The Insect (Insecta) Fauna of Plummers Island, Maryland: Brief Collecting History and Status of the Inventory

Author(s): John W. Brown and Stephen M. Bahr II
Source: Bulletin of the Biological Society of Washington, 15(1):54-64.
Published By: Biological Society of Washington
DOI: http://dx.doi.org/10.2988/0097-0298(2008)15[54:TIIFOP]2.0.CO;2
URL: http://www.bioone.org/doi/full/10.2988/0097-0298%282008%2915%5B54%3ATIIFOP%5D2.0.CO%3B2

The Insect (Insecta) Fauna of Plummers Island, Maryland: Brief Collecting History and Status of the Inventory

John W. Brown and Stephen M. Bahr, II

(JWB) Systematic Entomology Laboratory, P.S.I., Agricultural Research Service, U.S. Department of Agriculture, % National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, Washington, D.C. 20013-7012, U.S.A., e-mail: john.brown@ars.usda.gov;
(SMB) Department of Entomology, Texas A&M University, College Station, Texas 77843, U.S.A.

Abstract.—Plummers Island, a small site situated along the northern shore of the Potomac River in Montgomery County, Maryland, has been the research home of the Washington Biologists' Field Club for more than 100 years. Field work conducted by club members from 1901 to about 1925 resulted in the accumulation of thousands of insect specimens of all orders from the Island, most of which are deposited in the collections of the National Museum of Natural History, Smithsonian Institution. Little collecting was conducted from ca. 1930–1950. In the 1960s sampling by Karl Krombein focused on bees and wasps and that by Terry Erwin on carabid beetles. Since 1998 the Lepidoptera fauna, leaf beetles (Chrysomelidae), and darkling beetles (Tenebrionidae) all have been the subject of investigations. In 2005 and 2006 Malaise traps were deployed to sample other orders (e.g., Trichoptera, Diptera, Hyemenoptera). While the four major insect orders (i.e., Coleoptera, Diptera, Lepidoptera, and Hymenoptera) are represented by large numbers of historical specimens, only Lepidoptera have been surveyed thoroughly in recent times; notable exceptions include specific families: carabid beetles, leaf beetles, darkling beetles, sawflies, and bees and wasps. Based on an examination of the insect collection of the National Museum of Natural History and a review of relevant literature, we document 3012 insect species in 253 families, encompassing 18 insect orders: Collembola, Odonata, Dermaptera, Blattodea, Phasmatodea, Orthoptera, Psocoptera, Thysanoptera, Hemiptera, Neuroptera, Megaloptera, Coleoptera, Mecoptera, Trichoptera, Lepidoptera, Diptera, Siphonaptera, and Hymenoptera.

Key words.—Inventory, historical records, Washington Biologists' Field Club, Chesapeake and Ohio Canal National Historical Park, species turnover.

Over the last few decades it has become increasingly clear that active management of natural lands is essential for the maintenance of ecosystem viability and the preservation of the indigenous biota, and this is particularly true for native habitats adjacent to or surrounded by urbanization or other developed lands. In other words, intervention frequently is necessary to mitigate the negative impacts of habitat fragmentation, invasive species, diminishing air and water quality, and other types of ecological maladies. Management of natural lands begins with an understanding of what organisms are present; hence, inventories represent a critical first step in this process.

The Washington Biologists' Field Club was founded over a century ago with the goal of encouraging the study of natural history in the Washington, D.C. area. One of the primary objectives of the Club was to compile a thorough inventory of the Club's ''research station''—Plummers Island, a small site located along the northern edge of the Potomac River in Montgomery County, Maryland (Shetler et al. 2006). Since 1901, tens of thousands of specimens from the Island have accumulated in the collections of the National Museum of Natural History (USNM), Smithsonian Institution through field work by club members and other local biologists. A sign on the Island proudly boasts ''. . . the most thoroughly collected island in North America . . .'' Although the site may be ''the most thoroughly collected,'' the data for exceedingly few insect families have been compiled and evaluated, e.g., wasps (Krombein 1963b), carabid beetles (Erwin 1981), chrysomelid beetles (Staines 2004), and leaf-roller moths (Brown 2001).

Under contract to the U.S. National Park Service,

Figs. 1–6. Early entomologist members of the Washington Biologists' Field Club. 1, William H. Ashmead; 2, Waldo L. McAtee; 3, Raymond C. Shannon; 4, August Busck; 5, Herbert S. Barber; 6, Eugene A. Schwarz.

an inventory of insects collected on Plummers Island present in the USNM was undertaken in 2003–2004. We searched for and databased specimens of focal groups (i.e., Lepidoptera, Coleoptera, Diptera, Hymenoptera, and Heteroptera) collected on the site (which includes the Island proper and the adjacent mainland property south of the historic Chesapeake and Ohio Canal). Owing to budgetary constraints and the limited scope of the contract, the inventory of the USNM collection was far from comprehensive. For example, in Hymenoptera the Symphyta, bees, and wasps were inventoried, but ants and families of small Hymenoptera or Parasitica (e.g., Braconidae, Chalcidoidea) were not. Likewise, owing to the tremendous diversity of the order Coleoptera, only a few families were inventoried. Although the data for other families in these two orders are available in the collection, they have not yet been compiled. In addition to the collection-based inventory, we also investigated the primary literature for records of insects collected on Plummers Island.

The purposes of this report are to provide a brief history of insect collecting activities on the Island and brief synopses by order of the results of our collection- and literature-based investigations. A list of the species recorded from the Island is included as an appendix to this volume in which species described from the Island are indicated by an asterisk. The sequence of orders follows Triplehorn & Johnson (2005).

