BIOSYSTEMATIC INFORMATION: DIPTERISTS RIDE THE THIRD WAVE

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Abstract

Herein is an overview of our knowledge of the Diptera of America north of Mexico. About two-thirds of all the flies estimated to occur in America north of Mexico 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. A full and comprehensive inventory of the flies of America north of Mexico will require utilizing new technologies, training new dipterists, and finding permanent positions for them.

Introduction

Despite the title, this paper is an overview of our knowledge of the Diptera of America north of Mexico. The title emphasizes that the subject is Biosystematic Information; that today and tomorrow belong to the age of information -- the Third Wave; and that dipterists will ride this wave, not be drowned by it (Thompson & Knutson 1987; Steyskal 1988)!

Flies, gnats, maggots, midges, mosquitoes, keds, bots, et cetera are all common names for members of the order Diptera. This diversity of names documents the importance of the group to man and reflects the range of organisms in the order. The order is one of the four largest groups of living organisms. There are more known flies (more than 110,000 described species) than vertebrates. These insects are a major component of virtually all non-marine ecosystems. Only the cold Arctic and Antarctic ice caps are without flies! The economic importance of the group is immense. One need only consider the ability of flies to transmit diseases. Mosquitoes and black flies are responsible for more human suffering and death than any other group of organisms except for transmitted pathogens and man! Flies also destroy our food, especially grains and fruits. On the positive side of the ledger, outside their obviously essential roles in the ecosystem, flies are of little direct benefit to man. Some are important as experimental animals (*Drosophila*) and biological control agents of weeds and other insects.

The data for this preliminary report are derived from the Biosystematic Database of Diptera that we are building in Washington. Currently we have nomenclatural and distributional data on all the flies of America north of Mexico and world coverage for some dozen families. Also a data file is maintained on people who work on Diptera. And while preparing this summary, we queried several specialists about various questions.

Past

Our knowledge of the Diptera of America north of Mexico 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 Diptera of America north of Mexico, but that we began with a

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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 comprehensive work published. Works since that time have become more restricted 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 methods, and more geographic areas were discovered and explored. Fabricius spent his life travelling 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 of flies. Unfortunately, whereas Linneaus' work was comprehensive by definition, such status can not 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 19th century our knowledge of Diptera of America north of Mexico was in chaos: no comprehensive works, just descriptions scattered though 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, there was a leader to take up the task. Robert, Baron von der Osten Sacken, 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 Diptera of America north of Mexico 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 faciliated revisional work, as the size of the taxonomic unit to be studied could then be as small as a genus. With the master research plan (Fig. 1) set, the next hundred years (1888-1988) saw an alternation between descriptions (and revisions), catalogs (Aldrich 1905; Stone et al. 1965; Thompson 1990, in prep.), and manuals

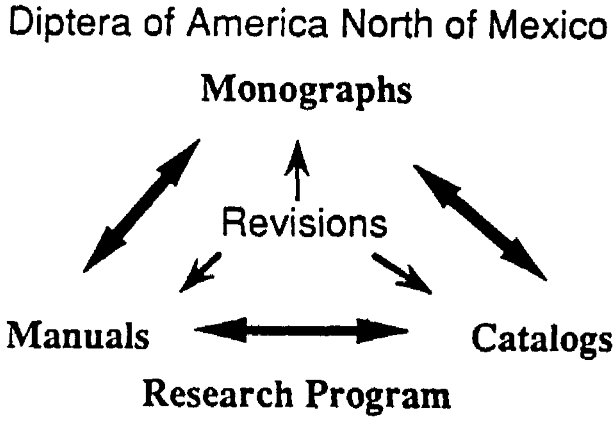

Figure 1

(Williston 1896, 1908; Curran 1934; McAlpine 1981-89), with a few monographs being done (Carpenter & LaCasse 1955, Hardy 1943 & 1945, Webb 1984, Hogue 1987). This century saw 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 19th 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 were in the first 150 years and at a rate never since exceeded. So, in summary, the history of nearctic Dipterology can be viewed as a series of seven periods (Fig. 2); a more detailed history of nearctic dipterology has been written by Stone (1980).

Diptera of America North Of Mexico

History

Period	Dates	Species	Rate
Linnaean	to 1760	57	5.7
Fabrician	to 1800	136	3.4
Wiedemann, etc	to 1850	1,677	33.5
Osten Sacken	to 1880	1,529	51.0
Williston	to 1910	3,365	112.3
Alexander, Curran	to 1950	7,299	182.2
"Us"	to TODAY	5,127	128.2

Figure 2. The columns are: **Period,** name of a prominent dipterist is used to characterize 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.

Present and Future

Given how our knowledge of Diptera of America north of Mexico 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, collection, and human) available or needed to solve the problem, and the approach to solving the problem (research program).

