pedictidae  | 13     | 16    | 149     | 157   | 80      | 8         | 4            | 1        | 2                   | 186               |
| Tipulidae   | 34     | 50    | 620     | 757   | 80      | 8         | 4            | 1        | 2                   | 775               |
| Psychodomorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Canthylloscelidae   | 3      | 5     | 3       | 3     | 75      | 33        | 2            | 0        | 4                   | 4                 |
| Psychodidae   | 33     | 42    | 123     | 162   | 50      | 20        | 4            | 0        | 3                   | 246               |
| Scatopsidae   | 19     | 22    | 77      | 84    | 80      | 5         | 2            | 0        | 3                   | 96                |
| Trichoceridae   | 3      | 6     | 30      | 36    | 90      | 20        | 2            | 0        | 3                   | 33                |
| Ptychopteromorpha   |        |       |         |       |         |           |              |          |                     |                   |
| Ptychopteridae  | 3      | 5     | 18      | 19    | 80      | 20        | 1            | 0        | 3                   | 23                |
| Tanyderidae   | 2      | 4     | 4       | 4     | 80      | 50        | 1            | 0        | 3                   | 5                 |
| Culicimorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Ceratopogonidae   | 78     | 111   | 614     | 692   | 65      | 5         | 60           | 2        | 3                   | 945               |
| Chaoboridae   | 4      | 9     | 13      | 29    | 90      | 70        | 2            | 1        | 4                   | 14                |
| Chironomidae  | 234    | 309   | 1112    | 1288  | 40      | 30        | 2            | 1        | 3                   | 2780              |
| Corethrellidae  | 2      | 3     | 5       | 5     | 70      | 20        | 2            | 1        | 3                   | 7                 |
| Culicidae   | 81     | 244   | 182     | 311   | 95      | 100       | 60           | 2        | 5                   | 192               |

Table 1.1. Nearctic Diptera Fauna – statistics by families.

| Taxon                     | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|---------------------------|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
|                           | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| Dixidae                   | 3      | 4     | 45      | 57    | 90      | 20        | 2            | 1        | 4                   | 50                |
| Simuliidae                | 25     | 50    | 242     | 311   | 80      | 100       | 6            | 3        | 5                   | 303               |
| Thaumaleidae              | 3      | 3     | 25      | 27    | 70      | 90        | 3            | 1        | 2                   | 36                |
| <b>Blephariceromorpha</b> |        |       |         |       |         |           |              |          |                     |                   |
| Blephariceridae           | 6      | 8     | 33      | 42    | 80      | 100       | 2            | 1        | 5                   | 41                |
| Deuterophlebiidae         | 1      | 1     | 6       | 6     | 80      | 100       | 1            | 1        | 5                   | 8                 |
| Nymphomyiidae             | 1      | 3     | 2       | 2     | 100     | 100       | 1            | 1        | 5                   | 2                 |
| <b>Bibionomorpha</b>      |        |       |         |       |         |           |              |          |                     |                   |
| Anisopodidae              | 7      | 13    | 9       | 13    | 75      | 40        | 3            | 2        | 3                   | 12                |
| Bibionidae                | 5      | 13    | 86      | 133   | 75      | 10        | 3            | 2        | 3                   | 115               |
| Bolitophiliidae           | 2      | 4     | 20      | 20    | 75      | 10        | 3            | 1        | 3                   | 27                |
| Cecidomyiidae             | 177    | 262   | 1247    | 1626  | 8       | 20        | 4            | 1        | 1                   | 15588             |
| Diadocidiidae             | 2      | 3     | 3       | 3     | 66      | 25        | 3            | 1        | 3                   | 5                 |
| Ditomyiidae               | 3      | 4     | 6       | 8     | 80      | 20        | 2            | 1        | 4                   | 8                 |
| Hesperiidae               | 1      | 2     | 1       | 1     | 100     | 100       | 2            | 1        | 4                   | 1                 |
| Keroplatidae              | 15     | 23    | 85      | 90    | 60      | 5         | 4            | 1        | 3                   | 142               |
| Lugistorrhiniidae         | 1      | 1     | 1       | 1     | 20      | 0         | 4            | 1        | 4                   | 5                 |
| Mycetophilidae            | 87     | 122   | 672     | 780   | 40      | 10        | 3            | 2        | 2                   | 1680              |
| Pachyneuridae             | 1      | 1     | 1       | 1     | 100     | 100       | 2            | 1        | 4                   | 1                 |
| Sciaridae                 | 24     | 32    | 172     | 193   | 30      | 6         | 6            | 6        | 1                   | 573               |

