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Number 54, 2020

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RESEARCH ARTICLE

SPECIES COMPOSITION AND HABITAT ASSOCIATIONS OF THE FISHES OF FLAT CREEK, APPOMATTOX RIVER DRAINAGE, VIRGINIA

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ABSTRACT

Flat Creek is a tributary of the Appomattox River system, James River drainage, in central Virginia. In 2016 and 2017, we conducted a fish survey on six mainstem and four tributary sites of Flat Creek. Limited sampling in previous surveys recorded 49 species including an upland population of Bridle Shiner, *Notropis bifrenatus*, a species in critical conservation need. We collected a total of 3,112 fish of 43 species in 10 families. We noted the first records of Spottail Shiner (*Notropis hudsonius*), Spotted Bass (*Micropterus punctulatus*), and Shield Darter (*Percina peltata*) in the system. Although Bridle Shiner was not found, we did collect American Eel (*Anguilla rostrata*) and Mud Sunfish (*Acantharchus pomotis*), two species of conservation need.

Keywords: Fish survey, Bridle Shiner, habitat.

INTRODUCTION

Flat Creek is a tributary to the Appomattox River system, James River drainage, Virginia. It is 54.4 km long, beginning slightly east of the town of Burkesville, Nottoway County, and flows northeast through Prince Edward, Nottoway, and Amelia counties before joining the Appomattox River (Fig. 1). The total gradient is 1.8 m/km with elevation ranging from 152.8 m at the headwaters to 53.9 m at its mouth. The Flat Creek watershed is 36,610 ha, which comprises 10.52% of the Appomattox drainage area. Primary land uses are forested (63%), pasture (13%), and cropland (11%) (Multi-Resolution Land Characteristics Consortium, 2011). Pasture is mostly for cattle production. Flat Creek is within the Piedmont physiographic province and specifically the Piedmont Lowland sub-province. Piedmont streams are highly entrenched with steep banks and substrates of sand, silts and clays (Jenkins & Burkhead, 1994). The low gradient produces short riffles, long runs, and medium pools. Pools are enhanced greatly by the presence of woody debris such as root wads and logs.

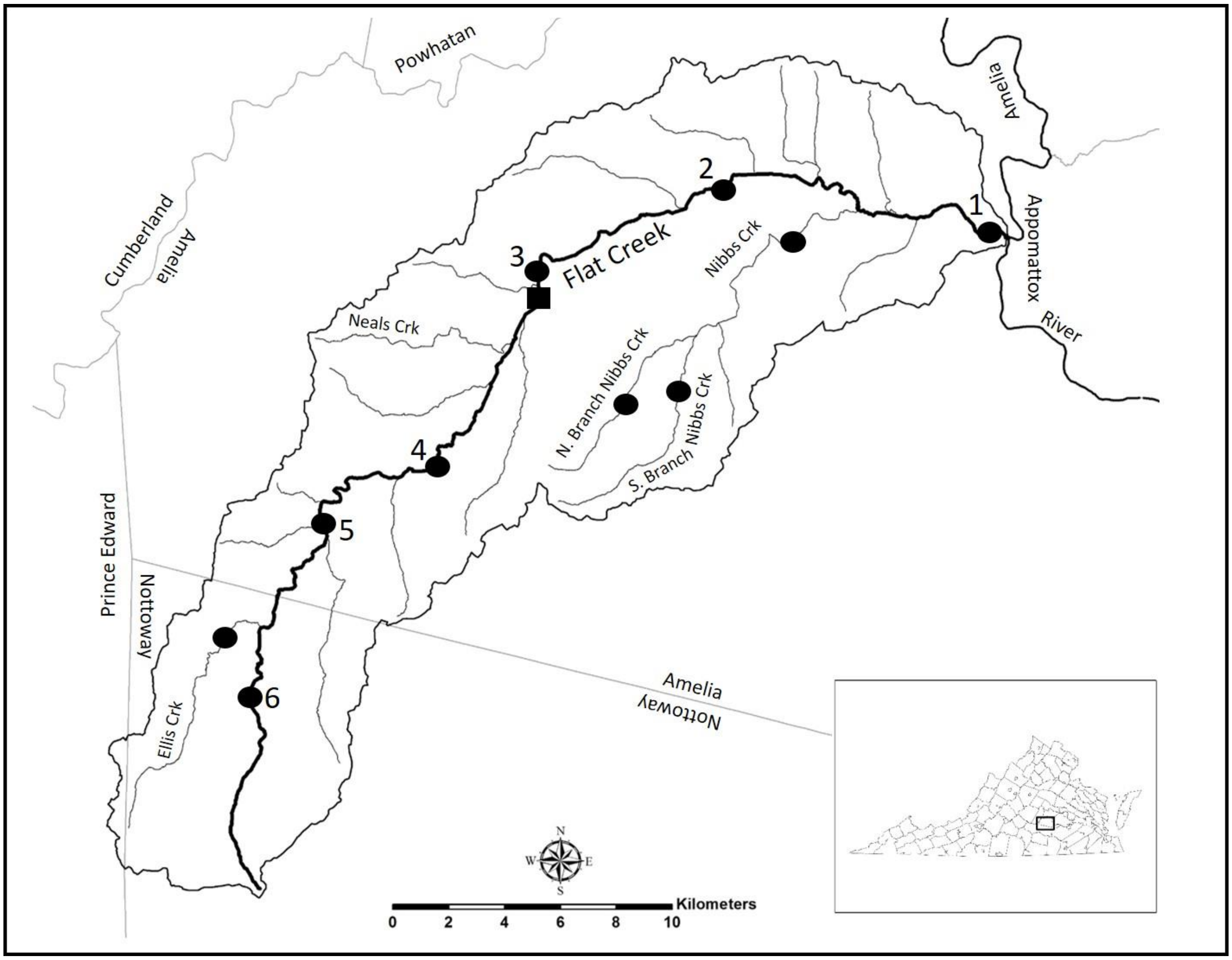

Figure 1. Locations of sampling sites (circles) in the Flat Creek watershed, Virginia. Numbered sites are located on Flat Creek mainstem while all others are on named tributaries. Square marker represents location of historic mainstem Bridle Shiner record.

Because of its smaller size, Flat Creek has only had limited investigations into its fish community. Since 1946, 49 fish species have been documented among 38 collections according to the Virginia Department of Game and Inland Fisheries' Fish and Wildlife Information database (VDGIF, 2016). Only one site was sampled prior to 1980. After 1980, multiple sites were sampled by various researchers and agencies (Table 1). The number of species collected during these surveys varied from 26 to 37. Although several surveys were conducted on both mainstem and tributary sites, sampling was sporadic and not comprehensive over its entire length.

Table 1. Fish sampling records in the Flat Creek system, Virginia. Most records are from Virginia Department of Game and Inland Fisheries' Fish and Wildlife Information Service (2016). These include Pre-1980s from various collectors, Robert Jenkins (Roanoke College), Virginia Department of Environmental Quality, and Virginia Commonwealth University data. Other records were compiled from Norman and Southwick (2014) and Starnes et al. (2016). Species are listed phylogenetically. Nomenclature follows Page et al. (2013).

Common name	Scientific name	Pre-1980	Jenkins 1983	Norman 1986-87	VDEQ 2009-13	VCU 2011	Starnes 2008-13
American Eel	*Anguilla rostrata*			X	X	X	
Gizzard Shad	*Dorosoma cepedianum*		X				
Chain Pickerel	*Esox niger*		X	X	X		X
Eastern Mudminnow	*Umbra pygmaea*			X			X
Golden Shiner	*Notemigonus crysoleucas*	X		X	X	X	X
Mountain Redbelly Dace	*Chrosomus oreas*	X		X	X	X	
Rosyside Dace	*Clinostomus funduloides*	X		X	X	X	
Blacknose Dace	*Rhynichthys atratulus*			X	X	X	
Fallfish	*Semotilus corporalis*	X	X	X		X	X
Creek Chub	*Semotilus atromaculatus*			X	X	X	
River Chub	*Nocomis micropogon*		X				
Bluehead Chub	*Nocomis leptocephalus*	X	X	X	X	X	X
Satinfin Shiner	*Cyprinella analostana*		X	X	X	X	X
Crescent Shiner	*Luxilus cerasinus*				X	X	
Common Shiner	*Luxilus cornutus*			X		X	X
Rosefin Shiner	*Lythrurus ardens*		X				X
Comely Shiner	*Notropis amoenus*			X			
Swallowtail Shiner	*Notropis procne*	X	X	X	X	X	X
Bridle Shiner	*Notropis bifrenatus*		X	X			X
Eastern Silvery Minnow	*Hybognathus regius*	X		X		X	X
Creek Chubsucker	*Erimyzon oblongus*			X	X	X	X

Table 1. Continued

Common name	Scientific name	Pre-1980	Jenkins 1983	Norman 1986-87	VDEQ 2009-13	VCU 2011	Starnes 2008-13
Northern Hogsucker	*Hypentelium nigricans*			X			X
Torrent Sucker	*Thorburnia rhothoeca*	X		X	X	X	
Blacktip Jumprock	*Moxostoma cervinum*			X			
White Sucker	*Catostomus commersoni*		X	X	X	X	
Channel Catfish	*Ictalurus punctatus*		X				
Yellow Bullhead	*Ameirus natalis*		X	X		X	X
Brown Bullhead	*Ameirus nebulosus*			X	X		
Margined Madtom	*Noturus insignis*	X	X	X	X	X	
Pirate Perch	*Aphredoderus sayanus*	X	X	X	X	X	X
Eastern Mosquitofish	*Gambusia holbrooki*		X		X		X
Mud Sunfish	*Acantharchus pomotis*		X		X		X
Flier	*Centrarchus macropterus*			X	X		X
Bluespotted Sunfish	*Enneacanthus gloriosus*		X	X	X		X
Warmouth	*Lepomis gulosus*	X		X	X		X
Green Sunfish	*Lepomis cyanellus*				X	X	
Redbreast Sunfish	*Lepomis auritus*		X	X	X	X	X
Bluegill	*Lepomis macrochirus*	X	X	X	X	X	X
Pumpkinseed	*Lepomis gibbosus*		X	X	X	X	X
Redear Sunfish	*Lepomis microlophus*		X		X		
Yellow Perch	*Perca flavescens*				X		
Stripeback Darter	*Percina notogramma*		X	X			X
Johnny Darter	*Etheostoma nigrum*	X		X	X	X	X

Table 1.
Continued

Common name	Scientific name	Pre-1980	Jenkins 1983	Norman 1986-87	VDEQ 2009-13	VCU 2011	Starnes 2008-13
Tessellated Darter	*Etheostoma olmstedi*		X		X		X
Glassy Darter	*Etheostoma vitreum*	X	X	X	X	X	X
Fantail Darter	*Etheostoma flabellare*	X	X	X	X	X	
Swamp Darter	*Etheostoma fusiforme*	X	X	X			X
Number of Species		16	26	37	32	26	30

Among the fish species known from Flat Creek, the Bridle Shiner (*Notropis bifrenatus*), a small minnow, is of particular interest. The species was first documented in Flat Creek in 1983 (VDGIF, 2016) and most recently collected in 2013 as part of a species status survey (Starnes et al. 2014). Throughout its range from Canada to South Carolina, the Bridle Shiner has been documented to be in decline, resulting in having conservation status in eight of the 11 states in which it occurs (Margolis, 2003). In Virginia, the shiner is a Tier I species of the state's Wildlife Action Plan (VDGIF, 2015) indicating that it is in critical need of conservation action. Because of its rarity and the disjunct nature of the Flat Creek population, Starnes et al. (2014) reported that the creek should be surveyed over much of its length and tributary system to determine just how truly localized the population is and whether it can withstand removal of stock. Based on its limited sampling and presence of a rare species, we determined that a comprehensive fish survey was needed on the Flat Creek system.

MATERIALS AND METHODS

We sampled six mainstem and four tributary sites (ranging 241 m – 594 m) between July 2016 and August 2017 (Fig. 1 and Table 2). Sites were selected based on accessibility, previous Bridle Shiner records, and distribution across the Flat Creek system. Total sample length of all sites combined was 3.845 km (Table 2).

Water samples were collected and water chemistry measured before entering the stream. We used a YSI 556 MPS meter for temperature (°C), specific conductivity (µS/cm), pH, and dissolved oxygen (mg/l). Turbidity (FNU) was measured using a LaMotte 2020 Turbidity Meter. Fish were sampled using a Smith-Root LR 24 backpack electroshocker and a 3 m x 2 m (3.1 mm mesh) seine net singularly or in combination. While moving in an upstream direction, 20 samples were collected at each site. Each fish sampling effort was restricted to a specific mesohabitat type (i.e., pool, riffle, run). We sampled mesohabitats in relative proportion to those present in the sample reach. After sampling fish, we estimated average depth, dominant substrate, habitat area, and presence of woody debris (logs and root wads) at each habitat. We used a modified Wentworth classification for substrate particles size (Cummins, 1962). Average wetted stream width (m) was determined by measuring stream width at five-equal spaced intervals along each sample reach.

Table 2. Fish sampling sites in the Flat Creek Watershed, Amelia, Nottoway and Prince Edward counties, Virginia.

Site	Stream	Adjoining Tributary	Distance above adjoining tributary (km)	Sample date	Sample Reach Coordinates Start	End	Sample Reach Distance (m)
1	Flat Creek	Appomattox River	0.0	25 July 2016	37.3920 -77.8730	37.3941 -77.8762	408
2	Flat Creek	Appomattox River	12.59	26 July 2016	37.4154 -77.9836	37.4115 -77.9876	594
3	Flat Creek	Appomattox River	21.14	26 July 2016	37.3910 -78.0623	37.3872 -78.0627	436
4	Flat Creek	Appomattox River	30.0	27 July 2016	37.3300 -78.2060	37.3273 -78.1065	383
5	Flat Creek	Appomattox River	37.50	24 Aug 2016	37.3077 -78.1548	37.3042 -78.1534	415
6	Flat Creek	Appomattox River	46.43	23 Aug 2016	37.2512 -78.1863	37.2487 -78.1855	298
EC	Ellis Creek	Flat Creek	1.09	23 Aug 2016	37.2745 -78.1899	37.2722 -78.1927	370
SBN	South Branch Nibbs Creek	Nibbs Creek	1.67	17 Aug 2017	37.3507 -78.0072	37.3481 -78.0075	292
NBN	North Branch Nibbs Creek	Nibbs Creek	4.25	17 Aug 2017	37.3407 -78.0312	37.3391 -78.0326	241
NC	Nibbs Creek	Flat Creek	2.52	16 Aug 2017	37.3982 -77.9546	37.3953 -77.9576	409

Most fish were identified, counted, and released soon after capture. A representative sample of all fish species and unidentified specimens were vouchered from each site and preserved in 10% buffered formalin. Specimens in need of further identification were processed at the Virginia Department of Game and Inland Fisheries Field Office, Blacksburg, Virginia. Assistance in identification was provided by Dr. Wayne Starnes, Fish Curator (Retired), North Carolina Museum of Natural History. All vouchers were deposited and cataloged at the Virginia Marine Institute Nunnally Ichthyological Collection, Gloucester, Virginia. Nomenclature and phylogenetic order of families follows Page et al. (2013).

For each site, water chemistry and stream habitat characteristics are summarized in Table 3. We calculated total area, average depth, and dominant substrate for each sampled mesohabitat type. Habitat association was determined by summing mesohabitat type where each species was collected and converting it into a percentage based on all habitat types. We use the terms “dominant” and “subdominant” in reference to the habitat type where the first and second highest number of individuals of a particular species were collected, respectively. A Student T-test was used to determine difference (evaluated at $\alpha = 0.05$) in water chemistry between mainstem and tributaries. We could not normalize habitat depth so we used a non-parametric Kruskal-Wallis test to determine differences in medians. A Dunn's post hoc test (Dunn, 1964) was conducted after a significant Kruskal-Wallis test. All statistical tests were conducted using PAleontological STatistical (PAST) ver. 3.23 software.

RESULTS

Habitat

All habitat data is summarized in Table 3. Among 200 samples, pools comprised 46%, runs 38.5%, and riffles 15.5%. Pools were significantly deeper ($p < 0.001$) than runs and riffles. Runs were significantly deeper ($p < 0.001$) than riffles. Sand (79%), gravel (11.5%), silt (9%) and cobble (0.5%) comprised the dominant substrate types over all habitat types. Sand dominated 82%, 86%, and 55% of pools, runs, and riffles, respectively. The remaining pools (17%) were dominated by silt while 10.5% of runs and 41% of riffles were composed of gravel. Wood debris was present at all sites and primarily associated with pool habitat. Stream width ranged from 2.2- 9.8 ($\bar{x} = 5.62$ m, SD = 2.18) over all sites.

Table 3. Habitat variables collected in the Flat Creek system, Virginia. Site numbers correspond to mainstem Flat Creek sites on Table 2. Tributaries are abbreviated as: EC – Ellis Creek; SBN – South Branch Nibbs Creek; NBN – North Branch Nibbs Creek; NC - Nibbs Creek.

	Site									
Variable	1	2	3	4	5	6	EC	SBN	NBN	NC
Temperature (°C)	27.8	26.9	28.8	26.3	21	21.5	22.3	23.4	23.2	23.4
pH	7.84	7.59	7.89	7.88	8.11	7.53	7.9	8.21	8.02	8.26
Specific Conductivity (µS/cm)	144	157	175	165	151	162	118	159	134	172
Dissolved Oxygen (mg/l)	7.77	5.06	8.35	5.56	7.4	7.3	7.3	7.89	4.83	6.75
Turbidity (FNU)	17.5	6.03	9.54	5.32	3.8	1.3	2.6	4.53	12.8	4.27
Avg. Stream Width (m)	8.9	7.5	8.1	4.1	6.0	5.9	2.2	3.2	4.3	6.0
% Pool	25	30	50	45	60	55	60	35	60	40
% Run	70	50	45	40	35	25	35	35	20	30
% Riffle	5	20	5	15	5	20	5	30	20	30
Pool Avg. Depth (m)	0.40	0.47	0.33	0.44	0.62	0.28	0.29	0.42	0.33	0.49
Run Avg. Depth (m)	0.27	0.24	0.24	0.19	0.31	0.10	0.16	0.10	0.14	0.22
Riffle Avg. Depth (m)	0.20	0.15	0.20	0.13	0.20	0.11	0.10	0.06	0.06	0.16
Dominant Substrate	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Gravel

Among water chemistry variables at all sites, temperature ranged from 21°C-28.78°C ($\bar{x}$ = 24.46° C, SD = 2.76), pH ranged from 7.53-8.26 ($\bar{x}$ = 7.92, SD = 0.24), specific conductivity ranged from 118 to 175 µS/cm ($\bar{x}$ = 153.7 µS/cm, SD = 17.6), dissolved oxygen ranged from 4.83 to 8.35 mg/l ($\bar{x}$ = 6.82 mg/l, SD = 1.24), and turbidity ranged from 1.3 to 17.3 FNU ($\bar{x}$ = 6.77 FNU, SD = 5.04). There were no significant differences ($p > 0.05$) when comparing water chemistry between mainstem and tributary sites.

Fish Sampling

We collected a total of 3,112 individuals of 10 families, 30 genera, and 43 species (Table 4). The most abundant species were Bluehead Chub, *Nocomis leptocephalus*, (635), Tessellated Darter, *Etheostoma olmstedi*, (248), and Satinfin Shiner, *Cyprinella analostana*, (236). In contrast, the rarest species (≤ 3 specimens) were Channel Catfish, *Ictalurus punctatus*, Spottail Shiner, *Notropis hudsonius*, Torrent Sucker, *Thoburnia rhothoeca*, Mud Sunfish, *Acantharchus pomotis*, Warmouth, *Lepomis gulosus*, Pumpkinseed, *Lepomis gibbosus*, and Redear Sunfish, *Lepomis microlophus*. Bridle Shiner was not observed during our survey.

Table 4. Distribution and abundance of fishes collected in the Flat Creek system, Virginia. Species are listed phylogenetically. Nomenclature follows Page et al., 2013. Site numbers correspond to mainstem Flat Creek sites on Table 2. Tributaries are abbreviated as: EC – Ellis Creek; SBN – South Branch Nibbs Creek; NBN – North Branch Nibbs Creek; NC - Nibbs Creek.

		Site										
Common name	Scientific name	1	2	3	4	5	6	EC	SBN	NBN	NC	Total
American Eel	*Anguilla rostrata*	5	4	4	-	1	-	-	-	-	2	16
Chain Pickerel	*Esox niger*	2	7	3	-	1	-	-	-	10	2	25
Eastern Mudminnow	*Umbra pygmaea*	-	-	2	-	-	6	2	-	21	1	32
Golden Shiner	*Notemigonus crysoleucas*	-	11	-	-	-	-	-	-	-	-	11
Mountain Redbelly Dace	*Chrosomus oreas*	-	-	-	-	-	-	13	-	-	-	13
Rosyside Dace	*Clinostomus funduloides*	-	-	-	-	8	20	63	22	-	-	113
Blacknose Dace	*Rhynichthys atratulus*	-	-	-	-	-	8	2	16	-	-	26
Fallfish	*Semotilus corporalis*	13	9	8	24	124	3	7	4	-	8	200
Creek Chub	*Semotilus atromaculatus*	-	-	-	2	2	63	70	42	2	3	184

Table 4
Continued

Common name	Scientific name	Site 1	2	3	4	5	6	EC	SBN	NBN	NC	Total
Bluehead Chub	*Nocomis leptocephalus*	5	15	4	56	65	88	219	84	1	98	635
Satinfin Shiner	*Cyprinella analostana*	91	73	10	17	31	-	-	-	-	14	236
Common Shiner	*Luxilus cornutus*	-	-	20	16	11	1	21	8	-	6	83
Rosefin Shiner	*Lythrurus ardens*	8	31	66	13	-	-	-	-	-	26	144
Comely Shiner	*Notropis amoenus*	6	3	23	9	16	-	-	-	-	-	57
Spottail Shiner	*Notropis hudsonius*	1	-	-	-	-	-	-	-	-	-	1
Swallowtail Shiner	*Notropis procne*	16	8	35	22	53	42	12	3	-	10	201
Eastern Silvery Minnow	*Hybognathus regius*	6	1	5	-	7	-	3	7	-	20	49
Eastern Creek Chubsucker	*Erimyzon oblongus*	-	1	3	-	-	-	-	-	12	1	17
Torrent Sucker	*Thorburnia rhothoeca*	-	-	-	-	-	-	-	13	-	10	23
White Sucker	*Catostomus commersoni*	-	-	4	3	6	-	13	-	-	2	28
Channel Catfish	*Ictalurus punctatus*	2	-	-	-	-	-	-	-	-	-	2
Yellow Bullhead	*Ameirus natalis*	1	-	4	-	2	5	1	5	4	-	22
Margined Madtom	*Noturus insignis*	1	7	3	3	6	5	1	7	3	4	40
Pirate Perch	*Aphredoderus sayanus*	1	5	18	1	14	15	7	1	68	15	145
Eastern Mosquitofish	*Gambusia holbrooki*	-	2	-	-	-	-	2	-	8	-	12
White Perch	*Morone Americana*	-	10	-	-	-	-	-	-	-	-	10
Mud Sunfish	*Acantharchus pomotis*	-	-	-	-	2	-	-	-	-	-	2

Table 4
Continued

Common name	Scientific name	Site 1	2	3	4	5	6	EC	SBN	NBN	NC	Total
Bluespotted Sunfish	*Enneacanthus gloriosus*	-	1	-	-	-	-	-	-	5	-	6
Spotted Bass	*Micropterus punctulatus*	-	1	1	4	1	-	-	-	-	-	7
Largemouth Bass	*Micropterus salmoides*	-	3	-	1	1	1	-	-	6	1	13
Warmouth	*Lepomis gulosus*	-	3	-	-	-	-	-	-	-	-	3
Green Sunfish	*Lepomis cyanellus*	-	-	-	2	17	17	5	-	1	1	43
Redbreast Sunfish	*Lepomis auritus*	7	5	34	16	13	6	1	2	13	5	102
Bluegill	*Lepomis macrochirus*	8	27	1	8	9	1	-	6	6	12	78
Pumpkinseed	*Lepomis gibbosus*	-	1	-	-	-	-	-	-	1	1	3
Redear Sunfish	*Lepomis microlophus*	-	-	-	-	-	-	-	-	2	1	3
Stripeback Darter	*Percina notogramma*	-	1	1	3	4	5	2	-	-	-	16
Shield Darter	*Percina peltata*	1	9	-	-	1	-	-	-	-	-	11
Tessellated Darter	*Etheostoma olmstedi*	1	2	28	11	26	37	14	33	45	51	248
Glassy Darter	*Etheostoma vitreum*	3	30	14	31	6	-	-	4	-	96	184
Fantail Darter	*Etheostoma flabellare*	1	3	2	17	4	4	6	4	-	10	51
Swamp Darter	*Etheostoma fusiforme*	-	2	-	-	-	-	-	-	2	-	4
Number of Specimens		179	276	294	266	435	327	464	261	210	400	3112
Species Richness		20	29	24	21	27	18	20	17	18	25	43

The Bluehead Chub, Margined Madtom, *Noturus insignis*, Pirate Perch, *Aphredoderus sayanus*, Redbreast Sunfish, *Lepomis auritus*, and Tessellated Darter were found at all survey sites. Species that were found at only one site were Spottail Shiner, Mountain Redbelly Dace, *Chrosomus oreas*, Golden Shiner, *Notomegnis crysoleucas*, Channel Catfish, White Perch, *Morone americana*, and Warmouth. Of the species collected, 10 were found in only mainstem sections, four in only tributary sections, and 29 in both. The average number of species per site was 21.9 (range 17-29). Site 2 yielded the most species at 29 and South Branch Nibbs Creek with the fewest at 17.

Of 43 species collected, 33 were dominant in pool, six in run, and four in riffle mesohabitats. Among pool-dominant species, seven were found only in pools, 23 were subdominant in runs, two subdominant in riffles, and one subdominant equally in runs and riffles. For species dominant in runs, one was found only in runs, five were subdominant in pools and one was subdominant in riffles. Only Blacknose Dace, *Rhynichthys atratulus*, Fantail Darter, *Etheostoma flabellare*, Glassy Darter, *Etheostoma vitreum*, and Torrent Sucker were found dominantly in riffles. The former three were subdominant in runs while the latter was subdominant in pools.

SPECIES ACCOUNTS

Family Anguillidae (Freshwater Eels)

Anguilla rostrata, American Eel: Only 16 specimens were collected at five sites. Most were found in pools (50%) and runs (44%) and infrequently with riffles (6%). The American Eel is catadromous and spends much of its adult life in freshwater streams and rivers. It is a Tier III species in the Virginia Wildlife Action Plan (VDGIF, 2015). The species was collected in several previous surveys.

Family Esocidae (Pikes and Mudminnows)

Esox niger, Chain Pickerel: We collected 25 specimens at six sites. The majority were found in pools (68%) while the remaining were in runs. The earliest record of this species was in 1983 by Dr. Robert Jenkins (VDGIF, 2016).

Umbra pygmaea, Eastern Mudminnow: A total of 32 specimens were collected at five sites. The species was most associated with pool (78%) and lesser in run (16%) and riffle (6%) habitat. The species was documented in two previous surveys.

Family Cyprinidae (Minnows)

Notemigonus crysoleucas, Golden Shiner: Eleven individuals were collected in a single pool at one mainstem site. The species was documented in several previous surveys.

Chrosomus oreas, Mountain Redbelly Dace: We found only 13 individuals in Ellis Creek. The species was associated with pool (61%) and run (39%) habitats. It was documented in several previous surveys.

Clinostomus funduloides, Rosyside Dace: We collected 113 individuals at two mainstem and two tributary sites. The species was found primarily in pools (83%), and to a lesser degree in runs (13%) and riffles (4%). It was documented in several previous surveys.

Rhinichthys atratulus, Eastern Blacknose Dace: Primarily a headwater species, it was found in one upper mainstem and two tributary sites. A total of 26 specimens were collected mostly in riffles (70%), infrequently in runs (25%) and rarely in pools (5%). The first species record was in 1986 (Norman & Southwick, 2014).

Semotilus corporalis, Fallfish: With a total of 200 specimens being found at six mainstem and three tributary sites, it was one of the most widely distributed and abundant species. The Fallfish was primarily found in pools (65%), occasionally in runs (34%), and rarely in riffles (1%). The species was documented in several previous surveys.

Semotilus artromaculatus, Creek Chub: The species was found in four upper mainstem and four tributary sites. Of the 184 individuals collected, most were in pools (85%) and infrequently in runs (11%) and riffles (4%). The first Creek Chub record was 1986 (Norman & Southwick, 2014).

Nocomis leptocephalus, Bluehead Chub: Totaling 635 specimens being found over all 10 sties, the species was the most abundant and widely distributed species. It was almost equally collected in pools (41%) and runs (38%) and infrequently in riffles (21%). The species was found in all previous surveys.

Cyprinella analostana, Satinfin Shiner: We collected Satinfin Shiner at five mainstem and one tributary site. It was the third most abundant species behind Bluehead Chub and Tesselated Darter. It was primarily found in runs (65%), uncommon in pools (32%), and rarely in riffles (3%). The species has been documented in all surveys since 1983 (VDGIF, 2016).

Luxilus cornutus, Common Shiner: The species was collected at four mainstem and three tributary sites. Of the 84 individuals collected, most were found in pools (69%), occasionally in runs (30%), and rarely in riffles (1%). The first record of Common Shiner was 1986 (Norman & Southwick, 2014).

Lythrurus ardens, Rosefin Shiner: We collected 144 individuals at the four lowest most sites and one site in Nibbs Creek. The species was slightly more prominent in pools (56%) than runs (40%) but only rarely caught in riffles (4%). The species was first collected in 1983 (VDGIF, 2016).

Notropis amoenus, Comely Shiner: The species was collected at five mainstem sites. Of the 57 specimens recorded, most were in pools (58%) and runs (42%). It was not found in riffles. The only other record of this species was in 1986 (Norman & Southwick, 2014).

Notropis hudsonius, Spottail Shiner: Only one Spottail Shiner was collected in a run at the lowest most site nearest the confluence with the Appomattox River. This is first record of the species in the Flat Creek system.

Notropis procne, Swallowtail Shiner: We collected 201 specimens at all six mainstem and three tributary sites. It was collected nearly equal in runs (48%) and pools (47%). Riffles were the least inhabited (5%). Swallowtail Shiner was documented in all previous surveys (VDGIF, 2016).

Hybognathus regius, Eastern Silvery Minnow: Although uncommon in the drainage, Eastern Silvery Minnow was distributed in four mainstem and three tributary sites. Of the 49 specimens collected, most were found in pools (78%) and infrequently in runs (20%) and rarely in riffles (2%). The species was documented before 1980 and occasionally afterwards (VDGIF, 2016).

Family Catostomidae (Suckers)

Erimyzon oblongus, Eastern Creek Chubsucker: Only 15 individuals were found from two mainstem and two tributary sites. The majority were present in pools (76%) and fewer in runs (24%). None were present in riffles. The species has been found in all surveys since 1986 (Norman and Southwick, 2014).

Hypentelium nigricans, Northern Hogsucker: The species was collected at four mainstem sites totaling 13 individuals. Most specimens were found in pools (54%) followed by runs (38%) and rarely in riffles (8%). The first documented species record was 1986 (Norman & Southwick, 2014).

Thoburnia rhothoeca, Torrent Sucker: Only 13 individuals were found in two tributary sites. Even though riffle habitat was relatively rare in our survey, it was primarily collected in riffles (77%), occasionally in pools (18%), and rarely in runs (5%). The species was documented before 1980 and occasionally afterwards (VDGIF, 2016).

Catostomus commersoni, White Sucker: Twenty-eight specimens were found at three mainstem and two tributary sites. The majority of individuals occupied pools (93%) and runs (7%) to a lesser degree. The species was first documented in 1983 (VDGIF, 2016).

Family Ictaluridae (Catfishes)

Ictalurus punctatus, Channel Catfish: Only two specimens were found in pool habitat at the most downstream site. The only other species record was an observation in 1983 (VDGIF, 2016).