Brief History of Insect Collecting

Among early members of the Washington Biologists' Field Club were several prominent entomologists (e.g., William H. Ashmead, August Busck, Waldo L. McAtee) and many avid field collectors. Among the most active field workers were Herbert S. Barber, August Busck, Waldo L. McAtee, Eugene A. Schwarz, and Raymond C. Shannon (Fig. 1, Table 1), most of whom collected insects of numerous orders, not just their specialties. Brief biographies of these early entomologists can be found in Perry (2007). Field work from 1901 to about 1925 resulted

in the accumulation of thousands of insect specimens from the Island, most of which are deposited in the collections of the USNM. Field activities waned by the late 1920s, with little or no collecting in the 1930s, 1940s, and 1950s. The 1960s and 1970s saw an increase in insect sampling, primarily by Karl Krombein (bees and wasps), Paul Spangler (beetles), and Terry Erwin (beetles). In the 1980s and 1990s collecting activities again waned, although Ronald McGinley and Beth Norden continued in Krombein's footsteps, sampling the bee and wasp fauna during several visits, and Robert L. Orr conducted field studies on the dragonflies and damselflies. In the late 1990s and early 2000s, Charles Staines conducted field work on the Island focused primarily on leaf beetles, as did Warren Steiner, focused on darkling beetles. Since 1998, John Brown and Michael Pogue have sampled the Lepidoptera fauna using blacklight traps (>50 nights). Most recently (2005 and 2006) Malaise traps have been deployed by John Brown and David Smith to sample other orders. Brown (2008) provides additional details on some aspects of the entomological history of the Island.

Because of the highly uneven sampling over the last 100 years, many groups are well represented by historical specimens but with few recent records (e.g., Diptera, Heteroptera, most Coleoptera), whereas in other groups recently collected material now outnumbers historical specimens (e.g., Odonata, Lepidoptera, Trichoptera). In a few groups, coverage is nearly even (e.g., Hymenoptera). Some groups have received virtually no attention (e.g., Ephemeroptera, Plecoptera).

Ordinal Accounts

Entognatha and Apterygota

The Entognatha (formerly considered to be insects) include Protura, Collembola (springtails), and Diplura, and the Apterygota (primitively wingless insects) include the Microcoryphia (bristletails) and Thysanura (silverfish). It is likely that these groups have been sampled on Plummers Island, especially as Collembola are among the most dominant arthropods in number and biomass in litter and soil, but specimens have not been studied. We discovered a single report of a collembolan by Hale (1972).

Order Ephemeroptera

Mayflies are soft-bodied insects with two or three threadlike cerci or tails. Larvae or naiads occur in a variety of aquatic habitats, and the Potomac River undoubtedly supports a rich fauna of mayflies. While there is no question that the USNM collection harbors numerous specimens of this order from the site, no one has studied the mayflies from Plummers Island in the collection, and we present no records.

Table 1.—Most prolific insect collectors on Plummers Island based on label data from specimens databased in USNM collection, listed chronologically (* frequently collected together so label data are "Barber and Schwarz"). Numbers based on data-mining efforts at USNM, so not comprehensive.

Collector	Years	# Specimens	Orders
A. Busck	1901–1920	1,150	Lepidoptera
H. Barber*	1902–1925	2,000	Coleoptera, Diptera, Heteroptera, Lepidoptera
E. Schwarz*	1903–1923	1,000	Coleoptera, Diptera, Hymenoptera, Lepidoptera
W. McAtee	1906–1919	3,350	Diptera, Heteroptera, Coleoptera
R. Shannon	1913–1917	2,200	Diptera, Coleoptera, Lepidoptera
K. Krombein	1957–1971	4,000	Hymenoptera
P. Spangler	1960–1972	760	Coleoptera, Heteroptera
D. Davis	1963–1972	500	Lepidoptera
T. Erwin	1974–1976	500	Coleoptera
J. Brown	1998–2005	2,250	Lepidoptera
M. Pogue	1999–2004	1,300	Lepidoptera

Order Odonata

Odonata include the dragonflies and damselflies. All North American species are predaceous as larvae and adults, feeding on insects and other small organisms. While the naiads are entirely aquatic, adults are conspicuous aerial predators. Owing to the aquatic lifestyle of the early stages, Odonata may be useful indicators of water quality under certain circumstances.

Odonata of Plummers Island were studied by Orr (1994, 1995) who documented 8 families: Aeshnidae, Calopterygidae, Coenagrionidae, Cordulegastridae, Gomphidae, Lestidae, Libellulidae, and Petaluridae. Orr's field work was conducted in 1994 (12 trips) and focused on immatures as well as adults. Some historical data on the Odonata fauna also can be gleaned from Donnelly (1961).

A database of the Odonata in the USNM collection includes records of 53 specimens. Based on all available sources (i.e., Donnelly 1961; Orr 1994, 1995; USNM database), 45 species in 27 genera, representing 8 families of Odonata are documented from the Island. The Odonata data are highly biased towards the 1990s, largely reflecting Orr's work on the site. Orr (1995) concluded that Plummers Island supports about 53% of the Odonata known from the general area, so additional sampling likely would increase the number of species. Orr also noted that 6 species collected historically were not found during his 1994 surveys.

Order Blattodea

Blattodea include the cockroaches and formerly were treated as a suborder or superfamily of Orthoptera (e.g., Borror et al. 1976). These insects are rec-

ognized by a distinctive oval, flattened shape with the head usually concealed under the pronotum. Our knowledge of the Blattodea of Plummers Island is based on a single older paper by McAtee & Caudell (1917), who listed 5 species of roaches in 2 families.

Order Phasmatodea

Phasmatodea include the walking sticks, also formerly treated as a suborder of Orthoptera (e.g., Borror et al. 1976). These insects are easily recognized by their resemblance to sticks, twigs, or leaves, from which they derive protection in the form of crypsis. Our knowledge of the walking sticks of the Island is based on the report by McAtee & Caudell (1917), who provided records of 2 species in 1 family.

Order Orthoptera

Orthoptera include grasshoppers, katydids, crickets, and relatives. One of the first published records of this order from Plummers Island is McAtee's (1908) detailed description of the behavior of the leaf-rolling cricket *Camptonotus carolinensis* (Gerstaecker) with illustrations of its shelter. A comprehensive treatment of the Orthoptera of Plummers Island was presented by McAtee & Caudell (1917), who cited numerous published references to specimens from the site. The 63 species in 8 families included by McAtee & Caudell (1917) are listed in the appendix of this volume. During recent survey efforts, two specimens of an unidentified Tetrigidae and several Tettigoniidae were collected in Malaise traps; we have no additional recent records.