Fauna--Statistics

Where we are today is best summarized by statistics on the fauna (Table 1), as well as some statistics on the human, collection, and literature resources. Trend curves plotted for genus and species group names (Figs. 3-4) 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 (47%) is probably too low, as Gagné estimates that there are some 14,000 undescribed species of gall midges in the Nearctic

Table 1.

DIPTERA OF AMERICA NORTH OF MEXICO - STATISTICS

Taxon Name	Genera Valid	Genera Names	Species Valid	Species Names	% Known Species	% Known Immatures	# Specialists World	# Specialists Nearctic	Status of Knowledge
1 Archaeodiptera									
1. Nymphomyiidae	1	1	1	1	50	100	1	1	4
2 Eudiptera									
2.1 Axymyiomorpha									
2. Axymyiidae	1	1	1	1	50	100	1	1	3
2.2 Polyneura									
2.2.1 Tipuliformia									
3. Cylindrotomidae	4	4	9	15	90	56	4	7	4
4. Limoniidae	27	89	663	721	83	5	4	7	2
5. Eriopteridae	25	56	477	518	73	4	4	7	2
6. Tipulidae	9	49	627	737	78	8	4	10	2
2.2.2 Psychodiformia									
7. Psychodidae	19	25	117	154	47	21	5	2	3
8. Trichoceridae	3	8	31	31	89	19	2	2	3
9. Anisopodidae	3	6	9	14	75	44	1	3	3
10. Scatopsidae	18	20	79	87	88	5	1	0	4
11. Synneuridae	2	11	3	3	75	33	1	1	4
2.2.3 Ptychopteriformia									
12. Tanyderidae	2	3	4	4	80	50	3	2	3
13. Ptychopteridae	3	5	18	19	82	17	1	2	3
2.2.4 Culiciformia									
2.2.4.1 Culicioidea									
14. Dixidae	3	5	47	59	92	21	1	2	4
15. Corethrellidae	1	3	5	5	71	20	2	2	3
16. Chaoboridae	3	8	14	29	88	71	2	1	4
17. Culicidae	12	51	165	291	94	100	60	6	5
2.2.4.2 Chironomoidea									
18. Thaumaleidae	3	3	7	9	70	86	3	1	2
19. Simuliidae	11	35	159	213	53	69	7	7	2
20. Ceratopogonidae	37	92	595	597	53	5'	120	8	3
21. Chironomidae	177	270	953	1,130	38	31	12	9	2
2.3 Oligoneura									
2.3.1 Blephariceriformia									
22. Blephariceridae	4	7	25	35	89	88	3	3	5
23. Deuterophlebiidae	1	1	4	4	57	100	2	1	3
2.3.2 Bibioniformia									
24. Pachyneuridae	1	1	1	1	50	100	3	1	3
25. Hesperinidae	1	2	1	2	50	100	2	1	4
26. Pleciidae	2	3	3	6	75	33	3	1	4
27. Bibionidae	3	4	77	118	77	8	2	2	4
2.3.3 Sciariformia									
28. Ditomyiidae	2	4	6	8	75	17	2	1	3
29. Diadocidiidae	1	3	4	4	67	25	3	1	3
30. Keroplatidae	9	20	86	95	59	5	4	1	3
31. Bolitophilidae	1	3	20	22	77	10	3	1	3
32. Mycetophilidae	74	95	718	825	38	8	4	2	2
33. Lygistorrhinidae	1	1	1	1	20	0	1	1	4
34. Sciaridae	8	27	157	167	27	6	5	1	1
35. Cecidomyiidae	179	241	1,141	1,477	8	18	4	1	1
2.4 Brachycera									
2.4.1 Homoedactyla									
2.4.1.1 Xylophagiformia									
36. Xylophagidae	5	8	25	35	83	20	2	3	4

Table 1 (cont.)