Ameiurus natalis, Yellow Bullhead: Although only 22 specimens were collected, it was widely distributed across four mainstem and three tributary sites. The species was found mostly in pools (74%) and less in riffles (16%) and runs (10%). The species was first documented in 1983 (VDGIF, 2016).

Noturus insignis, Margined Madtom: Of the 40 specimens observed, the species was found at all mainstem and tributary sites. It was distributed nearly equal among pools (39%), riffles (33%), and runs (28%). The species was documented in most surveys (VDGIF, 2016).

Family Aphredoderidae (Pirate Perch)

Aphredoderus sayanus, Pirate Perch: The species was common and widely distributed in the system. A total of 145 individuals were found over all sites with nearly half being collected at North Branch Nibbs Creek. Most were collected in pools (79%) and fewer in runs (19%) and riffles (2%). The species was found in all previous collections.

Family Poeciliidae (Liverbearer)

Gambusia holbrooki, Eastern Mosquitofish: Only 12 specimens were collected at one mainstem and two tributary sites. Most were found in pools (80%) with all others in runs (10%) and riffles (10%). The species was first collected in 1983 and only occasionally afterwards (VDGIF, 2016).

Family Moronidae (Temperate Basses)

Morone americana, White Perch: A total of 10 White Perch were collected in one seine haul of a pool at a mainstem site. The species was first documented in 2011 (Starnes et al., 2014).

Family Centrarchidae (Sunfishes)

Acantharchus pomotis, Mud Sunfish: Only two individuals were found in a pool at one mainstem site. The species was occasionally collected beginning in 1983 (VDGIF, 2016). Mud Sunfish is a Tier IV species in Virginia's Wildlife Action Plan (2015).

Enneacanthus gloriosus, Bluespotted Sunfish: The species was rare in the survey and collected in one mainstem and one tributary site. Bluespotted Sunfish were mostly collected in run (80%) and to a lesser degree, pool (20%) habitat. The species was first collected in 1983 (VDGIF, 2016).

Micropterus punctulatus, Spotted Bass: A total of seven Spotted Bass were collected at four mainstem sites. Most were collected in runs (57%) followed closely by pools (43%). No previous collection record was known for Flat Creek although the species is prominent in other Appomattox River tributaries (Norman & Southwick, 2014).

Micropterus salmonoides, Largemouth Bass: We found 14 individuals in four mainstem and two tributary sites. Most were collected in pools (83%) and infrequently in runs (17%). The first documented record for the species was in 2009 in Nibbs Creek (VDGIF, 2016).

Lepomis gulosus, Warmouth: The species was very rare with only three individuals at one mainstem site in pool habitat. It was known before 1980 and collected in several surveys afterwards (VDGIF, 2016).

Lepomis cyanellus, Green Sunfish: The species was found in three mainstem and three tributary sites. Of the 43 individuals collected, most were in pools (85%) and occasionally in runs (15%). Green Sunfish was first documented in 2011 (VDGIF, 2016).

Lepomis auritus, Redbreast Sunfish: Totaling 102 individuals and found at all mainstem and tributary sites, Redbreast Sunfish was the most common and widespread Centrarchid in our survey. Most specimens were found in pools (71%), occasionally in runs (26%), and rarely in riffles (3%). The species was first discovered in 1983 and has been found in all following surveys (VDGIF, 2016).

Lepomis macrochirus, Bluegill: The species was found at all mainstem and three tributary sites. It was most frequently collected in pools (90%) and rarely in runs (8%) and riffles (2%). Bluegill was found in all previous surveys (VDGIF, 2016).

Lepomis gibbosus, Pumpkinseed: Only three Pumpkinseeds were collected at one mainstem and two tributary sites. All specimens were collected in pools. The species was collected in all surveys since 1983 (VDGIF, 2016).

Lepomis microlophus, Redear Sunfish: Only three individuals were collected in two tributary sites. Two were found in pool (67%) and one (33%) in run habitats. Redear Sunfish was first recorded in 1983 and only once afterwards (VDGIF, 2016).

Family Percidae (Perches)

Percina notogramma, Stripeback Darter: Only 16 individuals were found at five mainstem and one tributary site. Most were collected in pools (69%), infrequently in runs (25%), and rarely in riffles (6%). The species was first collected in 1983 and occasionally afterwards (VDGIF, 2016).

Percina peltata, Shield Darter: The species was found at three mainstem sites. We collected 11 individuals in both runs (55%) and riffles (45%). None were present in pools. This is the first documented record of Shield Darter in Flat Creek although it was collected in other Appomattox River tributaries (Norman & Southwick, 2014).

Etheostoma olmstedi, Tessellated Darter: Totaling 248 individuals, Tessellated Darter was the second most abundant species. Additionally, it was widely distributed being found at all mainstem and tributary sites. The species could be considered a habitat generalist with nearly equal presence in pools (38%), runs (33%), and riffles (29%). It was found in three previous surveys beginning in 1983 (VDGIF, 2016).

Etheostoma vitreum, Glassy Darter: We found 184 specimens at four mainstem and two tributary sites. Most (52%) were found at one site on Nibbs Creek. Individuals were found in riffles (47%) and runs (45%), and rarely pools (8%). The species was present in all previous surveys (VDGIF, 2016).

Etheostoma flabellare, Fantail Darter: The species was found at all mainstem and three tributary sites. Among the 51 collected, most were found in riffles (64%), occasionally in runs (30%), and rarely in pools (6%). The species has been noted in most surveys (VDGIF, 2016).

Etheostoma fusiforme, Swamp Darter: Only four individuals were found at one mainstem and one tributary site. All individuals were collected in pool habitat. The species has been found in most surveys (VDGIF, 2016).

DISCUSSION

The Flat Creek fish community is characteristic of a medium-sized Piedmont stream dominated by pool/run mesohabitat and sand substrate. Of the 10 fish families represented, the majority of species were found in Cyprinidae (32%) and Centrarchidae (23%). Besides species such as Swallowtail Shiner, Satinfin Shiner, and Glassy Darter commonly known from Virginia’s Piedmont, Flat Creek also contained an interesting mix of those species found at the margins of their range and habitat limits. These include the pool-adapted Eastern Mudminnow, Swamp Darter, Mud Sunfish, and Bluespotted Sunfish that are typical of ponds and swamps of the Coastal Plain. Other species such as Fantail Darter, Blacknose Dace, and Torrent Sucker, which were found in riffle mesohabitats, are characteristic of mountainous, western regions of the state.

Our survey collected 43 species in the Flat Creek system bringing its total species to 52. Previous (post-1980) surveys averaged 30.2 (range 26-37) species. The next closest survey by species number was Norman & Southwick (2014) conducted in 1986-87 with 37 species. Similar to our survey, they sampled in both mainstem and tributary reaches, which provided a wide variety of habitats. In addition to the most species, our survey collected species not previously known in Flat Creek including Spottail Shiner, Spotted Bass, and Shield Darter. All of these species were present in mainstem sections of Flat Creek and none in tributaries. Although not collected by Norman & Southwick (2014) in Flat Creek, they did note the expansion of Spotted Bass, an introduced species, in other tributaries of the Appomattox River.

We were unable to find eight species reported in previous surveys. These include Gizzard Shad (*Dorosoma cepedianum*), River Chub (*Nocomis micropogon*), Crescent Shiner (*Luxilus cerasinus*), Bridle Shiner, Blacktip Jumprock (*Moxostoma cervinum*), Flier (*Centrarchus macropterus*), Yellow Perch (*Perca flavescens*), and Johnny Darter (*Etheostoma nigrum*). Among these species, Gizzard Shad and River Chub were only collected by Dr. Robert Jenkins (VDGIF, 2016) and Blacktip Jumprock and Yellow Perch by Norman & Southwick (2014). Multiple surveyors collected all other species. Blacktip Jumprock is native to the Roanoke River drainage and introduced in the James River drainage (Jenkins & Burkhead, 1994). The first record in the Appomattox system was four specimens in 1986 in Neal's Creek, a Flat Creek tributary (Norman & Southwick 2014). Although we did not sample this tributary, lack of Blacktip Jumprock at our sampling sites may indicate that the introduction was unsuccessful.

According to Jenkins & Burkhead (1994), all species we found were native to the James River drainage except Channel Catfish, Green Sunfish, Bluegill and Redear Sunfish. In addition, Largemouth Bass is considered introduced but possibly native and the Warmouth as native but possibly introduced. While native to the drainage, White Perch above the fall line is considered introduced. All introduced species are popular gamefish, and their presence is likely the result of stocking into local ponds and Lake Chesdin, a downstream reservoir.

Although we only recorded Tessellated Darter, both Johnny and Tessellated darters are known from previous surveys. Flat Creek occurs within an *olmstedi*/*nigrum* intergrade zone in the Chowan, James, and Roanoke drainages (Jenkins & Burkhead, 1994). In this zone, phenotypic resemblance between the two species can make identification extremely problematic. We addressed this issue by sending a subset of vouchered *E. olmstedi* specimens to the Near Laboratory at the Department of Ecology and Evolutionary Biology, Yale University to verify species identifications. Dr. Tom Near and Mr. Dan MacGuigan, PhD Candidate, are currently examining the phylogeography of the *Etheostoma nigrum* complex using mitochondrial and ddRAD data. Their examination indicated our specimens were *E. olmstedi* and possibly a distinct, geographically restricted species (D. MacGuigan, pers. comm.).

The most disappointing result of our study was not finding Bridle Shiner. The species was found in four surveys from 1983 to 2013 (Norman & Southwick, 2014; Starnes et al., 2014; VDGIF, 2016). In 1986, Norman & Southwick (2014) collected one specimen in North Branch Nibbs Creek. We sampled the same site but failed to find it. The only known mainstem Bridle Shiner site was originally sampled by Dr. Robert Jenkins in 1983 (VDGIF, 2016) and by Dr. Wayne Starnes (Starnes et al., 2014) in 2011 and 2013 (Fig. 1). We were unable to determine the number of specimens observed by Jenkins but Starnes found two and 10 specimens in 2011 and 2013, respectively.

In the early fall of 2016, accompanied by Dr. Wayne Starnes, we conducted an abbreviated survey at the known mainstem site for Bridle Shiner. No specimens were found but Dr. Starnes indicated that submerged aquatic vegetation (SAV), microhabitat where his specimens were collected, was absent. The nearest sampling during our full survey was 1.18 km downstream of the known Bridle Shiner site. Even though we sampled over 400 m and came within 0.74 km of his collection site, we were still unsuccessful. Starnes et al. (2014) recommended that Flat Creek be 1) surveyed over much of its length and tributary system to determine just how truly localized the Bridle Shiner population is and 2) whether it can withstand removal of stock for propagation purposes. If Bridle Shiner is still present in Flat Creek, it is extremely localized and additional survey effort is necessary prior to any consideration of species removal.

Despite not finding our target species, we did record the presence of two other species on Virginia's Wildlife Action Plan, the Mud Sunfish (Tier IV) and American Eel (Tier III). The presence of American Eel is notable because this catadromous species is able to navigate through the 256 m long and 22 m high George F. Brasfield dam located on the Appomattox River approximately 55 km downstream of its confluence with Flat Creek. Eel passage may have been assisted by a fish lift that has been operational on the dam since 2004 (Martin, 2019). It is unknown whether other migratory species such as Sea Lamprey (*Petromyzon marinus*), Blueback Herring (*Alosa aestivalis*), and Alewife (*Alosa pseudoharengus*) use this lift or can traverse this barrier (VDGIF, 2016).

Our study indicates that Flat Creek still has a diverse fish assemblage with only a few notable species absences and additions. If SAV is disappearing, water quality issues should be investigated. Because we sampled less than five percent of the Flat Creek mainstem, it is premature to conclude that Bridle Shiner is gone from the system. We recommend additional mainstem sampling be concentrated in those more difficult to access reaches.

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RESEARCH ARTICLE

LAND SNAILS AND SLUGS FROM A SUBURBAN YARD IN FAIRFAX COUNTY, VIRGINIA

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ABSTRACT

Land snails and slugs (Gastropoda: Caenogastropoda and Pulmonata) were surveyed in a suburban yard in Fairfax County, Virginia. Twenty-three species were documented from a 0.10 ha lot. *Discus rotundatus* is documented for the first time in Virginia. *Opeas pyrgula*, *Paralaoma servile*, and *Pupilla muscorum* are documented for the second time in Virginia and for the first time in Fairfax County.

Keywords: New state record, non-native species, urban habitat.

INTRODUCTION

During the coronavirus pandemic of 2020, I found myself spending more time in my yard than I had in the past 22 years. While pulling weeds along the edge of my concrete sidewalk, I discovered a pupillid land snail. Curious as to what species it might be, I brought it indoors for closer examination. I was surprised to find that it was *Pupilla muscorum*, a species that was not found at any National Park sites near the District of Columbia (Steury & Pearce, 2014), even though part of one of these parks is only two km from my home. This discovery led me to begin a more thorough inventory of the land snails and slugs of my suburban yard, the results of which are discussed below.

MATERIALS AND METHODS

Study Site

The study site is a 0.10 ha (0.246 acre) suburban yard located at 8316 Woodacre Street in Alexandria, Virginia. It is located on the Coastal Plain in Fairfax County. The home on this site was built in 1964 and occupies about one-fourth of the lot. The remaining area is covered in April and May by non-native turf grasses and various non-native weeds, especially, Indian strawberry (*Duchesnea indica* [Andrews] Teschem.), white clover (*Trifolium repens* L.), purple deadnettle (*Lamium purpureum* L.), common dandelion (*Taraxacum officinale* F.H. Wigg), common chickweed (*Stellaria media* [L.] Vill.), mouse-ear chickweed (*Cerastium* L. sp.), and corn speedwell (*Veronica arvensis* L.). Two weedy native species, slender yellow woodsorrel (*Oxalis dillenii* Jacq.) and dooryard violet (*Viola sororia* Willd.) are also common. Herbicides are not used on the site, nor is it fertilized. A fence row along the western boundary of the study site contains a row of mature trees including one red maple (*Acer rubrum* L.), two willow oaks (*Quercus phellos* L.), and six sweetgum (*Liquidambar styraciflua* L.). Leaf litter accumulates along the base of the fence row under the trees. A young red cedar (*Juniperus virginiana* L.) grows on north side of the house and a mature southern magnolia (*Magnolia grandiflora* L.) and a Chinese holly (*Ilex cornuta* Lindl. & Paxton) on the south side. The house is surrounded on three sides by azalea cultivars (*Rhododendron* L.). A decomposing brush pile that has been accumulating for about 20 years is located in the northwest corner of the lot.

Seven cover boards made of tile (n=2, 30.5 cm x 30.5 cm), plywood (n=2, 0.9 m x 0.9 m), or cardboard (n=3, 0.9 m x 0.9 m) were placed in various locations at the study site including, under leaf litter along the fence row, under the southern magnolia, near the brush pile, and in turf grass. The boards were left in place during April and May 2020. Cover boards placed in turf grass were moved to other turf grass locations every two weeks, while the other cover boards were left in place for the duration of the study. The underside of each board was examined for land snails and slugs three times per week. At least one voucher specimen was collected for each species observed, except for *Philomycus carolinianus*, which was documented with a photographic voucher (Fig. 1). Three juvenile slugs were captured and reared in captivity on a diet of carrots, cauliflower, and lettuce (see entry for *Limax maximus* in the list of species below). Specimens are deposited at the Carnegie Museum of Natural History (CMNH) in Pittsburgh, Pennsylvania. A tally was kept of the number of each species observed on each day. When a total of 30 individuals was observed for a species it was recorded as common during the month. Cover board data was supplemented by general searches in leaf litter, by examining logs pulled from the bottom of the brush pile, and by pulling Indian strawberry and other yard weeds to examine exposed soil in the lawn. Daytime surveys were aided by the use of 3.5 x eyeglasses, a 5 x magnifying glass, and a 16 x doublet. Leaf litter was not collected for sorting indoors, a method that may have produced additional specimens of small species. New state and county records are based on reviews of Dundee (1974), Hotopp et al. (2013), Hubricht (1985) and other literature cited in the list of species. Specimens were identified using several sources including Burch (1962), Eversham (2018), Hotopp et al. (2013), Kerney & Cameron (1979), Nature Spot (2020), Nekola & Coles (2010), Nekola et al. (2015), and Pilsbry (1948).

Figure 1. *Philomycus carolinianus* (Bosc) photographed in Fairfax County, Virginia, in a suburban yard at 8316 Woodacre Street, Alexandria, on 1 May 2020.

RESULTS AND DISCUSSION

Twenty-three species were documented from the study site including 16 species of snails and seven slugs. Thirteen species (56.5%) (7 snails and 6 slugs) found at the study site are non-native species. The most commonly observed species at the study site were the non-native slugs *Ambigolimax valentiana* and *Deroceras reticulatum,* the non-native snail *Discus rotundatus,* and the native snail *Triodopsis juxtidens*. *Discus rotundatus* is reported for the first time in Virginia, which documents a slight southern range extension from the District of Columbia (Steury & Steury, 2011). *Opeas pyrgula*, *Paralaoma servilis*, and *Pupilla muscorum* are documented from only one other Virginia county (or city), and for the first time in Fairfax County by this study (Hotopp et al., 2013; Steury & Pearce, 2014). Steury & Pearce (2014) did not report *Pupilla muscorum* or *Opeas pyrgula* among the 64 gastropod species documented from nearby national parks in the District of Columbia, Arlington and Fairfax Counties and City of Alexandria, Virginia, or Charles and Prince Georges Counties, Maryland. This survey of a 0.10 ha urban yard contained 35.9% of the number of gastropod species found in more than 2600 ha of nearby national park property. Only three species were found in May that were not documented in April.

The study demonstrates that some species preferring urban environments are likely underrepresented in biodiversity studies. Urban yards (at least those free of pesticides and fertilizers) provide habitat for several native and naturalizing species of snails and slugs and may be as proportionally biodiverse in other invertebrate taxa. The percentage of non-native species, compared to the entire gastropod fauna of an area, may be higher in some disturbed urban environments than in natural areas found in national parks. However, a study of the land snail fauna of 61 yards in Oklahoma (Bergey & Figueroa, 2016) reported that only 39.1% (9 of 32 snail species) were non-native. The same study reported the highest snail species richness in any yard to be 14 species (2 less than recorded in this study).

LIST OF SPECIES

Familial nomenclature and taxonomic order follow Bouchet & Rocroi (2005), except for Cionellidae, which follows Roth (2003). Generic and species names are listed alphabetically and follow Perez & Cordeiro (2008) and Turgeon et al. (1998). The number of specimens collected and the CMNH catalog number is given for each species. The number of individuals observed in April and May is listed if specimens were documented during the month. Taxa with more than 30 observations in a month are listed as “common.” The habitat where each taxon was observed is given. Non-native species are marked with an asterisk.

Family Cionellidae

**Cochlicopa lubrica* (Müller) – (4; CMNH 173967); April (13), May (14); lawn, under southern magnolia, leaf litter, brush pile, under shrubs near house. Kerney & Cameron (1979) describe *Cochlicopa lubrica* as a Holarctic species. However, it is likely that shells reported as *Cochlicopa lubrica* in North America are a mix of native and exotic species, with the native north American race being undescribed (Nekola, 2004). Almost certainly, all material from urban habitats in northeastern North America are the introduced European *Cochlicopa lubrica* and thus represent exotics (Jeff Nekola, pers. comm. 2020).

Family Pupillidae

**Pupilla muscorum* (Linnaeus) – (Fig. 2); (6; CMNH 173968); April (6), May (2); lawn. This species was previously documented in Virginia only from Frederick County (Hotopp et al., 2013). It is a non-native snail of European origin (Hotopp et al., 2013). It was not found at any national park sites near the District of Columbia (Steury & Pearce, 2014). Of the six specimens deposited at CMNH, three specimens possessed the parietal denticle sometimes found in this species, while the other three specimens lacked a denticle in the aperture.

Figure 2. *Pupilla muscorum*, collected in Fairfax County, Virginia, suburban yard at 8316 Woodacre Street, Alexandria, on 17 April 2020. Hash marks are in millimeters.

Family Strobilopsidae

Strobilops labyrinthicus (Say) – (3; CMNH 173969); April (5), May (1); under southern magnolia, brush pile.

Family Valloniidae

**Vallonia* cf. *excentrica* Sterki – (5; CMNH 173975); April (1), May (4); lawn. The aperture of this species is reflected toward the inner side, as in these five shells. However, it is difficult to distinguish from maturing shells of *Vallonia pulchella* Müller which has a lip that is reflected toward the outside of the shell as an adult. Both species have been reported from Fairfax County (Hotopp et al., 2013). *Vallonia pulchella* is the more common urban species on the East Coast (Jeff Nekola, pers. comm. 2020). *Vallonia excentrica* is clearly an exotic in North America, even though it was included by Hubricht (1985) in his range maps of native species. There are no pre-European fossils of *V. excentrica* and it is strictly limited to anthropogenic habitats (Jeff Nekola, pers. comm. 2020).

Family Vertiginidae

Gastrocopta contracta (Say) – (2; CMNH 173974); April (2), May (1); brush pile.

**Vertigo pygmaea* (Draparnaud) – (Fig. 3); (1; CMNH 173973); May (1); lawn. *Vertigo pygmaea* is probably not a native North American animal (Nekola & Coles, 2010).

Figure 3. *Vertigo pygmaea* collected in Fairfax County, Virginia, suburban yard at 8316 Woodacre Street, Alexandria, on 1 May 2020. This form of *V. pygmaea*, which lacks the crested callus on the palatal wall, resembles *Vertigo gouldii* (A. Binney) in the orientation of the primary teeth in the aperture, however, the two species are distinguished by the deeper depression on the outer shell surface over the palatal lamellae, the lack of a small basal lamella, and the less distinct shell striae present in *V. pygmaea*. Length 1.9 mm.

Family Subulinidae

**Opeas pyrgula* Schmacker and Boettger – (Fig. 4); (3; CMNH 173972); April (1), May (4); leaf litter. *Opeas pyrgula* was previously documented in Virginia only from Chesapeake City, in the southeastern corner of the Commonwealth. This snail is an Asian species naturalized in North America along the Gulf and Atlantic Coasts from Texas north to Pennsylvania (Hotopp et al 2013). This record extends its previously published range 226 km (140 mi) northward in Virginia, however there is also an older museum record at CMNH (catalog number 132762) of *O. pyrgula* from the City of Alexandria, collected on 30 November 2013, by Timothy Pearce.

Figure 4. *Opeas pyrgula* collected in Fairfax County, Virginia in a suburban yard at 8316 Woodacre Street, Alexandria, on 11 April and 15 May 2020. Hash marks are in millimeters.

Family Punctidae

**Paralaoma servilis* (Shuttleworth) – (3; CMNH 173976); April (1), May (2); lawn. This species has been reported as native to New Zealand (Brooks, 1999) and possibly Australia (Price & Webb, 2006), however, it is limited to anthropogenic sites in New Zealand and it is highly likely that those populations are themselves exotic (Jeff Nekola, pers. comm. 2020). The most likely origin for this species is western North America where *P. servilis* is found in native habitats from the Mexican border north to Anchorage, Alaska, and there are other closely related species in the Mexican highlands (Jeff Nekola, pers. comm. 2020). The first North American record east of the Mississippi River was documented from the City of Alexandria, Virginia (Steury & Pearce, 2014). These specimens are the first records for Fairfax County. Since its discovery in Virginia, photographs that are apparently of this species and with unverified geographical provenance have been uploaded to the iNaturalist website from sites reportedly in Alabama, Florida, Georgia, New

York, Ohio, Pennsylvania, and South Carolina (iNaturalist 2020). Jeff Nekola (pers. comm. 2020) has collected it in Boone, North Carolina.

Punctum minutissimum (I. Lea) – (1; CMNH 173977); May (1); brush pile. This species may be more common than reported. Due to its minute size, it could be easily overlooked using the collection methods employed during this study. At just over one mm at maturity, it is one of North America's smallest land snails.

Family Discidae

Discus rotundatus* (Müller) – (Fig. 5); (8; CMNH 173978); April (common), May (common); brush pile, lawn, under shrubs near house. **NEW STATE RECORD. *Discus rotundatus* is native to western and central Europe (Kerney & Cameron, 1979) and northern Africa (Algeria) (Pilsbry, 1948). In North America, it has been collected in Canada in British Columbia, Newfoundland, Nova Scotia, and Ontario and in the United States in California, Idaho, Massachusetts, Maine, New Jersey, New York, Pennsylvania, Vermont, Washington, and the District of Columbia (Dundee, 1974; Hanna, 1966; NatureServe, 2020; Pearce, 2008; Steury & Steury, 2011).

Figure 5. *Discus rotundatus* collected in Fairfax County, Virginia, in a suburban yard at 8316 Woodacre Street, Alexandria, on 3 April 2020. Two shells showing left, ventral view, and right, dorsal view. Hash marks are in millimeters.

Family Gastrodontidae

Ventridens ligera (Say) – (2; CMNH 173979); April (14), May (12); lawn, leaf litter.

Zonitoides arboreus (Say) – (10; CMNH 173980); April (19), May (23); leaf litter, brush pile, under southern magnolia, under shrubs near house.

Family Pristilomatidae

Hawaiia minuscula (A. Binney) – (10; CMNH 173985); April (29), May (14); lawn, leaf litter, brush pile, under southern magnolia, under holly.

Family Zonitidae

Glyphyalinia indentata (Say) – (2; CMNH 173984); April (14), May (9); lawn, leaf litter, under shrubs near house.

Family Limacidae

**Ambigolimax valentiana* (Férussac) – (2; CMNH 173983); April (common as juveniles), May (common); all habitats. This slug is native to the Iberian Peninsula of Europe (Roth and Sadeghian 2006) and formerly placed in the genus *Lehmannia*. Another synanthropic species, *Ambigolimax nyctelius*, is externally indistinguishable from this species and must be separated from it through analysis of their mtDNA barcoding gene, COI (*A. nyctelius*, n = 18 and *A. valentianus*, n = 11) (Vendetti, 2018). *Ambigolimax nyctelius* has only been reported in North America in Los Angeles County, California (2018) and in Washington, D.C. in 1960 (Quick, 1960). DNA barcoding of many slugs externally similar to *A. valentiana* from the Washington D.C. area may reveal that the cryptic species *A. nyctelius* is still present on the East Coast. *Ambigolimax valentiana* was the most commonly encountered slug during this study. As many as 39 individuals were observed during a single event under a 30.5 cm x 30.5 cm coverboard. These slugs were typically found huddled together, in groups of 4–7, rather than evenly distributed as were individuals of the other slug species found during this study.

**Limax maximus* Linnaeus – (Fig. 6); (2; CMNH 173982); April (8), May (15); under southern magnolia, under shrubs near house; leaf litter; lawn. This slug of European origin is the largest in the study area, reportedly reaching lengths of up to 20 cm (Kerney & Cameron, 1979). In the study area, juveniles of this species were often similar to each other in appearance, possessing broad,

Figure 5. *Limax maximus*, juvenile, found in Fairfax County, Virginia, in a suburban yard at 8316 Woodacre Street, Alexandria, on 3 April 2020. White arrow shows location of pale horseshoe shaped marking on the posterior edge of the mantle.

dark, lateral bands, a pale keel, and a pale horseshoe shaped mark on the posterior edge of the mantel (Fig. 5). Three juveniles with these markings were reared in captivity and all three developed into the more typical form a *L. maximus* with a spotted mantel.

Family Agriolomacidae

**Deroceras reticulatum* (Müller) – (1; CMNH 173981); April (common), May (common); all habitats. This slug, abundant at the study site, is introduced from Europe (Kerney and Cameron 1979). When stroked with a blade of grass it often produces a milky white mucus on its dorsal surface.

Family Arionidae

Arion* cf. *hortensis* Férussac – (1; CMNH 173986); April (5), May (10); leaf litter, under southern magnolia, under holly, lawn. This slug represents a species complex of European origin consisting of *A. hortensis*, *Arion distinctus*,** and *Arion owenii* (Kerney & Cameron, 1979) that can only be distinguished with certainty through dissection of mature adults, however *A. distinctus***,** and *A. owenii* have not yet been documented in Virginia (Hotopp et al., 2013). The dorsal and lateral surfaces of these specimens were black (*A. hortensis* is typically the darkest of the three species [Kerney & Cameron, 1979]). The sole was light grey when clean, but at the slightest disturbance these slugs produced a copious, orange mucus that made the light grey sole appear orange. Kerney & Cameron (1979) describe the sole of *A. hortensis* as orange or yellow. This species was more common at this study site than at nearby national park sites, where only one specimen was found (Steury & Pearce, 2014).

**Arion intermedius* (Normand) – (1; CMNH 173987); April (1), May (1); lawn. This is another slug introduced from Europe (Kerney & Cameron, 1979). It is the smallest slug in the study area, reaching only two cm at maturity. In this specimen, the dorsal and ventral sides are white and the head and tentacles are a contrasting blue-grey. The sole is pale grey when clean and was observed to produce a yellowish mucus around the periphery, and clear mucus in the middle, these eventually mixing to make the sole appear yellowish.

**Arion* cf. *subfuscus* (Draparnaud) – (1; CMNH 173988); May (1); crawling on sidewalk in early morning after nighttime rain. *Arion fuscus* (Müller) a species reportedly widespread in Europe and North America, is not certainly distinguishable from *A. subfuscus* by examination of external features (Eversham 2018), but it is not reported from the Mid-Atlantic area (Hotopp, 2013). This specimen measured 6.0 cm at full stretch and had orange body mucus. The sole mucus is reported by Eversham (2018) to be clear, as it appeared to be in this specimen. Interestingly, this species was abundant at nearby National Park sites (Steury and Pearce 2014), but only one specimen was found during this study.

Family Philomycidae

Philomycus carolinianus (Bosc) – (Fig. 1). May (1); brush pile. This was the only native slug found at the study site. Although difficult to discern in Fig. 1, the dark elongated spots, oriented in two parallel lines along each side of the dorsal center band, were clearly present. This character, coupled with a lack of lateral banding, separates this species from other Virginian *Philomycus*. Due to apparent rarity at the study site, only a photographic voucher (Fig. 1) was obtained for this species.

Family Polygyridae

Mesodon thyroidus (Say) – (1; CMNH 173989); April (1); leaf litter.

Triodopsis juxtidens (Pilsbry) – (4; CMNH 173990); April (common), May (common); all habitats.

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RESEARCH ARTICLE

OBSERVATIONS ON THE BEHAVIOR, BIOLOGY, AND DISTRIBUTION OF THE EASTERN HERCULES BEETLE, *DYNASTES TITYUS* (LINNAEUS) (COLEOPTERA: SCARABAEIDAE; DYNASTINAE) IN VIRGINIA

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ABSTRACT

The New World genus *Dynastes* reaches its northernmost extent in the United States with two species, *Dynastes grantii* and *D. tityus* (Linnaeus), the latter of which is widespread in eastern United States, including Virginia. Notes on the biology and distribution of *D. tityus* in Virginia are presented, along with observations on their feeding and mating behaviors on green ash trees (*Fraxinus pennsylvanica* Marshall) in Southampton County during the summer of 2019. The apparent dependence on ash trees of both species of American *Dynastes* that occur north of Mexico for attracting and locating mates is briefly discussed in light of their possible endangerment due to the ever-expanding range of the invasive Emerald Ash Borer, *Agrilus planipennis* Fairmaire.

Keywords: *Agrilus*, *Apis*, conservation, Emerald Ash Borer, *Panopoda*, *Vanessa*, *Xyloryctes*.

INTRODUCTION

Species of the New World *Dynastes* are among the largest of all beetles. The males are easily recognized by the long, forward-projecting pronotal horn, while the unarmed females bear a single tubercle on the frons. The genus was recently revised by Huang (2017), who recognized 15 species distributed from northern South America northward to the United States, as well as a few islands in the Caribbean. The validity of several Central and South American "forms" recognized as valid species has been questioned by some workers (Ratcliffe & Cave, 2017).