Order Dermaptera

Dermaptera (earwigs) are easily recognized by the forcep-like cerci that extend posteriorly from the abdomen. While a few species are predaceous, the majority of earwigs feed on dead and decaying vegetable matter and living plant material. Although the USNM Dermaptera collection is fairly extensive, we found only one species represented by specimens from Plummers Island—*Labia minor* (Linnaeus); the same species was reported from Plummers Island by McAtee & Caudell (1917).

Order Plecoptera

Stoneflies are medium-sized, soft-bodied insects commonly encountered near streams and lakes. The aquatic larvae are somewhat elongate and flattened, with long cerci. Although the order has been sampled on Plummers Island, with specimens collected in blacklight and Malaise traps, the material has not yet been studied.

Order Psocoptera

Psocoptera are small, soft-bodied insects commonly known as psocids or barklice. Wingless species that occur in houses and other buildings are known as booklice. In outdoor situations they feed on mold, algae, and pollen; in urban settings they feed on paper (books) and other organic substances. While the USNM collection contains many specimens of psocids from Plummers Island (3 families, 16 species), all are from the first part of the 20th century. It is highly likely that many of the previously recorded species are still present on the site, but there have been no recent collections to document the current psocid fauna.

Order Thysanoptera

The order Thysanoptera is comprised of minute, slender-bodied insects known as thrips. Most thrips are plant feeders, attacking flowers, leaves, fruit, twigs, or buds, but some are predaceous on mites and other small arthropods. Our knowledge of the thrips fauna of Plummers Island is based on a single report by Hood (1917), who presented records of 57 species from the Island and an additional 12 species from nearby (e.g., Cabin John, Great Falls). Of the 57 species reported from the site, 9 were described from the Island.

Order Hemiptera (Suborder Heteroptera)

The suborder Heteroptera, commonly known as true bugs, is a large and diverse group. Adults and nymphs are equipped with piercing-sucking mouthparts that are used for plant-feeding and predation on a variety of organisms ranging from other insects to mammals. Life styles, likewise, are diverse from aquatic to terrestrial. We documented 209 species in 31 families of true bugs from the USNM collection and databased 3277 records; most of the specimens were collected by Herbert Barber, Waldo McAtee, Eugene Schwarz, and Paul Spangler. There are no published reports of species from the site, except for the mention of an aphid predator by Leonard (1966). Recent Malaise trap sampling yielded small numbers of true bugs, but they have not yet been studied.

Order Hemiptera (Suborders Auchenorrhyncha and Stenorrhyncha)

Previously treated as the order Homoptera, Auchenorrhycha and Stenorrhyncha now are considered suborders of Hemiptera. They include the soft-bodied and slow moving groups, such as aphids, whiteflies, and scale insects, and the more active hoppers, such as spittlebugs, leafhoppers, planthoppers, and cicadas. Although we captured no data on Homoptera from the USNM collection, we include in the appen-

dix the aphids reported from Plummers Island by Leonard (1966, 1968), the membracids listed by McAtee (1921), the cercopids or spittle-bugs reported by McAtee (1920), and the cicadas documented by McAtee (1927). These sources combined include records of 98 species of Auchenorrhyncha and Stenorrhyncha.

Order Neuroptera

Neuroptera are comprised of lacewings, antlions, owlflies, and a few other small groups. The order contains mostly predaceous species, including one family that feeds on freshwater sponges (i.e., Sisyridae), but one family is parasitic (i.e., Mantispidae). This order is treated in detail by Flint (2008b) who documents 9 species in 8 genera and 4 families.

Order Megaloptera

The Megaloptera includes dobsonflies, fishflies, and alderflies, formerly included in Neuroptera. Dobsonflies are large insects with aquatic larvae in streams and rivers known as helgrammites; alderflies are much smaller, usually dark colored, and also aquatic as larvae; and fishflies have aquatic larvae that live in ponds, lakes, and backwaters of streams. Flint (2008b) presents records of 1 species of Sialidae (alderflies) and 5 species of Corydalidae (dobsonflies and fishflies) collected in 2004 and 2005.

Order Coleoptera

Coleoptera, the beetles, are the largest and most diverse order of insects, including approximately 40% of the described species in the class Insecta. The order has invaded virtually every terrestrial habitat and microhabitat, and many families have radiated into aquatic situations as well. Their feeding habits include scavenging, plant-feeding, predation, fungivory, and parasitism. Beetles vary in size from less than a millimeter to over 15 centimeters in length. The forewings are modified into a pair of thickened covers called elytra, which function as a protective sheath.

We captured records of only 16 families of Coleoptera (ca. 5200 database records), probably representing less than 25% of the families present on Plummers Island. We documented 600 species in the 16 families. Three families have been studied thoroughly on the Island, based on historical records as well as recent field work: Carabidae by Erwin (1981), Chrysomelidae by Staines (2004), and Tenebrionidae by Steiner (2008). Staines (2008a, b, c, d, e, f) presents synopses of several families (i.e., Cerambycidae, Chrysomelidae, Coccinellidae, Dytiscidae, Hydrophilidae, and Silphidae) based primarily on the historical holdings of the USNM.

The majority of beetle families are represented by moderate samples from 1900–1925, but with few or no records from recent times. The greatest shortcomings in the Plummers Island database for Coleoptera are the total absence of some major families (e.g., Elateridae, Buprestidae), the superficial coverage of others (e.g., Scarabaeidae, Staphylinidae, Curculionidae), and the paucity of recent records for most.

Material from Plummers Island has been used in numerous revisions and other published treatments on Coleoptera, both historical and contemporary, including Barber (1951) (Lampyridae), Spangler (1962) (Dytiscidae), Jeannel (1963) (Carabidae), Karren (1966) (Chrysomelidae), Butte (1968a, b, c) (Chrysomelidae), Smetana (1974, 1978, 1980, 1985) (Hydrophilidae), Perkins (1981) (Hydraenidae), Peck (1982) (Leptinidae), Hoffman et al. (2002) (various families), Staines & Staines (1999) (Chrysomelidae), Steiner (2000) (Cerophytidae), and others.