DIPTERA OF AMERICA NORTH OF MEXICO - STATISTICS

Taxon Name	Genera Valid	Genera Names	Species Valid	Species Names	% Known Species	% Known Immatures	# Specialists World	# Specialists Nearctic	Status of Knowledge
2.4.2.2.2.2.4.2.3 Ephydroinea									
67. Drosophilidae	17	35	196	217	98	34	8	1	3
68. Camillidae	1	1	1	1	100	0	1	0	3
69. Curtonotidae	1	2	1	1	50	0	1	2	3
70. Campichoetidae	1	2	2	3	100	0	1	1	4
Ephydridae family group									
71. Diastatidae	1	3	8	9	57	0	1	2	4
72. Ephydridae	67	102	440	514	81	25	12	6	3
2.4.2.2.2.2.4.3 Nothyboidea									
73. Periscelididae	1	4	3	4	75	67	0	1	3
74. Psilidae	3	8	32	36	89	6	1	1	2
2.4.2.2.2.2.4.4 Muscoidea									
2.4.2.2.2.2.4.4.1 Tanypezoinea									
75. Tanypezidae	2	3	3	5	50	33	2	1	3
2.4.2.2.2.2.4.4.2 Calyptratae									
76. Scatophagidae	32	69	148	202	74	14	0	2	2
77. Anthomyiidae	35	93	523	697	84	6	6	1	3
78. Fanniidae	3	8	108	139	93	9	2	2	4
79. Muscidae	45	116	617	921	89	6	4	5	2
Tachinidae family group									
80. Calliphoridae	23	38	85	139	81	35	2	5	4
81. Oestridae	6	21	52	75	69	96	2	2	3
82. Sarcophagidae	97	157	358	452	85	28	2	2	2
83. Rhinophoridae	2	2	2	3	100	100	1	0	3
84. Tachinidae	327	793	1,340	1,733	77	7	3	5	1
85. Hippoboscidae	17	24	43	64	96	16	3	3	3
2.4.2.2.2.2.4.4.3 Micropezoinea									
86. Cypselosomatidae	1	1	2	2	67	0	1	0	3
Micropezidae family group									
87. Neriidae	2	4	2	4	67	50	1	1	3
88. Micropezidae	8	21	36	50	90	11	2	2	3
2.4.2.2.2.2.4.4.4 Diopsioinea									
89. Diopsidae	1	1	2	2	100	50	1	0	1
2.4.2.2.2.2.4.4.5 Sciomyzoinea									
90. Coelopidae	2	4	5	4	100	20	1	2	3
91. Dryomyzidae	4	11	11	17	85	36	1	2	3
92. Sciomyzidae	21	53	188	243	94	53	5	4	3
Sepsidae family group									
93. Ropalomeridae	1	1	1	1	20	0	1	1	3
94. Sepsidae	10	11	34	54	85	24	3	1	2
95. Cremifaniidae	1	1	2	2	67	50	2	1	4
2.4.2.2.2.2.4.4.6 Anthomyzoinea									
96. Heleomyzidae	31	43	152	163	87	10	3	1	3
97. Anthomyzidae	3	6	10	13	67	10	2	1	1
98. Asteiidae	6	6	19	21	63	0	1	1	3
99. Opomyzidae	3	5	12	14	80	25	1	2	4
100. Sphaeroceridae	40	66	199	243	66	5	3	5	2
101. Chryomyidae	3	3	9	10	60	0	0	0	2
102. Aulacigastridae	3	4	5	5	71	20	1	2	2

Table 1 (cont.)

Diptera of America North of Mexico - Statistics

Taxon Name	Genera Valid	Genera Names	Species Valid	Species Names	% Known Species	% Known Immatures	# Specialists World	# Specialists Nearctic	Status of Knowledge
2.4.1.2 Stratiomyiformia									
37. Xylomyidae	2	5	10	12	91	40	1	2	3
38. Stratiomyidae	42	73	259	384	93	12	3	4	2
2.4.1.3 Tabaniformia									
39. Rhagionidae	9	16	115	153	74	5	2	2	2
40. Pelecorhynchidae	2	3	8	9	80	25	2	0	3
41. Athericidae	2	2	4	4	100	25	2	1	4
42. Tabanidae	25	45	329	545	84	36	14	9	3
43. Vermileonidae incertae sedis	1	1	2	2	100	100	2	1	3
2.4.1.4 Nemestriniformia									
44. Acroceridae	7	13	61	79	76	5	1	2	2
45. Nemestrinidae	3	7	7	10	88	43	1	1	3
2.4.2 Heterodactyla									
2.4.2.1 Pleroneura									
46. Bombyliidae	62	104	904	1,096	60	2	4	2	3
47. Hilarimorphidae	1	1	27	27	90	0	0	1	4
48. Therevidae	28	40	139	157	66	7	4	3	2
49. Scenopinidae	6	8	128	131	91	1	0	1	4
50. Asilidae	97	131	1,011	1,211	80	2	4	6	2
51. Apioceridae	2	3	66	66	97	0	1	1	4
52. Mydaidae	7	8	48	59	96	2	2	1	3
2.4.2.2 Eremoneura									
2.4.2.2.1 Orthogenya									
53. Empididae	35	66	436	473	75	3	3	6	2
54. Hybotidae	25	38	287	314	76	1	4	5	2
55. Microphoridae	3	4	23	23	77	0	3	5	2
56. Dolichopodidae	55	86	1,293	1,469	81	1	3	3	1
57. Atelestidae	1	1	2	2	40	0	2	1	2
2.4.2.2.2 Cyclorrhapha									
2.4.2.2.2.1 Paracyclorrhapha									
2.4.2.2.2.2 Eucyclorrhapha									
2.4.2.2.2.2.1 Acroptera									
58. Lonchopteridae	1	2	4	5	100	25	1	0	3
2.4.2.2.2.2.2 Atriata									
2.4.2.2.2.2.2.1 Platypezidea									
59. Platypezidae	18	21	76	84	95	11	1	0	3
2.4.2.2.2.2.2.2 Phoridea									
60. Phoridae	52	71	393	450	52	9	3	3	3
2.4.2.2.2.2.2.3 Syrphidea									
61. Pipunculidae	8	12	117	153	59	3	4	0	3
62. Syrphidae	85	323	807	1,422	90	7	10	7	2
2.4.2.2.2.2.2.4 Schizophora									
2.4.2.2.2.2.2.4.1 Lonchaeoidea									
63. Lonchaeidae	9	9	126	131	63	10	1	2	2
64. Cryptochetidae	1	2	1	1	100	100	0	0	3
2.4.2.2.2.2.2.4.2 Lauxanioidea									
2.4.2.2.2.2.2.4.2.1 Lauxanioinea									
65. Lauxaniidae	29	38	157	275	79	6	2	2	2
2.4.2.2.2.2.2.4.2.2 Chamaemyioinea									
66. Chamaemyiidae	6	15	55	67	50	27	1	2	2