Table 1.1.1. Nearctic Diptera Fauna — statistics by families.

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|---|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
| Taxon   | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|   | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| Axyomyiomorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Axyomyiidae   | 1      | 1     | 1       | 1     | 60      | 100       | 2            | 1        | 4                   | 2                 |
| BRACHYCERA  |        |       |         |       |         |           |              |          |                     |                   |
| Stratiomyomorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Stratiomyidae   | 46     | 117   | 312     | 516   | 90      | 15        | 4            | 1        | 2                   | 347               |
| Xylomyiidae   | 2      | 21    | 12      | 15    | 90      | 40        | 2            | 1        | 3                   | 13                |
| Tabanomorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Acroceridae   | 9      | 18    | 62      | 82    | 75      | 5         | 2            | 1        | 2                   | 83                |
| Athericidae   | 2      | 2     | 4       | 4     | 100     | 25        | 2            | 1        | 4                   | 4                 |
| Nemestrinidae   | 3      | 9     | 8       | 11    | 90      | 40        | 2            | 1        | 3                   | 9                 |
| Oreoleptidae  | 1      | 1     | 1       | 1     | 100     | 100       | 3            | 3        | 4                   | 1                 |
| Rhagionidae   | 10     | 15    | 105     | 143   | 75      | 5         | 3            | 1        | 4                   | 140               |
| Spaniidae   | 3      | 3     | 13      | 16    | 75      | 0         | 3            | 1        | 4                   | 17                |
| Tabanidae   | 39     | 65    | 394     | 624   | 85      | 33        | 10           | 3        | 3                   | 464               |
| Xylophagidae  | 5      | 26    | 28      | 49    | 80      | 20        | 3            | 2        | 4                   | 35                |
| Vermileonomorpha  |        |       |         |       |         |           |              |          |                     |                   |
| Vermileonidae   | 1      | 1     | 3       | 3     | 100     | 33        | 1            | 0        | 3                   | 3                 |
| Asiloidea   |        |       |         |       |         |           |              |          |                     |                   |
| Apioceridae   | 2      | 3     | 64      | 66    | 95      | 0         | 1            | 1        | 4                   | 67                |
| Apsilocephalidae  | 1      | 1     | 1       | 1     | 100     | 0         | 1            | 1        | 3                   | 1                 |

Table 1.1.1. Nearctic Diptera Fauna – statistics by families.