Order Mecoptera

The small order Mecoptera is comprised of the scorpionflies, which are characterized by males having an upturned, curled abdomen, giving the body a somewhat scorpionlike aspect. Flint (2008a) presents records of 5 species in 2 families based on the USNM collection. While there are historical records for 4 of the 5 species, we have recent records of only 2, almost certainly the result of collecting bias rather than changes in the fauna.

Order Trichoptera

The Trichoptera, commonly known as caddisflies, are the sister group to Lepidoptera. Caddisflies have aquatic larvae, which include net-spinning and case-building larvae, with cases of varying architecture built from bits of leaves, twigs, sand grains, small pebbles, and other materials. Most case-making larvae are plant-feeders, but many of the net-spinners are filter feeders on fine particulate organic matter. Adults are attracted to light and can be sampled reliably using blacklight and Malaise traps. The data on this order are based on a limited amount of blacklight collecting in the summer and fall of 2004 and 2005, and Malaise traps deployed from April through September 2005. Flint (2008c) presents records and discussions of 28 species in 8 families.

Order Lepidoptera

Lepidoptera, comprised of the butterflies and moths, are one of the four largest orders of holometabolous (groups that undergo complete metamorphosis) insects. Nearly all North American species are phytophagous or plant feeding, but a few specialize on fungus and/or detritus. Owing to their plant-feed-

ing habits, many species are pests of crops, ornamentals, and forest trees. Species such as the gypsy moth (*Lymantria dispar* Linnaeus) may elicit control measures that have an adverse affect on other biotic elements.

Because many Washington Biologists' Field Club members have been interested in Lepidoptera, both historically and in recent times, the USNM collection is extraordinarily rich in specimens of this order. Records from numerous moth families are scattered throughout the taxonomic literature (e.g., Busck 1906a, b, 1907a, b, 1908, 1909; Busck & Heinrich 1922, Heinrich 1923, 1926, 1956; Clarke 1941, Hodges 1964, 1969; Adamski & Hodges 1986), and many species were described from series of specimens collected either entirely or in part on Plummers Island. Tortricidae (Brown 2001), Nolidae, Erebidae, Noctuidae (Pogue 2008), Limacodidae (Lill 2008), Crambidae, Pyralidae (Solis 2008), and the butterflies (Vann 2008) have been investigated on the site.

We compiled about 8100 museum database records representing about 836 species in 48 families. The data for Lepidoptera are probably the most thorough for any order treated herein. Nonetheless, it is likely that the inventory of Lepidoptera of the site is still incomplete. Brown et al. (2008) present summaries of the status of our knowledge of each family recorded from the Island.

Order Diptera

The Diptera or flies comprise one of the four largest insect orders. Adults are characterized by a unique modification of the hindwings into a pair of structures called halteres. The larvae of flies occupy a wide range of ecological niches from aquatic and semiaquatic to terrestrial. Adults likewise exhibit a broad array of life styles from saprophagous to predaceous and blood-feeding.

We compiled records of 617 species of Diptera in 44 families; we did not capture data for most families of Nematocera (midges and mosquitos). Our data for this order are highly biased toward the early part of the 20th century (1900–1925), with most specimens colleted by Herbert Barber, Albert Fisher, Waldo McAtee, and Raymond Shannon, with few recent records. In addition to specimen records, numerous literature records of Diptera from Plummers Island are present in a series of papers treating the Diptera of the District of Columbia: Asilidae (McAtee & Banks 1920), Rhagionidae (Malloch et al. 1931), Syrphidae (Banks et al. 1916), Tabanidae (McAtee & Walton 1918), and ''Tromoptera'' (Cole et al. 1924). Ceratopogonidae of the Island were reported in a series of papers by Wirth et al. (1977) and Wirth & Grogan (1979, 1981). Mathis & Mathis (2008) provide a contemporary review of the Ephydridae of Plummers Island.

Order Siphonaptera

Fleas are small wingless insects that feed as adults on the blood of birds and mammals. Their bodies are strongly flattened laterally, and they are equipped with long hindlegs well suited for jumping. Eckerlin (2008) provides a report on the 10 species in 4 families recorded from Plummers Island.

Order Hymenoptera

Hymenoptera, probably the second largest order of insects, exhibit the greatest complexity of behavior, culminating in social organization in many families. The order is divided into two suborders: Symphyta (sawflies) and Apocrita (ants, bees, and wasps). The order includes plant-feeders, nectar-gatherers, predators, and parasitoids, along with the most important pollinators of vascular plants. The reduction and/or loss of native pollinators over the last two to three decades has become an issue of global concern (e.g., Stubbs & Drummond 2002, Strickler & Cane 2003); hence, there is considerable interest in this group from a conservation perspective.

Data-mining for this order resulted in about 5700 records, mostly of the aculeate families (bees and wasps) representing 416 species in 144 genera and 36 different families. The Hymenoptera of Plummers Island were studied extensively by Krombein (1959, 1962a, b, 1963a, b, 1964), who reported on Bethylidae, Chrysididae, Dryinidae, Mutillidae, Pompilidae, Rhopalsomatidae, Scoliidae, Sierolomophidae, Sphecidae, Tiphiidae, and Vespidae. While most of his published work focused on small groups or even single species, his 1963b paper presents an annotated list of species known from the site. Virtually all of Krombein's material is deposited in the USNM. The bees were the subject of investigation by Ronald McGinley and Beth Norden in the early 1980s. Based on historical records from the USNM and Malaise trap sampling from 2005 and 2006, Smith (2008) provides a review of the Symphyta and select families of Apocrita known from the Island; Norden (2008) presents a list of the bees.

In general, the Hymenoptera data are highly biased toward 1900–1925 and 1951–1975, and towards wasps and bees. The early records reflect the survey work and enthusiasm of early club members, and the latter data are virtually all the results of Krombein's and McGinley's collecting activities on the site—both were active members of the Washington Biologists' Field Club. The greatest shortcoming in the Hymenoptera database is the absence of ''micro-hymenoptera''—the small parasitoids and seed-feeders (e.g.,

Table 2.—Total numbers of insect species documented from Plummers Island by order.