Table 1 (cont.)

DIPTERA OF AMERICA NORTH OF MEXICO - STATISTICS

Taxon Name	Genera		Species		% Known		# Specialists		Status of
	Valid	Names	Valid	Names	Species	Immatures	World	Nearctic	Knowledge
2.4.2.2.2.2.2.4.4.7 Agromyzoinea									
103. Clusiidae	4	8	37	44	86	11	1	1	3
104. Agromyzidae	32	44	732	830	80	4	12	2	3
2.4.2.2.2.2.2.4.4.8 Tephritionea									
105. Odiniidae	3	3	11	11	79	27	2	1	3
106. Tethinidae	5	7	26	28	72	0	1	2	2
107. Canacidae	4	5	6	6	86	17	1	1	3
Chloropidae family group									
108. Acartophthalmidae	1	1	2	2	100	0	1	0	3
109. Carnidae	3	4	15	20	65	20	1	1	3
110. Milichiidae	12	22	44	50	59	9	1	1	2
111. Chloropidae	53	74	282	367	53	4	3	2	1
112. Conopidae	9	15	68	143	97	9	2	1	3
Tephritidae family group									
113. Richardiidae	6	6	10	12	71	10	0	1	3
114. Piophilidae	15	17	40	54	73	25	1	0	4
115. Pallopteridae	3	3	9	9	53	0	0	0	3
116. Otitidae	42	66	134	165	89	4	3	3	2
Tephritidae									
118. Tephritidae	53	83	297	368	85	34	6	8	3
119. Platystomatidae	4	6	41	45	82	0	3	3	2
120. Pyrgotidae	5	5	8	15	89	25	1	2	3
2.4.2.2.2.2.2.4 Schizophora incertae sedis									
121. Braulidae	1	1	1	1	100	100	1	1	3
TOTALs	2.356	4.405	19.562	24.485	47	2			

Region (1,141 species currently described), an estimate based on the assumption that gall midges are host specific (monophagous) (see Gagné 1983: 9-11, 1989: 15). If gall midges are ignored, then the estimate of percentage-fauna-known increases to about 68%. 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 characters of the male genitalia. 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 (1948-52) and for those of higher flies by Ferrar (1987). About 98%, or all families except Culicidae and Blephariceridae, need revision. To produce a more meaningful measure of the status of our knowledge of Diptera of America north of Mexico, I have defined 6 levels of taxonomic knowledge based on comprehensiveness and quality of publications.

Level 0 - Species descriptions only.

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.