Dynastes is postulated to have originated in South America and the lineages that produced the North American taxa originated after the closure of the Panama Isthmus 3.5 Mya (Huang, 2016). The Transverse Volcanic Belt and the Sierra Madre del Sur funneled dispersing ancestors of North American *Dynastes* both westward and eastward (Ratcliffe & Cave, 2017). Today, the genus reaches its northernmost extent in the United States with two species. *Dynastes grantii* Horn is a montane species that occurs in southwestern Utah, Arizona, western New Mexico, and south to northern Mexico, while *D. tityus* (Linnaeus) is primarily a lowland species that is widespread in eastern United States from New York south to Florida, west to southeastern Kansas, Oklahoma, and eastern Texas (Huang, 2017; Ratcliffe & Cave, 2017).

Dynastes tityus is a very distinctive (Fig. 1) and widespread species in Virginia. Ratcliffe & Cave (2017) recorded following counties and independent cities: Accomack, Albemarle, Alexandria, Amelia, Amherst, Arlington, Bedford, Botetourt, Brunswick, Buckingham, Chesterfield, Culpeper, Emporia, Fairfax, Falls Church, Fauquier, Franklin, Halifax, Hanover, Henrico, Loudon, Louisa, Lunenburg, Lynchburg, Madison, Manassas, Martinsville, Montgomery, Nelson, New Kent, Newport News, Northampton, Page, Pittsylvania, Portsmouth, Powhatan, Prince Edward, Prince George, Prince William, Rappahannock, Richmond (city), Roanoke (city), Rockingham, Tazewell, Virginia Beach, Westmoreland, Williamsburg, and Wise. To these we add the counties and cities of Campbell, Chesapeake, Cumberland, Danville, Essex, Fairfax, Frederick, Fredericksburg, Gloucester, Goochland, Greensville, Isle Of Wight, King George, King William, Mathews, Orange, Patrick, Petersburg, Pulaski, Roanoke (county), Salem, Scott, Shenandoah, Smyth, Spotsylvania, Stafford, Suffolk, Surry, Sussex, Warren, Warrenton, Washington, York (iNaturalist.net, 2020), and Southampton (personal observation).

Figure 1. Male eastern Hercules beetle, *Dynastes tityus* (Linnaeus). Fort Eustis, Newport News. (Photo by Arthur V. Evans)

Elytral base color change has been noted in both living (Manee, 1915; Prokop, 1969; Ritcher, 1966; Sun et al., 2017) and pinned specimens of *D. tityus* (Fattig, 1933). The reversible elytral color change in living beetles shifts from yellow-green in a dry state to deep brown in a wet state, reflecting varying degrees of water absorption (Sun et al., 2017). During periods of high humidity, water replaces air inside the voids of the elytra's spongy internal structure composed of laminated chitin and protein.

Females lay their eggs during the month of August in large cavities at or near the base of several species of hardwood trees, especially mature oaks and other hardwoods, and occasionally pines with trunk diameters of 1–1.5 meters (Wray, 1959; Glaser, 1976; Harpootlian, 2001). Crumbling heartwood and other woody debris within these cavities are utilized as food for the developing larvae (Fig. 2).

Figure 2. Larvae of *Dynastes tityus*. James River Park System, City of Richmond. (Photo by Arthur V. Evans)

Oviposition sites with substantial accumulations of woody debris may be used by multiple females over several years before the food supply is depleted (Glaser, 1976). Several similar cavities with either narrow or broad entrances located in central Virginia (City of Richmond, Caroline and Hanover counties) were readily identified as being occupied by developing *Dynastes* larvae by the presence of the distinctly flattened and rectangular fecal pellets (Fig. 3) measuring about 10 mm in length.

Figure 3. Fecal pellets of larval *Dynastes tityus*. Fort A. P. Hill, Caroline County. (Photo by Arthur V. Evans)

Under artificial conditions, the first instar larvae hatch within a week from elongate, white to yellowish eggs and take about two years to reach adulthood, but may require as many as three years to complete their development in the wild (Glaser, 1976). Pupation occurs in late summer within oval, thick-walled cases constructed of the larva's fecal pellets and surrounding woody debris. Adults eclose from the pupa (Fig. 4) in about a month, but remain inactive with their pupal cases until the following summer (Ratcliffe & Cave, 2017). For example, in the aftermath of a severe weather event (Tropical Storm Gaston in September of 2004), Evans found a single pupal case in the hollowed-out base of a toppled oak in Joseph Bryan Park in Richmond. The case was brought indoors and partially opened to reveal a fully developed female that remained within the case until April, 2005 and died in February of 2006. She was kept on a diet of various soft fruits (bananas, cantaloupe, nectarines, and peaches) and a 50% solution of maple syrup and water. Outdoors, *D. tityus* is reported to feed on tree sap and decaying apples, figs, peaches, pears, and plums (Manee, 1915; Cartwright, 1976; Ratcliffe & Cave, 2017). In captivity, adult *D. tityus* live about 6–23 months (Krell & Krell, 2015).

Adult males and females are typically encountered at lights at night, especially from June through August. Individuals and mating pairs are found on the slender limbs of ash trees where they scrape off the bark and feed on sap (Manee, 1915; Cartwright, 1976). Cartwright (1976), based on observations made nearly 50 years previously, recalled that he "… glanced upward into a small ash tree and discovered more beetles all over the tree, clinging to limbs up to an inch and a half in diameter. The tree was about 15–20 feet tall. Each beetle, it legs wrapped around the limb, appeared to be pushing a small ball of excelsior, feeding on the sap of the inner bark. When handled, the male gave off a strong, characteristic, penetrating odor".

Figure 4. Male pupa of *Dynastes tityus.* James River Park System, City of Richmond. (Photo by Arthur V. Evans)

The establishment of the invasive Emerald Ash Borer, *Agrilus plannipes* Fairmaire (Coleoptera: Buprestidae), in Virginia and elsewhere in North America threatens the survival of all species of ash. Thus, information on the distribution and biology *D. tityus* is essential for their conservation, especially with regards to recognizing the dependence of the adults on ash for attracting and locating mates.

MATERIALS AND METHODS

The initial discovery of *D. tityus* at the study site occurred during the summer of 2018 when the senior author noticed a male Hercules beetle scraping bark on an ash limb during the day, with a moth feeding on the exposed sap along beside him. Returning to the site that evening, that same a male beetle was observed still scraping the bark and surrounded by Red-lined Panopodas, *Panopoda rufimargo* (Hübner) (Lepidoptera: Erebidae) (Fig. 5).

Following are the observations made during the summer of 2019 by the senior author in Sedley, Southampton County (36.82964º N, -76.98842º W), located in the southeastern Virginia Coastal Plain. The soil type is sandy loam, and the ground is slightly elevated from a stream that's approximately 150 feet (45.7 meters) away, providing the study site with good drainage. In addition to Green Ash (*Fraxinus pennsylvanica* Marshall), the study site is also populated with Loblolly Pine (*Pinus taeda* L.), Sourwood (*Oxydendrum arboretum* (L.) DC), American Holly (*Ilex opaca* Alton), and River Birch (*Betula nigra* L.), as well as an abundance of Common Greenbrier (*Smilax rotundifolia* L.) and Blueberry (*Vaccinium* sp.).

Figure 5. Male *Dynastes tityus* scraping bark at night while surrounded by Red-lined Panopodas, *Panopoda rufimargo* (Hübner). Sedley, Southampton County. (Photo by John Bunch)

The observations of *D. tityus* began in mid-June of 2019. Observations began daily before 7 AM and continued throughout the day until sometime before or close to dusk. All the beetles were observed on Green Ash bordering a rural backyard. Occasionally individual beetles were identified by their unique elytral markings (see Figures 4-5 in Kim & Brou, 2019). Initial observations were made with the aid of a pair of Minolta Compact 10x23.5 binoculars, but beetles located on bare limbs were easy to spot with the naked eye. Photographs at the site were made with a Sony a58 mounted on a tripod and outfitted with a Sigma DG 70-300 zoom lens. Temperatures were obtained with a lab-grade mercury thermometer manufactured by American Scientific Products. The height off the ground was measured using a 30-foot bamboo pole.

Precipitation was measured by a rain gauge in increments of hundredths of an inch. Rain data was supplied to the Community Collaborative Rain, Hail & Snow Network, sponsored by the National Oceanic and Atmospheric Administration.

RESULTS

The search for beetles began in mid-June 2019. The first beetle, a male, was observed on an ash tree on 29 June at 7 AM at a height of 13 feet above the ground on a limb about 1-1.5 inches in diameter. He had already begun to peel back the bark. This beetle was observed peeling the bark, off and on, throughout day right up until dusk; no other beetles were observed at or near the feeding site. During the week prior to this observation, the days were hot and muggy, with high temperatures ranging from 88ºF to 93ºF.

The next morning (30 June), the same beetle (confirmed by comparing markings on the elytra with the beetle from the previous day) was still working the bark at the 13'site. Another male (later identified as "WC" based on its unique elytral markings—see details for 6 July) was seen working a limb similar in size at a height of 25 feet. The limb diameter chosen by both males appeared to be most suitable because it allowed them to easily grip the limb with their legs as they worked the bark. The high temperature that day reached 94ºF and there was a mid to late afternoon thundershower that produced 0.05 inches of rain.

On 1 July the same two beetles were still in place in their respective locations and there were no changes in their activity from the previous day (30 June). The high temperature on this day was 86ºF.

Observations continued to be made throughout the day on 2 July, and as dusk approached, a male beetle was discovered on its back under the 13-foot location and was apparently dying. Comparing this dying beetle with photos taken previously revealed that it was the very first male that was observed back on 29 June at the 13' location. It had been replaced by another beetle. Both this and the remaining male at the 25-foot location continued to engage in bark peeling through 5 July, with no females appearing at either location. Up to this time, the daily progress of these two beetles was monitored before 7 AM and at different times throughout the day until just before dusk. The high temperatures for this period are as follows: 2 July - 93°, 3 July - 94°, 4 July - 95°, 5 July - 91°. An evening thunderstorm on 4 July produced 0.14 inches of rain.

On the morning of 6 July, the male at the 13-foot location had disappeared. A female had joined the male at the 25-foot location and the pair was observed throughout the day. They remained in constant contact with one another, with the female continually peeling bark as the male copulated with her. The peeled away bark was curled, looking as though it had been stripped away with a knife, and consisted of long stringy fibers (Fig. 6). The male was easily identified by markings on its right elytron resembling the letters "WC" that resembled an inscription with a fine tip permanent marker (Fig. 7), hereafter referred to as WC. That same day, a second dead male *D. tityus* was found under the ash trees. That day, the temperature reached 92° F and a thunderstorm late in the day produced 0.16 inches rain.

The following morning (7 July), the mating pair was still together, but had moved about a foot down the limb, stripping the bark as they went. An intense thunderstorm passed over the site later that day, producing 1.46 inches of rain. After the storm, WC disappeared and was not seen for the rest of the day. While copulating, the female always maintained a firm hold on the branch, but WC, grasping only the female, likely lost his grip during the storm.

Figure 6. Male *Dynastes tityus* peeling bark an ash branch. Sedley, Southampton County. (Photo by John Bunch)

Figure 7. Male *Dynastes tityus* with elytral markings resembling 'WC' attending a female as she strips bark along an ash branch Sedley, Southampton County. (Photo by John Bunch)

On 8 July, a pair of beetles, including WC, was once again occupying the 25-foot location. Based on comparisons of the elytral markings of female beetles photographed previously at this location over the past two days, WC's mate was a different female. This same morning, an unaccompanied female occupied the 13-foot location and was peeling bark. She remained alone at this location throughout the day, and was gone the next morning. The high temperature for the day was 88°F and there was a brief afternoon thunderstorm that produced 0.08 inches of rain.

At 7 AM the next day (9 July), no beetles were observed at the 13-foot site. At the 25-foot location, there was a mating pair still present, now accompanied by another male (Fig. 8). As the day progressed, the second male confronted WC several times by moving up and down the limb. WC always turned to face the rival male, either remaining over or beside the female at all times. No physical contact between the males was observed. Compared with photos taken the previous day, it appeared that the female on this day was a different individual than the female that accompanied WC the day before. This day was decidedly cooler with the high temperature reaching only 84°F.

Figure 8. Pair of *Dynastes tityus* with another male nearby. Sedley, Southampton County. (Photo by John Bunch)

On the morning of 10 July, only WC remained at the 25-foot location. Throughout the day, the male remained on the branch with some of his legs splayed out, appearing as if he had died in place. However, by the next morning (11 July), he was not only alive and well, but was accompanied by yet another female. To date, based on the photographic record, it appeared that WC had attracted at least four females to this site. The high temperature for 10 July was 91°F, followed the next day by a high of 94°F and an evening thunderstorm produced 0.54 inches of rain.

No *D. tityus* were observed anywhere on 12 July. The day was sunny, and humid, reaching a high of 90°F. By 7AM the next day (13 July), WC had returned to the 25-foot location and was near a female. By carefully comparing the photos taken on a daily basis of the females observed through this breeding season, this was female number 5. The pair remained together at the same spot for the entire day. The day was humid and the high temperature was 91°F.

At 6:30 the next morning (14 July), a mating pair of beetles, including WC, were still together at the 25-foot site, along with another male further down the limb. It is not clear whether this female was the same individual observed with WC the day before. By 2 PM that afternoon, both the female and second male were gone. WC was seen running quickly down the limb, possibly in search of the female; this was the first time that any of the beetles were observed moving quickly. By 7 PM that evening, WC was still alone on the branch. The day was humid and the high temperature was 94°F.

A single male was still present at the 25-foot site at 7 AM on 15 July, but his position on the limb made it impossible to see the elytral markings to determine whether it was WC or another beetle. The site wasn't checked again until 8:30 PM that evening and, in the fading light, it was evident that a male beetle was still on the branch. The day was humid and the high temperature was 92ºF. At 7 AM the next morning (16 July) is was determined that the lone male at the 25-foot site as WC. A Red Admiral, *Vanessa atalanta* (Linnaeus) (Lepidoptera: Nymphalidae), was observed visiting the stripped bark below and some distance away from the beetle. A video was made of WC raising and lowering his head while wiping the sides of his face or scraping his mouth with the front femora and possibly tibiae. The high temperature for the day was 95°F, with a slight afternoon thunderstorm dropping only 0.07 inches of rain.

By 7 AM the next morning (16 July), based on unique markings seen on the elytra, a sixth female joined WC at the 25-foot site. A European Honeybee, *Apis mellifera* Linnaeus (Hymenoptera: Apidae), visited the exposed tree sap next to the mating pair. By 10:30 AM the female had left and WC appeared, once again, to be searching for her by moving up and down the small limb. At 5PM, no *Dynastes* were in evidence and this is the last day that WC was observed. The high temperature for the day was 97°F. No beetles were observed on 18 July and the temperature for that day reached 96°F.

Observations continued daily through 31 July and the last live Hercules beetle of the summer was seen on 19 July. The day was very hot with a high temperature of 96ºF. 20 July through 31 July showed high temperatures ranging from 79° (heavy rain date of 23 July) to 100°. During the observational time period addressed in this paper ranging from mid-June through 31 July, males and females were only observed at the 13-foot and 25-foot sites and in no other places in the trees. From 20 July to 4 September, four more dead male *Dynastes tityus* were found on the ground under the stand of green ash trees (20 July, 6 and 15 August, 4 September). Over the course of the study period, a total of six dead male beetles were found, while no dead females were ever encountered. Additional ash trees in the vicinity were searched, but no sites other than the 13-foot and 25-foot locations were found.

DISCUSSION

As far back as the summer of 2001, the senior author and his wife noted a strong scent on hot, humid nights that was likened to blueberries. With lots of *Vaccinium* growing in the immediate vicinity, it was simply assumed that these plants were the source of the odor. However, when handling one of the dead males encountered in this study, Bunch noted the same blueberry scent on his fingers. Manee (1915) and Cartwright (1976) both noted that males gave off a strong odor that has been variously characterized as disagreeable, penetrating, and/or pungent. It is possible that males produce this odor to attract females, but this hypothesis needs testing.

The larvae of both species of *Dynastes* in the United States are generalist feeders on dead wood, especially that of hardwoods. However, the adults appear to be dependent on ash (*Fraxinus*) as a means of attracting and locating mates, with courting males peeling back bark and chewing into the cambium of living ash branches (Manee, 1915; Menke & Parker, 1988; Bouchard, 2014; Wagner & Todd, 2016; personal observation). The wounds created by these beetles leave distinctive scars that remain visible on living for several years (personal observation). We are not aware of any published accounts of bark peeling or mating by either species taking place on any trees other than ash. Whether or not female are attracted to the odors produced by the males, volatiles produced by ash wounds resulting from beetle feeding, or a combination thereof is unknown and certainly worthy of further investigation.

Recently, both species of *Dynastes* in the United States, along with 96 other insect herbivores dependent on various ash species, were considered at risk of high endangerment as a direct result of the environmental damage caused by the invasive Emerald Ash Borer (EAB), *Agrilus planipennis* Fairmaire (Wagner & Todd, 2016). All North American species of ash appear susceptible to the wood-boring activities of their larvae and, while not currently known in the West, EAB is widespread in the East where they have killed tens of millions of trees (United States Department of Agriculture, Animal and Plant Health Inspection Service, 2020); since 2008, EAB has become established throughout most of Virginia (Virginia Department of Forestry, 2020).

The loss of ash threatens *D. tityus* and another Virginia dynastine scarab *Xyloryctes jamaicensis* (Drury) thought to be an ash specialist as a larva (Ratcliffe & Cave, 2017). If both *D. tityus* and *X. jamaicensis* are wholly dependent on ash during any part of the life cycle, then both species are at risk of significant population reductions or extirpation if ash is reduced or eliminated from parks and forests. The potential negative impacts of the Emerald Ash Borer on these and other ash specialists in Virginia requires further study.

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RESEARCH ARTICLE

A BASELINE INVENTORY OF WATERFOWL FROM SURFACE MINE WETLANDS IN THE VIRGINIA COALFIELDS

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ABSTRACT

Surface mining activities result in multiple changes to the structure and function of ecosystems across the Appalachian Mountains of the eastern United States, including the creation of numerous wetlands via the construction of artificial retention ponds and flattened topography that alters surface runoff. While past work has assessed the impacts of such wetland creation on native Appalachian wildlife, little is still known about if and how wetlands created on active and former surface mines are used by waterfowl taxa. We performed a seasonal study of wetlands on two former surface mine complexes in Wise County, Virginia in 2016 and 2017 to assess waterfowl species' use of such wetland habitats. We found substantial waterfowl diversity at wetlands on former surface mines, encompassing 16 species and including both native residents and passage migrants. Nearby unmined wetlands had similar diversity, with 19 species inventoried over the same period. Several of these species are uncommon within the Appalachian region and seem to be tied to the passage of high-latitude storm systems in winter months. Our results suggest that wetland creation on former surface mines may supplement available habitat for both resident and migratory waterfowl across the Virginia coalfields, and we provide a preliminary inventory of such taxa that can guide future work.

Keywords: Appalachia, coal, ecology, pond, wildlife.

INTRODUCTION

The Appalachian Mountains of the eastern United States have experienced extensive landscape change as a result of surface coal extraction, with an estimated 5900 km^2 of surface-mined and reclaimed habitats created as a result of mineral extraction to date (Townsend et al., 2009; Pericak et al., 2018). These activities have had pronounced impacts on habitats within the Appalachian region, particularly with respect to the conversion of temperate hardwood forest ecosystems to grassland or shrubland habitats on reclaimed surface mines. Reduced forest cover and replacement by grasslands, for example, is a driver of altered ecosystem dynamics on mined sites (Zipper et al., 2011; Gurung et al., 2018), while altered topography and fragmented ridgetop forests exert substantial control over the ecology of terrestrial taxa (Wickham et al., 2013; Hinkle et al., 2018; Maigret et al., 2019; Margenau et al., 2019).

Surface mining activities also result in the widespread creation of wetland habitats on formerly steeply-sloped terrain. Many wetlands on surface mines are formed incidentally from topographic changes that reduce surface runoff and enhance the pooling of water following precipitation events, while others are intentionally constructed as retention or settling ponds to mitigate water quality concerns related to sedimentation and runoff (Wieder, 1989; Atkinson & Cairns, 1994; Atkinson, 2010). While few estimates exist in the literature of how much new wetland area has been created due to surface mining regionwide, mining practices have likely driven the large-scale creation of new wetland habitats in physiographic regions that were not historically characterized by a high density or number of wetland habitats due to steep terrain (Tiner, 1986; Thompson et al., 2007).

Past research has shown that surface mine-associated wetlands increase habitat availability for a number of taxa, including herpetofauna (Lacki et al., 1992; Lannoo et al., 2009), mammals (Brenner & Hofius, 1990; Lacki et al., 1991), and birds (Rumble, 1989; McKinstry & Anderson, 2002). However, little information currently exists related to the use of mine-associated wetlands by waterfowl in the central Appalachian region, particularly from the coalfields of the Cumberland Mountains in eastern Kentucky and southwestern Virginia. Nevertheless, this region is located between two major waterfowl flyways (Lincoln, 1935; Nichols et al., 1995), with presumably a diverse regional species pool that may make use of wetlands formed on former surface mines. Understanding this habitat use will be critical to both managing wetlands on former surface mines as wildlife habitat and understanding the regional dynamics of waterfowl populations across the broader landscape.

From November 2016 to April 2017, we performed a survey of waterfowl at wetlands on two former surface mine complexes in Wise County, Virginia—the most heavily surface mined county in Virginia and one of the most mining impacted counties in the Appalachian region. Our goal was to produce the first formal inventory of waterfowl taxa using mine-associated wetlands across the Virginia coalfields. We also examined waterfowl diversity at two naturally occurring wetland complexes across the same area to compare waterfowl use of natural habitats with those artificially created on former surface mines.

METHODS

We selected two wetland habitats for study from two large surface mine complexes in Wise County, Virginia: a 120 ha surface mine on Dale Ridge near Coeburn, Virginia and a 100 ha surface mine encompassing the headwaters of Yellow Creek near Wise, Virginia (Fig. 1). Wetlands on both sites were large (>0.5 ha) impoundments constructed for sediment retention and erosion control and were surrounded primarily by large monocultures of planted, non-native vegetation (*Elaeagnus umbellata* and *Lespedeza sericea*), with *Typha* spp. as the predominant emergent vegetation in the wetlands proper. All wetlands were of similar age, being constructed in the 1980s-1990s, and none were associated with any inventoried locations experiencing acid mine drainage or related water quality issues (Virginia DMME, 2020), due to their reliance primarily on surface runoff.

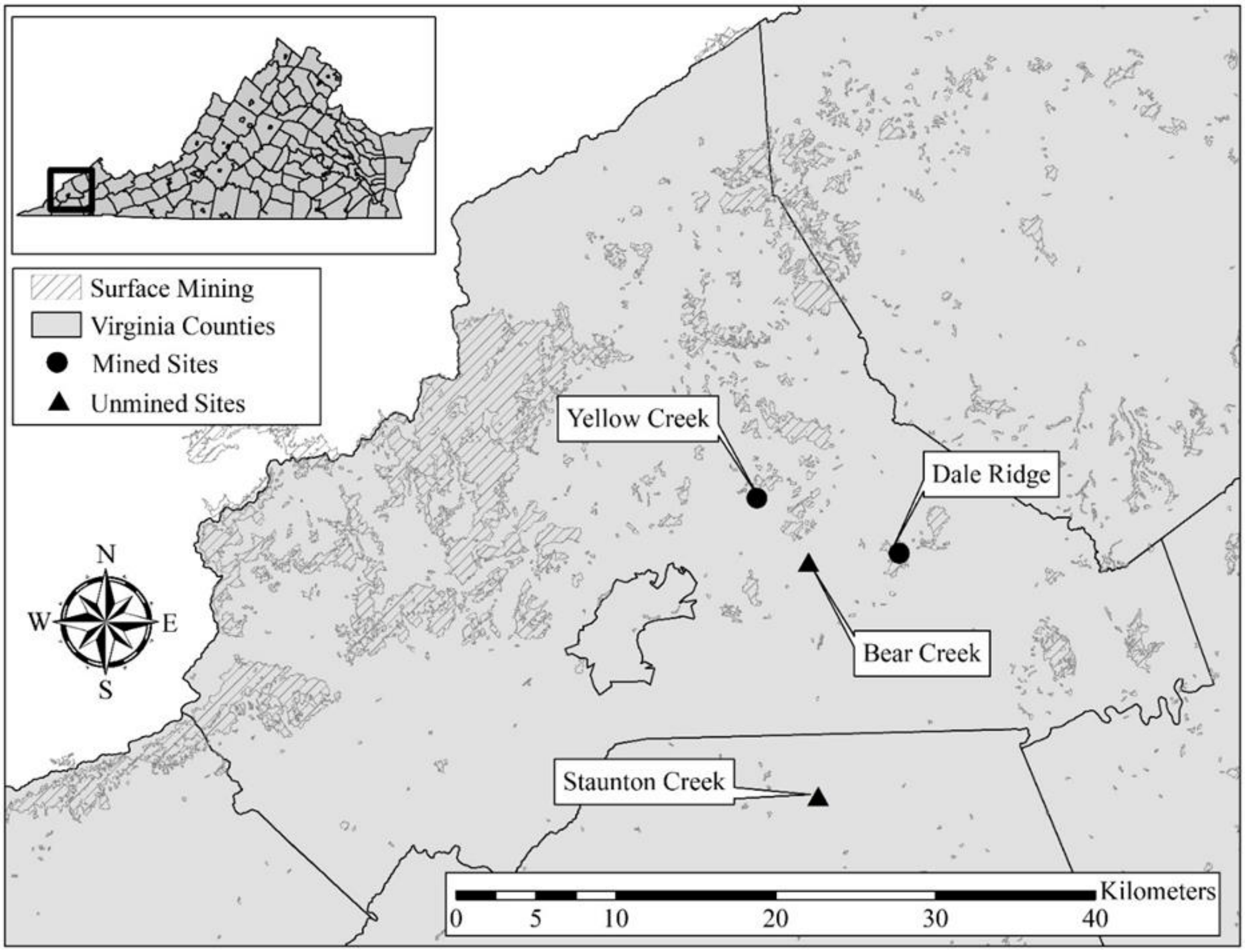

Figure 1. Map of study sites. Highlighted area in inset map denotes location of the study area relative to the rest of Virginia. Surface mining polygons were derived from data originally published by Pericak et al. (2018).

In addition to mine-associated wetlands, we also performed waterfowl inventories at two wetland habitats not associated with surface mines (Fig. 1). The first was a 1.42 ha wetland formed due to beaver impoundments on Staunton Creek on the south slope of Stone Mountain. This site is surrounded by dense mixed hardwood forest, with predominantly open water and emergent vegetation in the wetland proper. The second site was a 2.42 ha wetland located near the headwaters of Bear Creek near Wise, Virginia. This site is surrounded by mixed hardwood forest interspersed with planted White Pine (*Pinus strobus*) and is characterized by predominantly open water. We estimated the wetland area, canopy cover, and proportion of open water at all sites using 0.3 km pixel resolution orthophotography (Virginia Geographic Information Network, 2017) in ArcGIS v.10.1 and field visits to each wetland. General wetland habitat characteristics were similar across all sites, with the exception of the mined/unmined context of each wetland (Table 1).

Table 1. Habitat characteristics of four wetlands used for waterfowl inventories in 2016 and 2017.

Wetland	**Type**	**Size** (ha)	**Elevation** (m asl)	**Canopy Cover** (%)	**Open Water** (%)	**Predominant upland vegetation**
Dale Ridge	Mined	1.61	1990	8.1	71.4	Scrub/Shrub
Yellow Creek	Mined	0.94	2500	0	70.6	Scrub/Shrub
Bear Creek	Unmined	2.42	2550	8.7	73.6	Mixed Hardwood Forest
Staunton Creek	Unmined	1.42	1670	59.2	38.0	Mixed Hardwood Forest

Accessibility restrictions imposed by a high regional rate of private landownership precluded a fully random selection of wetlands from the broader region as study sites, although we selected individual wetlands at random from available public lands and accessible surface mines.

We inventoried waterfowl by way of automated surveys using a Bushnell eight-megapixel Trophy Cam motion-sensitive game camera (Overland Park, Kansas) installed at each site. Game cameras were installed on 1 November 2016 and sampled until 1 April 2017, with visits made approximately every other week during this time period to check camera operation and download photographs. While it was not possible to place the entirety of each wetland within each camera's field of view, we chose locations for camera installation at each site along the wetland margin that provided the maximum viewable extent of both the wetland and adjacent vegetation along its margin.

We supplemented automated sampling with regular vantage-point surveys at each site. Vantage-point surveys were performed by selecting a location above the wetland that provided the best view of the habitat, with weekly surveys (also from 1 November 2016 to 1 April 2017) conducted at one-hour intervals randomized within the constraints of site accessibility. We then recorded the species seen in both vantage-point surveys and automated game camera observations, pooling these data to create a list of detected species at each site. We used species accumulation curves (Gotelli & Caldwell 2001) following the completion of the sampling period to assess species richness against overall sampling effort across mined and unmined sites. We also grouped species inventoried during our surveys into classifications reflecting their regional status (native breeding, native non-breeding, or passage migrant) using distributional data provided by the IUCN Red List for Birds (BirdLife International 2019).

RESULTS

We recorded 23 total waterfowl species at the wetland sites inventoried for this study (Table 2) across 875 game camera observations and 19 hours of vantage point surveys. While overall species richness was similar between mined and unmined wetlands (16 versus 19 species, respectively), there was some turnover in species between these general types of sites. Specifically, we recorded three species (*Anas crecca*, *Mareca americana*, and *Anser rossii*) at mined sites but not from unmined sites in the same general vicinity. By contrast, we recorded seven species (*Anas rubripes*, *Aythya collaris*, *Oxyura jamaicensis*, *Mergus merganser*, *Anser caerulescens*, and *Anser albifrons*) at unmined sites that were not observed at wetlands on nearby mined sites. Species accumulation curves approached an asymptote across both mined and unmined wetland groups (Fig. 2), suggesting adequate sampling of local waterfowl fauna across these wetland types.

Table 2. Waterfowl taxa detected across wetlands on mined and unmined sites in the Virginia coalfields in 2016-2017. Plus signs denote detection; species statuses reflect those defined by the IUCN Red List for Birds (BirdLife International 2019). "Unknown/Not Inventoried" denotes species lacking regional coverage in the aforementioned dataset.