Order	# Families	# spp.
Collembola	1	1
Odonata	8	45
Dermaptera	1	1
Blattoidea	2	5
Phasmatodea	1	2
Orthoptera	8	63
Psocoptera	6	16
Thysanoptera	5	57
Hemiptera	36	307
Neuroptera	7	9
Megaloptera	2	6
Coleoptera	16	597
Mecoptera	3	5
Trichoptera	12	28
Lepidoptera	48	836
Diptera	45	617
Siphonaptera	5	10
Hymenoptera	47	416
TOTAL	253	3,012

Braconidae, Chalcidoidea), which are remarkably diverse.

Discussion

Table 2 lists the number of species (3012) and families (253) of insects documented from Plummers Island. For the majority of insect families, the data are the result of highly uneven sampling over the last 100 years. For example, although there are significant numbers of older records of Diptera, Coleoptera, and Heteroptera, the paucity of recent records prohibits comparisons between the historical and current faunas. In contrast, several families in the orders Odonata, Coleoptera, and Lepidoptera provide the opportunity to assess changes in species composition since the early part of the 20th century, if only in a superficial manner.

Odonata.—The dragonflies and damselflies were studied relatively recently by Orr (1995), and the data are somewhat biased toward his efforts. The number of documented species increased from 18 (1901–1930) to 36 (1990–2000). For 4 families (i.e., Aeschnidae, Coenagrionidae, Lestidae, and Libellulidae) there appears to be insufficient early data to assess change; for 3 families (i.e, Cordulegastridae, Gomphidae, and Petaluridae), there is some evidence of decline; and for 1 family (i.e., Calopterygidae), there is no change in species richness, but turnover is 100%. Because the order is intimately associated with aquatic situations, putative changes in the Odonata fauna may reflect changes in the availability and/or quality of aquatic habitats in the immediate vicinity of Plummers Island.

Coleoptera.—Two families of beetles, Carabidae and Chrysomelidae, are represented by adequate historical and recent data, and both have been the subject of intensive study. Erwin (1981), Staines & Staines (1998), and Staines (2004) found beetle species richness had diminished over the last 75–100 years, and all studies implicated habitat change and natural succession of the vegetation, in part, as the primary mechanisms responsible for changes in the fauna. Erwin (1981) suggested that the decline in species richness of carabid beetles was accompanied by a change in species composition from open-habitat species to forest dwellers, from wingless species to winged species, and from species of larger size to species of smaller size. He concluded that these changes, in part, reflect successional development of the vegetation, but also cautioned that they may reflect more subtle changes not yet fully understood.

Lepidoptera.—Of the 48 families of butterflies and moths documented from Plummers Island, 25 appear to have been sampled adequately enough (i.e., both historical and recent data) to evaluate changes in the fauna. Of these 25 families, 14 declined in species richness, 3 stayed relatively unchanged (±10%), and 8 showed an increase in species richness between 1901–1920 and 1990–2006. However, it must be stressed that changes in species richness may simply reflect sampling bias rather than actual changes in the fauna. A few of the families that increased in species richness (e.g., Lymantriidae, Lasiocampidae, Yponomeutidae) have done so through augmentation of the existing fauna by adventive or introduced species. For others (e.g., Arctiidae, Gelechiidae), the reason for the increase is unknown. Conspicuous declines were documented for Coleophoridae (45%), Pyralidae (20%), and Tortricidae (17%). The large number of historical records of these families suggests that they were sampled adequately in early times, and because the first author (and students) and Mike Pogue have sampled Lepidoptera on the Island on over 50 dates over the last 8 years, it is likely that the recent fauna has been sampled adequately as well. Because nearly all Lepidoptera are phytophagous or plant-feeding in the larval stage, putative changes in the moth and butterfly fauna may reflect changes in the vegetation of the Island and surrounding area.

Similar patterns of decline in species richness or in populations of specific species as a result of succession or ''habitat maturation'' have been reported for a variety of bird species (e.g., Karr 1968, Morgan & Freedman 1987, Hunt 1998) and/or bird faunas (e.g., Willis 1974, Willis & Eisenmann 1979, Karr 1982). Litvaitis (1993) hypothesized that forest maturation was the mechanism behind regional declines of several bird and mammal species that require early successional habitat in the northeastern U.S. Our findings in at least two families of beetles (i.e., Carabidae and Chrysomelidae) and several families of Lepidoptera (e.g., Coleophoridae, Pyralidae, Tortri-

cidae) suggest this may be true for some invertebrates as well.

In general, the insect fauna of Plummers Island appears to be tracking changes in the vegetation and overall habitat (and/or larval host plant) availability. Species richness in those groups that require open and/or successional habitats has declined. Groups that feed on woody vegetation and/or trees, such as Limacodidae (slug caterpillars), have remained fairly stable in terms of species richness. The site supports a variety of widespread non-native or weedy species, but these few elements probably have a limited impact on the indigenous fauna. However, gypsy moth, an important forest pest in the region, was abundant on the site in 2006 (based on pheromone traps, Malaise traps, and visual observations), suggesting that it is as successful on the site as elsewhere in the eastern U.S.

The preservation of Plummers Island through passive management (i.e., the interruption of activities that degrade habitat) has allowed the site to revert to a somewhat homogeneous, subclimax community that supports fewer species than were present prior to implementation of this management strategy. This and other studies (e.g., Morris & Web 1987, Hunt 1998) suggest that the maintenance of at least some successional habitat may be critical for the maintenance of species richness in some groups, including invertebrates. The logical assumption behind this suggestion is that greater habitat heterogeneity will promote greater species richness. Tree gaps, open fields, and edges may make a significant contribution to heterogeneity, which in turn contributes to high biodiversity.

The historical insect data associated with Plummers Island provide a unique opportunity to better understand ecological succession, conservation, and biodiversity, and lend insight into consequences of some management activities. However, additional surveys of groups such as Coleoptera, Lepidoptera, Diptera, Heteroptera, and Hymenoptera will greatly increase the value of the historical data, allowing a more in-depth perspective into changes in the insect fauna. Likewise, current inventory work will provide the baseline data critical for assessing changes in the future.