Figure 3

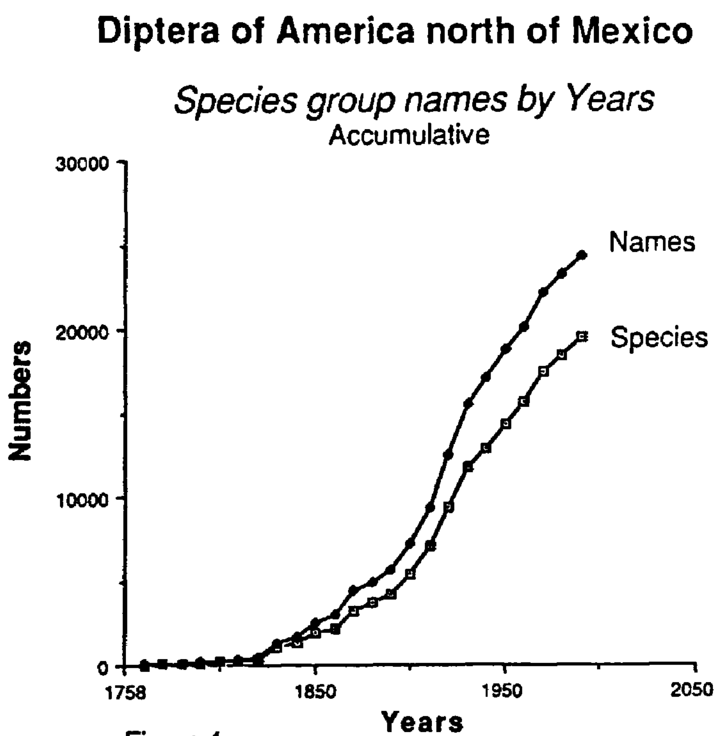

Figure 4

Level 2 - Keys to some (about 50%) species. Keys reliable, based on non-variable characters (such as male genitalia) and usually illustrated.

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: Pratt & Pratt (1980), Vockeroth (1986), Thompson (1981).

Level 4 - Revisions. Taxon revised, with keys to most or all adults; all species redescribed; nomenclature, types and literature revised. Examples: Michelsen (1988), Mathis (1982), Brown (1987); Thompson (1980), Griffiths (1982-84).

Level 5 - Monographs. Same as revisions, but immature stages also covered. Example: Hogue (1973, 1987).

Level 4 and 5 are very similar, but differ only in comprehensiveness. The work of Griffiths (1982) 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. When our knowledge of Diptera of America north of Mexico is viewed in terms of these levels (Fig. 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 two families of North American flies have been effectively treated, the mosquitoes and net-winged midges!

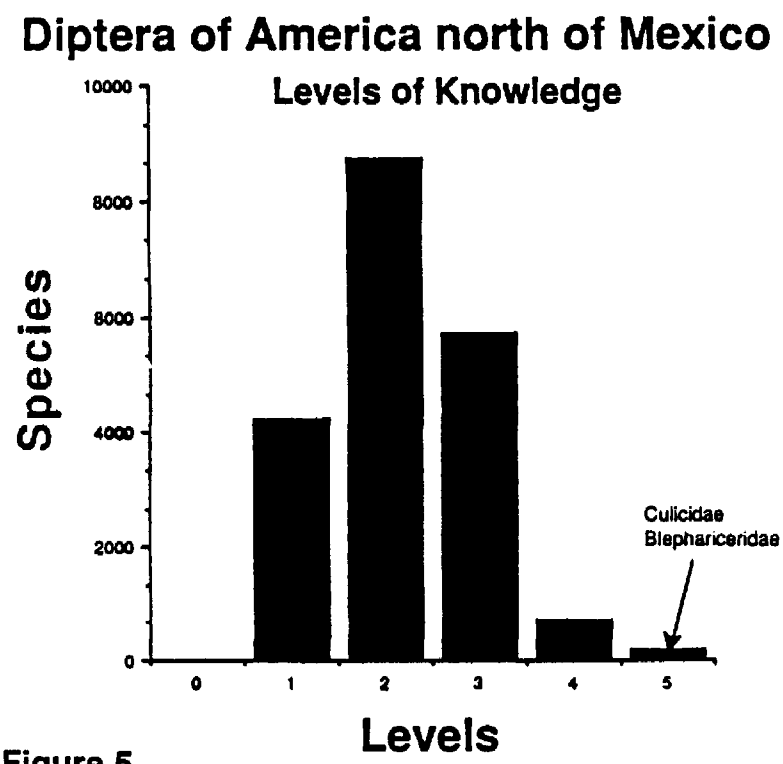

Figure 5

Our knowledge of Diptera phylogeny is good: The sister group of Diptera is almost certainly a mecopteran, probably phenetically and cladistically related to Nannochristidae; the major monophyletic groups of flies have been blocked out; within the grade "Nematocera," the relationships among the family group taxa have been largely deciphered [The two competing theories (Griffiths 1987; Wood & Borkent 1989) differ only on the interpretation of a few characters]; within the grade "Brachycera," the major monophyletic clusters have been identified (Woodley 1989), but much needs to be done to define monophyletic families; among the cyclorrhaphous flies, monophyletic families have been defined by greatly restricting the scope of these taxa, so much still needs to be discovered to cluster these microfamilies. While the classification of the Diptera of America 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 concept of the pupiparous Diptera. Under a cladistic approach as used here,[1] 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 higher (Schizophora) flies (Fig. 6)!