Species Name	Common Name	Mined Sites	Unmined Sites	Regional Status
Aix sponsa	Wood Duck	+	+	Native Resident
Anas acuta	Northern Pintail	+	+	Passage Migrant
Anas crecca	Green-Winged Teal	+		Passage Migrant
Anas platyrhynchos	Mallard	+	+	Native Resident
Anas rubripes	American Black Duck		+	Native Non-Breeding
Anser albifrons	Greater White-Fronted Goose		+	Unknown/Not Inventoried
Anser caerulescens	Snow Goose		+	Unknown/Not Inventoried
Anser rossii	Ross's Goose	+		Unknown/Not Inventoried
Aythya affinis	Lesser Scaup	+	+	Passage Migrant
Aythya americana	Redhead	+	+	Passage Migrant
Aythya collaris	Ring-Necked Duck		+	Passage Migrant
Aythya marila	Greater Scaup	+	+	Unknown/Not Inventoried
Branta canadensis	Canada Goose	+	+	Native Non-Breeding
Bucephala albeola	Bufflehead	+		Passage Migrant
Fulica americana	American Coot	+	+	Passage Migrant
Lophodytes cucullatus	Hooded Merganser	+	+	Native Resident
Mareca americana	American Wigeon	+		Unknown/Not Inventoried
Mareca strepera	Gadwall	+	+	Unknown/Not Inventoried
Mergus merganser	Common Merganser		+	Unknown/Not Inventoried
Mergus serrator	Red-Breasted Merganser		+	Passage Migrant
Oxyura jamaicensis	Ruddy Duck		+	Passage Migrant
Podilymbus podiceps	Pied-Billed Grebe	+	+	Native Resident
Spatula discors	Blue-Winged Teal	+	+	Passage Migrant

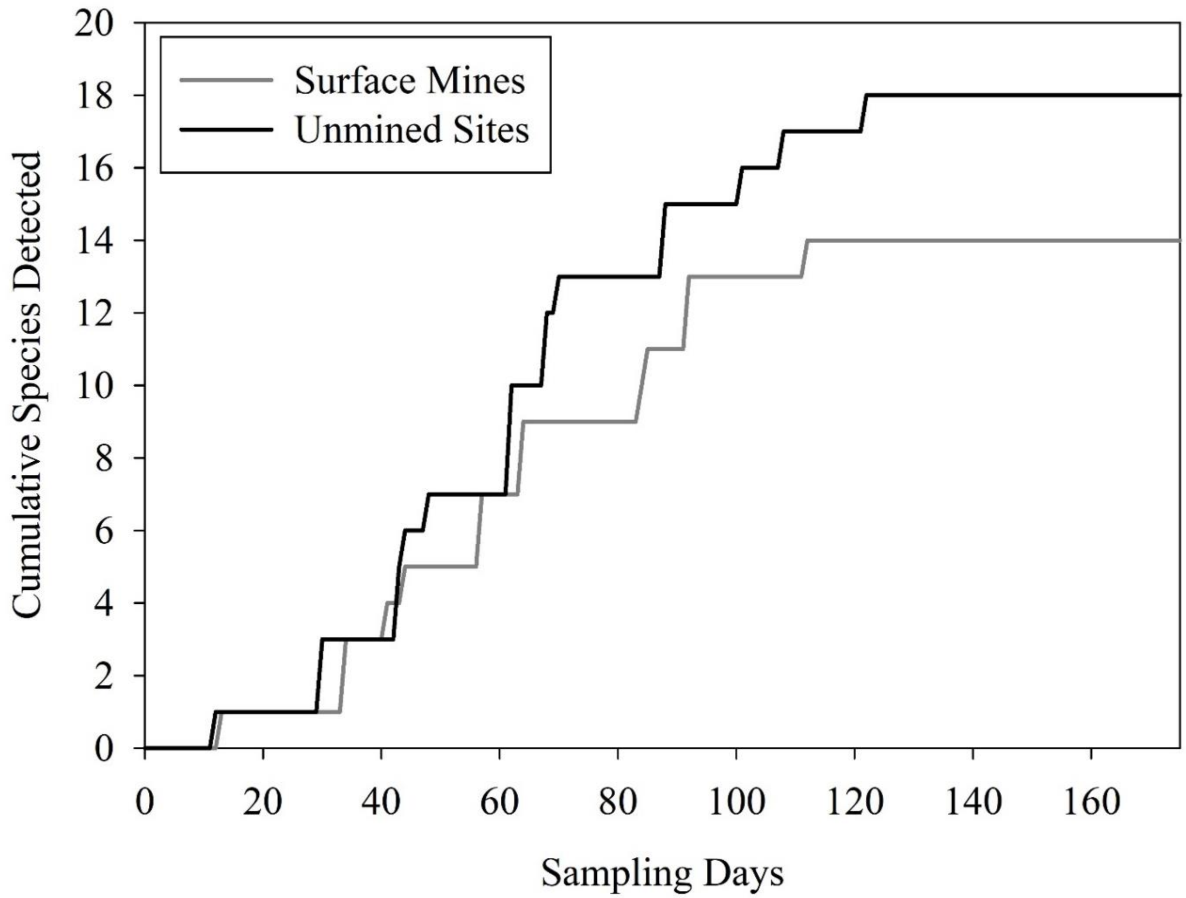

Figure 2. Species accumulation curves for unmined (black line) and mined (gray line) sites during automated waterfowl sampling in 2016 and 2017.

Waterfowl recorded across all wetlands were primarily passage migrants that were generally observed following the passage of large storm systems during winter and early spring. Most initial observations of species were recorded in December and January (Table 3), particularly in the 24-48 hours following the passage of such weather systems. Waterfowl observations recorded by automated game cameras peaked during early morning, particularly just prior to and after local sunrise, with a secondary peak in late afternoon and evening (Fig. 3). Most species recorded during surveys are known from the larger physiographic context of the study area, although three species (*Anser caerulescens*, *Anser rossii*, and *Anser albifrons*) are considered uncommon across this region and form, to our knowledge, the first recorded observations of these species from the Virginia coalfields in the peer-reviewed literature.

Table 3. Waterfowl detections by month at four study sites across southwest Virginia in 2016-2017. Dale Ridge and Yellow Creek are wetlands formed on former surface mines; Bear Creek and Staunton Creek are naturally-occurring wetlands not associated with surface mines. Shaded months for a species indicate detection during that month.

	Dale Ridge					Yellow Creek					Bear Creek					Staunton Creek				
Species	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar
Aix sponsa	■	■	■	■	■												■	■	■	■
Anas acuta			■															■		
Anas crecca			■	■																
Anas platyrhynchos	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■
Anas rubripes																		■		
Anser albifrons																		■		
Anser caerulescens																		■		
Anser rossii			■																	
Aythya affinis			■															■		
Aythya americana		■															■			
Aythya collaris													■							
Aythya marila			■															■		
Branta canadensis		■	■	■	■											■	■	■		
Bucephala albeola			■																	
Fulica americana		■															■			
Lophodytes cucullatus		■	■				■	■					■							
Mareca americana									■											
Mareca strepera									■					■						
Mergus merganser																		■		
Mergus serrator														■						
Oxyura jamaicensis														■						
Podilymbus podiceps		■	■				■	■				■	■							
Spatula discors								■										■	■	

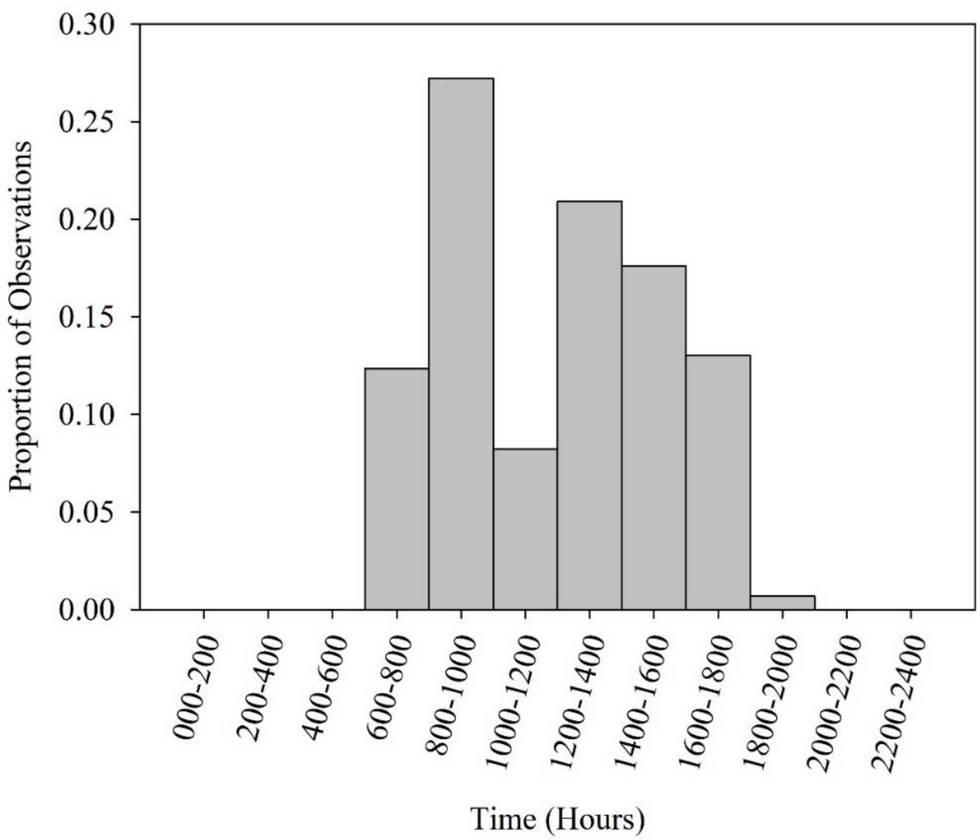

Figure 3. Proportion of game camera images collected at various times of day across all sites during 2016 and 2017.

DISCUSSION

To our knowledge, our work provides the first survey of waterfowl from surface mine associated wetlands in the Virginia coalfields region and from the Cumberland Mountains region of southwest Virginia, in general. We found substantial waterfowl diversity within this region, both at artificial wetlands on former surface mines and wetlands not associated with mined lands. Our overall inventory of waterfowl taxa is indicative of species known from both the Mississippi and Atlantic Flyways (Bellrose, 1968; Heusmann & Sauer, 2000), with most taxa being passage migrants inventoried during and shortly after the passage of major storm systems during winter months. Such storm systems – which typically occur as low pressure systems passing to the north or south of the central Appalachian region, leading to winter weather conditions following a frontal passage – are one of the predominant weather scenarios leading to prolonged cold air and snowfall across the southern and central Appalachians (Perry et al., 2007; Perry et al., 2010). Past studies have found that such storm systems and related measures of winter severity (consecutive days of cold temperatures, snow depth, and snow cover duration) are a major factor influencing the timing and intensity of North American waterfowl migrations (Notaro et al., 2014; Schummer et al., 2014).

We noted many of our observations of passage migrants, particularly those species consisting only of observations of one or a few individuals on a single survey visit, co-occurring with the passage of strong storm systems and associated outbreaks of cold temperatures and snowfall across our study area. In fact, the majority of our waterfowl observations occurred during December and January, when such storm systems were most active during our study period. By contrast, we did not observe dramatic changes in observations of more year-round wetland residents, such as Wood Ducks, Canada Geese, and Mallards, corresponding with these same storm systems. While this suggests that significant winter storm systems may facilitate the movement of some migratory waterfowl species into the Cumberland Mountains, our small number of sampled wetlands and a lack of context data in the form of past waterfowl surveys within our study area precludes a definitive link between the passage of weather systems and waterfowl movements within the region. Our observations, however, present opportunities for future, hypothesis-driven work seeking to investigate a link between weather conditions and waterfowl movements within the central Appalachians, similar to those observed in other states (Schummer et al., 2010).

We found highly similar waterfowl species at wetlands on both mined and unmined sites, despite some variability in species composition across individual wetlands. Wood Ducks and Mallards both appeared to be especially abundant at wetlands on former surface mines and unmined reference sites. Both species are common at naturally-occurring wetlands in the broader Appalachian region and have been inventoried in multiple previous studies (Boynton, 1994; Bulluck & Rowe, 2006; Zimmerman et al., 2015). However, we additionally recorded seven species that we found exclusively at wetlands associated with unmined sites and three species exclusively associated with wetlands formed as a result of surface mining activities.

One outstanding question not addressed by our dataset is whether such taxa inventoried solely at mined or unmined sites are reflective of an actual preference for particular habitat types. Because our survey methodology primarily used automated survey methods that did not allow for a comprehensive assessment of the entirety of each site nor information regarding the frequency of recaptures in game camera images, we did not feel confident using count data to make inferences about the relative abundance of waterfowl species at each site. This is especially relevant since our game cameras likely captured multiple images of the same individuals moving throughout wetlands during particular days. Similarly, it is likely that we may have missed observations of uncommon species, despite species accumulation curves suggesting a relatively thorough sampling effort.

Similarly, our mined and unmined sites were located within substantially different landscape contexts related to the history of surface mining (or lack thereof) at a given site. The typical forest types across our study region are generally mixed mesophytic forests interspersed with more xeric hardwood forests on upland ridges (Braun, 1942). However, surface mining activities replace these forest types with grass or shrub-dominated environments that often are characterized by exotic or invasive vegetation and facilitate changes to ecosystem services following mining (Zipper et al., 2011; Gurung et al., 2018). These differences ultimately result in more open-canopy wetlands and may also influence wetland plant assemblages and other structural characteristics of wetlands that may be key to resident fauna (Branduzzi et al., 2020), although little work has been performed in our immediate study region to gauge these specific impacts. Disentangling if and how the landscape contexts of wetlands on surface mines impact waterfowl presence and abundance differently from local-scale wetland features may be especially crucial for future work expanding on our data.

As a result of the aforementioned limitations, we are cautious about making inferences about the relative rarity of particular species, as well as inferences about the apparent absence of particular species from general groupings of wetlands within a mined or unmined context. Our data are instead best viewed as a preliminary checklist of waterfowl using mine-associated wetlands across the Virginia coalfields rather than a definitive assessment of differences between waterfowl assemblages on mined and unmined sites. Future researchers may want to build upon this preliminary inventory to perform a more robust assessment of the detection of waterfowl taxa and their relative abundances at wetlands on both mined and unmined sites. Such a comparison may shed light on individual species' preferences for types of sites, as well as associations between those species and particular habitat variables at the local or landscape scale that are influenced by mineral extraction activities.

Nevertheless, our surveys detected several species, including the Greater White-Fronted Goose, Snow Goose, and Ross's Goose, that are more commonly encountered in regions well west (Prevett & MacInnes, 1972; Alisauskas, 1998; Abraham et al., 2005) and east (Hill &Frederick, 1997; Gauthier et al., 2005) of the Cumberland Mountains and, to our knowledge, have never been inventoried from the Virginia coalfields in the scientific literature. One of these species (Ross's Goose) was present at constructed wetlands associated with a former surface mine, and our encounters with each species were constrained to a single observation during vantage point surveys, most following the passage of major storm systems. These observations were likely the result of migratory behavior associated with such storm systems (Smith & Hayden, 1984), and all of these species have been informally reported in separate citizen science datasets from the larger region surrounding our study sites in past years (eBird, 2019). However, the use of artificial wetlands on former surface mines by Ross's Goose appears to be a novel habitat report for the central Appalachian region.

More broadly, our data suggest that the creation of artificial wetlands on surface mines across central Appalachia has not been inconsequential to waterfowl taxa—a factor that may be of interest to land and wildlife managers. We found evidence of substantial use of mine-associated wetlands by waterfowl, including by passage migrants and year-round residents. Wetlands on surface mines are often located in high-elevation environments that are typically not predisposed to natural wetland formation, given the proclivity for upland wetlands in the Cumberland

Mountains to form infrequently and be relatively small in size (Thompson et al., 2007, 2012). Beyond the general increase in the number and density of wetlands as a result of surface mining, an examination of the elevational and structural differences in wetland habitats between mined and unmined sites in the central Appalachian coalfields may help researchers gain further insight into if and how wetlands on former surface mines are influencing habitat availability for waterfowl and other wetland-associated taxa.

Our data also were limited to the presence of waterfowl species and did not address parameters related to the health or demography of waterfowl populations. The selection of wetland habitats by waterfowl at any given site may be driven by factors such as food availability and water quality (Longcore et al., 2006; Kaminski & Elmberg, 2014) - features that may be influenced by mineral extraction and subsequent reclamation activities and were not addressed by our presence-only dataset. Past work, for example, has found that some mine-associated wetlands, such as tailings ponds and retention basins, may present a toxicity risk to waterfowl when acidity and metal levels are high (Isanhart et al., 2011). Our study sites did not contain any such known contamination issues, although it is plausible that some wetland sites throughout the Appalachian coalfields may present similar risks. While our inventory provides a foundation for addressing the management of regional waterfowl populations on wetlands associated with former surface mines, these questions will be crucial for appropriately designing management guidelines for such taxa in future work.

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RESEARCH ARTICLE

THE NATURAL HISTORY OF THE MARSH RICE RAT, *ORYZOMYS PALUSTRIS*, IN EASTERN VIRGINIA

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ABSTRACT

The marsh rice rat, *Oryzomys palustris*, is a common rodent in tidal marshes of eastern Virginia, including those on the barrier islands. It also is present in grassy old fields in upland habitats in the coastal plain and parts of the piedmont of Virginia. This report summarizes what has been learned in recent decades about the population biology of this species in Virginia, including aspects of behavior, density, diet, distribution, genetics, habitats, mammal associates, and reproduction.

Keywords: Barrier Islands, Chesapeake, Eastern Shore, old fields, tidal marshes

INTRODUCTION

The marsh rice rat, *Oryzomys palustris*, is a medium-sized, long-tailed rodent (Fig. 1) found in tidal marshes and nearby grassy uplands in the southeastern US. It is semi-aquatic (Esher et al., 1978; Forys & Dueser, 1993) and readily takes to water to escape danger and to catch some animal components of its diet. In Virginia, coastal saline marshes on the Eastern Shore, lower Chesapeake Bay, and south to Back Bay National Wildlife Refuge are primary habitat. *O. palustris* also is present in brackish marshes and wetlands along the big rivers flowing into the Chesapeake Bay, but the details of its inland distributions, especially on the western shore of the Chesapeake Bay, are not well known. Along the James River, its distribution extends past the fall line west of Richmond (Pagels et al., 1992), and the rice rat is present at Fort A. P. Hill, just south of the Potomac River near Fredericksburg (Bellows et al., 2001a).

In the mid-to-late 1990s, five Old Dominion University graduate students conducted field studies in seaside tidal marshes owned by The Nature Conservancy (TNC) in Northampton County on Virginia's Eastern Shore. Monthly trapping provided capture-mark-recapture (CMR) information on the small mammal community in two marshes, one located south of the village of Oyster and the other east of Townsend. In each marsh, a row by column grid was established so that density (number per hectare) could be determined and information on habitat, movement, and dispersion could be recorded. Part of each grid was flooded each day but the landward parts were flooded only during storm and monthly high tides; these flooding regimes also determined the types of vegetation on the grid as well as the foods available for the small mammals living in these habitats.

Figure 1. Adult rice rat showing typical coloration and long tail. Photo purchased from Alamy.

A Fitch live trap (Rose, 1994), held by a rubber band to a Styrofoam™ float, was placed at each coordinate on the grids, tethered to a numbered stake with a monofilament line. This system allowed the trap to move up and down with the tide, yet remain within a meter of the stake. Each month, usually during the new moon, bait (bird seed and sunflower seeds) was placed in the traps in the late afternoon and the traps were checked the next two mornings. Each captured mammal was given a numbered ear tag, weighed (g), its reproductive status evaluated, and then it was released at the point of capture. Traps were locked open between periods of trapping. The objective was to evaluate the lives of marked (tagged) individuals, i.e., to examine their changes in reproductive condition, their movement, the vegetation they ate and in which they were captured, their lifespans, and other aspects of their biology. The longest field study, 23 consecutive months

(Bloch & Rose, 2005), produced the best information on density for both *Oryzomys palustris* and its codominant species, the meadow vole (*Microtus pennsylvanicus*).

Monthly samples of adult rice rats for necropsy were taken from nearby seaside marshes; these provided information on stomach contents (diet), body measurements, and details of reproduction, such as litter size and seasonal changes in reproductive organs (Rose & Dreelin, 2011). The stomach contents were analyzed for details of plant and animal foods eaten during different months and seasons (Rose & McGurk, 2006). (The skeletons were sent to the National Museum of Natural History). The frequency and distribution of herbaceous and woody plants on the grids were evaluated and the structure of the vegetation was measured; this information made it possible to determine which plants were selected or avoided, and to relate use by the rice rats to the structure and composition of the habitat (Sowell, 1995).

In the early 2000s, two 1-ha CMR grids were established in southern Chesapeake, both also on TNC properties. These former agricultural fields were two years removed from cultivation so the vegetation of both was dominated by early-colonizing grasses and sedges. As is typical of agricultural fields in this region, the highly organic soils are made arable by a century-old series of deep and shallower ditches. Winter flooding is common in these fields and as a result many wetlands plants, such as sedges, rushes, and spikerushes, were present in slight depressions or near the ditches in these grassy old fields. Each grid was trapped monthly for 3-4 years until shrubs and saplings mostly replaced the herbaceous vegetation, after which seasonal trapping was used to monitor the decline and disappearance of old field small mammals (including rice rats), and the appearance of forest-dwelling mammals. In all, the small mammal community on each grid was evaluated for 8 or more years (Rose et al., 2018).

General characteristics

The marsh rice rat (hereafter "rice rat") is medium in size, with adult body mass of 40-80 g. The sexes are similar in size, with males often somewhat larger. The dorsal pelage is gray with flecks of brown and white, and the tapered tail, almost as long as the combined length of head and body, is dark above and lighter below, with no clear line separating dark from light. The belly fur is nearly white, as are the toes. Thus, the coloration of this semi-aquatic rodent blends well with its background whether seen from above or from below. The toes, four on front feet and five on hind feet, are long and supple, enabling rice rats to climb into emergent vegetation during times of flooding, to catch insects, or to enter birds' nests to eat eggs or nestlings, as they sometimes do (e.g., Kale, 1965). The rice rat has no webbing on its toes and no flattening of the tail, features seen in other native semi-aquatic rodents, such as muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*).

Distribution

Oryzomys is a South American genus with only three species reaching into the US, *O. couesi* just barely into southern Texas and *O. argentatus* in southern Florida. *Oryzomys palustris* has a broader US distribution, with populations along the Gulf Coast and southeastern states, with coastal populations in the mid-Atlantic region extending as far north as Delaware (Schantz, 1943) and southern New Jersey (Wolfe, 1982). Inland populations often are associated with the Mississippi and Ohio rivers and their larger tributaries; some even extend to southern Illinois (Hoffman et al., 1990; Eubanks et al., 2011). In Virginia, the rice rat is found throughout the coastal plain, including the barrier islands (Dueser et al., 1979) and in the piedmont as far west as

Cumberland County, about 65 km west of Richmond (Pagels et al., 1992). Rice rats are common in the freshwater marshes of the Potomac River at George Washington Birthplace National Monument in Westmoreland County (Painter & Eckerlin, 1993), and Bellows et al. (2001b) trapped a small number of rice rats in upland forest in Caroline County, south of Fredericksburg. Much remains to be learned about its distribution along the rivers and marshes of piedmont Virginia.

Rice rats are the most numerous small mammal on the barrier islands of Virginia, being found on 9 of 11 islands trapped by Dueser and his colleagues (Dueser et al., 1979) and later known from 21 of 24 islands (Loxterman et al., 1998). Experimental studies revealed rice rats were able to swim from one island to another, crossing water barriers as great as 300 m (Forys and Dueser, 1993), likely explaining why rice rats are present on many more islands than poorer swimmers, such as meadow voles or white-footed mice (*Peromyscus leucopus*).

ONTOGENY AND REPRODUCTION

Early studies of growth and development date from those of Svihla (1931), who collected rice rats in the bayou country of coastal Louisiana and raised them in the laboratory to learn about their diets, mating behavior, gestation length, and growth and development of young. Like the young of most rodents, rice rats are born naked, blind, and helpless. The weight of neonates ranged from 2.35–4.0 g, with an average of 3.14 g. The eyes open at 6 days and young are weaned at 11 days (Svihla, 1931). Vibrissae (whiskers) are present at birth, perhaps to assist in finding a nipple. Neonates from pregnant females collected at Chincoteague Island, Virginia, were slightly heavier (3.7 g), with head and body length of 42 mm and tail of 19 mm (Hamilton, 1946). At two days, weight was about 5 g, the back was becoming darker, and each youngster was active and vocalizing. By four days, the young could crawl, the back was well haired, with shoulders dark gray washed with fulvous (reddish), but the belly was still naked. Average weight was 6.3 g, head-body length was 52 mm, and the tail 30 mm (Hamilton, 1946). At six days, the body length was 59 mm, and the body was well furred with grizzled brownish gray above and white belly. By eight days, each young, now with juvenile pelage, was very active and fled the nest if disturbed. With a mean weight of 8.9 g, the average head-body length was 62 mm and the tail 41 mm. By 10 days, the young ate solid food, had an average weight of 10.2 g, a head-body length of 69 mm, and tail of 47 mm (Hamilton, 1946). Young are weaned at 11-13 days, after which they gain 1.0 to 1.5 g per day until about three weeks of age. After that, growth rate slows so juveniles become sub-adults (40 g) at two months and are full grown (50-80 g) at four months (Hamilton 1946). As adults, the head-body length is only slightly longer than the tail length. It is likely that slow growth continues as long as the animal lives; few rice rats live as long as 12 months in Virginia (Bloch & Rose 2005).

Details of litter size and reproductive indices of both sexes for rice rats from eastern Virginia are derived from the 103 rice rats whose stomachs were analyzed for diet, plus 26 other rice rats from nearby tidal marshes, and 41 rice rats collected on Fisherman Island in January and February 1982. No rice rats were caught for necropsy in January-February 1996 (when population density was very low on the contemporaneous grids trapped by Bloch & Rose [2005]) so the samples from Fisherman Island (7 km from Townsend) provided information on reproduction during January-February.

Females with embryos were collected from April to October, and there was almost no evidence of breeding activity in either sex during the other 4-5 months (Rose & Dreelin, 2011).

The average litter size for the 16 pregnant females was 4.63 and litter size did not vary among months, between females having one or multiple litters, or between subadult and adult females. The smallest pregnant female weighed 34 g and because embryonic bumps in the uterus do not appear until about day 11 or 12 of pregnancy, this female probably weighed about 25 g when inseminated.

Fertility in male rodents is determined by the presence of convolutions (rather than loops) in the cauda epididymides (Jameson, 1950), the structures in which mature sperm are stored. Convolutions were present in males 2-4 weeks before and after the April-October breeding season of females (Rose & Dreelin, 2011), a pattern often seen in seasonally breeding rodents in temperate latitudes (e.g., Rose and Gaines, 1978; Bergstrom and Rose, 2004). Both testes and seminal vesicles showed substantial regression with the approach of winter, an energy-saving adaptation that is especially valuable for rodents with a tropical origin (such as *O. palustris*) but now living in temperate environments. The average mass (weight) of paired testes, expressed in mg/10 g of body mass, was greater in spring and summer (50.9 to 113.7) than during November (14.1) and December (7.3 - Rose & Dreelin, 2011). The values for the males from Fisherman Island from January 1982 were 11.73 ± 8.2 (SE) but increased to 51.17 ± 4.6 (SE) for February 1982, when growth of testes foretells the coming breeding season. The seminal vesicles (also in mg/10 g of body mass) showed similar patterns: greater in spring and summer (36.7 to 139.6) than in November (13.9) and December (2.5 - Rose & Dreelin, 2011). Thus, in eastern Virginia, rice rats are seasonal breeders with almost no adults breeding during the 4 or 5 coldest months.

In other locations, such as near Raleigh, NC, pregnant rice rats were collected from March-November so the reproductive period was longer there (Brimley, 1923) than on the Eastern Shore. In a study near Galveston, Texas, reproductive indices of both sexes showed evidence of moderate reproduction in winter, in both wetland and upland plant communities (Kruchek, 2004). Overall, higher proportions of breeders lived in wetlands than in uplands. In coastal Louisiana, breeding ended in October of one year but continued throughout the next winter (Negus et al., 1961). In a tidal marsh of southern Delaware, pregnant and lactating females were observed from March to late summer, which represents the length of the breeding season at this northernmost location on the Atlantic Coast (Edmonds and Stetson, 1993).

ECOLOGY

Density

The density of *Oryzomys palustris* populations fluctuated during the annual cycle in the Eastern Shore tidal marshes, with highest densities achieved mostly in October or into early winter (Bloch & Rose, 2005: Figure 1; Rose & March, 2013). Density averaged 9.3 ± 0.8 (SE) individuals/ha and never exceeded 15/ha at Oyster, but averaged 48.2 ± 5.6 per ha at Townsend. The peak density at Townsend was greater than 60/ha in October 1995 but was ≥ 80/ha the next autumn, extending from September 1996 through February 1997 (The average densities of meadow voles were similar on both grids across the study, so these two rodents were truly co-dominants in these seaside tidal marshes). The average residency times for rice rats were similar at the two sites: 3.78 ± 0.6 (SE) months (Oyster) and 4.40 ± 0.3 (SE) months (Townsend - Bloch & Rose, 2005). The maximum residency (or trap-revealed lifespan) of *O. palustris* was 12 months at Oyster and 18 months at Townsend. Overall, average body mass did not differ between sexes, sites, or among seasons, but individuals at Townsend were heavier than those from Oyster in summer and autumn, but not in winter or spring (Bloch & Rose, 2005). The sex ratio was male-biased (214:148) at Townsend but not at Oyster (38:23). The largest proportion of males in breeding condition at Townsend was observed in summer and lowest proportion in winter, but females had similar proportions in every season. At Oyster, small sample sizes prevented an analysis of seasons but 18 of 19 males and 15 of 16 females were potential breeders in summer (Bloch & Rose, 2005).

Densities in other studies also are highly variable, perhaps due in part to different methodologies. In 0.64 ha grids trapped monthly on Assateague Island, Virginia, the highest densities, of 20-30/ha, also were seen in late autumn (Cranford & Maly, 1990). But Porter and Dueser (1982), who trapped along transects across Assateague Island, from beach dunes to tidal marshes, caught only 5 rice rats in tidal marshes. In the wetlands near Galveston, Texas, high densities of 11-13/ha were recorded in summer and autumn but in the nearby uplands, high densities of only 4-5/ha were seen in winter and spring (Kruchek, 2004). Densities in Louisiana were similar: mostly 4-6/ha but ranging up to 18/ha in mid-winter (Negus et al., 1961).

Habitats

In southeastern Virginia, rice rats can be expected in all habitats dominated by grasses and sedges, their principal foods in our region. They are more predictably found in salt and freshwater tidal marshes than in upland old fields, but dispersing rice rats can be found in almost any habitat in Virginia, including (rarely) in upland forests (e.g., Pagels et al., 1992; Bellows et al., 2001b). In upland communities in southern Chesapeake, rice rats were early colonizers of grassy fields but disappeared from one grid after three years, perhaps due to the numerical dominance by meadow voles and hispid cotton rats (Rose et al., 2018). On the other grid, where the transition from old field to forest was much slower, they persisted in low numbers to the end of the 9-year study.

In the tidal marshes of the Eastern Shore, the dominant plants are *Salicornia europea* (glasswort) in the intertidal zone and *Spartina patens* (salt cordgrass), *Baccharis halimifolia* (saltbush) and *Phragmites australis* (common reed) in the landward area (Sowell, 1995). The herbaceous vegetation at Steelman's Landing (Townsend) was both taller and denser than the vegetation at Oyster, but Oyster had a higher proportion of woody vegetation. Based on trapping results, rice rats moved significantly farther into the open marsh in summer than they did in the cool months, and they used areas with less dense vegetation compared to areas used by meadow voles, especially in summer (Sowell, 1995).

Community composition

In the Eastern Shore tidal marshes we found equal numbers of meadow voles and rice rats, plus much smaller numbers of white-footed mice, house mice (*Mus musculus*), short-tailed shrews (*Blarina brevicauda*), and eastern mole (*Scalopus aquaticus*), the latter a rarity in live traps (Bloch & Rose, 2005; Rose and March, 2013). In the upland habitats of southern Chesapeake, other common species were hispid cotton rats (*Sigmodon hispidus*), eastern harvest mice (*Reithrodontomys humulis*), short-tailed shrews, and more rarely golden mice (*Ochrotomys nuttalli*), woodland voles (*Pitymys pinetorum*), and least shrews (*Cryptotis parva* – Rose et al., 2018).

Diet

Detailed information on diet is based on the rice rats collected in every month from Eastern Shore tidal marshes (Rose & McGurk, 2006). All 103 stomachs contained dicotyledonous plants and 82 percent had monocotyledonous plants in their stomachs, so plants were important dietary components in these habitats that were flooded twice each day. The principal dicots were glasswort (*Salicornia* sp.), a succulent that gets inundated each tidal cycle, and cattail (*Typha latifolia*) and saltbush *(Baccharis halimifolia*), both located farther landward and only inundated during storm or monthly high tides. The four commonly eaten monocots were salt grass (*Spartina alterniflora*), salt meadow hay (*S. patens*), panic grasses (*Panicum* sp.), and black needle-rush (*Juncus roemerianus*). Of these, the last species can withstand the longest periods of indundation. The distribution and frequencies of these common plants in the of inundation. The distribution of tidal marshes were evaluated by Sowell (1995). In general, numbers of captured small mammals closely tracked the density of the vegetation: denser vegetation, more mammals.

Further, 61% of stomachs had crabs and insects and 38 percent had snails in the stomach (Rose and McGurk, 2006). The crabs were fiddler crabs (*Uca minax*) and the insects were a mix of grasshoppers, crickets, and other small soft-bodied arthropods. The common snail was the periwinkle, *Littorina irrorata*, which is attached to vegetation and often is stranded above the mud during low tide. The catholic diet of rice rats was evident because 38% of stomachs contained all five classes of food. Unlike the diet in other rice rat studies (e.g., Sharp, 1987), no fish were detected.