| Taxon             | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|-------------------|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
|                   | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| Apistomyiidae     | 1      | 1     | 1       | 1     | 100     | 0         | 0            | 0        | 3                   | 1                 |
| Asilidae          | 109    | 152   | 1073    | 1253  | 80      | 2         | 8            | 2        | 3                   | 1341              |
| Bombuliidae       | 66     | 114   | 991     | 1194  | 70      | 2         | 6            | 1        | 3                   | 1416              |
| Hilarimorphidae   | 1      | 2     | 27      | 27    | 90      | 0         | 1            | 1        | 4                   | 30                |
| Mydidae           | 11     | 18    | 75      | 87    | 95      | 2         | 3            | 1        | 3                   | 79                |
| Mythicomyiidae    | 8      | 15    | 183     | 207   | 70      | 0         | 2            | 1        | 3                   | 261               |
| Scenopinidae      | 10     | 15    | 148     | 151   | 90      | 1         | 2            | 0        | 4                   | 164               |
| Therevidae        | 30     | 39    | 164     | 199   | 90      | 10        | 4            | 2        | 4                   | 182               |
| Empidoidea        |        |       |         |       |         |           |              |          |                     |                   |
| Atelestidae       | 1      | 2     | 2       | 2     | 50      | 0         | 3            | 3        | 2                   | 4                 |
| Brachyistomatidae | 10     | 13    | 17      | 18    | 75      | 0         | 6            | 2        | 2                   | 23                |
| Dolichopodidae    | 54     | 102   | 1383    | 1558  | 80      | 1         | 6            | 2        | 1                   | 1729              |
| Empididae         | 40     | 63    | 468     | 511   | 75      | 3         | 6            | 2        | 2                   | 624               |
| Hybotidae         | 29     | 54    | 316     | 333   | 75      | 1         | 6            | 2        | 2                   | 421               |
| Iteaphila group   | 2      | 2     | 18      | 23    | 75      | 1         | 6            | 2        | 2                   | 24                |
| Oreogetonidae     | 1      | 1     | 8       | 8     | 75      | 1         | 6            | 2        | 2                   | 11                |
| CYCLORRHAPHA      |        |       |         |       |         |           |              |          |                     |                   |
| Aschiza           |        |       |         |       |         |           |              |          |                     |                   |
| Lonchopteridae    | 1      | 2     | 5       | 7     | 100     | 25        | 1            | 0        | 3                   | 5                 |
| Phoridae          | 64     | 118   | 421     | 485   | 50      | 10        | 3            | 1        | 3                   | 842               |

Table 1.1. Nearctic Diptera Fauna — statistics by families.

| Taxon                 | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|-----------------------|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
|                       | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| Pipunculidae          | 17     | 26    | 158     | 198   | 70      | 5         | 5            | 1        | 3                   | 226               |
| Platypezidae          | 15     | 29    | 77      | 86    | 90      | 10        | 1            | 0        | 3                   | 86                |
| Syrphidae             | 191    | 357   | 818     | 1420  | 90      | 10        | 15           | 2        | 2                   | 909               |
| Calyptratae           |        |       |         |       |         |           |              |          |                     |                   |
| Anthomyiidae          | 40     | 123   | 691     | 881   | 80      | 10        | 5            | 1        | 4                   | 864               |
| Calliphoridae         | 18     | 39    | 103     | 163   | 90      | 50        | 3            | 1        | 4                   | 114               |
| Fanniidae             | 3      | 8     | 111     | 144   | 90      | 10        | 3            | 0        | 4                   | 123               |
| Hippoboscidae         | 27     | 53    | 43      | 63    | 95      | 15        | 3            | 1        | 3                   | 45                |
| Muscidae              | 43     | 118   | 632     | 920   | 90      | 10        | 6            | 1        | 2                   | 702               |
| Oestridae             | 8      | 27    | 59      | 70    | 70      | 95        | 3            | 1        | 3                   | 84                |
| Rhiniidae             | 1      | 3     | 1       | 2     | 100     | 100       | 3            | 0        | 4                   | 1                 |
| Rhinophoridae         | 2      | 6     | 4       | 5     | 100     | 100       | 2            | 0        | 3                   | 4                 |
| Sarcophagidae         | 80     | 201   | 451     | 624   | 85      | 30        | 5            | 2        | 2                   | 531               |
| Scathophagidae        | 38     | 62    | 151     | 215   | 75      | 15        | 1            | 1        | 2                   | 201               |
| Tachinidae            | 374    | 921   | 1440    | 1843  | 75      | 10        | 6            | 2        | 1                   | 1920              |
| Acalyptratae Neriodea |        |       |         |       |         |           |              |          |                     |                   |
| Cypselosomatidae      | 2      | 2     | 3       | 3     | 66      | 0         | 1            | 0        | 3                   | 5                 |
| Micropezidae          | 12     | 25    | 37      | 50    | 90      | 10        | 3            | 1        | 3                   | 41                |
| Neriidae              | 2      | 3     | 2       | 3     | 66      | 50        | 1            | 0        | 3                   | 3                 |

Table 1.1.1. Nearctic Diptera Fauna – statistics by families.