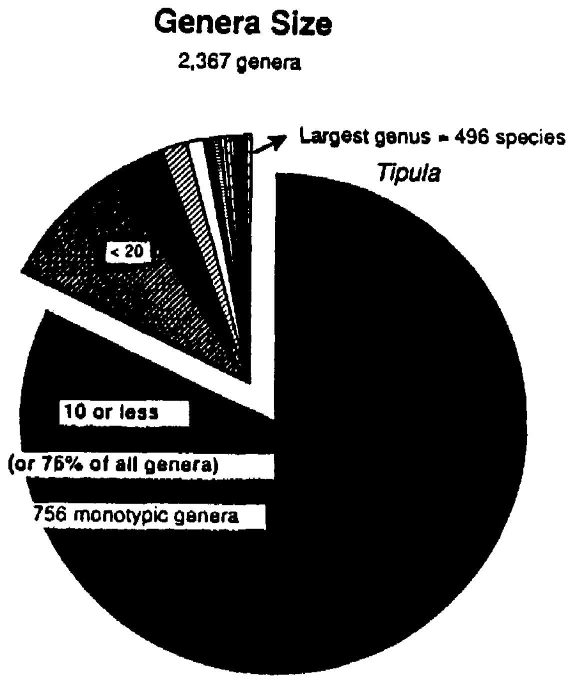

Figure 6

[1]The cladistic approach implemented requires that all taxa be monophyletic and of at least Cretaceous in 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) and Griffiths (1972, MS); other sources are Oostebroek (1986), Krivosheina (1969, 1986), Matile (1986), Chvala (1983), and D. K. McAlpine (1985). The conventions used follow Wiley (1981) and Griffiths (1972).

On morphology and terminology, North American dipterists have adapted the treatment given in the nearctic Manual (McAlpine, J. F. 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, 1984a).

Resources--Literature

The current literature resources for Diptera are excellent. Our research program has been and is based on three interrelated core publications (Fig. 1): catalogs, manuals, and monographs. Catalogs are the indexes to the diffuse literature of keys, descriptions, and biological data; manuals are the keys to the smallest operational taxonomic group (that is, the genus); and monographs are the ultimate syntheses of all that is known about a taxonomic group, usually a family or subfamily. Today, these categories of publications are represented by the Manual of Nearctic Diptera (McAlpine et al. 1981-89), the Flies of the Nearctic Region series, and the Catalog of the Diptera of America north of Mexico (Stone et al. 1965), which will shortly be superceded by the Systematic Database of Nearctic Flies (Thompson, in prep.). The fascicle on Blephariceridae (Hogue 1987) in the Flies of Nearctic Region series is, without a doubt, the best example of a monographic treatment of a nearctic insect group. Similarly, the Manual of Nearctic Diptera represents the best ordinal treatment of any insect group for any region in the world. However, the new Systematic Database of Nearctic Flies will not be 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); comprehensive character surveys (Ferrar 1987); 2) identification aids (Darsie & Ward 1981 or Spencer & Steyskal 1986); 3) regional treatments (Wood et al. 1979); 4) type collection listings (Arnaud 1979); 5) annotated bibliographies (West & Peters 1973); and 6) biographies (Shor 1971) with technical summaries (Arnaud & Owen 1981). These examples are the best of their genre; comprehensive listings of literature resources for Diptera of America north of Mexico are found in the Manual and the Catalog.

The area where dipterists lag behind their colleagues is in journals. We do not have a society as the coleopterists or lepidopterists do, and, hence, there are no special journals devoted exclusively to Diptera (but narrowly, there are some devoted to only mosquitoes!). We also have very few international newsletters as compared to the hymenopterists, for example (Bullock 1988). However, we are improving. This spring a new Nearctic Diptera Society will hold its first meeting in Florida.

What of the future? Literature has always been one of the major stumbling blocks for systematics, as the International Code of Zoological Nomenclature (ICZN 1985) has enshrined priority as its basic operating principle. The future is bright as this stumbling block will be removed forever by advances in technology and changes in our Code. Technology such as xerography now allows anyone to have an exact copy of any original publication, if they know where a copy exists. 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 of large volumes of information, such as compact disk read-only memory (CD-ROM), mean that future publications will be inexpensive and easy to use. For example, Die Fliegen der Palaearctic Region (Lindner 1924), which runs to over 16,000 pages, would cost approximately $960,000 to be printed at today's publication costs, and sells for about $3,000 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 1/4 inch disk!! The only hope for completing an inventory of our biota is to use new technologies! This is also now recognized by the ICZN. At the recent meeting of the Section on Zoological Nomenclature of the International Union of Biological Sciences at Canberra (ICZN 1989, IUBS 1989), there was virtually unanimous approval to do away with those aspects of the Code that retard our science. In terms of literature, this means drawing a new starting line to eliminate the unproductive and costly searching for old names. Time and space do not permit me to go into details, but, in essence, we may well follow the example of bacteriology and develop a registration system for names (Ride & Younes 1986: 70).