Eighty-four percent of stomachs had hairs but these seem likely to have been consumed during auto-grooming rather from eating other small rodents, such as *Mus musculus*, the house mouse, which is a common part of the small mammal community in Virginia tidal marshes. If house mice had been eaten by rice rats, some bone fragments or teeth would have been present in stomachs; none was found.

The heavy reliance on herbaceous vegetation in the diet of Virginia rice rats contrasts sharply with diets in other populations. For example, the diet of rice rats in tidal marshes near Galveston, Texas, was 65% aquatic organisms (mostly killifish, grass shrimp, fiddler crabs, periwinkles), 5% insects, and only 30% wetland vegetation (Kruchek, 2004). In the nearby upland, the diet shifted somewhat (40% aquatic organisms and 55% wetland plants), but still consisted heavily of animal foods.

Rice rats in Texas coastal prairies ate 90% or more animal foods in all seasons except summer, when animal foods dropped to 54%, and energy-rich dicots were 37%; the rest of the diet was 4% monocots and 5% dicot fruits (Kincaid and Cameron, 1982). Animal foods were mostly insects, including pupae in winter.

Rice rats in Georgia salt marshes were even more carnivorous, with some animals having almost 100% of stomach contents consisting of animal foods (Sharp, 1967). The animal foods were mostly insects and small crabs (*Uca* and *Sesarma*), plus larvae of the rice borer (*Chilo* spp), which rice rats had to extract from *Spartina* stems. When fed only plant foods in the lab, young adult rice rats lost weight whereas those on animal foods, or even grains, did not (Sharp, 1967). Rice rats certainly are opportunistic carnivores, eating eggs and nestlings of ground- or marsh-nesting birds (Brunjes & Webster, 2003; Kale, 1965; Nesmith & Cox, 1985; Post, 1981). Birds that nest in marsh grasses, reeds, or cattails are especially vulnerable. In one study, rice rats moved into a colony of nesting Boat-tailed Grackles near Tampa, Florida, where they destroyed many nests, eating eggs, nestlings, and twice even partially eating adult female grackles on the nest, resulting in the colony abandoning the site (Bancroft, 1986). In brief, rice rat diets are variable and probably tend heavily to animal foods when those are abundant.

Predators

As with other small mammals, rice rats are prey for a host of avian and terrestrial predators. Wolfe (1982) lists many of these predators but that list has since been expanded to include bobcats (Tumlison & McDaniel, 1990). In Virginia, barn owls are major predators of rice rats, as revealed by studies of owl pellets collected on Fisherman Island (Blem & Pagels, 1973) and Presquile National Wildlife Refuge, 12 miles downriver from Richmond (Jackson et al., 1976). Elsewhere, rice rats are major foods of owls, as expected for nocturnal mammals (Wolfe, 1982), and Northern Harriers (*Circus hudsonius*), which hunt by gliding just over the tops of grasslands or tidal marshes, are important predators too (Harris, 1953). We have no new information on predators of rice rats either in Northampton County but owls, red foxes (*Vulpes vulpes*), and feral cats (*Felis cattus*) likely are important ones. In southern Chesapeake, a rice rat was among the six mammal species eaten by timber rattlesnakes (*Crotalus horridus*) (Goetz et al. 2016).

Parasites

Their omnivorous diet exposes rice rats to more parasites than infect herbivorous rodents, and indeed rice rats are host to many kinds of ecto- and endoparasites. In his examination of the parasites of rice rats in Florida, Kinsella (1988 and references therein) showed that although nematodes are common in rice rats from both fresh- and saltwater marshes, rice rats in saltwater marshes also have large burdens of trematodes, a class of parasites mostly absent in freshwater marshes. Little is known of the parasites of rice rats in eastern Virginia, except for being occasional hosts to the dog ticks (*Dermacentor variabilis*) and Gulf coast ticks, *Amblyomma maculatum* (H. Gaff, pers. comm.). Also, R. Eckerlin (pers. comm.) has collected the flea *Stenoponia americana* from a rice rat in Accomack County and the flea *Orchopeas leucopus* from a rice rat in the Dismal Swamp.

BEHAVIOR

Oryzomys palustris is considered to be the most carnivorous rodent in eastern North America. Among US rodents, only grasshopper mice in the genus *Onychomys*, common in the semi-deserts of the Southwest, eat a higher proportion of animal foods than does the rice rat (Wilson & Ruff, 1999).

Auto-grooming is an important behavior, in part because when rice rats are in the water, groomed and oiled fur prevents water from reaching the body surface. Furthermore, the bubble of air around the outer fur of a diving rice rat provides insulation from the usually colder surrounding water. The observation that 84 percent of stomachs contained hairs (Rose & McGurk, 2006) supports the notion that auto-grooming is an important and potentially time-consuming behavior of everyday life for rice rats.

Several studies have examined the swimming ability of rice rats, starting with those in the lab by Esher and colleagues (Esher et al., 1978). In a study of rice rats on three islands on the Eastern Shore of Virginia, 11 rice rats of all sex and age categories swam from the smallest island (with the highest population density) to the larger islands across a saltwater gap of 50 to 300 m;

none returned to the smallest island (Forys and Dueser, 1993). Bellows et al. (2001b) caught a rice rat in a minnow trap set in a beaver pond at Fort A. P. Hill, indicating its readiness to hunt for prey in shallow water.

At least four times I have caught one each of rice rat and cotton rat in a very full Fitch trap. (Fitch traps are multiple-capture traps and a second animal can enter by pushing up and slithering under the dropped door, now also being captured.) Because the rice rat is so pugnacious while being handled and the cotton rat so docile by comparison, I would have expected the rice rat to attack the larger cotton rat but in all cases, neither rat was injured.

Unlike other small mammals in our region, almost no rice rats are captured in late pregnancy, and few juveniles are trapped either. This indirect evidence suggests that pregnant and lactating rice rats may alter their behavior, especially their foraging behaviors, in late pregnancy, perhaps about the time nests are built to hold the young and during early days of nursing their young. The details of peri-natal behaviors may be important to understand in evaluating the transmission of ticks and their associated diseases.

GENETICS

Some research has been conducted on the genetics of rice rats from eastern Virginia. Forys and Moncrief (1994) used two methods to evaluate gene flow among mainland rice rats and those from four nearby barrier islands by: (1) monitoring the movement of tagged, dispersing animals from one place to another and (2) using genetic information from 13 polymorphic loci of these rice rats. The results of the two methods were not congruent; the former method estimated dispersal at 0.75 migrants per generation whereas the indirect (genetic) method estimated 0.09 migrants per generation. The other genetic study (Loxterman et al., 1998) compared mainland and barrier island populations of *O. palustris* for their amounts of genetic variation. The populations of rice rats from nine islands had an average heterozygosity of 2.4% with 6.7% polymorphic loci. These levels of variation were greater than for rice rats from mainland populations, reflecting the higher levels of gene flow due to the ability of rice rats to move among islands.

CONSERVATION STATUS

Nationally, *Oryzomys palustris* is a species of least concern (G5), except perhaps at the northern limits of its distribution in the Midwest (Illinois and Ohio) and on the East Coast, where populations might be moving northward in recent decades but recent surveys are lacking. In Virginia, the marsh rice rat is considered a species of Least Concern (S5).

REMARKS

The name, *Oryzomys palustris*, is derived from the Latin genus for rice, *Oryza*, and the Latin name for mouse, *mys*. The name "*palustris*" in Latin means "marshy" or "swampy," referring to these rodents being caught in rice fields of coastal South Carolina in the 1830s.

Much of the information in this report is based on the research conducted in partial fulfillment of requirements for M. S. degrees in the Department of Biological Sciences at Old Dominion University by Christopher P. Bloch, Erin A. Dreelin, John A. March, Allison L. Sowell, and Shannon Wright McGurk, all of whom conducted their research in tidal marshes in Northampton County. Numerous fellow graduate students assisted in this field research conducted

on the Eastern Shore and in southern Chesapeake (the latter are coauthors in Rose et al., 2018). Thanks to Ralph Eckerlin for providing information on fleas he has collected from rice rats over the years. I am grateful to The Nature Conservancy for permission to use of their land for these ecological studies. These studies were conducted under permits issued by the Virginia Department of Game and Inland Fisheries (thanks, Shirl Dressler) and before the Old Dominion University Animal Care and Use Committee evaluated research proposals for the study of wild mammals in nature. We followed the guidelines for ethical conduct of field research on mammals as recommended by the American Society of Mammalogists, the latest of which is Sikes et al. (2016). Since 2008, field research protocols have been evaluated and approved by the ODU Animal Care and Use Committee.

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RESEARCH ARTICLE

AN ANNOTATED CHECKLIST OF THE COLEOPTERA OF THE SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER: THE AQUATIC FAMILIES

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ABSTRACT

A total of 47 species of aquatic beetles were found in a two-year inventory of the Smithsonian Environmental Research Center: Dytiscidae- 15 species; Gyrinidae- 1 species; Noteridae- 1 species; Haliplidae- 2 species; Hydrophilidae- 13 species; Hydrochidae- 4 species; Elmidae- 1 species; Heteroceridae- 2 species; Ptilodactylidae - 2 species; and Scirtidae- 6 species.

Keywords: Coleoptera, beetles, annotated checklist, Maryland.

INTRODUCTION

Beetles from a number of families are found in aquatic habitats. In North America alone there are ten different families in which both larvae and adults of nearly all species are aquatic, three in which at least one stage is aquatic, two in which the larvae occur in water or in the underwater parts of plants and the adults are semiaquatic. These all live in fresh, saline, and mineral inland waters. This does not include species of five other families which live in the intertidal zone of ocean beaches. In addition, there are many species which burrow in wet mud and sand or hunt and hide under debris and stones at water's edge.

The majority of water beetles prefer shallow water, where they hide among aquatic plants and underwater debris near the shore. Few species occur in deep water and none are found inhabiting the open ocean.

Members of the family Dytiscidae (predaceous diving beetles) are found in lentic and lotic habitats. They are extremely well-adapted to aquatic life. Many are strong swimmers. Species are predators and scavengers as larvae and adults. Larger species often feed on fish, anuran larvae or other small vertebrates. Smaller species are effective predators on invertebrates, especially mosquito larvae. Many species are good fliers and are able to quickly colonize new bodies of water or disperse when their habitat dries up (Wilson, 1923).

Oviposition occurs terrestrially usually in either moss or debris or in cracks in wood. There are three larval instars and each is aquatic. Larvae, as well as adults, must surface for oxygen though there is circumstantial evidence that some species do not need to surface; the larvae of *Coptotomus* have abdominal gills. Pupation generally occurs on the land near the water in a small earthen cell (Wilson, 1923).

Dytiscids are frequently encountered and fairly easy to identify. The North American dytiscid fauna of 475 species is well studied (Larson et al., 2000; Roughley & Larson, 2001). There are 84 species reported from Maryland (Staines, 1986a).

According to the Maryland Natural Heritage Program, the following species are candidates for endangered or threatened species in the state: *Agabetes acuductus* (Harris), *Hoperius planatus* Fall, *Hydrocolus deflatus* (Fall), and *Laccophilus schwarzi* (Fall) (Anonymous, 2003).

Most Gyrinidae (whirligig beetles) skate on the surface of ponds, lakes, and streams; but a few species cling to roots on undercut stream banks. When disturbed, they dive and scatter widely. Adults are scavengers, feeding on insects floating on the water surface; larvae are predaceous, feeding on the immature stages of other aquatic insects (Roughley 2001a). There are 56 species in four genera in North America (Roughley, 2001a), of which 20 species are known from Maryland (Staines, 1986a).

Haliplidae (crawling water beetles) are easily distinguished by the enlarged hind coxal plates. Adults are feeble swimmers; they are most often found crawling along submerged vegetation on the edge of small ponds, lakes or quiet streams and often found in mats of filamentous algae. Some species are known to fly and have been captured in black light traps. There are 67 species known from North America (Roughley, 2001b). There are 13 species known from Maryland (Staines, 1986a).

Noteridae (burrowing water beetles) burrow through the substrate of ponds, marshes, and temporary pools with emergent vegetation. Larvae and adults are primarily predaceous, feeding on immature insects and eggs, but they will also eat dead insects. The life cycle is unknown for all North American species. There are six genera and 14 species known from North America (Roughley, 2001c). There are four species known from Maryland (Staines, 1986a).

The family Hydrochidae consists of small (1.5 to 5.5 mm) species which live in pools and ponds. The Nearctic species were revised by Hellman (1975) but the thesis was never published. Makhan (1994, 1995, 2001, 2002) has claimed to have described a number of Hellman's species. Unfortunately, Makhan's descriptions are short and vague so as to be useless and his illustrations are of very poor quality or are misleading, so that his names cannot be assigned to a species. This taxonomic situation needs to be resolved (Jäch, 2006); Worthington et al., (2016) has started the process. There are 26 species in North America (Van Tassell, 2001), with 13 species known from Maryland (Staines 1986b). According to the Maryland Natural Heritage Program *Hydrochus spangleri* Hellman (Coleoptera: Hydrochidae), is a state endangered species (Anonymous, 2003).

Members of the family Hydrophilidae (water scavenger beetles) are mainly aquatic but the subfamily Sphaeridiinae is terrestrial and lives in animal dung, fungi, and decaying plant material. Aquatic species are found in stagnant pools, littoral areas of lakes and ponds, shallow quiet water of streams, and springs. Aquatic species are predaceous as larvae; adults are predaceous on snails or other small invertebrates, omnivorous or phytophagous. A number of aquatic species are important predators of mosquito larvae. *Hydrophilus triangularis* Say has been reported as a pest in fish hatcheries (Wilson, 1923). Known larvae are predaceous but the biology is unknown for most North American species (McCorkle, 1967; Smetana, 1985).

The 225 North American species are fairly well known (Van Tassell, 2001). There are 103 species reported from Maryland, of which 75 are aquatic and 28 terrestrial (Staines, 1986b).

According to the Maryland Natural Heritage Program *Hydrochara occulata* d'Orchymont and *Sperchopsis tessellatus* Ziegler (Coleoptera: Hydrophilidae) are candidates for endangered or threatened status (Anonymous, 2003).

The Scirtidae (marsh beetles), formerly known as the Helodidae or Elodidae, are aquatic as larvae but terrestrial as adults. Larvae are found in ponds and streams, water-filled tree holes, overflow from springs, and other wet places. There are seven genera and 50 species recorded from the United States and they are in need of revision (Young, 2002). The Maryland fauna has not been documented.

The Elmidae (riffle beetles) are most often found in clear, fast-moving streams and are used as indicators of water purity. They are frequently collected by kicking over stones in small streams or by examining overhanding roots, vegetation, or debris in the water. Adults of some species are terrestrial and a few species fly to lights. Both adults and larvae feed on plant material. There are 27 genera and nearly 100 species found in North America (Shepard, 2002). The Maryland fauna has not been studied.

The Heteroceridae (variegated mud-loving beetles) are semiaquatic. Larvae and adults live in burrows in damp mud and sand where they tunnel to locate prey and plant material. Many species fly to lights. Pacheco (1964) revised the family but his work has not been generally accepted (Miller, 1988). There are three genera and 38 species known from North America (Katovich, 2002). Staines (1983[1985]) recorded ten species from Maryland.

The Ptilodactylidae (ptilodactylid or toed-winged beetles) are primarily tropical in distribution. Depending on the species, larvae occur in and feed on decaying vegetation in aquatic or damp terrestrial habitats (LeSage & Harper, 1976; Ivie, 2002). Adults are taken at lights or beaten from vegetation, usually near riparian habitats (LeSage, 1991; Ivie, 2002). Adult Ptilodactylinae feed on spores (Stribling & Seymour, 1988), otherwise little is known about the feeding habits of other subfamilies. There are five genera and 13 species known from North America (Ivie, 2002). The species are very similar, males can often be identified and females cannot be identified.

There are few published inventories of Maryland aquatic beetles. Staines & Staines (2005) reported 42 species from three families from Eastern Neck National Wildlife Refuge. Staines (2008a, b) reported 36 species from three families on Plummers Island. Staines (2008c) reported 39 species from six families from Fort Washington and Piscataway National Parks. Staines (2009) reported 44 species from six families from Patuxent Research Refuge, North Tract. Staines (1986a) reported 13 species of Haliplidae, four species of Noteridae, 20 species of Gyrinidae, and 84 species of Dytiscidae from Maryland. Staines (1986b) reported three species of Helophoridae, 13 species of Hydrochidae, and 48 aquatic Hydrophilidae from Maryland.

MATERIALS AND METHODS

The Smithsonian Environmental Research Center (SERC) [38°33'17.57"N; 76°33'14.29"W] consists of approximately 1,477 ha of hardwood-dominated forest, ponds, creeks, rivers, tidal marshes, and 19.3 km of protected shoreline along the Rhode River and upper Chesapeake Bay in Anne Arundel County, Maryland (SERC, 2018). Forests on the main campus of SERC can be broadly classified into three main types: (1) the majority (~85%) is a Tulip-poplar *(Liriodendron tulipifera* L.) association; (2) a moist lowland assemblage, comprised of American sycamore (*Platanus occidentalis* L.), ash (*Fraxinus* spp.), elms (*Ulmus* spp.), river birch (*Betula nigra* L.), and other woody vegetation along freshwater streams; and (3) a somewhat xeric assemblage that fringes tidal marshes, consisting of chestnut oak (*Quercus prinus* L.), white oak (*Quercus alba* L.), black gum (*Nyssa sylvatica* Marshall), mountain laurel (*Kalmia latifolia* L.), blueberries (*Vaccinium* spp.) and other woody vegetation.

Like much of the eastern United States, SERC's forest age and structure reflect historical agricultural activities and local history. SERC's main campus was mostly fallow from the end of the Civil War to approximately 1915, when it was used as a dairy farm with grazing pastures and fields for feed production until 1945. Thus, the majority of SERC's contemporary forests are from 70-150 years old (McMahon et al., 2010; Higman et al., 2016).

Freshwater inputs into the Rhode River are primarily from the North Fork Muddy Creek, South Fork Muddy Creek, and their lower order streams. These streams are associated with several swamps, beaver impoundments, and seasonal wetlands which range from small, tannin-rich, ephemeral wetlands, to larger and clear-water permanent ponds.

On the opposite side of the Rhode River the BiodiversiTREE plots are about 30 acres containing 24,000 trees of 16 species of ecologically important deciduous trees planted in 75 plots. These plots were established over 30 years ago (SERC, 2018). In the annotated species list this area is referred to as Zones 5 and 6.

The goal of this project is to inventory the Coleoptera of the SERC. Collecting techniques was visual survey followed by sweeping or beating the vegetation of the area. Other collecting techniques used were pitfall traps (both baited and unbaited), head lamping, black lighting, and checking lights around buildings on the main campus.

Field work was conducted from 11 May to 24 October 2018, 30 March to 23 October 2019, and 19-20 March 2020. Voucher specimens are deposited in the SERC and the Department of Entomology Collection, Natural History Museum, Smithsonian Institution.

RESULTS

Family Dytiscidae

Agabus gagates Aubé is commonly found in woodland pools, generally where the water is shaded and cool and has an accumulation of organic debris on a soft substrate. It is also found in beaver ponds, flooded pastures, tire ruts, and stream margins. Adults are attracted to lights. (Michael & Matta, 1977; Larson et al., 2000; Ciegler, 2003). Specimens were collected on 3 April 2019 in a vernal pool at the intersection Back Road & 11-6 and on 27 May 2019 at black light along Connector Trail between Fox Point Rd. and Java History Trail.

Agabus punctatus Melsheimer prefers shallow, semi-permanent ponds and pools especially woodland vernal pools (Michael & Matta, 1977; Hilsenhoff, 1993; Ciegler, 2003). Specimens were taken on 25 May at black light at the intersection of Back Road & 11-6.

Copelatus glyphicus (Say) is collected in ponds, pools, puddles, hollow trees, leaf litter, and temporary pools. Adults are attracted to lights (Ciegler, 2003). This species feeds on copepods, ostracods, ceratopogonid larvae, and *Podura aquatica* L. (Collembola) (Spangler, 1962). Specimens were taken at black light on 23 June 2018 at Reed Education Center, on 25 May at the intersection of Back Road & 11-6, on 27 May 2019 along Connector Trail between Fox Point Rd. and Java History Trail, on 25 July 2019 along Contees Watershed Trail, on 26 July at Java History Trail and boardwalk, and on 17 June 2019 along Java History Trail.

Desmopachria convexa (Aubé) is found in swamps and ponds with emergent vegetation and algae; eggs are placed in a gelatinous matrix and attached to plant stems (Barman, 1973); adults were collected from ponds, especially smaller ponds in open areas; they also were found in marshes, bogs, swamps, and ditches (Hilsenhoff, 1994). A single specimen was taken on 30 March 2019 by dip net in the ponds around Mathias Lab.

Graphoderus liberus (Say) is common in woodland pools but has been collected in open pools and ponds (Michael & Matta, 1977). Specimens were taken at black light on 27 June 2019 at Back Road opposite NEON tower and on 26 July 2019 at Java History Trail and boardwalk.

Hydrovatus pustulatus Melsheimer is collected from open ponds; several also were collected from marshes, especially larger ones. Life Cycle: Adults occurred 31 March to 1 November. Almost 97% were collected from May through September (65% in July and August). Teneral adults occurred 25 June to 19 October, 92% of them 18 July to 14 September. I believe adults overwinter in ponds because 14 were collected in October and November. Apparently oviposition is delayed until late spring and early summer, with peak oviposition occurring at different times in different years. The life cycle is probably univoltine because occurrence of the teneral adults follows a normal curve that peaks in early August (Hilsenhoff, 1994). A single specimen was taken on 30 March 2019 by dip net in the ponds around Mathias Lab.

Hygrotus nubalis (LeConte) is collected in a variety of aquatic habitats, including dense emergent grasses and rushes along the margins of small pools, pools in gravel pits, and ponds (Michael & Matta, 1977; Larson et al., 2000; Ciegler, 2003). This is primarily a summer species with most individuals being collected after June (Hilsenhoff, 1994). A single specimen was taken on 30 March 2019 by dip net in the ponds around Mathias Lab.

Ilybius oblitus Sharp prefer ponds or pools without detritus or leaf litter (Michael & Matta, 1977); collected from clear pools with emergent grasses and rushes, one specimen collected at light (Larson, 1987); in *Typha* stand in detritus laden marsh (Barman et al., 2001). Specimen were taken on 11 May 2019 by dip net in the ponds around Mathias Lab and at black light on 20 May 2019 at Frog Haven.

Laccophilus fasciatus rufa Melsheimer is most commonly found in exposed, muddy or silty bottomed temporary ponds. It is a pioneer species found in newly formed aquatic habitats. Adults are attracted to lights (Young, 1954; Michael & Matta, 1977; Larson et al., 2000; Ciegler, 2003). This species over winters as adults; mating and oviposition begins in the spring. Unlike other species of *Laccophilus*, it does not require vegetation to oviposit. Pupation lasts from 6 to 8 days. This species breeds throughout the warmer months (Sizer et al. 1998). Specimens were taken by dip net on 6 June 2018 at pond at intersection of Dock & Contees Wharf Roads and the pond at parking lot of main campus; and at black light on 26 June 2019 in the fields opposite the Sellman House.

Laccophilus maculosus Say is found in both forested and grassland shallow pools and ponds usually with emergent vegetation. Adults have been collected at black light. This is a pioneer species, often the first to find a new body of water (Zimmerman, 1970; Michael & Matta, 1977; Larson et al., 2000; Ciegler, 2003). Larvae of *L. maculosus* are excellent swimmers; the swimming fringes on the legs are well-developed on all legs so that they can swim without moving the body; the abdomen and cerci are only used for steering. Larvae crawl on aquatic plants very slowly seeking prey. They breathe by raising the tip of the abdomen to the surface of the water and can remain underwater for an hour or more before needing more oxygen. Pupation occurs in the soil, often quite a distance from water (Wilson, 1923). Specimens were taken by dip net on 30 March 2019 in the Ponds around Mathias Lab.

Neoporus blanchardi (Sherman) is found in shaded springs with sandy bottoms, in seepage springs, and adults at light (Larson et al., 2000; Ciegler, 2003). Specimens were taken on 20 May 2019 at Frog Haven by black light and on 21 May 2019 by dip net at the intersection of Contees Wharf & Dock Roads.

Neoporus carolinus (Fall) is found in slow boggy streams and ditches (Larson et al., 2000); rivers, lakes, ponds, and shallow pools (Ciegler, 2003). Specimens were taken on 20 May 2019 at Frog Haven by black light.

Neoporus clypealis (Sharp) is found in streams of various sizes, backwaters, spring ponds, and ponds adjacent to streams, rarely found in other types of ponds or ditches (Hilsenhoff, 1995); in emergent vegetation along the margins of slow marshy streams, in beaver ponds, small lakes (Larson et al., 2000); in rivers, swamps, and adults are attracted to lights (Ciegler, 2003). Specimens were taken by dip net on 6 June 2018 at pond at the intersection of Dock & Contees Wharf Roads; on 30 March in the ponds around Mathias Lab; and at black light on 26 June 2019 in fields opposite Sellman House.

Thermonectus ornaticollis (Aubé) is most commonly found in semi-permanent, clear-water ponds with grassy margins; adults are attracted to lights (Michael & Matta, 1977; Ciegler, 2003). Specimens were taken at black light on 26 June 2019 in fields opposite Sellman House.

Uvarus granarius (Aubé) is found on mats of vegetation along shallow bodies of water; they are especially common in woodland pools and bogs (Larson et al., 2000). Specimens were taken by flotation on 21 May 2019 at the pond at the intersection of Contees Wharf & Dock Roads.

Family Gyrinidae

Dineutus emarginatus (Say) is found in ponds, lakes, slow moving rivers and swamps; adults are attracted to lights (Ciegler, 2003; Realzola et al., 2007). King et al. (2000) found this species in cypress-gum swamps. Specimens were taken by dip net on 6 June 2019 at the pond at the intersection of Contees Wharf & Dock Roads

Family Haliplidae

Haliplus fasciatus Aubé is collected in permanent pools, the margins of slow-flowing streams, lakes, ponds, creeks, and swamps (Matta, 1976; Ciegler, 2003). Specimens were taken by dip net on 17 October 2018 at Frog Haven.

Peltodytes muticus (LeConte) is found in lakes, rivers, ponds, canals, bays; and adults are also taken at black light (Matta, 1976; Ciegler, 2003). Young (1954) usually collected this species in association with various filamentous algae. They may be taken in numbers from various standing water habitats. Matheson (1912) noted that mating takes place in late April and May. The small, brownish eggs are attached to the stems of aquatic plants and hatch in about 2 weeks. There are three larval instars: the first last about six days, the second last from 8 to 10 days, and the third last from 7 to 10 days. Mature larvae leave the water seeking pupation sites. They construct a pupal cell in damp soil and pupate 7 to 10 days later. Adults emerge in about 14 days and remain in the pupal cell for several days to harden. Specimens were taken by dip net at Frog Haven on 6 June 2018 and 17 October 2018 and on 30 March 2019 in ponds around Mathias Lab.

Family Noteridae

Hydrocanthus iricolor Say prefers ponds with debris in the bottom; adults are attracted to lights (Staines, 1988; Ciegler, 2003). A single specimen was collected by dip net on 30 March 2019 in ponds around Mathias Lab.

Family Hydrochidae

Hydrochus excavatus LeConte is a coastal plain species that occurs in a variety of pools, ponds, and streams; adults are attracted to lights (Hellman, 1975). Specimens were taken on 6 June 2018 by dip net in the pond at the parking lot near Mathias Lab.

Hydrochus inaequalis LeConte is collected near ponds, ditches, and small pools using ultraviolet light (Ciegler 2003); near ponds in coastal savannah, mixed mesic forest, mixed forest, pine forest, and bottomland hardwood forest, near swamps, and in a field of cultivated cotton, as well as various streams and rivers, using black lights, mercury vapor lights, and sun lamps (Worthington et al., 2016). Specimens were taken at black light on 20 May 2019 at Frog Haven.

Hydrochus rugosus Mulsant occurs in sink hole ponds, along the margins of lakes, cypress swamps, and small streams found on or near aquatic vegetation or floatage and has been collected using ultraviolet lights (Ciegler, 2003; Young, 1954); collected in mixed pine-oak forest, coastal savannah, near streams, rivers, marshes and swampy areas, as well as small and large impoundments using black light traps, flight intercept traps, and mercury vapor lights (Worthington et al., 2016). Specimens were taken by dip net on 30 April 2019 along Contees Wharf Trail.

Hydrochus scabratus Mulsant is collected along the margin of streams (Hilsenhoff, 1995). Specimens were taken by dip net on 6 June 2018 at the pond at the intersection of Dock & Contees Wharf Roads.

Family Hydrophilidae

Anacaena limbata (Fabricius) was introduced from Europe and is widely distributed throughout North America. (Smetana, 1988; Arnett, 1983). This species is found in a wide variety of aquatic habitats but seems to prefer the shallow standing water of small pools or ponds. Matta (1974) found specimens along the grassy margins of streams. In New York, this species lays eggs in May. Egg cases are round, about 1.13 mm long and 1.08 mm wide, they are flattened on top forming a slightly concave area where the filament attaches. Egg cases contain from 5 to 10 eggs, which hatch in 8 to 10 days (Richmond, 1920). Specimens were taken at black light on 20 May 2019 at Frog Haven, on 26 July 2019 at Java Trail and boardwalk, and on 12 August 2019 along Back Road.17 June 2019.

Anacaena suturalis (LeConte) Matta (1974) and Testa & Lago (1994) found this species in pools and swampy or grassy margins; Young (1954) found it to be abundant in streams in uplands and flatlands. Ciegler (2003) reported the species from rivers, streams, and lakes. Specimens were taken on 6 June 2018 at the pond in parking lot near Mathias Lab by flotation; at black light on 17 June 2019 along Java History Trail, and 26 June 2019 in fields opposite Sellman House.

Berosus ordinatus LeConte is found among algae in woodland pools, in ponds with waterlilies, and in pools separated from rivers (Testa & Lago, 1994). Specimens were taken at black light on 12 August 2019 along Back Road.

Berosus striatus (Say) prefers ponds of various types but individuals have been collected in streams, algal mats, lakes, and ditches; adults are attracted to lights (Testa & Lago, 1994). Matta (1974) stated that this species seems to prefer deeper water. Hilsenhoff (1995) reported that adults overwinter probably in terrestrial habitats. They enter ponds in the spring to mate and oviposit. Most larvae complete development during the summer. An occasional larva may overwinter. Specimens were taken by dip net on 5 June 2018 in pond at the intersection of Contees Wharf and Dock Roads.

Cercyon pygaemus (Illiger) is often found in wet habitats among debris and dung (especially horse and cow), fungi, carrion, decaying organic matter, and compost piles; adults are attracted to lights (Smetana, 1978). Schulte (1985) found that, after hatching, the larvae disperse into the substrate and wander for several days before feeding. During larval development, larvae consume from 25 to 30 fly larvae. There are three larval instars; the first instar lasts from 3 to 4 days, the second from 2 to 3 days, and the third from 9 to 11 days. The pupal stage lasts from 3 to 5 days. A single specimen was taken from an unidentified fungus on 23 October 2018 along Contees Trail.

Cymbiodyta blanchardi (Horn) is found in running water (Smetana, 1974); ponds and seepages (Ciegler, 2003). Specimens were taken by dip net on 6 June 2018 at Frog Haven and 23 April 2019 in vernal pool at Back Road and 11-6.

Cymbiodyta semistriata (Zimmermann) is found in small, spring fed streams (Hilsenhoff, 1995) and collected in black light traps (Testa & Lago, 1994). A single specimen was taken by flotation in a spring seep along Discovery Trail on 3 April 2019.

Cymbiodyta vindicata Fall is collected by sifting humus, or from sphagnum moss, spring seepages, and streams; adults are attracted to lights (Smetana, 1974; Testa & Lago, 1994). Hilsenhoff (1995) found this species most often in swamps and other boggy situations. Specimens were collected by dip net on 30 April 2019 along Contees Wharf Trail and by black light on 20 May 2019 at Frog Haven.