Acknowledgments

Specimen data from the USNM collection were captured by Robert Copeland (Diptera), Mark Metz (Diptera: Syrphidae), Virginia Power (Lepidoptera and Hemiptera), Charles Staines (Coleoptera), and Kira Zhaurova (Coleoptera and Hymenoptera). David Furth functioned as the Smithsonian Institution contract administrator for the project funded by the NPS, and Carol Youmans provided additional assistance with the contract. Charles Staines provided valuable historical literature on insect inventories on the site. Reed Watkins assisted in the identification of Pterophoridae. Oliver Flint provided identifications of Trichoptera, Neuroptera, Megaloptera, and Mecoptera, and directed us to areas of the collection likely to provide relevant data. Terry Erwin (Coleoptera: Carabidae), Thomas Henry (Hemiptera: Heteroptera), Steven Lingafelter (Coleolptera: Cerambycidae), Wayne Mathis (Diptera: Ephydridae), Gary Miller (Hemiptera: Aphididae), Beth Norden (Hymenoptera: bees), Allen Norrbom (Diptera), David Smith (Hymenoptera), Warren Steiner (Coleoptera: Tenebrionidae), F. Christian Thompson (Diptera), and Norman Woodley (Diptera) provided comments and corrections to sections, particularly the appendix, dealing with taxa with which they have expertise. Grants from the Washington Biologists' Field Club, both historically and in recent times, provided funding for much of the field work on the Island. Richard Brown (Mississippi State University), Norman Woodley (USDA, Systematic Entomology Laboratory), Thomas Henry (USDA, Systematic Entomology Laboratory), and Brian Scholtens (College of Charleston, South Carolina) provided reviews of the text.

Literature Cited

Adamski, D., & R. W. Hodges. 1996. An annotated list of North American Blastobasinae (Lepidoptera: Gelechioidea: Coleophoridae).—Proceedings of the Entomological Society of Washington 98:708–740.

Banks, N., C. T. Greene, W. L. McAtee, & R. C. Shannon. 1916. District of Columbia Diptera: Syrphidae.—Proceedings of the Biological Society of Washington 29:173–204.

Barber, H. S. 1951. North American fireflies of the genus *Photuris.* Smithsonian Miscellaneous Collections 117, vi + 58 pp.

Borror, D. J., D. M. De Long, & C. A. Triplehorn. 1976. An introduction to the study of insects, 4th edition. Holt, Rinehart and Winston, New York, 852 pp.

Brown, J. W. 2001. Species turnover in the leafrollers (Lepidoptera: Tortricidae) of Plummers Island, Maryland: Assessing a century of inventory data.—Proceedings of the Entomological Society of Washington 103:673–685.

———. 2008. The invertebrate fauna of Plummers Island, Maryland: Introduction and background.—Bulletin of the Biological Society of Washington 15:1–10.

———, M. E. Epstein, K. Vann, R. A. Watkins, S. M. Bahr, II, & E. M. Kolski. 2008. An overview of the Lepidoptera (Insecta) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:65–74.

Busck, A. 1906a. Notes on some tortricid genera with descriptions of new American species.—Proceedings of the Biological Society of Washington 19:173–182.

———. 1906b. New American Tineina.—Canadian Entomologist 38:121–125.

———. 1907a. A review of the tortricid subfamily Phaloniinae with descriptions of new American species.—Journal of the New York Entomological Society 15:19–36.

———. 1907b. New genera and species of American Microlepidoptera.—Journal of the New York Entomological Society 15:134–140.

———. 1908. A generic revision of American moths of the family

Oecophoridae with descriptions of new species.—Proceedings of the United States National Museum 35(1644):187–207.

———. 1909. Notes on Microlepidoptera, with descriptions of new North American species.—Proceedings of the Entomological Society of Washington 11:87–103.

———, & C. Heinrich. 1922. Life history of *Ethmia macelhosiella* Busck.—Proceedings of the Entomological Society of Washington 24:1–9.

Butte, J. G. 1968a. Revision of the tribe Chalepini of America north of Mexico (Coleoptera: Chrysomelidae). I. Genus *Xenochalepus* Weise.—Coleopterists Bulletin 22:45–62.

———. 1968b. Revision of the tribe Chalepini of America north of Mexico (Coleoptera: Chrysomelidae). II. Genus *Chalepus* Thunberg.—Journal of the New York Entomological Society 76:117–133.

———. 1968c. Revision of the tribe Chalepini of America north of Mexico (Coleoptera: Chrysomelidae). III. Genus *Odontota* Chevrolat.—Coleopterists Bulletin 22:101–124.

Clarke, J. F. G. 1941. Revision of the North American moths of the family Oecophoridae, with descriptions of new genera and species.—Proceedings of the United States National Museum 90:33–286.

Cole, F. R., J. R. Malloch, & W. L. McAtee. 1924. District of Columbia Diptera: Tromoptera (Cyrtidae, Bombyliidae, Therevidae, Scenopidae).—Proceedings of the Entomological Society of Washington 26:181–195.

Donnelly, T. W. 1961. The Odonata of Washington, D.C., and vicinity.—Proceedings of the Entomological Society of Washington 63:1–13.

Eckerlin, R. P. 2008. The fleas (Insecta: Siphonaptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:158–159.

Erwin, T. L. 1981. The ground beetles of a temperate forest site (Coleoptera: Carabidae): An analysis of fauna in relation to size, habitat selection, vagility, seasonality, and extinction.—Bulletin of the Biological Society of Washington 5: 104–224.

Fischer, M. 1967. Die nearktischen Arten der Gattung *Synaldis* (Hymenoptera, Braconidae, Alysiinae).—Polskie Pismo Entomologiczne 37:431–478.

Flint, O. S., Jr. 2008a. Scorpionflies and hangingflies (Insecta: Mecoptera) from Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:127–129.

———. 2008b. The Neuroptera and Megaloptera—lacewings, hellgrammites, etc.—collected on and near Plmmers Island, Maryland in 2004 and 2005.—Bulletin of the Biological Society of Washington 15:130–132.

———. 2008c. Trichoptera (Caddisflies) Collected on and Near Plummers Island, Maryland in 2004 and 2005.—Bulletin of the Biological Society of Washington 15:121–126.

Hale, M. E. 1972. Natural History of Plummers Island, Maryland, XXI. Infestation of the lichen *Parmelia baltimorensis* Gyel. & For. by *Hypogastrura packardi* Folsom (Collembola).—Proceedings of the Biological Society of Washington 85: 287–296.