Resources--Collection

Detailed statistics are not available for the Diptera holdings of various collections. A survey to accumulate such statistics is underway (Evenhuis and Thompson, in prep.). Type depository data has been included in the Systematic Database of Nearctic Flies for some names. Preliminary analysis [based on a sample of 6,753 species group names out of a total of 24,485 names] suggests that, for types, the major depositories are: 1) the United States National Collection (USNM, 2,625 [acronyms follow those of Flies of Nearctic Region series (Griffiths 1980: viii-xiii)]); 2) Canadian National Collection (CNC, 995); 3) the California Academy of Sciences (CAS, 424); 4) the British Museum of Natural History (BMNH, 389) and 5) the Museum of Comparative Zoology (MCZ, 363). After these collections, the following have large holdings of types: American Museum of Natural History (AMNH, 167); Academy of Natural Sciences (ANSP, 240); Illinois Natural History Survey (INHS), University of Kansas (UKaL) and Cornell University (CU). Many foreign museums, especially those in Paris (MNHN, 108), Copenhagen (UZMC), Vienna (NMW), Berlin (ZMHU, 117), Stockholm (106) and Lund (ZIL), 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 America north of Mexico. Once the Museum of Comparative Zoology (MCZ) had this honor. One hundred years ago, the MCZ had the best fly collections, but today it rctains 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 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 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.

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, and the Red Hills in Alabama. Unfortunately, given the history of declining support for surveys and museum programs, the prospects of obtaining the necessary material seem dim.

Resources--Human

Some 777 people have contributed to our knowledge of Diptera of America north of Mexico; the major contributors are listed in Figs. 7-8. Today, we know some 347 people working on Diptera of America north of Mexico (out of a data file on some 1,536 workers world-wide). 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).

Entomologists, who are not employed to do systematic work (51).

University-based systematists, who may also be required to teach, do extension work, and/or curate (37).

Museum-based systematists, who also may be required to curate and do identifications (24).

Retired entomologists, who devote much of their time to systematics (35).

For the remainder (192), insufficient data were available to classify them in one of the above groups [The respondents were not asked about their occupations, only about their interests!].

Unfortunately, no data are available on the amount of time spent on 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 of time. Productivity varies widely among systematists; 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 systematists have described fewer than 100! So, the measure of man-years will not translate to what we really want to know, which is how much research is being done. How much research is being done is best measured by quantity of research results -- the number of genera, species, and names published (Figs. 9-10). 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. However, while quantity of taxa described has decreased, the quality of the work has increased, that is, the percentage of taxa that are valid.

The future for human resources in Diptera is poor. We are not training many new dipterists. We have lost by retirement those key teachers, such as Alexander of Massachusetts, Berg of Cornell, Byers of Kansas, Cook of Minnesota, Schlinger of California, Hardy of Hawaii, who had trained this generation of dipterists. Only Steve Marshall of Guelph, Monty Wood of the Biosystematics Research Centre in Ottawa, and the Maryland Center for Systematics utilizing the dipterists in Washington, have active programs for training dipterists. The future of the program at the University of Alberta, where George Ball worked with Doug Craig and Graham Griffiths to train a core of dipterists, is uncertain pending George's replacement. No short courses are offered in Diptera systematics.

Research Program

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

Diptera of America North of Mexico
Leading Specialists

Specialist	Names	% Valid
Loew	1,292	80
Alexander	1,249	93
Coquillett	1,044	76
Felt	1,018	76
Malloch	878	73
Melander	730	61
Walker	797	92
Curran	680	65
Van Duzee	641	81
Osten Sacken	467	87

(777 authors in total)

Figure 7

Diptera of America North of Mexico
Top Ten Living Specialists

Specialist	Names	% Valid
Huckett	404	87
Wirth	320	100
Sabrosky	168	96
Steyskal	164	90
Harmston	156	94
Saether	150	87
Hardy	144	86
Griffiths	114	97
Gagne	113	94
Townes	108	99

Figure 8

The columns in figures 7 & 8 are: **Specialist** = last name of person; **Names** = the total number of Nearctic species group names proposed by the specialist; **% Valid** = the percentage of these names that are currently considered valid.