Hydrochara obtusata (Say) is found in farm ponds and similar lentic situations (Malcolm, 1971); is found in a wide various of aquatic habitats but seems to prefer swallow water with rich vegetation, adults commonly come to lights (Smetana, 1980); is found in shallow ponds and marshes (Hilsenhoff, 1995); in ditches (Williams et al., 2007). Specimens were taken at black light on 20 May 2019 at Frog Haven, on 27 May 2019 along Connector Trail between Fox Point Rd. & Java History Trail, and on 27 June 2019 on Back Road opposite NEON tower.

Paracymus subcupreus (Say) is found in a wide variety of aquatic habitats but prefers shallow, standing water with abundant organic matter (Matta, 1974; Testa & Lago, 1994). Smetana (1988) also reports the species from semiaquatic habitats such as wet moss and grass tufts. Adults are attracted to lights (Hilsenhoff, 1995). Most oviposition occurs in May. Eggs are not enclosed in a case but are tied together with strands of silk. Each female lays between 10 and 15 eggs. Eggs hatch in about 7 days. Pupation begins in mid-July but continues into September; pupal cells are formed about 25 mm below the surface near the water’s edge. The pupal period lasts about 4 days (Richmond, 1920). Specimens were taken by flotation on 30 March 2019 in ponds near Mathias Lab.

Tropisternus blatchleyi d'Orchymont prefers shallow pools and ponds with thick vegetation but may be found in any quiet water habitat (Testa & Lago, 1994). Testa & Lago (1994) found the species in brackish ponds with salinity from 3.5 to 10.0 ppt. Adults are attracted to lights (Ciegler, 2003). Hosseinie (1976) studied the biology of this species. Egg case construction and egg laying occur about one week after mating. Egg cases are laid on debris in the water and hatch in 5 to 9 days. There are three larval instars: the first lasting 5 to 9 days, the second 5 to 11 days, and the third 15 to 23 days. Larvae feed on any prey they can capture. Feeding occurs on the surface with the larval head and apex of the abdomen out of the water. Larvae can swim in both a forward and backward direction. Pupation occurs in moist soil and last 10 to 16 days. Specimens were taken by dip net on 6 June 2018 in pond at intersection of Contees Wharf and Dock Roads and at black light on 12 August 2019 along Back Road.

Tropisternus lateralis nimbatus (Say) is very common and can be found in shallow standing water. It prefers areas with dense rooted vegetation and may occur in running water if the vegetation at the margin is thick enough; adults are attracted to lights (Matta, 1974; Testa & Lago, 1994). Wilson (1923) found that this subspecies attaches egg cases to aquatic vegetation. Pupation occurs quite a distance from the water where the larva constructs a pupal chamber 2 to 2½ inches beneath the surface and remains 2 to 3 days prior to pupating. Young (1960) reported *T. lateralis nimbatus* commonly in newly formed aquatic habitats. Ryker (1975) found that females attracted males by calling chirps. Zalom & Grigarick (1980) found that early instar larvae fed mostly on copepods while third instar larvae fed on chironomids and conspecific larvae. Hilsenhoff (1995) reported that *T. lateralis nimbatis* overwinter as both adults and eggs; there are two generations per year in Wisconsin. Testa & Lago (1994) collected specimens in brackish ponds with salinity of up to 6.0 ppt. Hosseinie (1976) reported that eggs hatched in 3 to 7 days. There are three larval instars: the first lasts 2 to 4 days, the second 3 to 5 days, and the third 12 to 18 days. The pupal period lasts from 9 to 14 days. He also stated that reduced feeding rates resulted in increased instar duration, decreased survival rate, and an overall reduction in size in each life stage. Cook & Kennedy (2000) found that larvae were not able to survive the drying of pools by entering a resting stage. First and second instar larvae perished within 24 hours of the pool totally drying. If large enough third instar larvae could successfully pupate and emerge as adults. Adults emigrate from the pool as it dried. Specimens were collected by dip net on 6 June 2018 and 21 May 2019 in pond at the intersection of Contees Wharf and Dock Roads.

Tropisternus quadristriatus (Horn) prefers the margins of estuaries and brackish pools and is seldom collected in fresh water (Matta 1974); it is also attracted to black lights (Testa & Lago, 1994). Specimens were collected at black light on 20 May 2019 at Frog Haven.

Family Heteroceridae

Heterocerus pallidus Say is gregarious and inhabits the immediate vicinity of permanent or temporary, flowing or stagnant, clear or murky bodies of water, where the surface of sand is covered with a thin layer of mud (Kaufmann & Stansly, 1979). Specimens were taken on 20 May at Frog Haven and 26 June 2019 in the fields opposite the Sellman House at black light.

Tropicus pusillus (Say) is collected on margins of ponds (Blatchley, 1910); consistently collected from intermittent creek beds, drainage ditches, and sandy ponds, attracted to lights (King & Lago, 2012). Specimens were taken on 20 May at Frog Haven and 26 June 2019 in the fields opposite the Sellman House at black light.

Family Scirtidae

Contacyphon perplexus (Blatchley) is taken from flowers and beaten from vegetation (Blatchley, 1914); sweeping vegetation in bogs (Young 1988). Specimens were taken at black light on 20 May 2019 at Frog Haven.

Contacyphon variabilis (Thunberg) is collected sweeping vegetations in bogs (Young, 1988). Specimens were taken by sweeping vegetation on 4 April 2019 along Squirrel Loop Trail; at black light on 20 May 2019 at Frog Haven, on 25 May 2019 at the intersection of Back Road & 11-6, on 27 May 2019 along Connector Trail between Fox Point Rd. & Java History Trail, on 26 July 2019 on Java History Trail & boardwalk, and on 12 August 2019 along Back Road.

Exneria ruficollis (Say) is taken by beating vegetation of trees and shrubs (Blatchley, 1910). Specimens were taken sweeping vegetation on 23 April 2019 at Frog Haven.

Prionocyphon discoideus (Say) is collected by beating vegetation and at lights (Blatchley, 1910); larvae are found in still water along margins of pools and feed on decomposing leaves (Good 1924). Specimens were taken at black light on 26 July 2019 at Java History Trail and boardwalk and by head lamping on 12 August 2019 along Back Road.

Prionocyphon limbatus LeConte larvae are found in shady places in still water near the shore when leaves are found on the surface. They feed on decomposing leaves and pupate in the wet soil along the margin. Adults are active and are found among the leaves along the margins of pools, they were not beaten from surrounding vegetation (Good, 1924). Specimens were collected sweeping vegetation on 30 April 2019 along Contees Wharf Trail

Sacodes thoracica (Guérin) larvae develop in tree holes, adults are found on tree trunks, and are attracted to light (Evans, 2014); captured in Lindgren funnel traps (Webster et al., 2016). Specimens were taken by sweeping vegetation on 23 April 2019 at Frog Haven.

Family Elmidae

Stenelmis quadrimaculata Horn is collected in lakes and marl bogs (Blatchley, 1910; Brown, 1972); on submerged wood (Hilsenhoff & Schmude, 1992). Specimens were taken at black light on 26 June 2019 in fields opposite Sellman House.

Family Ptilodactylidae

Ptilodactyla angustata Horn has been collected sweeping vegetation, in sticky traps, and at lights (Ciegler, 2003). Specimens were collected sweeping vegetation on 19 June 2019 near Reed Education Center and on 26 June 2019 in fields opposite Sellman House.

Ptilodactyla serricollis (Say) has been beaten from vegetation along the margins of lakes and marshes (Blatchley, 1910); taken at light (Johnson & Freytag, 1978). Specimens were collected at black light on 27 May 2019 along Connector Trail between Fox Point Rd. and Java History Trail.

Ptilodactyla sp. ♀. A single specimen was collected at black light on 1 June 2019 near Reed Education Center.

DISCUSSION

The 47 species found at SERC suggests a diverse and healthy water beetle fauna for the SERC. Hopefully, the data reported here will provide a baseline for future monitoring to track changes in populations and species at SERC. No threatened or endangered species were observed.

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RESEARCH ARTICLE

AN ANNOTATED CHECKLIST OF THE COLEOPTERA OF THE SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER: THE SCARABAEOIDEA

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ABSTRACT

Forty-seven species of Scarabaeiodea are reported from two years of field work at the Smithsonian Environmental Research Center, Edgewater, Maryland. There were one Passalidae, three Geotrupidae, 41 Scarabaeidae, and two Trogidae.

Keywords: Biodiversity, insects, Maryland.

INTRODUCTION

The Scarabaeiodea contains about 35,000 described species (Ratcliffe, 2002). It consists of the families Geotrupidae Latreille (earth-boring dung beetles), Glaphyridae MacLeay (bumble bee scarab beetles), Glaresidae Kolbe (enigmatic scarab beetles), Hybosoridae Erichson (scavenging scarab beetles), inclusive of Ceratocanthidae White (pill scarab beetles), Lucanidae Latreille (stag beetles), Ochodaeidae Mulsant and Rey (sand-loving scarab beetles), Passalidae Leach, (bess beetles), Pleocomidae LeConte (rain beetles), Scarabaeidae Latreille (scarab beetles), and Trogidae MacLeay (hide beetles) (Bouchard et al., 2011).

The Passalidae is a family of beetles known variously as bessbugs, bess beetles, betsy beetles, patent leather beetles or horned passalus beetles. Nearly all of the approximately 500 species are tropical. They are subsocial beetles that live in groups within rotting logs or stumps. The beetles will excavate tunnel systems within rotting wood where the females then lay their eggs. They care for their young by preparing food for them and helping the larvae construct the pupal case. Both adults and larvae must consume adult feces which have been further digested by microflora for a time. There are four species known from the United States (Schuster, 2002). Staines (1984[1986]) reports one species from Maryland.

The Geotrupidae are strong burrowers. For most species the term dung beetle is a misnomer. Most adults and larvae feed on fungi or appear not to feed. Where the biology is known, the adults invariably furnish the larval food. Most of the species dig nearly vertical burrows; at the bottom they construct one to four cells and provision them with food. The larval food for most species in the tribe Geotrupini consists of dead leaves and other surface litter; however, in two or three species of *Geotrupes* and at least one of *Mycotrupes*, the larval food consists of cow or horse dung. In the tribe Bolboceratini, adults feed on fungi, some are attracted to fermenting malt, and others seemingly do not feed. In the genera *Bolboceras*, *Bolbocerosoma*, and *Eucanthus*, larval food consists of very finely divided humus occurring near the ground surface. This is transported down the burrow and formed into a brood cell. Development is usually rapid, taking approximately 60 days from egg to adult. In many species, at least a few adults live for more than a year, so there is some overlapping of generations. In the case of *Bolboceras*, eggs, larvae, pupae, and adults have all been taken together in a series of branching burrows. As is true for the entire subfamily, after the initial provisioning, the adults do not tend the young. All the species in this subfamily, adults and at least some larvae (*Geotrupes*), are able to produce sound, but what role this serves, if any, remains unknown (Howden, 1955, 1964).

Geotrupidae contains 11 genera and 62 species and subspecies known for the U. S. (Howden, 1984). Staines (1984[1986]) reported 19 species from Maryland.

The Scarabaeidae are a biologically diverse family. Species feed on plants, carrion, dung, fungi, pollen, or are decaying wood feeders, are termite, ant, or vertebrate nest associates. In the Neotropics the dung and carrion species of the subfamily Scarabaeinae have been shown to be excellent indicator species assemblages of overall biodiversity (Favila & Halffter, 1997; Spector, 2006). The group has not been evaluated as an indicator species assemblage in temperate areas. A number of introduced *Onthophagus* are widespread in the United States and have become the dominant species where found (Hoebeke & Buecke, 1997). This would indicate a potential negative impact on the native species competing for dung, however, there has been no study documenting this.

Species can be collected in baited pitfall traps, in Malaise traps, in flight-intercept traps, at black light, by head lamping, under bark, in dung, in fungi, and by sweeping and beating foliage.

The 1700 North American species of Scarabaeidae are fairly well studied (Ratcliffe et al., 2002); a few genera need revision. Staines (1984[1986]), Glaser (1987), and Simons & Price (2019) record 215 species from Maryland.

The Trogidae, sometimes called hide beetles, have a distinctive warty or bumpy appearance. They are scavengers and are among the last species to visit and feed on carrion and are most often found on the dry remains of dead animals. Both adults and larvae eat feathers, fur, and skin. Some species are found in bird and mammal nests. Details of the life histories of many species are poorly known, since many are specialized to particular types of nests. They are often overlooked by predators and collectors due to their behaviors of covering their bodies with soil and becoming motionless when disturbed (Vaurie, 1955).

The family Trogidae, found worldwide, includes about 300 species contained in five genera; 37 species are found in the U.S. (Vaurie, 1955). Staines (1984[1986]) reported 19 species from Maryland.

MATERIALS AND METHODS

The Smithsonian Environmental Research Center (SERC) [38°33’17.57”N; 76°33’14.29”W] consists of approximately 1,477 ha of hardwood-dominated forest, ponds, creeks, rivers, tidal marshes, and 19.3 km of protected shoreline along the Rhode River and upper Chesapeake Bay in Anne Arundel County, Maryland (SERC, 2018). Forests on the main campus of SERC can be broadly classified into three main types: (1) the majority (~85%) is a Tulip-poplar *(Liriodendron tulipifera* L., Magnoliaceae) association; (2) a moist lowland assemblage, comprised of American sycamore (*Platanus occidentalis* L., Platanaceae), ash (*Fraxinus* spp., Oleaceae), elms (*Ulmus* spp., Ulmaceae), river birch (*Betula nigra* L., Betulaceae), and other woody vegetation along freshwater streams; and (3) a somewhat xeric assemblage that fringes tidal marshes, consisting of chestnut oak (*Quercus prinus* L.), white oak (*Quercus alba* L., Fagaceae), black gum (*Nyssa sylvatica* Marshall, Nyssaceae), mountain laurel (*Kalmia latifolia* L., Ericaceae), blueberries (*Vaccinium* spp., Ericaceae) and other woody vegetation.

Like much of the eastern U.S., SERC’s forest age and structure reflect historical agricultural activities and local history. SERC’s main campus was mostly fallow from the end of the Civil War to approximately 1915, when it was used as a dairy farm with grazing pastures and fields for feed production until 1945. Thus, the majority of SERC’s contemporary forests are from 70-150 years old (McMahon et al., 2010; Higman et al., 2016).

Freshwater inputs into the Rhode River are primarily from the North Fork Muddy Creek, South Fork Muddy Creek, and their lower order streams. These streams are associated with several swamps, beaver impoundments, and seasonal wetlands which range from small, tannin-rich, ephemeral wetlands, to larger and clear-water permanent ponds.

On the opposite side of the Rhode River the BiodiversiTREE plots are about 30 acres containing 24,000 trees of 16 species of ecologically important deciduous trees planted in 75 plots. These plots were established over 30 years ago (SERC, 2018). In the annotated species list this area is referred to as Zones 5 and 6.

The goal of this project was to inventory the Coleoptera of the SERC. Collecting techniques include visual survey followed by sweeping or beating the vegetation of the area. Other collecting techniques used were pitfall traps (both baited and unbaited), head lamping, black lighting, and checking lights around buildings on the main campus.

Field work was conducted from 11 May to 24 October 2018, 30 March to 23 October 2019, and 19-20 March 2020. Voucher specimens are deposited in the SERC and the Department of Entomology Collection, Natural History Museum, Smithsonian Institution.

RESULTS

Family Passalidae

Odontotaenius disjunctus (Illiger) was found in decaying logs (Staines, 1984[1986]). Specimens were taken under bark on 30 May 2018 along Java History Trail, on 4 June 2018 along the Discovery Trail, on 10 April 2019 on Hog Island and Fox Point, and at black light on 23 June 2018 at the Reed Education Center.

Family Geotrupidae

Eucanthus lazarus (Fabricius) has been collected in pastures, at lights (Staines, 1984[1986]) and in flight intercept traps (Kriska & Young, 2002). Specimens were taken head lamping on 17 May 2019 along Connector Trail between Fox Point Road and Java History Trail.

Geotrupes blackburnii (Fabricius) adults dig burrows which they pack with dung or leaf litter for the larvae (Howden, 1955); collected from dung, carrion, decaying fungi, chicken feathers, salt trap, and at light (Staines 1984[1986]). Specimens were collected off raccoon roadkill on 30 April 2019 along Contees Wharf Road.

Geotrupes horni Blanchard has been collected in fungi, and adult burrows were found under fungi and cow dung (Howden, 1955); in dung, at light (Staines, 1984[1986]); hand collected in flight and in flight intercept traps (Kriska & Young, 2002). Specimens were collected in a horse dung baited pitfall trap on 16-17 April 2019 near the water tower.

Family Scarabaeidae

Aidophus parcus (Horn) is a detritivore (Gordon, 1983). Specimens were collected in deer dung on 24 April 2019 in the field at the intersection of Contees Wharf and Dock Roads.

Anomala marginata (Fabricius) is found in pastures (Staines, 1984[1986]). Specimens were taken at black light on 27 June 2019 at Back Road opposite the NEON tower.

Anomala orientalis (Waterhouse) is an introduced species whose larvae feed on the roots of grasses and other plants (Staines, 1986). Specimens were taken at black light on 23 June 2018 at Reed Education Center.

Ataenius abditus (Haldeman) has been taken at light (Staines, 1984[1986]). Specimens were taken at black light on 26 June 2019 in the field opposite Sellman House.

Ataenius figurator Harold has been found at light, in sheep manure, and carrion (Harpootlian, 2001). Specimens were taken at black light on 20 May 2019 at Frog Haven.

Ataenius spretulus (Haldeman) has been taken in dung, fungi, on dead cicada, and at light (Staines, 1984[1986]); hand collected in flight from cultivated grasses (sports fields, golf courses, lawns) (Kriska & Young, 2002). Specimens were taken at black light on 26 July 2019 at Java Trail and boardwalk and 20 March 2020 near Mathias Lab.

Ataenius strigatus (Say) has been taken in dung and carrion (Staines, 1984[1986]); at light, in pitfall traps baited with human dung or pig dung, sifted from leaf litter, and hand collected in flight, at dusk over old fields (Kriska & Young, 2002). Specimens were taken at black light on 23 June 2018 at the Reed Education Center.

Ateuchus histeroides Weber has been collected in dung, fungi, dead fish, and at light; it is most common in wooded areas (Staines, 1984[1986]). Specimens were taken at black light on 25 May 2019 at the intersection of Back Road and 11-6.

Blackburneus stercocorsus (Melsheimer) has been collected in dung and at lights (Staines 1984[1986]); in pitfall traps baited with human or pig dung, and in leaf litter near a fallen tree in mesic hardwood forest (Kriska & Young, 2002). Specimens were taken at black light on 26 June 2019 in the field opposite Sellman House.

Calamosternus granarius (Linnaeus) has been collected in dung, fungi, grass, and at lights (Staines 1984[1986]); in pitfall traps baited with human or pig dung, in flight intercept traps, on a dead raccoon and a dead deer, and among beach debris on the shore of Lake Michigan (Kriska & Young, 2002). Specimens were taken at black light on 27 June 2019 at Back Road opposite the NEON tower.

Cyclocephala borealis Arrow has been collected on turf, pigweed, and at light (Staines, 1984[1986]). Specimens were taken at black light on 23 June 2018 at the Reed Education Center and on 26 June 2019 in the field opposite Sellman House.

Dynastes tityus Linnaeus feeds in decaying logs and is taken at light (Glaser, 1976). A single male was taken at black light on 12 August 2019 along Back Road.

Dyscinetus morator (Fabricius) has been taken at lights and remains in the area hiding under debris during the day (Woodruff, 1970), feeds on rice (*Oryza sativa* L., Poaceae) (Anonymous, 1953), pangola grass (*Digitaria decumbens* Stent., Poaceae) pastures (Anonymous 1956), caladium bulbs (*Caladium x hortulanum*, Araceae), cranberry (*Vaccinium macrocarpon* Ait., Ericaceae) (Woodruff, 1970), corn (*Zea mays* L., Poaceae) (Anonymous, 1980), carrot (*Daucus carota* L., Apiaceae), radish (*Raphanus sativus* L., Brassicaceae), lettuce (*Lactuca sativa* L., Asteraceae) (Foster et al., 1986), waterhyacinth (*Eichhornia crassipes* (Mart.) Solm, Pontederiaceae) and is associated with wet soils and marsh areas (Buckingham & Bennett, 1989). Specimens were taken at black light on 20 May at Frog Haven, on 25 May 2019 at the intersection of Back Road and 11-6, on 12 August 2019 along Back Road, and on 20 March 2020 near Mathias Lab.

Euphoria herbacea (Olivier) has been collected on flowers of several plants and on ripening fruit (Staines, 1984[1986]). Specimens were taken sweeping vegetation in the forest plots of Zone 5.

Eupleurus subterraneus (Linnaeus), an introduced species, is a generalist (Gordon, 1983). Specimens were taken at black light on 27 May 2019 on Connector Trail between Fox Point Road and Java History Trail.

Germarostes aphodioides (Illiger) has been collected under bark and at light (Staines, 1984[1986]). Specimens were taken at black light on 20 May 2019 at Frog Haven and on 25 May 2019 at the intersection of Back Road and 11-6.

Labarrus pseudolividus (Balthasar) has been collected at light, in sand, in sheep dung, and in carrion (Harpootlian, 2001). Specimens were taken at black light on 27 May 2019 along Connector Trail between Fox Point Road and Java History Trail.

Maladera castanea (Arrow), an introduced species, has been collected on the foliage of many plants and at lights (Staines, 1984[1986]). Specimens were taken at black light on 23 June 2018 at Reed Education Center, on 20 May 2019 at Frog Haven, on 25 May 2019 at the intersection of Back Road and 11-6, on 26 June 2019 in the field opposite Sellman House, and by head lamping on 26 June 2019 along Contees Wharf Road.

Onthophagus hecate (Panzer) has been collected in dung, fungi, carrion, rotten vegetables, malt traps, and at light (Staines, 1984[1986]); in pitfall traps baited with carrion or human or pig dung, and in flight intercept traps (Kriska & Young, 2002). Specimens were collected in horse dung baited pitfall traps on 16-17 April 2019 near the water tower and 11 May 2019 in the meadow in front of Mathais Lab, by sweeping vegetation on 23 April 2019 in Zone 5, on 9 May 2019 on a dead mole at Sellman House, and by sweeping vegetation on 1 May 2019 near Reed Education Center.

Onthophagus taurus (Schreber), an introduced species, has been collected in cow and horse dung (Harpootlian, 2001). Specimens were taken in deer dung on 7 May 2019 along Java Trail.

Oscarinus rusicola (Melsheimer) has been collected in dung and at light (Staines, 1984[1986]); in pitfall traps baited with human or pig dung, and in flight intercept traps (Kriska & Young, 2002). Specimens were taken in a horse dung baited pitfall trap on 11 May 2019 in the meadow in front of Mathias Lab and at light on 19 June 2019 around Mathias Lab.

Oscarinus silvanicus (Cartwright) has been collected in deer dung (Staines, 1984[1986]). Specimens were collected in deer dung on 24 April 2019 in the field at the intersection of Contees Wharf and Dock Roads.

Pelidnota punctata (Linnaeus) has been collected on grape vine (*Vitis*, Vitaceae) and at light (Staines, 1984[1986]); three adults were reared from pupae found in an unidentified, very decayed tree stump (Kriska & Young, 2002). Specimens were taken at black light on 27 June 2019 at Back Road opposite the NEON tower.

Phanaeus vindex MacLeay has been collected in cow dung (Staines, 1984[1986]); in pitfall traps baited with human or pig dung (Kriska & Young, 2002); in horse dung (Rentz & Price, 2016; in carrion and rotting fruit (Price et al., 2012). A single male was taken in deer dung on 16 May 2019 along Contees Wharf Road.

Phyllophaga anxia (LeConte) has been collected from the leaves of beech (*Fagus*), birch (*Betula*), dogwood (*Cornus*, Cornaceae), elm (*Ulmus*), walnut (*Juglans*, Juglandaceae), and willow (*Salix*, Salicaceae) (Luginbill & Painter, 1953); larvae were the only species found in Wisconsin cranberry beds (Katovich et al., 1998); at UV light and in turf grasses and irrigated silvicultural sites (balsam fir and white pine plantations) (Kriska & Young, 2002). Specimens were taken at black light 25

May 2019 at the intersection of Back Road and 11-6 and on 27 May 2019 on Connector Trail between Fox Point Road and Java History Trail.

Phyllophaga fraterna Harris has been collected from the leaves of beech (*Fagus*), dogwood (*Cornus*), elm (*Ulmus*), sycamore (*Platanus*), walnut (*Juglans*), and willow (*Salix*) (Luginbill & Painter, 1953). Specimens were collected by sweeping vegetation on 7 May 2019 along Java Trail and at black light on 20 May 2019 at Frog Haven.

Phyllophaga futilis (LeConte) has been collected from the leaves of beech (*Fagus*), birch (*Betula*), elm (*Ulmus*), maple (*Acer*, Aceraceae), mulberry (*Morus*, Moraceae), walnut (*Juglans*), and willow (*Salix*) (Luginbill & Painter, 1953); at light; adults are common in gardens and at porch lights (Kriska & Young, 2002). Specimens were taken at black light on 12 August 2019 along Back Road.

Phyllophaga gracilis (Burmeister) has been collected from the leaves of beech (*Fagus*), elm (*Ulmus*), sycamore (*Platanus*), walnut (*Juglans*), and willow (*Salix*) (Luginbill & Painter, 1953); at UV light and in flight intercept traps, in oak barrens and savanna habitat (Kriska & Young, 2002). Specimens were taken at black light on 12 August 2019 along Back Road.

Phyllophaga hirsuta (Knoch) has been collected from the leaves of beech (*Fagus*), dogwood (*Cornus*), maple (*Acer*), rose (*Rosa,* Rosaceae), and walnut (*Juglans*) (Luginbill & Painter, 1953). Specimens were taken at black light on 23 June 2018 at Reed Education Center.

Phyllophaga hirticula (Knoch) has been collected from the leaves of beech (*Fagus*), birch (*Betula*), elm (*Ulmus*), honeysuckle (*Lonicera*, Caprifoliaceae), magnolia (*Magnolia*, Magnoliaceae), rose (*Rosa*), and willow (*Salix*) (Luginbill & Painter, 1953); at light (Kriska & Young, 2002). Specimens were taken at black light on 23 June 2018 at Reed Education Center.

Phyllophaga implicata (Horn) has been collected from the leaves of beech (*Fagus*), dogwood (*Cornus*), elm (*Ulmus*), sycamore (*Platanus*), walnut (*Juglans*), and willow (*Salix*) (Luginbill & Painter, 1953); at light (Kriska & Young, 2002). Specimens were taken by sweeping vegetation on 30 April 2019 in Zone 6.

Phyllophaga latifrons (LeConte) has been collected from the leaves of beech (*Fagus*) and walnut (*Juglans*) and in Japanese beetle traps (Luginbill & Painter, 1953). Specimens were taken at black light on 23 June 2018 at Reed Education Center.

Phyllophaga micans (Knoch) has been collected from the leaves of beech (*Fagus*), birch (*Betula*), dogwood (*Cornus*), elm (*Ulmus*), maple (*Acer*), walnut (*Juglans*), and willow (*Salix*) (Luginbill & Painter, 1953). Specimens were taken at light on 11 May 2018 at Mathais Lab, and at black light on 20 May 2019 at Frog Haven, on 25 May at the intersection of Back Road and 11-6, on 27 May 2019 on Connector Trail between Fox Point Road and Java History Trail, and on 17 June 2019 along Java History Trail.

Phyllophaga quercus (Knoch) has been collected from the leaves of beech (*Fagus*), elm (*Ulmus*), magnolia (*Magnolia*), walnut (*Juglans*), and willow (*Salix*) (Luginbill & Painter, 1953). Specimens were taken at light on 26 September 2019 around Mathais Lab.

Popillia japonica Newman, an introduced species, feeds on the roots of plants as larvae and on foliage of numerous plants as adults (Staines, 1984[1986]). Specimens were taken by sweeping vegetation and by visual survey on 26 June 2018 in forest plots of Zone 6 and on 19 July 2018 along Contees Wharf Road.

Serica carolina Dawson has been collected in decaying logs, leaf mold, and at light (Staines, 1984[1986]). Specimens were taken beating vegetation on 7 June 2019 along Java History Trail.

Serica intermixta Blatchley has been taken at UV light, in flight intercept and unbaited Lindgren funnel traps, and under leaf litter in a sandy blow (Kriska & Young, 2002). Specimens were taken at black light on 27 May 2019 on Connector Trail between Fox Point Road and Java History Trail.

Serica opposita Dawson has an unknown biology. Specimens were taken at black light on 20 May 2019 at Frog Haven and on 25 May at the intersection of Back Road and 11-6.

Serica sp. A single female specimen was taken at black light on 27 May 2019 on Connector Trail between Fox Point Road and Java History Trail. Females of the genus *Serica* are not identifiable without associated males.

Stenotothorax badipes (Melsheimer) has been collected on a red squirrel carcass and at light (Staines 1984[1986]); in a gray squirrel nest in a hollowed, fallen tree and in tree hole leaf litter in oak barrens and savanna (Kriska & Young, 2002). Specimens were taken at black light on 23 June 2018 at Reed Education Center.

Tomarus gibbosus (DeGeer) has been collected on plant roots and at light (Staines, 1984[1986]). Specimens were taken beating vegetation on 1 June 2019 near Reed Education Center.

Tomarus relitcus (Say) has been collected under rubbish and at lights (Staines, 1984[1986]). Specimens were taken at black light on 23 July 2019 along Contees Watershed Trail and on 26 July 2019 at Java History Trail and boardwalk.

Valgus canaliculatus (Olivier) feed on the nectar of flowers (Ritcher, 1958); have been collected from beech (*Fagus* sp.), buckthorn (*Ceanothus* sp., Rhamnaceae), dogwood (*Cornus* sp.), hawthorn (*Crataegus* sp., Rosaceae) (Blatchley, 1910), and mock orange trees (*Philadelphus* sp., Hydrangeaceae) (Ritcher, 1966). Adults have been observed on honeysuckle (*Lonicera* sp.), meadowsweet (*Spiraea* spp., Rosaceae), goat's beard (*Aruncus* sp., Rosaceae), blackberry (*Rubus* sp., Rosaceae), oswego tea (*Monarda didyma* L., Lamiaceae), oxeye daisy (*Chrysanthemum leucanthemum* L., Asteraceae), Queen Anne's lace (*Daucus carota* L., Apiaceae), wild hydrangea (*Hydrangea arborescens* L., Hydrangeaceae), yarrow (*Achillea millefolium* L., Asteraceae), hickory (*Carya* sp., Juglandaceae), oak and white oak (*Quercus* sp. and *Quercus alba* L.), southern magnolia (*Magnolia grandiflora* L.), and pine and loblolly pine (*Pinus* sp. and *Pinus taeda* L., Pinaceae) (Jameson & Swoboda, 2005). Specimens were taken from flowers on 5 June 2018 at the intersection of Contees Wharf and Dock Roads.

Xyloryctes jamaicensis (Drury) has been collected in leaf mold and at light (Staines, 1984[1986]); Stephan (1967) observed that adults feed and oviposit on or near the roots of white ash trees, *Fraxinus americana* L., usually in more sandy soil. A single specimen was taken at light on 26 September 2019 along Dock Road.

Family Trogidae

Trox aequalis Say has been found in bird and mammal nests (Vaurie, 1955). A single specimen was taken at black light on 20 March 2020 near Mathias Lab.

Trox hamatus Robinson has been collected in carrion, in mammal nests, feathers, and at light (Vaurie, 1955); in flight intercept traps and pitfall traps baited with carrion or pig dung/malt/molasses (Kriska & Young, 2002). A single specimen was taken at black light on 27 May 2019 on Connector Trail between Fox Point Road and Java History Trail.

DISCUSSION

Most inventory work on Maryland Scarabaeiodea has focused on the dung beetles (Price et al., 2012; Nemes & Price, 2015; Rentz & Price, 2016; Simons et al., 2018; Simons & Price, 2019). Our results of 14 dung associated species is comparable to the 19 species found in two sites in Wicomico and Worchester Counties (Price et al., 2012), 15 species on Assateague Island, Worchester County (Rentz & Price, 2016), and 22 species at seven sites on Maryland's eastern shore (Simons et al., 2018).