Heinrich, C. 1923. Revision of the North American moths of the subfamily Eucosminae of the family and Olethreutinae. United States National Museum Bulletin 123, 298 pp.

———. 1926. Revision of the North American moths of the subfamilies Laspeyresiinae and Olethreutinae.—U.S. National Museum Bulletin 132, 216 pp.

Hodges, R. W. 1964. A review of the North American moths of the family Walshiidae.—Proceedings of the U.S. National Museum 115:289–330.

———. 1969. Nearctic Walshiidae—notes and new taxa (Lepidoptera: Gelechioidea).—Smithsonian Contributions in Zoology 18, 30 pp.

Hoffman, R. L., S. M. Roble, & W. E. Steiner, Jr. 2002. Thirteen additions to the known beetle fauna of Virginia (Coleoptera: Scirtidae, Bothrideridae, Cleridae, Tenebrionidae, Melyridae, Callirhipidae, Cerambycidae, Chrysomelidae).—Banisteria 20:53–61.

Hood, J. D. 1917. An annotated list of the Thysanoptera of Plummer's Island, Maryland.—Insecutor Inscitiae Menstruus 5: 53–65.

Hunt, P. D. 1998. Evidence from a landscape population model of the importance of early successional habitat to the American redstart.—Conservation Biology 12:1377–1388.

Jeannel, R. 1963. Supplément a la monographie des Anillini (1). Sur quelques espèces nouvelles de l'Amérique du Nord.—Revue Française d'Entomologie 30:145–152.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois.—Condor 70:348–357.

———. 1982. Population variability and extinction in the avifauna of a tropical land bridge island.—Ecology 63:1975–1978.

Karren, J. 1966. A revision of the genus *Exema* of America north of Mexico (Chrysomelidae, Coleoptera).—University of Kansas Science Bulletin 46:647–695.

Krombein, K. 1959. Natural History of Plummers Island, Maryland, XII. A biological note on *Trypoxylon richardsi* Sandhouse.—Proceedings of the Biological Society of Washington 72:101–102.

———. 1962a. Natural History of Plummers Island, Maryland, XIII. Descriptions of new wasps from Plummers Island (Hymenoptera: Aculeta).—Proceedings of the Biological Society of Washington 75:1–18.

———. 1962b. Natural History of Plummers Island, Maryland, XVI. Biological notes on *Chaetodactylus krombeini* Baker, a parasitic mite of the megachilid bee, *Osmaria* (*Osmia*) *lignaria* Say (Acarina: Chaetodactylidae).—Proceedings of the Biological Society of Washington 75:237–250.

———. 1963a. A new *Chrysura* from Plummers Island, Maryland (Hymenoptera, Chrysididae).—Entomological News 74: 149–152.

———. 1963b. Natural History of Plummers Island, Maryland, XVII. Annotated list of the wasps (Hymenoptera: Bethyloidea, Scolioidea, Vespoidea, Pompiloidea, Sphecoidea).—Proceedings of the Biological Society of Washington 76: 255–280.

———. 1964. Natural History of Plummers Island, Maryland, XVIII. The hibiscus wasp, an abundant rarity, and its associates (Hymenoptera: Sphecidae).—Proceedings of the Biological Society of Washington 77:73–112.

Leonard, M. D. 1966. Natural History of Plummers Island, Maryland, XIX. Annotated list of the aphids (Homoptera: Aphididae).—Proceedings of the Biological Society of Washington 79:117–126.

———. 1968. Further records of aphids from Plummers Island, Md. (Homoptera: Aphididae).—Proceedings of the Entomological Society of Washington 70:84.

Lill, J. T. 2008. Catepillar-host plant relationships recorded from Plummers Island, Maryland (Insecta: Lepidoptera).—Bulletin of the Biological Society of Washington 15:75–79.

Litvaitis, J. A. 1993. Response of early successional vertebrates to historic changes in land use.—Conservation Biology 7:866–873.

Malloch, J. R., C. T. Greene, & W. L. McAtee. 1931. District of Columbia Diptera: Rhagionidae.—Proceedings of the Entomological Society of Washington 33:213–220.

Mathis, W. N., & D. Mathis. 2008. Shore flies (Insecta: Diptera: Ephydridae) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:173–191.

McAtee, W. L. 1908. Notes on an orthopterous leaf roller.—Entomological News 19:488–491.

———. 1920. Cercopidae of the vicinity of Washington, D.C., with the descriptions of new varieties of *Clastoptera* (Homoptera).—Proceedings of the Biological Society of Washington 33:171–176.

———. 1921. Membracidae of the vicinity of Washington, D.C.—Proceedings of the Biological Society of Washington 34: 123–134.

———. 1927. Cicadidae of the vicinity of Washington, D.C.—Proceedings of the Entomological Society of Washington 29:70–72.

———, & N. Banks. 1920. District of Columbia Diptera: Asilidae.—Proceedings of the Entomological Society of Washington 22:13–33.

———, & A. N. Caudell. 1917. First list of the Dermaptera and Orthoptera of Plummer's Island, Maryland, and vicinity.—Proceedings of the Entomological Society of Washington 19:100–122.

———, & W. R. Walton. 1918. District of Columbia Diptera: Tabanidae.—Proceedings of the Entomological Society of Washington 20:188–206.

Morgan, K., & B. Freedman. 1987. Breeding bird communities in a hardwood forest succession in Nova Scotia.—Canadian Field Naturalist 100:506–519.

Morris, M. G., & N. R. Webb. 1987. The importance of field margins for the conservation of insects. *In* M. Way & P. W. Greig-Smith, eds., Field Margins. BCPC Monograph No. 35. BCPC Publications, Thornton Heath.

Norden, B. B. 2008. A checklist of the bees (Insecta: Hymenoptera) and their floral hosts at Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:168–172.

Orr, R. L. 1994. Baseline survey of Odonata (dragonflies and damselflies) of the C&O Canal National Historical Park (Potomac River Corridor). Unpublished report to C&O National Historical Park, 16 October 1994.

———. 1995. Odonata of Plummers Island.—Argia 7(1):6–8.