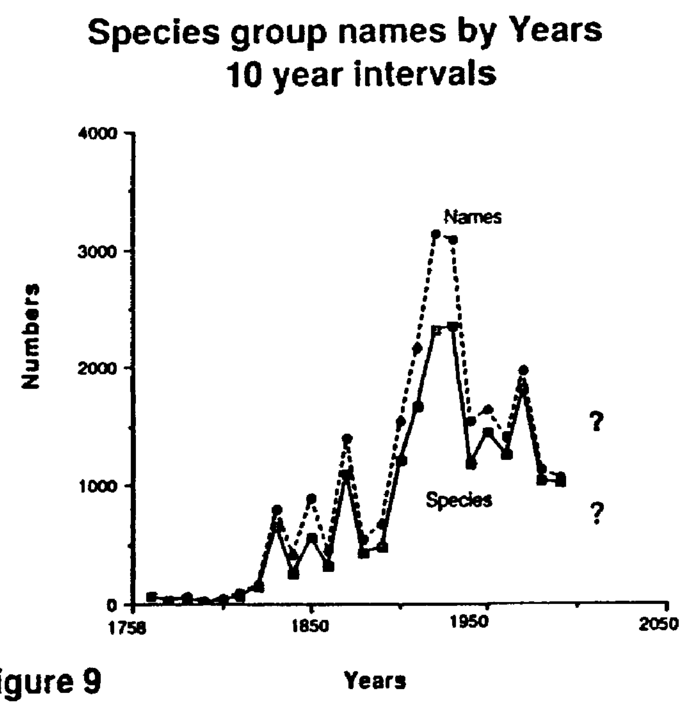

Figure 9

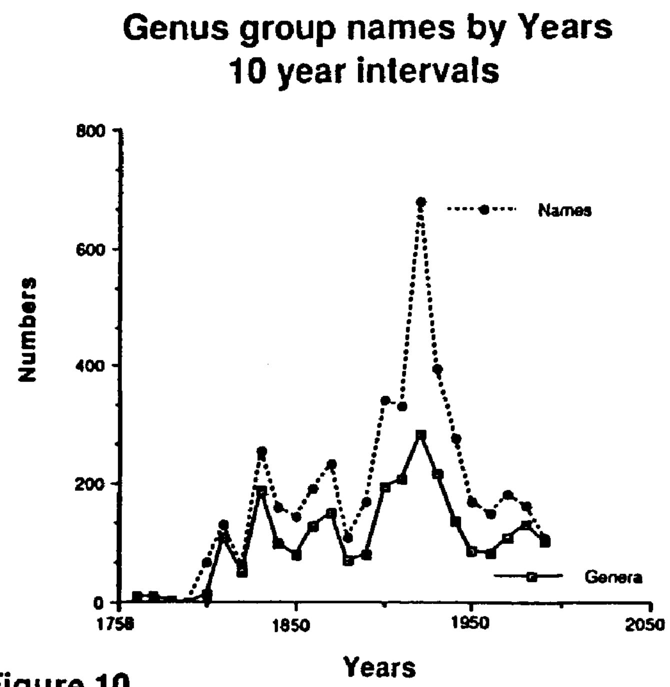

Figure 10

and distribution of results. We should be using more automated tools in our research: for example, simple word processing to sophisticated data analysis (PAUP, Hennig 86) and presentation (DELTA) software (see Thompson in Knutson et al. 1987). We should also not forget who supports our research and should provide our results in user-friendly interactive "expert" systems so all can obtain biosystematic information directly. At the Systematic Entomology Laboratory, we are developing a prototype Biosystematic Information Database and Expert System to demonstrate the increased productivity for scientists and greater accessibility for users that the integration of these new technologies will bring.

Priorities. What taxa should be studied first and what taxa should be ignored? Most families of flies require urgent, priority work, as only Culicidae and Blephariceridae 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, 1987b, 1988) stated, an essential humanistic goal, and the time remaining to complete this task is short due to the rapid deterioriation of the environment. To set priorities, one needs criteria. Given that the only appropriate goal is a comprehensive knowledge of our biota, the criterion for deciding which taxon deserves the highest priority for revision is which is most threatened by extinction. Unfortunately, we don't 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 revisional 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 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!

Environmental effects. Is there any evidence that flies are affected by acid rain or other air pollutants? 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 three questions can not be answered readily 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, then Diptera are affected. 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 been on this 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, among the flower flies, the species (*Ocyptamus parvicornis* Loew) has been proposed as an endangered species (Weems, in litt.). Why? Because it has been collected rarely! That, however, is an artifact. Flower fly workers usually collect during the day and at flowers. This species apparently is nocturnal, as I have seen it in APHIS-PPQ light trap surveys from the Miami area. The life history of the fly is now known. The species predates mealybugs on lignumvitae (Eisner, in litt.), so a proper survey of its populations could be made easily.

Summary

Today, the study of Diptera of America north of Mexico is at a turning point. An assessment and basic synthesis of our knowledge of flies has been completed. What we know about flies is embodied in our database and the Manual. About two-thirds of all the flies estimated to occur in America north of Mexico have now been named. Unfortunately, less than one percent of these flies is treated comprehensively in monographs and less than a quarter has been throughly revised. To complete the task, a full and comprehensive inventory of the flies of America north of Mexico will require the utilitization 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 8 "Alexanders" (560 SYs) to finish the job of just naming the flies of America north of Mexico!

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