The only published inventory of Maryland Scarabaeiodea is Fritzler & Strazanac (2012) from Catoctin Mountain Park, Frederick County. They found five species of Geotrupidae, 17 of Scarabaeidae, and one Trogidae using pitfall traps.

One surprising result was the lack of any Lucanidae. Larvae of this small family are found in damp, decaying wood and the adults are attracted to lights (Milne, 1933; Hoffman, 1937; Mathieu, 1969). We did much work on decaying wood and black lighting in various parts of SERC but obtained none of the eight species known from Maryland (Staines, 1984[1986]).

Our results of 47 species show a healthy Scarabaeiodea fauna at SERC. The three Geotrupidae and two Trogidae are comparable to Fritzlar & Strazanac (2012). The increased number of Scarabaeidae reflect the varied collecting methods employed in the SERC survey.

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RESEARCH ARTICLE

AN ANNOTATED CHECKLIST OF THE COLEOPTERA OF THE SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER: THE STAPHYLINOIDEA

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ABSTRACT

The Staphylinoidea of the Smithsonian Environmental Research Center was inventoried over a two-year period. A total of 35 species were collected- four Silphidae and 31 Staphylinidae. Thirteen Staphylinidae are recorded from Maryland for the first time.

Keywords: Biodiversity, insects, Maryland, new state records.

INTRODUCTION

Staphylinoidea is a very large and diverse group of beetles with a worldwide distribution. It consists of the following families: Agyrtidae C.G. Thomson (primitive carrion beetles), Hydraenidae Mulsant (minute moss beetles), Leiodidae Fleming (round fungus beetles), Ptiliidae Erichson (featherwing beetles), Silphidae Latreille (carrion beetles), and Staphylinidae Latreille (rove beetles) (Bouchard et al., 2011).

The family Silphidae are large beetles, l0-35 mm long, and are frequently associated with decaying organic material. They are most commonly observed on vertebrate carcasses which gives the group the common name of carrion beetles. Adults of the genus *Nicrophorus* bury small vertebrate carcasses that has given them the common name of sexton beetles or burying beetles. There are 30 species in eight genera in North America, north of Mexico (Anderson & Peck, 1985; Peck, 2000).

Maryland Silphidae are fairly well documented. Shubeck & Blank (1982), Staines (1987, 1989, 2008), Dyer & Price (2013), and Fritzler & Strazanac (2012) document 18 species in four genera from Maryland.

The family Staphylinidae (rove beetles) is one of the largest families of beetles with approximately 64,000 species worldwide (Irmler et al., 2018; Newton, 2019). In North America, there are 568 genera with over 4500 species (Newton et al., 2000, Newton, 2019). Staphylinids are generally recognized by their short, truncate elytra that leaves most of the abdomen exposed. Rove beetles occur in almost every type of habitat and eat almost everything except living tissues of higher plants. Most are predators of other insects and invertebrates, but many feed on fungi or decaying organic matter (Thayer, 2016). Adults of most species are nocturnal but a few genera are diurnal.

The Maryland fauna is poorly studied. Most Maryland specimens are in the unidentified section of various museums and collections. There are 343 species documented from Maryland (Brattain et al., 2019).

MATERIALS AND METHODS

The Smithsonian Environmental Research Center (SERC) [38°33'17.57"N; 76°33'14.29"W] consists of approximately 1,477 ha of hardwood-dominated forest, ponds, creeks, rivers, tidal marshes, and 19.3 km of protected shoreline along the Rhode River and upper Chesapeake Bay in Anne Arundel County, Maryland (SERC, 2018). Forests on the main campus of SERC can be broadly classified into three main types: (1) the majority (~85%) is a Tulip-poplar *(Liriodendron tulipifera* L., Magnoliaceae) association; (2) a moist lowland assemblage, comprised of American sycamore (*Platanus occidentalis* L., Platanaceae), ash (*Fraxinus* spp., Oleaceae), elms (*Ulmus* spp., Ulmaceae), river birch (*Betula nigra* L., Betulaceae), and other woody vegetation along freshwater streams; and (3) a somewhat xeric assemblage that fringes tidal marshes, consisting of chestnut oak (*Quercus prinus* L.), white oak (*Quercus alba* L., Fagaceae), black gum (*Nyssa sylvatica* Marshall, Nyssaceae), mountain laurel (*Kalmia latifolia* L., Ericaceae), blueberries (*Vaccinium* spp., Ericaceae) and other woody vegetation.

Like much of the eastern U.S., SERC's forest age and structure reflect historical agricultural activities and local history. SERC's main campus was mostly fallow from the end of the Civil War to approximately 1915, when it was used as a dairy farm with grazing pastures and fields for feed production until 1945. Thus, the majority of SERC's contemporary forests are from 70-150 years old (McMahon et al., 2010; Higman et al., 2016).

Freshwater inputs into the Rhode River are primarily from the North Fork Muddy Creek, South Fork Muddy Creek, and their lower order streams. These streams are associated with several swamps, beaver impoundments, and seasonal wetlands that range from small, tannin-rich, ephemeral wetlands, to larger and clear-water permanent ponds.

On the opposite side of the Rhode River the BiodiversiTREE plots are comprised of about 30 acres containing 24,000 trees of 16 species of ecologically important deciduous trees planted in 75 plots. These plots were established over 30 years ago (SERC, 2018). In the annotated species list this area is referred to as Zones 5 and 6.

The goal of this project is to inventory the Coleoptera of the SERC. The primary collecting techniques were visual surveys followed by sweeping or beating the vegetation of the area. Other collecting techniques used were pitfall traps (both baited and unbaited), carrion traps, head lamping, black lighting, and checking lights around building on the main campus.

Field work was conducted from 11 May to 24 October 2018, 30 March to 23 October 2019, and 19-20 March 2020. Voucher specimens are deposited in the SERC and the Department of Entomology Collection, Natural History Museum, Smithsonian Institution.

RESULTS

A total of 35 species were collected, including four Silphidae and 31 Staphylinidae. In the following list of species, each entry contains a general habitat description and details of specific collections on SERC.

Family Silphidae

Nicrophorus orbicollis Say is nocturnal and more commonly found on cold-blooded carrion (Shubeck, 1976). Anderson (1982) found this species more commonly in forested areas and is attracted to light. Specimens were taken on 8 May 2019 at Sellman House on a dead mole (*Scalopus aquaticus* (L.) [Mammalia: Talpidae]) and on 25 July 2019 along Contees Watershed Trail at black light.

Necrophila americana (Linnaeus) may be found on carrion or fungi. Cole (1942) found that this species was equally active on carrion in wooded areas and exposed locations. Shubeck (1971) found this species was active during the day. Specimens were taken on 6 June 2018 at Frog Haven sweeping vegetation, on 30 April 2019 along Contees Wharf Road on roadkill racoon (*Procyon lotor* (L.) [Mammalia: Procyonidae]), on 7 September 2019 at Mathias Lab on dead bluefish (*Pomatomus saltatrix* (L.) [Perciformes: Pomatomidae]), and on 26 September 2019 at Mathias Lab at light.

Oiceoptoma inaequale (Fabricius) may be found year-round in carrion. Cole (1942) found this species to be more numerous on carrion in exposed locations. Shubeck (1971) found this to be a diurnal species. Specimens were taken on 30 April 2019 along Contees Wharf Road on roadkill raccoon.

Oiceoptoma noveboracenais (Forster) is usually found on carrion but occasionally can be taken on fungi. Cole (1942) found this species more numerous in wooded areas. Anderson (1982) found that it was the first species active in the spring and was found in all habitats sampled. Shubeck et al. (1981) found this species to be bivoltine in New Jersey and to be a diurnal species. Specimens were collected on a dead goat (*Capra aegagrus hircus* (L.) [Mammalis: Bovidae]) at Mathias Lab on 19 March 2020.

Family Staphylinidae
Subfamily Aleocharinae

Aleochara (Aleochara) lata Gravenhorst is introduced from Europe and is widely distributed in the eastern and southern United States. Adults have been collected from human feces, armadillo dung, and carcasses of animals (deer [*Odocoilus virginianus* (Zimmermann), Mammalia: Cervidae] skunk [*Mephitis mephitis* (Schreber), Mammalia: Mephitidae], opossum [*Didelphis virginiana* (Kerr), Mammalia: Didelphidae], snake, and fish). Some were collected using malaise traps and carrion-baited pitfall traps. They are predators on various flies (Diptera). (Klimaszewski 1984). Specimens were taken at Sellman House on 11 May 2019 sweeping vegetation, and on 15 June 2019 at Sellman House on dead common carp (*Cyprinus carpio* (L.) [Cypriniformes: Cyprinidae]).

Falagria dissecta Erichson has been collected by sifting (Blatchley, 1910), in cow dung (Valiela, 1969), from cow and sheep dung (Kessler et al., 1974), from decaying vegetation, animal carcasses, in rodent nests, in pitfall traps, and at black lights (Hoebeke 1985). Cervenka & Moon (1991) found this predaceous species in cow dung. Specimens were collected under bark on 12 April 2019 along Back Road and on 9 May 2019 along Java History Trail.

Subfamily Omaliinae

Olophrum obtectum Erichson has been collected from moss along a stream margin, sweeping vegetation along a stream margin, from a Berlese sample of a decayed stump, at light, and from emergent *Carex* (Cyperaceae) in an alder (*Alnus*, Betulaceae) swamp (Campbell, 1983). Single specimens were collected on 3 April 2019 in a stump hole along Discovery Trail and on 16-17 April 2019 in an unbaited pitfall trap near the water tower.

Omalium rivulare (Paykull) can be collected by sifting litter in forests and along wet areas, in fungi, on flowers, by sweeping, in pan traps placed in grassy areas, and under stones near water (Brunke et al., 2011). A single specimen was taken on 19 March 2020 at the intersection of Contees Wharf and Dock Roads. **NEW STATE RECORD**.

Subfamily Oxytelinae

Carpelimus difficilis (Casey) has an unknown biology. Other members of this genus are found in periaquatic situations and in leaf litter (Newton et al., 2000) Adults were taken in horse dung baited pitfall traps on 17-18 April 2019 near the water tower.

Platystethus americanus Erichson is common in cattle dung (Sanders & Dobson, 1966; Valiela 1969). Smith et al. (1987) found this species to be a predator of the stable fly, *Stomoxys calcitrans* (L.) (Diptera: Muscidae). It prefers open areas and is most active in the afternoon (Hunter et al., 1991). It appears to be a spring species in Florida and requires both dung and fly larvae for females to produce eggs (Hu & Frank, 1995). Specimens were collected sweeping vegetation on 17 May 2019 along Back Road. **NEW STATE RECORD**.

Subfamily Paederinae

Achenomorphus corticinus (Gravenhorst) has been collected under carrion and in pitfall traps in pine forests (Blatchley, 1910; Klipzigetal et al., 2012). Specimens were collected sweeping vegetation on 11 May 2019 near Sellman House, and on 17 May 2019 along Back Road. **NEW STATE RECORDS**.

Homoeotarsus bicolor Gravenhorst is generally riparian and occurs along river margins (Brunke, et al. 2011). They are found under stones, debris, and in fungi (Webster & DeMerchant, 2012).

Specimens were collected by visual observation near Reed Education Center on 23 June 2018 and at black light on 25 May 2019 along Back Road. **NEW STATE RECORD**.

Homoeotarsus cribatus LeConte most adults are collected along river margins. Adults were collected from flood debris and drift material, and from under a cobblestone (Webster & DeMerchant, 2012). Specimens were collected at black light on 20 May 2019 at Frog Haven, on 25 May 2019 along Back Road, and on 27 June 2019 at Back Road near the NEON tower. **NEW STATE RECORD**.

Homoeotarsus pallipes (Gravenhorst) is found under stones and debris near water (Webster & DeMerchant, 2012). Specimens were collected at black light on 20 May 2019 at Frog Haven, on 26 June 2019 in the field opposite Sellman House, and on 27 June 2019 at Back Road near the NEON tower.

Lathropinus picipes (Erichson) has an unknown biology. Specimens were collected under bark on 9 April 2019 along Java History Trail and on 10 April 2019 on Hog Island. **NEW STATE RECORD**.

Paederus littorarius Gravenhorst is found under stones in damp areas (Blatchley, 1910) and grasslands (Bulan & Barrett, 1971). Specimens were collected at black light on 26 June 2019 in the field opposite Sellman House.

Pinophilus latipes Gravenhorst is found beneath logs and stones in upland forests (Blatchley, 1910). Specimens were collected sweeping vegetation on 7 May 2019 in the maintenance area near the Mathias Lab.

Subfamily Pselaphinae

Ceophyllus monilis LeConte is found beneath the bark of rotten stumps (Blatchley, 1910); they have been associated with *Lasius umbratus* (Nylander), *L americanus* Emery, L. *nearcticus* Wheeler, and possibly *L. claviger* (Rodger) (Hymenoptera: Formicidae) (Hamilton 1886; Schwarz, 1890; Wickham, 1894; Park, 1932, 1935). Specimens were taken at black light on 12 August 2019 along Back Road.

Subfamily Scaphidinae

Bacocera falsata Achard is found in fungi (Blatchley 1910). Adults were collected under bark on 17 May 2019 along Back Road. **NEW STATE RECORD**.

Scaphidium piceum Melsheimer is found beneath bark of old, fungus-covered beech (*Fagus*, Fagaceae) logs (Blatchley, 1910). Specimens were collected head lamping on 27 June 2019 and on 12 August 2019 along Back Road.

Scaphisoma suturale LeConte is found under decaying leaves (Blatchley, 1910). Specimens were collected in unbaited pitfall traps on 10-11 May 2019 in the meadow near Mathias Lab. **NEW STATE RECORD**.

Subfamily Staphylininae

Ontholestes cingulatus Gravenhorst is found in dung and decaying fruits (Voris, 1939); cow dung (Sanders & Dobson, 1966); and in fungi and carrion where it feeds on fly larvae (Alcock, 1991). Specimens were collected on 16-17 April 2019 in a horse dung baited pitfall trap near the water tower.

Phinonthus lomatus Erichson is found in dung, fungi, and carrion in low moist areas (Blatchley, 1910; Shea, 2005). Specimens were collected near a carrion trap on 11 May 2019 near Sellman House.

Platydreus violaceous (Gravenhorst) is a common species found in mesic to swampy forests, primarily under the loose bark of dead hardwood trees including oaks (*Quercus*), maples (*Acer*, Aceraceae), basswood (*Tilia*, Malvaceae), horse chestnut (*Aesculus*, Sapindaceae), hackberry (*Celtis*, Ulmaceae), beech (*Fagus*), and hickory (*Carya*, Juglandaceae). It occurs less frequently under the bark of white pine (*Pinus strobus* L., Pinaceae), in rotting wood, and under logs. The few records in rotting fungi, on carrion, or on dung probably do not reflect habitat preferences (Brunke et al., 2011). Two specimens were taken by visual survey on 19 March 2020 at the intersection of Contees Wharf and Dock Roads.

Platydreus zonatus (Gravenhorst) has an unknown biology. Other members of this genus are found in dung, carrion, fungi, ground litter, under bark, and in wet areas (Newton et al., 2000). Specimens were collected sweeping vegetation on 7 May 2019 in the maintenance area near Mathias Lab, and on 9 May 2019 around the Java Farm house ruins.

Quedius capucinus Gravenhorst is found underground in litter, moss, compost, and in carrion and dung (Blatchley, 1910; Mank, 1923). This species feeds on *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) (Schmitt 1999), and prefers wooded habitats and is a day flier (Hunter et al., 1991). Specimens were collected at black light on Contees Wharf Trail and on 12 August 2019 along Back Road.

Stenistoderus rubripennis (LeConte) has an unknown biology. Specimens were collected under bark on 12 April 2019 along Back Road.

Sunius confluentus Say is found in fungi, beneath bark, and in decaying vegetation (Blatchley, 1910). Adults run rapidly when disturbed. Specimens were collected under bark on 12 April 2019 along Back Road. **NEW STATE RECORD**.

Subfamily Steninae

Stenus flavicornis Erichson adults feed on insect eggs (Andow, 1990). Other members of this genus are found in sunny spots along muddy or sandy shores of lakes, ponds, and streams (White, 1983). Specimens were collected on 6 June 2018 in the pond at the parking lot at the main compound and on 23 April 2019 at Frog Haven.

Subfamily Tachyporinae

Bolitobius cingulatus Mannerheim is rare in Indiana (Blatchley, 1910) but common in lawns in Kentucky (Cockfield & Potter 1984). Adults were collected sweeping vegetation on 17 May 2019 along Back Road. **NEW STATE RECORD**.

Coproporus laevis LeConte has been collected in dead vegetation along streams, swamps or shallow lakes (Campbell, 1975); and in pitfall traps in pine (*Pinus*) forests (Klipzigetal et al., 2012). Specimens were collected under bark on 10 April 2019 on Hog Island, and on 12 April 2019 and 17 May 2019 along Back Road.

Dinaraea angustula (Gyllenhal) is an introduced species associated with soil and organic debris in agricultural fields and disturbed urban meadows. It is also found in marsh litter, in leaf litter in mixed forests, in compost, under bark of decaying spruce logs, amongst vegetation on a coastal sand dune, in litter in a cattail marsh, in leaf litter along a vernal pond, and in drift material along a lakeshore (Webster et al., 2009, Klimaszewski et al., 2010, 2011). Specimens were collected on 24 May 2018 along Contees Trail. **NEW STATE RECORD**.

Lordithon anticus (Horn) is uncommon in Indiana (Blatchley, 1910); it has been collected by Berlese funnel in deciduous forest leaf litter, in pitfall traps, and from a rotting pine log and nearby leaf litter (Campbell, 1982). Specimens were collected under bark of an unidentified hardwood on 17 May 2019 along Back Road.

Sepedophilus crassus (Gravenhorst) adults are frequently collected from rotten wood, from deep layers of decaying leaves, and from bracket fungi and mushrooms (Campbell, 1976). Specimens were collected off an unidentified shelf fungus on 9 May 2019 along Java History Trail.

Tachyporus jocosus LeConte has been collected in Berlese samples of deciduous leaf litter, from fleshy fungi in deciduous forests, at lights, swept from roadside vegetation, and from fields of alfalfa (*Medicago*, Fabaceae), crimson clover (*Trifolium incarnatum* L., Fabaceae), and Bermuda grass (*Cynodon dactylon* L. Poaceae) (Campbell 1979). It is common in lawns in Kentucky (Cockfield & Potter, 1984). Specimens were collected in an unidentified fungus on 23 October 2018 along Contees Trail. **NEW STATE RECORD**.

DISCUSSION

Four inventories of Maryland silphids have been published. Shubeck & Blank (1982) collected eight species at Cheltenham, Prince George's County. Staines (2008) found seven species collected at Plummers Island, Montgomery County from 1905-2004. Fritzler & Strazanac (2012) collected five species at Catoctin Mountain Park, Frederick County. Dyar & Price (2013) found eight species at Nassawango Creek Preserve, Wicomico County. The four species collected at SERC is slightly lower than the other inventories, but still indicates a healthy silphid fauna.

The 31 staphylinid species found at SERC represents 9.0% of the known Maryland fauna and suggests a diverse and healthy Staphylinoidea fauna at SERC. The detection of 13 Staphylinidae new to Maryland highlights the lack of study this group has received from local naturalists. Hopefully, the data reported here will provide a baseline for future monitoring to track changes in populations and species at SERC and encourage others to inventory other areas.

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RESEARCH ARTICLE

AN ANNOTATED CHECKLIST OF THE COLEOPTERA OF THE SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER: THE CHRYSOMELOIDEA

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ABSTRACT

A total of 59 species of Chrysomeloidea were detected in a two year inventory at the Smithsonian Environmental Research Center. A total of 10 Cerambycidae species, and 48 Chrysomelidae species were collected.

Keywords: Biodiversity, insects, Maryland.

INTRODUCTION

Chrysomeloidea Latreille contains more than 63,000 described extant species (Ślipiński et al., 2011). It contains the families Chrysomelidae Latreille, Cerambycidae Latreille, Megalopodidae Latreille, Vesperidae Mulsant, Oxypeltidae Lacordaire, Disteniidae J. Thomson and Orsodacnidae C.G. Thomson (Reid, 2014).

Chrysomelidae (leaf beetles) is one of the largest families of beetles with approximately 50,000 described species worldwide (Lopatin, 1977). This makes the family second only to the Curculionidae (weevils, Insecta: Coleoptera) and with over twice the species richness of birds and mammals combined (Klausnitzer, 1981). The Chrysomelidae are very diverse biologically and most species are diurnal. The biology of the species known to occur in the Mid-Atlantic States is summarized in Staines & Staines (2001).

There are 1,700 species of Chrysomelidae known from North America (Riley et al., 2003). 407 species are reported from Maryland (Staines & Staines, 2009). Adults may be collected by sweeping and beating foliage, from flowers, with Malaise traps, flight intercept traps, black lights, and by head lamping food plants.

The Cerambycidae (long horned wood boring beetles) is a large family with over 26,000 species worldwide and 900 species in North America (Turnbow & Thomas, 2002). Adults feed on bark, leaves, pollen, or not at all. Larvae bore into stems of herbaceous plants, roots, and wood. Some species are serious pests of shade and forest trees or processed lumber.

Adults can be collected using blacklight, Malaise, and flight-intercept traps, and by head lamping, sweeping and beating foliage, and examining flowers at which adults feed on pollen. There are 253 species reported from Maryland (Staines, 1987; Glaser, 1992), one of which, *Dryobius sexnotatus* Linsley, is listed as endangered by the state of Maryland (Anonymous, 2016).

MATERIALS AND METHODS

The Smithsonian Environmental Research Center (SERC) [38°33’17.57”N; 76°33’14.29”W] consists of approximately 1,477 ha of hardwood-dominated forest, ponds, creeks, rivers, tidal marshes, and 19.3 km of protected shoreline along the Rhode River and upper Chesapeake Bay in Anne Arundel County, Maryland (SERC, 2018). Forests on the main campus of SERC can be broadly classified into three main types: (1) the majority (~85%) is a tulip-poplar *(Liriodendron tulipifera* L., Magnoliaceae) association; (2) a moist lowland assemblage, comprised of American sycamore (*Platanus occidentalis* L., Platanaceae), ash (*Fraxinus* spp., Oleaceae), elms (*Ulmus* spp., Ulmaceae), river birch (*Betula nigra* L., Betulaceae), and other woody vegetation along freshwater streams; and (3) a somewhat xeric assemblage that fringes tidal marshes, consisting of chestnut oak (*Quercus prinus* L.), white oak (*Quercus alba* L., Fagaceae), black gum (*Nyssa sylvatica* Marshall, Nyssaceae), mountain laurel (*Kalmia latifolia* L., Ericaceae), blueberries (*Vaccinium* spp., Ericaceae) and other woody vegetation.

Like much of the eastern U.S., SERC’s forest age and structure reflect historical agricultural activities and local history. SERC’s main campus was mostly fallow from the end of the Civil War to approximately 1915, when it was used as a dairy farm with grazing pastures and fields for feed production until 1945. Thus, the majority of SERC’s contemporary forests are from 70-150 years old (McMahon et al., 2010; Higman et al., 2016).

Freshwater inputs into the Rhode River are primarily from the North Fork Muddy Creek, South Fork Muddy Creek, and their lower order streams. These streams are associated with several swamps, beaver impoundments, and seasonal wetlands which range from small, tannin-rich, ephemeral wetlands, to larger and clear-water permanent ponds.

On the opposite side of the Rhode River the BiodiversiTREE plots are about 30 acres containing 24,000 trees of 16 species of ecologically important deciduous trees planted in 75 plots. These plots were established over 30 years ago (SERC, 2018). In the annotated species list this area is referred to as Zones 5 and 6.

The goal of this project is to inventory the Coleoptera of the SERC. Collecting techniques was visual survey followed by sweeping or beating the vegetation of the area. Other collecting techniques used were pitfall traps (both baited and unbaited), head lamping, black lighting, and checking lights around building on the main campus.

Field work was conducted from 11 May to 24 October 2018, 30 March to 23 October 2019, and 19-20 March 2020. Voucher specimens are deposited in the SERC and the Department of Entomology Collection, Natural History Museum, Smithsonian Institution.

Numerous papers were used in the identifications of species. The basic references were Ciegler (2007) and Kingsolver (2004) for Chrysomelidae and Lingafelter (2007) for

Cerambycidae. Numerous generic revisions and papers on the biology of various species were also used and are cited for the individual species.

RESULTS

Family Cerambycidae

Eburia quadrigeminata (Say) larvae bore in the heartwood of *Quercus* (oak), *Fagus* (beech, Fagaceae), *Fraxinus* (Oleaceae), *Carya* (hickory, Juglandaceae), *Acer* (maple, Aceraceae), and *Ulmus* (elm). Adults are attracted to light (Staines, 1987). A single specimen was taken at black light along Back Road on 12 August 2019.

Heterachthes quadrimaculatus Haldeman larvae are found in *Carya* and *Liriodendron tulipifera* L., adults are attracted to light (Staines, 1987). A single specimen was taken at black light in the fields opposite Sellman House on 26 June 2019.

Microgoes oculatus (LeConte) has been collected from *Carya* (hickory), *Quercus* (oak), and *Fagus* beech (Staines, 1987). A single specimen was taken at black light on 12 August 2019 along Back Road.

Molorchus bimaculatus Say has been collected from flowers of *Cornus* (dogwood, Cornaceae) and *Viburnum* (Adoxaceae), larvae mine dead branches of hardwoods (Staines, 1987). Specimens were collected from *Cornus florida* flowers in Zone 6 on 23 April 2019.

Neanda brunnea (Fabricius) larvae feed on rotting logs of *Acer*, *Tilia* (basswood, Malvaceae), *Quercus*, *Populus* (Salicaceae), *Castanea* (chestnut, Fagaceae), *Liriodendron tulipifera*, *Ulmus*, and *Pyrus* (pear, Rosaceae). Adults are attracted to light (Linsley, 1962a). Specimens were collected head lamping on 26 July 2019 along Java History Trail and by head lamping and black light on 12 August 2019 along Back Road.

Neoclytus horridus (LeConte) breeds in *Quercus* branches (Glaser, 1992). A single specimen was collected at black light on 27 May 2019 along the Connector Trail between Fox Point Rd. & Java History Trail.

Oberea tripunctata Swederus breeds in *Alnus* (Betulaceae) and *Rhododendron* (Ericaceae) (Staines, 1987). A single specimen was collected sweeping vegetation on 9 July 2018 in the forest plots in Zone 6.

Oeme rigida (Say) breeds in *Juniperus virginiana* L. (eastern read cedar, Cupressaceae) and *Taxodium distichum* (L.) Rich. (bald cypress, Cupressaceae) (Linsley, 1962b). Specimens were collected at black light on 23 June 2018 at Reed Education Center.

Tetraopes tetrophthalmus (Forster) larvae and adults feed on *Asclepias* spp. (Apocynaceae) (Staines, 1987). Specimens were collected on 6 June 2018 off *Asclepias* sp. In the gardens near Mathias Lab and on 21 June 2019 in fields opposite Sellman House.

Tylonotus bimaculatus Haldeman has been taken at light; *Fraxinus*, *Betula* (birch), *Juglans nigra* L. (black walnut, Juglandaceae), *Carya*, *Liriodendron tulipifera*, *Ulmus*, and *Ligustrum* (privet, Oleaceae) (Staines, 1987). A single specimen was taken at black light on 27 June 2019 at Back Road opposite NEON tower.

Family Chrysomelidae

Acalymma vittatum (Fabricus) has listed hosts of *Ambrosia trifida* L. (giant ragweed, Asteraceae); *Arachis hypogaea* L. (peanut, Fabaceae); *Aster lateriflorus* (L.) Britt. (wild aster), *Aster sagittifolius* Wedemeyer (arrow-leaved aster), *Aster tardiflorus* L. (late flowering aster) (Asteraceae); *Beta vulgaris* L. (beet, Chenopodiaceae); *Brassica* (mustard, Brassicaceae); *Citrullus vulgaris* Schrad. (watermelon, Curcurbitaceae); *Citrus* (Rutacea);, *Cucurbita* (squash, Curcurbitaceae); *Geranium maculatum* L. (cranesbill, Geraniaceae); *Pyrus arbutifolia* (L.) L. (red chokeberry), *Pyrus communis* L. (pear), *Malus* (apple) (Rosaceae); *Sechium edule* (Jacq.) Sw. (chayote), *Sicyos angulatus* L. (bur-cucumber) (Curcurbitaceae); *Solanum melongena* L. (eggplant), *Solanum tuberosum* L. (potato) (Solanaceae); *Solidago altissima* L. (tall goldenrod), *Taraxacum officinale* Weber, *T. erythrospermum* Andrz. (dandelions) (Asteraceae); *Urtica gracilis* Ait. (nettle, Urticaceae); and *Phaseolus vulgaris* L. (snap bean, Fabaceae) (Wilcox, 1979). Specimens were taken sweeping vegetation on 23 April 2019 in fields opposite Sellman House.

Agroiconta bivittata (Say) feeds on Convolvulaceae, having been recorded from *Calystegia sepium* (L.) R. Br., *Convolvulus*, *Ipomoea batatas* (L.) Lam., and *I. pandurata* (L.) G. F. W. Mey. (Balsbaugh & Hays, 1972). Specimens were taken feeding on *Convolvulus* sp. on 23 August 2018 in forests plots of Zone 5.

Altica foliaceae LeConte has been collected on *Cakile edentula* (Bigl.) Hook. (sea rocket, Brassicaceae) (Balsbaugh & Hays, 1972). Taken on *Vigna unguiculata* (L.) Walp. (cowpea) in Arkansas (Rouse & Medvedev, 1972). Specimens were taken sweeping vegetation on 16 May 2019 along Contees Wharf Road.

Altica litigata Fall has been collected on *Heterotheca subaxillaris* (Lam.) Britt. & Rusby (Asteraceae) in South Carolina (Kirk, 1969). Specimens were taken sweeping vegetation on 19 June 2019 near Reed Education Center.

Brachypnoea clypealis (Horn) has been repeatedly collected on *Amaranthus spinosus* L. (spiny amaranth, Amaranthaceae) in Alabama (Balsbaugh & Hayes, 1972). Rouse & Medvedev (1972) reported specimens taken on *Desmodium* (Fabaceae). Flowers et al. (1994) report that *Eupatorium* and *Ambrosia* Asteraceae) appear to be the true host plants of this species in Florida. Specimens were taken sweeping vegetation on 16 May 2019 along Contees wharf Road, on 9 July 2019 in forest plots of Zone 5, and on 19 July 2019 in fields opposite Sellman House.

Brachypnoea convexa (Say) specimens have been hand-picked specimen from *Rudbeckia* (coneflower, Asteraceae), and others swept from areas where the plant grows (Riley & Enns, 1979). Noted on greater ragweed, *Ambrosia trifida,* in Indiana (Blatchley, 1910). Specimens were taken sweeping vegetation on 26 June 2019 in fields opposite Sellman House.

Brachypnoea puncticollis (Say) has been collected on rose (*Rosa*) (Wilcox, 1954). Hatch (1971) reported apple (*Malus*), grape (*Vitis*), strawberry (*Fragaria*, Roseacae), and pear, peach and plum (*Prunus*) as hosts. Wheeler & Hoebeke (1985) observed feeding on leaves of *Physocarpus opulifolius* (L.) Maxim. (ninebark, Rosaeace). Hight (1990) noted moderate numbers on purple loosestrife, *Lythrum salicaria* L. (Lythraceae). One Missouri collection of several specimens was from honey locust, *Gleditsia triacanthos* L. (Fabaceae) (Riley & Enns, 1979). Specimens were taken sweeping vegetation on 9 July 2018 in forest plots of Zone 5.

Capraita circumdata (Randall) has been found these feeding on *Fagus grandifolia* Ehrhart (American beech), *Juglans cinerea* L. (walnut), *Plantago lanceolata* L. (Plantaginaceae), and adults and eggs on *Verbena urticifolia* L. (Verbenaceae) (Blake, 1927). Balsbaugh & Hays (1972) collected it most frequently on *Vaccinium* (blueberry). Specimens were collected sweeping vegetation on 23 April 2019 in Zone 5.