| Taxon                 | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|-----------------------|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
|                       | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| <b>Diopsoidea</b>     |        |       |         |       |         |           |              |          |                     |                   |
| Diopsidae             | 1      | 2     | 2       | 2     | 100     | 100       | 1            | 0        | 5                   | 2                 |
| Psilidae              | 7      | 9     | 32      | 39    | 90      | 10        | 1            | 0        | 2                   | 36                |
| Strongylophthalmyidae | 1      | 2     | 1       | 2     | 100     | 50        | 2            | 1        | 4                   | 1                 |
| Tanypeziidae          | 1      | 1     | 2       | 3     | 100     | 50        | 1            | 1        | 3                   | 2                 |
| <b>Conopoidea</b>     |        |       |         |       |         |           |              |          |                     |                   |
| Conopidae             | 11     | 17    | 74      | 154   | 90      | 10        | 6            | 3        | 3                   | 82                |
| <b>Tephritoidea</b>   |        |       |         |       |         |           |              |          |                     |                   |
| Lonchaeidae           | 8      | 13    | 136     | 141   | 60      | 10        | 2            | 0        | 2                   | 227               |
| Pallopteridae         | 4      | 4     | 9       | 9     | 70      | 0         | 1            | 0        | 3                   | 13                |
| Piophilidae           | 10     | 17    | 37      | 49    | 70      | 25        | 1            | 0        | 4                   | 53                |
| Platystomatidae       | 7      | 13    | 44      | 49    | 80      | 0         | 2            | 0        | 2                   | 55                |
| Pyrgotidae            | 6      | 7     | 11      | 20    | 90      | 25        | 1            | 0        | 3                   | 12                |
| Richardiidae          | 6      | 10    | 8       | 10    | 75      | 10        | 1            | 0        | 3                   | 11                |
| Tephritidae           | 53     | 101   | 372     | 545   | 85      | 33        | 8            | 2        | 4                   | 438               |
| Ulidiidae             | 47     | 75    | 139     | 175   | 90      | 5         | 2            | 0        | 2                   | 154               |
| <b>Lauxanioidea</b>   |        |       |         |       |         |           |              |          |                     |                   |
| Chamaemyiidae         | 8      | 9     | 80      | 90    | 70      | 30        | 2            | 1        | 2                   | 114               |
| Lauxanidae            | 30     | 35    | 157     | 179   | 80      | 10        | 2            | 1        | 2                   | 196               |

Table 1.1. Nearctic Diptera Fauna — statistics by families.

| Table 1.1.1. Nearctic Diptera Fauna — statistics by families. |        |       |         |       |         |           |              |          |                     |                   |
|---|--------|-------|---------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
| Taxon   | Genera |       | Species |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|   | Valid  | Names | Valid   | Names | Species | Immatures | World        | Nearctic |                     |                   |
| Sciomyzoidea  |        |       |         |       |         |           |              |          |                     |                   |
| Coelopidae  | 4      | 5     | 5       | 6     | 100     | 20        | 2            | 1        | 4                   | 5                 |
| Dryomyzidae   | 4      | 6     | 8       | 15    | 85      | 33        | 2            | 1        | 4                   | 9                 |
| Helcomyzidae  | 1      | 3     | 1       | 1     | 100     | 0         | 1            | 1        | 4                   | 1                 |
| Heterocheilidae   | 1      | 8     | 1       | 2     | 100     | 0         | 1            | 1        | 4                   | 1                 |
| Ropalomeridae   | 2      | 2     | 2       | 2     | 80      | 0         | 1            | 1        | 3                   | 3                 |
| Sciomyzidae   | 22     | 47    | 196     | 243   | 95      | 50        | 5            | 1        | 3                   | 206               |
| Sepsidae  | 9      | 16    | 34      | 54    | 85      | 20        | 2            | 0        | 2                   | 40                |
| Opomyzoidea   |        |       |         |       |         |           |              |          |                     |                   |
| Agromyzidae   | 29     | 44    | 763     | 858   | 80      | 33        | 10           | 2        | 4                   | 954               |
| Anthomyzidae  | 5      | 6     | 21      | 24    | 66      | 10        | 2            | 1        | 1                   | 32                |
| Asteiidae   | 5      | 6     | 17      | 19    | 66      | 0         | 1            | 1        | 3                   | 26                |
| Aulacigastridae   | 1      | 1     | 3       | 3     | 70      | 20        | 2            | 2        | 3                   | 4                 |
| Clusiidae   | 6      | 11    | 41      | 51    | 90      | 10        | 3            | 2        | 4                   | 46                |
| Fergusoninidae  | 1      | 1     | 1       | 1     | 100     | 100       | 1            | 0        | 4                   | 1                 |
| Odiniidae   | 3      | 4     | 11      | 12    | 80      | 30        | 3            | 2        | 4                   | 14                |
| Opomyzidae  | 3      | 5     | 11      | 13    | 80      | 25        | 1            | 1        | 4                   | 14                |
| Periscelididae  | 3      | 5     | 7       | 7     | 80      | 66        | 2            | 2        | 4                   | 9                 |