Peck, S. B. 1982. A review of the ectoparasitic beetles of North America (Coleoptera: Leptinidae).—Canadian Journal of Zoology 60:1517–1527.

Perkins, P. D. 1981. Aquatic beetles of the family Hydraenidae in the Western Hemisphere: Classification, biogeography and inferred phylogeny (Insecta: Coleoptera). Quaestiones Entomologicae 16, 554 pp.

Perry, M. C. (ed.). 2007. The Washington Biologists' Field Club: Its Members and Its History (1900–2006). Washington Biologists' Field Club, x + 342 pp.

Pogue, M. G. 2008. Inventory of the Nolidae, Erebidae, and Noctuidae (Insecta: Lepidoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15: 107–120.

Shetler, S. G., S. S. Orli, E. F. Wells, & M. Beyersdorfer. 2006. Checklist of the vascular plants of Plummers Island, Maryland. Contribution XXVIII to the Natural History of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 14, 58 pp.

Smetana, A. 1974. Revision of the genus *Cymbiodyta* Bed. (Coleoptera: Hydrophilidae).—Memoirs of the Entomological Society of Canada 93, 113 pp.

———. 1978. Revision of the subfamily Sphaeridiinae of America norht of Mexico. (Coleoptera: Hydrophilidae).—Memoirs of the Entomological Society of Canada 105, 292 pp.

———. 1980. Revision of the genus *Hydrochara* Berth. (Coleoptera: Hydrophilidae).—Memoirs of the Entomological Society of Canada 111, 100 pp.

———. 1985. Revision of the subfamily Helophorinae (Coleoptera: Hydrophilidae).—Memoirs of the Entomological Society of Canada 131, 154 pp.

Smith, D. R. 1969. Nearctic sawflies I. Blennocampinae: Adults and larvae (Hymenoptera: Tenthredinidae).—U.S. Department of Agriculture Technical Bulletin No. 1397, 179 pp. + 19 pls.

———. 2008. Hymenoptera (Insecta) of Plummers Island, Maryland: Symphyta and select families of Apocrita.—Bulletin of the Biological Society of Washington 15:160–167.

Solis, M. A. 2008. Pyraloidea and their known hosts (Lepidoptera: Insecta) from Plummers Island.—Bulletin of the Biological Society of Washington 15:88–106.

Spangler, P. J. 1962. Biological notes and description of the larva and pupa of *Copelatus glyphicus* (Say) (Coleoptera: Dytiscidae).–Natural History of Plummers Island, Maryland, XIV.—Proceedings of the Biological Society of Washington 75:19–24.

Staines, C. L. 2004. Changes in the chrysomelid (Coleoptera) community over a 95-year period on a Maryland river island (USA). Pp. 613–622 *in* P. Jolivet, J. A. Santiago-Blay, & M. Schmitt, eds., New developments in the biology of Chrysomelidae. Academic Publishing, The Hague.

———. 2008a. Chrysomelidae or leaf beetles (Insecta: Coleoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:141–144.

———. 2008b. Cerambycidae or longhorned wood-boring beetles (Insecta: Coleoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:145–148.

———. 2008c. Coccinellidae or ladybird beetles (Insecta: Coleoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:149–150.

———. 2008d. Hydrophiloidea (Insecta: Coleoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:151–152.

———. 2008e. Dytiscidae or predaceous diving beetles (Insecta: Coleoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:153–155.

———. 2008f. Silphidae or carrion beetles (Insecta: Coleoptera) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:156–157.

———, & S. L. Staines. 1998. The leaf beetles (Insecta: Coleoptera: Chrysomelidae): potential indicator species assemblages for natural area monitoring. Pp. 233–244 *in* G. D. Therres, ed., Conservation of biological diversity: A key to the restoration of the Chesapeake Bay Ecosystem and beyond. Maryland Department of Natural Resources, Annapolis, Maryland.

Steiner, W. E., Jr. 2000. Records and habitat of the ''rare click beetle,'' *Cerophytum pulsator* (Haldeman), in Virginia and Maryland (Coleoptera: Cerophytidae).—Banisteria 15:43–45.

———. 2008. A checklist of the darkling beetles (Insecta: Coleoptera: Tenebrionidae) of Maryland, with notes on the species recorded from Plummers Island through the 20th century.—Bulletin of the Biological Society of Washington 15: 133–140.

Steinman, H. 1989. World catalogue of Dermaptera. Series Entomologica 43, 933 pp.

Strickler, K., & J. H. Cane (eds.). 2003. For non-native crops, whence pollinators of the future. Thomas Say Publications in Entomology 28.

Stubbs, C. S., & F. A. Drummond (eds.). 2002. Bees and crop pollination—crisis, crossroads, conservation. Thomas Say Publications in Entomology 26.

Triplehorn, C. A., & N. F. Johnson. 2005. Borror and Delong's introduction to the study of insects. Thompson, Brook/Cole, 864 pp.

Vann, K. 2008. Inventory of the butterflies (Insecta: Lepidoptera: Papilionidae, Pieridae, Lycaenidae, Nymphalidae, Hesperi-

idae) of Plummers Island, Maryland.—Bulletin of the Biological Society of Washington 15:80–87.

Willis, E. O. 1974. Populations and local extinctions of birds on Barro Colorado Island, Panama.—Ecological Monographs 44:153–169.

———, & E. Eisenmann. 1979. A revised list of the birds of Barro Colorado Island, Panama.—Smithsonian Institution Contributions in Zoology 291.

Wirth, W. W., N. C. Ratanaworabhan, & D. H. Messersmith. 1977. Natural History of Plummers Island, Maryland, XXII. Biting midges (Diptera: Ceratopogonidae). 1. Introduction and key to genera.—Proceedings of the Biological Society of Washington 90:615–647.

———, & W. L. Grogan. 1979. Natural History of Plummers Island, Maryland, XIV. Biting midges (Diptera: Ceratopogonidae). 2. The species of the tribes Heteromyiini and Sphaeromini.—Proceedings of the Biological Society of Washington 91:847–903.

———, & ———. 1981. Natural History of Plummers Island, Maryland, XXV. Biting midges (Diptera: Ceratopogonidae). 3. The species of the tribe Stilobezziini.—Bulletin of the Biological Society of Washington 5, 102.