Table 1.1. Nearctic Diptera Fauna – statistics by families.

| Taxon                  | Genera |       | Species      |       | % Known |           | #Specialists |          | Status of Knowledge | Estimated species |
|------------------------|--------|-------|--------------|-------|---------|-----------|--------------|----------|---------------------|-------------------|
|                        | Valid  | Names | Valid        | Names | Species | Immatures | World        | Nearctic |                     |                   |
| <b>Carnoidea</b>       |        |       |              |       |         |           |              |          |                     |                   |
| Acartophthalmidae      | 1      | 1     | 2            | 2     | 100     | 0         | 1            | 0        | 3                   | 2                 |
| Braulidae              | 1      | 1     | 1            | 2     | 100     | 100       | 1            | 1        | 3                   | 1                 |
| Canacidae              | 5      | 5     | 12           | 13    | 90      | 20        | 1            | 1        | 3                   | 13                |
| Carnidae               | 4      | 5     | 20           | 25    | 65      | 20        | 2            | 2        | 3                   | 31                |
| Chloropidae            | 54     | 82    | 302          | 380   | 60      | 5         | 2            | 1        | 1                   | 503               |
| Cryptochetidae         | 1      | 2     | 1            | 1     | 100     | 100       | 0            | 0        | 3                   | 1                 |
| Milichiidae            | 12     | 18    | 43           | 51    | 60      | 10        | 1            | 1        | 4                   | 72                |
| Tethinidae             | 6      | 9     | 28           | 32    | 70      | 0         | 1            | 2        | 3                   | 40                |
| <b>Sphaeroceroidea</b> |        |       |              |       |         |           |              |          |                     |                   |
| Chyromyidae            | 3      | 3     | 9            | 11    | 60      | 0         | 1            | 0        | 2                   | 15                |
| Heleomyzidae           | 32     | 56    | 152          | 186   | 85      | 10        | 3            | 0        | 3                   | 179               |
| Sphaeroceridae         | 46     | 71    | 283          | 307   | 70      | 5         | 6            | 3        | 3                   | 404               |
| <b>Ephydroidea</b>     |        |       |              |       |         |           |              |          |                     |                   |
| Camillidae             | 1      | 2     | 4            | 4     | 100     | 0         | 1            | 0        | 3                   | 4                 |
| Curtonotidae           | 1      | 3     | 1            | 1     | 50      | 0         | 0            | 0        | 3                   | 2                 |
| Diastatidae            | 1      | 5     | 8            | 12    | 60      | 0         | 2            | 1        | 4                   | 13                |
| Drosophilidae          | 33     | 74    | 248          | 315   | 95      | 33        | 8            | 1        | 3                   | 261               |
| Ephydriidae            | 70     | 97    | 484          | 554   | 80      | 25        | 10           | 3        | 3                   | 605               |
|                        |        |       | <b>21454</b> |       |         |           |              |          |                     | <b>44175</b>      |

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