Capraita obsidana (Fabricius) can be found feeding on *Ilex verticillata* (L.) A. Gray (winterberry, Aquilfoliaceae) and *Euonymus americanus* L. (strawberry bush, Celastraceae) (Blake, 1927). Balsbaugh & Hays (1972) collected on *Vaccinium* (blueberry). Sholes (1987) added *Quercus* (oak). Flowers et al. (1994) reported *Callicarpa americana* L. (French mulberry, Verbenaceae) as a host in Florida. Specimens were collected sweeping vegetation on 30 April 2019 along Contees Wharf Trail

Capraita subvittatum (Horn) Sholes (1987) listed *Aster divaricatus* L. as the primary host, with *A. macrophyllus* L., *Mimulus ringens* L. (Allegheny monkey flower, Phrymaceae), *Veronica officinalis* L. (common speedwell, Asteraceae), and flowers of *Amelanchier* (shad bush, Rosaceae) as additional hosts. Riley & Enns (1979) reported this species as feeding on. *Verbascum thapsus* L. (common mullein, Scrophulariaceae), *Physostegia virginiana* (L.) Benth. (obedience plant, Lamiaceae) and collected on *Pentstemon* (beard-tongue, Plantaginaceae). Specimens were collected sweeping vegetation on 30 April 2019 in Zone 5.

Cassida rubiginosa Müller this introduced species feeds on the thistles *Cirsium arvense C. discolor* (Muhl.) Spreng., *C. vulgare* (Savi) Tenore, *Carduus nutans* L., *C. acanthoides* L., and *Arctium minus* (Hill) Bernh. (burdock) (Asteraceae) (Wilcox, 1979). Ward & Pienkowski (1978a) studied the biology of this species and later determined it is an ineffective biological control agent of thistles, due to high mortality and parasitism (Ward & Pienkowski, 1978b). Specimens were collected feeding on *Cirsium arvense* near Java Farm ruins on 8 June 2018 and 23 April 2019.

Chaetocnema fuscula White is reported "from B. Blue stem" and "on *Lespedeza sericea*" (= *cuneata* (Dum.-Cours) G. Don) (Chinese bush clover, Fabaceae) (White, 1996). Specimens were collected sweeping vegetation on 23 April 2019 in Zone 5.

Chaetocnema minuta Melsheimer is associated with corn, *Solidago*, and *Dirca palustris* L. (leatherwood, Thymelaeaceae) and, from the literature, as common on *Aesculus flava* Sol. (yellow buckeye, Sapindaceae) (White, 1996). A single specimen was taken in a horse dung baited pitfall trap near the water tower on 17-18 April 2019. Other specimens were collected sweeping vegetation on 23 April 2019 in Zone 5, on 25 April 2019 at Frog Haven, and 25 April 2019 in the fields opposite Sellman House.

Charidotella sxpunctata bicolor (Fabricius) has been collected from *Calystegia sepium* (L.) R. Brown (Convolvulaceae) and is considered it an occasional pest of sweet potato (*Ipomoea batatas* (L.) Lamarck [Convolvulaceae]) (Barrows, 1979). Specimens were collected by visual inspection at the forest plots in Zone 6 on 9 July 2018 and on Hog Island on 2 May 2019.

Chrysochus auratus (Fabricius) feeds on various species of *Apocynum* (Apocynaceae) (Wilcox, 1979). Specimens were collected on *Apocynum* sp. by visual inspection on 26 Kune 2018 in the forest plots of Zone 5, on 9 July 2019 in forest plots of Zone 6, and 19 July 2019 along Contees Wharf Road.

Colaspis brunnea (Fabricius) feeds on *Arachis hypogaea* (peanut), *Fragaria* (strawberry), *Phaseolus lunatus* L. (lima bean), *Prunus angustifolia* Marsh. (Chickasaw plum), *Prunus persica* (L.) Batsch. (peach), and *Zea mays* L. (corn, Poaceae) (Blake, 1974). Riley & Enns (1979) noted many specimens on *Medicago sativa* L. (alfalfa) and *Trifolium* (clover) in Missouri. Altieri & Whitcomb (1979) reported feeding on *Chenopodium ambrosiodes* in Florida. Wheeler & Mengel (1984) observed feeding on *Polygonum perforatum* L. (mile-a-minute). Specimens were taken on 23 June 2018 at black light at Reed Education Center and sweeping vegetation in fields opposite Sellman House on 26 June 2019.

Crepidodera nana (Say) feeds on 10 different *Salix* sp. (Salicaceae) (Parry 1986). Specimens were taken on *Salix* sp. at Frog Haven on 23 April 2019.

Cryptocephalus calidus Suffrian in Florida, Blatchley (1924) reported the species as scarce on huckleberry (*Gaylussacia* or *Vaccinium*) and other low shrubs. A single specimen were taken on 19 July 2018 off *Coreopsis* flower along Contees Wharf Road.

Demotina modesta Baly this introduced species has been collected on *Quercus nigra* L. (Riley et al., 2001). Specimens were collected off *Quercus* sp. on 26 June 2018 in the forest plots in Zone 5.

Diabrotica undecimpunctata howardi Barber is found on *Arachis hypogaea* (peanut), *Cucumis melo* L. (cantaloupe), *Spinacia oleracea* L. (spinach, Chenopodiaceae), *Zinnia* Asteraceae), and *Phaseolus vulgaris* (snap bean) (Wilcox, 1979). Hilgendorf & Goeden (1981) listed this species on *Helianthus annuus* L. (Asteraceae) in Georgia and Texas. Wheeler & Mengel (1984) observed feeding on *Polygonum perforatum* (L.) H. Gross (knotweed, Polygonaceae). Wheeler & Hoebeke (1985) observed feeding on leaves of *Physocarpus opulifolius*. Considered a “specialist” on *Solidago* (goldenrod) by Messina & Root (1980). Specimens were collected on 6 June 2018 in garden near Mathias Lab, on 26 June 2018 in forest plots on 26 June 2018 in forest plots in Zone 5, and on 19 June 2019 along Contees Wharf Road,.

Disconycha caroliniana (Fabricius) Balsbaugh & Hays (1972) noted 3 specimens collected on loblolly pine, *Pinus taeda* L. (Pinaceae). Collected sweeping "rescue grass" (Kirk, 1970). Blatchley (1924) noted numbers of specimens swept from flowers of a tall St. Johnswort (*Hypericum*, Hypericaceae). Specimens were collected sweeping vegetation in meadow in front of Mathias Lab on 11 May 2019.

Disconycha glabrata (Fabricius) has been collected on *Amaranthus spinosus* (spiny amaranth) and *A. retroflexus* L. (Duckett, 1920). Balsbaugh & Hays (1972) noted collections from sweeping *Salix* (willow) and *Trifolium incarnatum* L. (red clover, Fabaceae). Hemenway & Whitcomb (1968) and Garman (1891) recorded the biology of this species. Specimens were collected sweeping vegetation on 7 May 2019 at Frog Haven and on 11 May 2019 in meadow in front of Mathias Lab.

Disconycha pensylvanica (Illiger) has been collected on *Polygonum* (Blake, 1933). Specimens were collected sweeping vegetation on 6 June 2018 and 23 April 2019 at Frog Haven.

Epitrix fasciata Blatchley feeds on *Brassica* (wild mustard), *Cucurbita* (squash), and several solanaceous plants (White & Barber, 1974). Specimens were collected on sweeping vegetation on 23 April 2019 in fields opposite Sellman House.

Epitrix fuscula Crotch has been collected on *Cirsium* (thistle) and *Trifolium* (clover) (Balsbaugh & Hays, 1972). Wilcox (1979) listed a number of solanaceous plants as hosts. Specimens were collected feeding on *Solanum carolinense* on 24 May 2018 along Contee Wharf Trail, on 5 June 2018 at the intersection of Contees Wharf and Dock Roads, on 6 June 2018 in parking lot near Mathias Lab, on 9 July 2018 in forest pots in Zone 6, on 19 July 2018 along Contee Wharf Trail, on 23 April 2019 in fields opposite Sellman House, on 30 April 2019 in Zone 5, and on 6 May 2019 along Contees Wharf Road.

Exema canadensis Pierce has been collected on *Ambrosia* (ragweed), *Betula* (birch), *Cornus* (dogwood), *Corylus* (hazelnut), *Erigeron quercifolius* Lam. (fleabane), *Haplopappus phyllocephalus* DC. (goldenweed, Asteraceae), flowers of *Prunus virginiana* L. (choke cherry), *Rubus* (blackberry), *Salix* (willow), *Sambucus canadensis* L. (American elder, Adoxaceae), *Solidago altissima* L. (tall goldenrod), *Solidago neglecta* T. & G. (swamp goldenrod), and *Ulmus* (elm) (Karren, 1966). Messina & Root (1980) considered this species a specialist on goldenrod. Specimens were collected sweeping vegetation on 23 April 2019 in Zone 5 and 16 May 2019 along Contees Wharf Road.

Gibbobruchus mimus (Say) larvae develop in *Cercis canadensis*, *C. occidentalis* and *Bauhinia lunarioides*. Adults have been collected on flowers of numerous other species of plants which are not the larval hosts: *Fraxinus* (ash), *Magnolia* sp., and *M. grandiflora* L. (southern magnolia, Magnoliaceae) (Kingsolver, 2004). Specimens were collected weeping vegetation along Contees Wharf Road on 16 May 2019 and from beating redbud in front of Mathias Lab on 7 and 23 September 2019.

Longitarsus pygmaeus Horn has been recorded from tall dead grass [Poaceae] (Blatchley, 1924), but the beetles probably do not feed on this plant (Clark et al. 2004). Specimens were collected sweeping vegetation on 23 April 2019 in the fields opposite Sellman House.

Longitarsus testaceous Melsheimer has been collected on *Cirsium* (Wilcox, 1979). A large series were collected from *Eupatorium perforatum* L. in Missouri (Riley & Enns 1979). Specimens were collected sweeping *Euparorium* on 30 April 2019 in Zone 6, on 7 May 2019 in the maintenance area, and on 16 May 2019 along Contees Wharf Road.

Myochrous denticollis (Say) as cited as a pest of corn in Kansas (Douglass, 1929). Blatchley (1924) reported this species on grass, ferns, *Zea mays*, huckleberry (*Vaccinium*) flowers, and once in a carrion trap, in Florida. Additional hosts cited from label data by Blake (1950) include on *Helenium* roots and on *H. tenuifolium* Nutt. (Asteraceae) in Texas, cotton (*Gossypium*, Malvaceae), sugarcane (*Saccharum officinarum* L., Poaceae), turnip (*Brassica rapa*), *Ambrosia*, and many from Iowa from "B. Blue stem" (*Andropogon*?). A single specimen was taken sweeping vegetation on 23 April 2019 in Zone 5.

Neochlamisus gibbosus (Fabricius) Karren (1972) listed the following plant records: adults in series with larvae on species of *Rubus* (*Eubatus)*, *Phleum pratense* L. (timothy, Poaceae), *Quercus* (oak), *Salix* (willow), and *Triticum* (wheat, Poaceae). A single specimen was taken sweeping vegetation on 23 April 2019 in Zone 5.

Neofidia viticida (Melsheimer) has been collected on *Vitis* (wild grape), *Parthenocissus* (woodbine, Vitaceae) and at lights in Missouri (Riley & Enns, 1979). A single specimen was taken sweeping *Vitis* on 15 June 2019 near Reed Education Center.

Odontota dorsalis (Thunberg) larvae mine and adults feed on the leaves of *Robinia pseudoacacia* L. (black locust), *R. hispida* L. (bristly locust), *Sophora japonica* L. (Japanese pagodatree), and *Glycine max* (L.) Merrill (soybean) (Fabaceae) (Ford & Cavey, 1985). In spring before mating, adults feed on a wide variety of plants, including many not related to the fabaceous larval hosts (Williams 1989). Occasionally, adults are collected in black light traps. Haviland (1943) and Fritz (1983) studied the biology of this species. Larvae were observed mining leaves of *Robinia pseudoacacia* on 21 September 2019 near Reed Education Center.

Odontota mundula (Sanderson) larvae mine and adults feed on the leaves of hog peanut, *Amphicarpa bracteata* (L.) Fernald (Fabaceae) (Butte, 1968; Ford & Cavey, 1985). A single specimen was taken sweeping vegetation on 17 May 2019 along Back Road.

Ophraella notulata (Fabricius) marsh-elder, *Iva oraria* (Bartlett) Fern. & Grisc. (Asteraceae) is reported as a (reliable) host for larvae and adults (LeSage, 1986). Welch (1978) described the biology of this species. Specimens were collected beating *Iva* on 19 June 2019 near Reed Education Center.

Oulema sayi (Crotch) *Commelina virginica* L. (Commelinaceae) is the larval and adult host (White, 1993). Specimens were collected sweeping *Commelina virginica* on 23 August 2018 in forest plots of Zone 6 and 7 May 2019 in maintenance area.

Paria fragariae Wilcox adult feeding has been observed on leaves of *Physocarpus opulifolius* (ninebark) (Wheeler & Hoebeke 1985). Hight (1990) noted moderate numbers on purple loosestrife, *Lythrum salicaria*. Specimens were collected sweeping vegetation on 23 April 2019 in Zone 5.

Paria pratensis Balsbaugh has been collected on prairie rose, *Rosa setigera* Mich. (Balsbaugh 1970). This species is variable in markings and Barney et al. (2010) reported a number of specimens which are intermediate between *P. fragariae* and *P. pretensis*. However, these specimens match the description of *P. pratensis*. Three specimens were taken at black light on 20 March 2020 near Mathias Lab.

Paria quadrinotata (Say) specimens have been taken on *Juglans*, *Carya*, *Corylus*, *Prunus*, *Sorbus*, *Crataegus*, *Passiflora*, *Rubus*, *Malus*, and *Juniperus* (Wilcox, 1957). Wheeler & Hoebeke (1985) observed feeding on leaves of *Physocarpus opulifolius* (ninebark). Specimens were taken sweeping vegetation on 9 July 2018 in forest plots in Zone 6 and 30 April 2019 along Contees Wharf Road.

Paria sexnotata (Say) has been collected from Virginia red cedar, *Juniperus virginiana* (Wilcox, 1957). Specimens were taken sweeping vegetation on 7 May 2019 in the maintenance area.

Paria thoricaca (Melsheimer) is commonly found sweeping goldenrod, *Solidago*, in Missouri prairies (Riley & Enns, 1979). Balsbaugh & Hays (1972), cited hosts as *Amaranthus retroflexus* L., *Aster*, *Fragaria virginiana* Duch. (strawberry) and *Trifolium* (clover). Specimens were taken sweeping vegetation on 19 June 2019 near Reed Education Center.

Phyllotreta striolata (Fabricius) has been collected from a number of crucifer and other hosts for adults and the following as hosts for the root-feeding larvae: cabbage, horseradish, radish, and turnip (Smith, 1985). Specimens were taken sweeping *Brassica* sp. 23 April 2019 in Zone 5 and on 30 April 2019 along Contees Wharf Trail.

Plagiodera versicolora (Laicharting) has preferred hosts of *Salix nigra* Marshall (black willow) and *S. alba vitellina* (L.) Koch (golden willow), noted that it also feeds on *S. babylonica* L. (weeping willow) and *S. lucida* Muehlenburg (shiny willow), and estimated 3-4 generations a year in Massachusetts (Hood, 1940). Wade & Breden (1986) noted that *Salix interior* Rowlee (sand bar willow) was preferred over *S. nigra* in Illinois. Hight (1990) noted moderate numbers on purple loosestrife, *Lythrum salicaria*. Larvae and adults were collected off *Salix* sp. on 5 June 2018 at intersection of Contees Wharf and Dock Roads and on 7 May 2019 at Frog Haven.

Stenispa metallica (Fabricius) larvae feed on developing leaves in the crown of *Scirpus atrovirens* Willd. (bullrush), and adults were collected on the larval host and *Carex stricta* (sedge) (Cyperaceae) (Ford & Cavey, 1985). Specimens were taken sweeping *Scirpus atrovirens* on 30 April 2019 along Contees Wharf Trail and on 16 May 2019 along Contees Wharf Trail.

Sumitrosis rosea (Weber) larvae mine the leaves of various Fabaceae, especially *Robinia pseudoacacia* (black locust) and *Desmodium* (tick-trefoil) (Ford & Cavey, 1985). A single specimen was taken sweeping vegetation on 6 June 2018 at ponds at Frog Haven.

Systena hudsonias (Forster) recorded host plants are *Ambrosia artemisiifolia* (common ragweed) and *A. trifida* L. (giant ragweed) (Wilcox, 1979). Williams (1990) observed that this beetle is most often associated with the Asteraceae, including *Arctium minus*, *Aster nova-angliae* L. (New England aster), *Chrysanthemum maximum* Raymond, *Eupatorium fistulosum* Barratt., *Helianthus* *annuus*, and *Rudbeckia hirta* L. (black-eyed susan), and that it was also abundant on *Mentha spicata* L. (spearmint, Lamiaceae) and *Verbena urticifolia* L. On goldenrods, *Solidago* (Messina & Root 1980). Specimens were collected sweeping vegetation on 26 June 2019 in fields opposite the Sellman House.

Tymnes tricolor (Fabricius) has been recorded from ironweed [*Vernonia*] (Asteraceae); hornbeam [*Carpinus caroliniana* Walt.], hazel [*Corylus*], *Ostrya virginiana* (Mill.) K. Koch (Betulaceae); chestnut [*Castanea*], *Quercus* (Fagaceae); *Carya illinoinensis* (Wang.) K. Koch, hickory [*Carya*], *Juglans* (Juglandaceae); tulip tree [*Liriodendron tulipifera* L.] (Magnoliaceae); blackberry [*Rubus*] (Rosaceae); and wild grape [*Vitis*] (Vitaceae) (Clark et al., 2004). Specimens were collected by visual inspection on 5 June 2109 along Java History Trail and by sweeping vegetation on 19 June 2019 at the intersection of Contees Wharf and Dock Roads.

Xanthonia villosula (Melsheimer) is commonly swept from oak (*Quercus*), in Kansas (Douglass 1929). Beaten from hazel (*Corylus*) and oak in Indiana (Blatchley, 1910). Reported from *Crataegus punctata* Jacq. (Rosaceae), in New York, by Wellhouse (1922). One record as beaten from wax myrtle (*Myrica*) was cited by Blatchley (1924) for Florida. Specimens were collected beating *Quercus* on 19 June 2019 near Reed Education Center.

DISCUSSION

There are few published inventories which deal with Mid-Atlantic States Chrysomeloidea. Most distribution information is scattered in various taxonomic papers.

Staines (1987) and Glaser (1992) presented checklists of 253 Cerambycidae seen in various insect collections and data-mining the literature. Staines (2008b) reported the 63 species collected on Plummers Island, Montgomery County, Maryland from 1902-2004. Steury & MacRae (2014) found 80 species from George Washington Memorial Parkway, Fairfax County, Virginia. The 10 specimens found at SERC is surprisingly low since the habitat for various species is present. Additional work needs to focus on this family.

Staines & Staines (2001), Staines (2004, 2008a) reported 161 Chrysomelidae collected on Plummers Island from 1902-1997. Only 47 species were collected during a focused inventory on the island (Staines, 2004). Cavey et al. (2013) documented 107 chrysomelids from George Washington Memorial Parkway. The 48 species found at SERC is lower than expected. However, since most chrysomelids are open field, woods-edge, and early successional species (Staines 2004), habitats not common on SERC, it is not that unexpected.

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Banisteria 54: 127–132

RESEARCH ARTICLE

PORROCAECUM ENCAPSULATUM (NEMATODA: ASCARIDIDA: TOXOCARIDAE) IN NORTHERN SHORT-TAILED SHREWS FROM VIRGINIA

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ABSTRACT

Northern short-tailed shrews collected in six counties in Virginia were examined for the presence of subcutaneous encysted larvae of nematodes. Fifty-three of 266 (19.9%) shrews were found infected with from 1 to 17 larval *Porrocaecum encapsulatum* cysts. Worms were always one per cyst and 39.6% had one cyst per infected shrew. However, 32 shrews (60.4%) contained 2 or more cysts and sometimes of different size classes. This is the first report of this nematode from Virginia.

Keywords: *Blarina brevicauda,* cysts, larvae, nematode, parasite, subcutaneous.

INTRODUCTION

Encysted larvae of three species of ascarid nematodes of the genus *Porrocaecum* are known from shrews and moles in eastern United States. Adult *Porrocaecum* worms have been reported from birds from Asia, Europe, North America, and South America but no life cycle data link the North American larval forms in mammals with adult worms in birds. Bird hosts of species of *Porrocaecum* include accipiters, strigids, ardeids, anatids, and passerines (Yamaguti, 1961). The few life cycles that are known for species of *Porrocaecum* include two hosts. Adult worms in the intestine of a bird release eggs that enter the soil in the bird feces. Earthworms ingest the eggs, and development to an infectious stage occurs. When the earthworm is ingested by the bird, adult worms develop in the intestine of the definitive host (Levin, 1961; Yamaguti, 1961).

The three species found in shrews and moles in the United States are 1. *Porrocaecum ensicaudatum* (Zeder, 1800) found unencysted in the intestinal lumen of *Blarina brevicauda* (Say) (Oswald, 1958; Wittrock & Hendrickson, 1979), 2. *P. americanum* (Schwartz, 1925), whose cysts are found attached to mesenteries or abdominal organs of *B. brevicauda* (Chandler & Melvin, 1951; Oswald, 1958; Wittrock & Hendrickson, 1979), and 3. *P. encapsulatum* Schwartz, 1925, whose cysts are typically found in subcutaneous sites in *B. brevicauda* and a mole (Schwartz, 1925; Chandler & Melvin, 1951; Oswald, 1958; Huffman & Penner, 1981). We document the first report of *Porrocaecum encapsulatum* from the Northern short-tailed shrew, *Blarina brevicauda*, in Virginia, with some observations on its biology.

MATERIALS AND METHODS

We captured 266 Northern short-tailed shrews, using live traps, snap traps, and pitfall traps in six counties in Virginia between 1985 and 1992. Some were prepared as museum specimen study skins and some were kept as fluid preserved specimens. From fresh or fluid preserved shrews we removed the skin and nematode cysts were searched for adhered to the connective tissue covering the dorsal musculature. Cysts were pulled off with forceps and preserved in vials containing clean 70% ethanol (Appendix 1).

We measured eighty-six preserved cysts that were not ruptured or distorted by forceps pressure using a metric ruler and dissecting microscope at 7X magnification. All cysts were opened and the number of worms was counted. Because the worms were coiled and fragile, only 12 worms were measured and some were cleared in lacto-phenol to confirm specific identification. The worms were identified accurately because of these criteria: encysted, subcutaneous, large size (20mm or more), pointed posterior end. The shrews and the nematodes were deposited into the Virginia Commonwealth University Mammal Collection which has subsequently been acquired by and incorporated into collections of the Virginia Museum of Natural History, Martinsville, VA.

RESULTS

We found encysted larvae in 53 (19.9%) of the 266 shrews examined. Infected shrews had one or more cysts that were all collected from subcutaneous sites (listed in Appendix 1). All the nematode larvae, numbering 134, were identified as *Porrocaecum encapsulatum*. Each cyst contained a single worm that was coiled in the cyst sometimes with the anterior end and sometimes with the posterior end outermost. All the worms were larval forms. Cysts measured 1.5-4.0mm in diameter. Mean cyst size was 2.75mm (SD 0.69).The number of cysts per host animal varied from 1-17. Most shrews (21 = 39.6%) had a single cyst but 15 had 2 cysts, 5 had 3 cysts, 6 had 4 cysts, 4 had 5 cysts, and one each had 7 and 17 cysts. The mean number of cysts per host = 2.6 (SD 1.55).

For the 32 samples containing 2 or more cysts from a single host shrew, 22 had all the cysts of about equal size. But 10 samples with 2 (n=6) or 3 (n=4) worms had multiple size cysts. For example, shrew 5984 had 4 cysts, 2 of which measured 1.5mm and 1.6mm in length and 2 that measured 2.5 and 3.0 mm in length. The coiled condition of the worms made it difficult to measure them. Twelve worms ranged from 21mm to 45mm in length with mean of 30.1mm (SD 7.1).

The geographic occurrences of the infected shrews by county in Virginia are summarized as follow: Augusta Co. 5; Bath Co. 2; Cumberland Co. 17; Grayson Co. 1; Highland Co. 22; and Rockingham Co. 6. It was an animal from Cumberland County that had the 17 cyst infection.

DISCUSSION

Reports of the occurrence of *P. encapsulatum* have been made from Washington, D.C. which is the type locality (Schwartz, 1925), Pennsylvania (Chandler & Melvin, 1951), Ohio (Oswald, 1958), North Carolina (Miller, et al., 1974), and Connecticut (Huffman & Penner, 1981). This is the first record of *P. encapsulatum* from Virginia. The infections seem to be fairly widespread in the eastern United States and in Virginia. The prevalence of infections in Virginia is 19.9% and where it has been recorded it is generally low: 4.8% in Connecticut, 4.3% in North Carolina, and 12.9% in Ohio.

Our nematode cysts were recovered only from subcutaneous sites as were those of Oswald (1958), Huffman & Penner (1981), and Schwartz (1925), but Miller et al. (1974) reported some encysted *P. encapsulatum* from abdominal mesenteries in *Blarina brevicauda*. We did not examine abdominal sites. An additional host with subcutaneous cysts, the Hairy-tailed mole, *Parascalops breweri* (Bachman) was reported from Pennsylvania by Chandler & Melvin (1951).

Our data indicate that infections may result from multiple exposures to infection resulting in 2 or more size classes of cysts and larvae in one shrew. The disparity of size of the enclosed larvae indicates that considerable growth occurs during the cyst stage in the shrew host.

Although Northern short-tailed shrews may be active at any time of day, they are primarily active nocturnally (Linzey, 1998). Because owls are also nocturnal and are known to ingest shrews as a regular part of their diet (Mumford & Whitaker, 1982), and George et al. (1986) list 6 genera of owls with species known to prey on *B. brevicauda*, we suggest that *P. encapsulatum* larvae may mature to adult worms in the intestine of owls. Schwartz (1925) had suggested that hawks and owls were the likely definitive hosts. If earthworms are the required invertebrate hosts of these nematodes then the shrew or mole is a paratenic host that is important in transmission dynamics of the infection but not a required part of the life cycle. Oswald (1958) fed cysts of *P. encapsulatum* to chicks (*Gallus gallus* L.) and to two screech owls [*Otus asio* (L.)] but no infections resulted. Such animal studies are difficult today often because of institutional restrictions (IACUC) but molecular studies may be the best way to connect the larval forms to the adult worms to complete the life cycle.

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We thank Nancy Moncrief of the Virginia Museum of Natural History for making shrew collection records available to us. Some shrews and all nematode cysts were collected by David M. Feldman as part of his Master of Science Thesis, Ecological significance of brown adipose tissue in the Northern short-tailed shrew (*Blarina brevicauda*). May 1993, Viii+54pp. Department of Biology, Virginia Commonwealth University. The Virginia Division of Game and Inland Fisheries provided collecting permits to J. Pagels. Valuable comments by two reviewers greatly improved the manuscript.

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Appendix 1. Collection data for *Blarina brevicauda* in Virginia and number of *Porrocaecum encapsulatum* cysts in each shrew.

Accession Number	County	Date of capture	Fluid (F) or unspecified (X)	Number of cysts
VCU-04349	Highland	18 Jul 1985	F	2
VCU-04897	Highland	07 Sep 1985	F	3
VCU-04905	Highland	07 Sep 1985	F	4
VCU-04909	Highland	16 Nov 1985	F	1
VCU-04915	Highland	10 May 1986	F	2
VCU-04940	Highland	18 Apr 1986	F	2
VCU-05128	Highland	28 Sep1985	F	1
VCU-05604	Grayson	20 Sep 1988	F	1
VCU-05638	Cumberland	05 Oct 1989	F	2
VCU-05795	Highland	13 Oct 1989	X	1
VCU-05950	Cumberland	16 Apr 1990	X	1
VCU-05980	Cumberland	01 Jun 1990	X	2
VCU-05983	Cumberland	01 Jun 1990	X	4
VCU-05984	Cumberland	01 Jun 1990	X	4
VCU-06007	Cumberland	16 Jun 1990	X	2
VCU-06008	Cumberland	16 Jun 1990	X	1
VCU-07214	Cumberland	2 Sep 1990	X	2
VCU-07231	Cumberland	16 Sep 1990	X	7
VCU-07232	Cumberland	30 Sep 1990	X	5
VCU-07600	Rockingham	06 Jul 1987	F	1
VCU-07601	Rockingham	8 May 1987	F	1
VCU-07612	Rockingham	27 Oct 1987	F	1
VCU-07617	Augusta	13 Oct 1989	F	2
VCU-07620	Augusta	31 Aug 1987	F	1
VCU-07679	Highland	05 Oct 1991	F	1
VCU-07700	Highland	05 Oct 1991	F	2
VCU-07702	Highland	05 Oct 1991	F	1
VCU-07710	Highland	05 Oct 1991	F	1
VCU-07728	Highland	06 Oct 1991	F	3
VCU-07729	Highland	06 Oct 1991	F	1
VCU-07731	Highland	06 Oct 1991	F	1
VCU-07733	Highland	06 Oct 1991	F	4
VCU-08305	Rockingham	14 Apr 1988	X	3
VCU-08310	Rockingham	02 Oct 1988	X	1
VCU-08324	Cumberland	29 Feb 1992	X	2
VCU-08334	Cumberland	12 Mar 1992	X	1
VCU-08336	Augusta	08 Mar 1992	X	1
VCU-08337	Augusta	08 Mar 1992	X	5
VCU-08392	Augusta	19 Dec 1991	X	4
VCU-08400	Cumberland	11 Dec 1991	X	17

Appendix 1
Continued

Accession Number	County	Date of capture	Fluid (F) or unspecified (X)	Number of cysts
VCU-08404	Cumberland	12 Dec 1991	X	2
VCU-08415	Cumberland	26 Jan 1992	X	5
VCU-08420	Highland	21 Sep 1990	X	3
VCU-08421	Highland	21 Sep 1990	X	1
VCU-08423	Highland	21 Sep 1990	X	1
VCU-08425	Highland	21 Sep 1990	X	2
VCU-08534	Cumberland	04 Apr 1992	F	2
VCU-09020	Highland	17 May 1992	F	4
VCU-09021	Highland	17 May 1992	F	2
VCU-09113	Rockingham	14 Sep 1991	F	1
VCU-10034	Highland	May-Jul 1992	X	2
VCU-10127	Bath	24 Jul 1992	X	3

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SHORTER CONTRIBUTIONS

LOCAL COMPILATION OF AN ANNOTATED BUTTERFLY CHECKLIST

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Since 2015, volunteers from two non-profit organizations, the Coastal Virginia Wildlife Observatory and the Historic Rivers Chapter of Virginia Master Naturalists, have been developing an annotated checklist of butterflies (Superfamily Papilionoidea) and skippers (Superfamily Hesperioidea). The goal of the project is to document details of species in the greater Williamsburg area of Virginia, which encompasses the City of Williamsburg and two adjacent counties (James City and York). This year's fifth edition documents 94 species, providing information gleaned from the literature on flight periods, host plants, habitats, broods, and behaviors, and observations made by volunteers. The idea for the project was based on a similar annotated checklist for birds that was compiled for the same general area.

The area has an impressive diversity of butterflies, and there is an increasing number of people who are interested in documenting them. The core group of butterfly enthusiasts promotes activities that involve novice master naturalists and others in the community. For example, in 2014, members established the Williamsburg Annual Butterfly Count, sponsored by the North American Butterfly Association (NABA) and entered it as a master naturalist citizen science project. Additional spring and fall surveys take place in multiple Williamsburg locations, including Bioblitzes sponsored by the Colonial National Historical Park. Members also promote participation in annual NABA counts in other locations in Virginia. Several members of the group regularly participate in weekly year-round “Wildlife Mapping” activities that provide data on all fauna. In addition, members submit photos of sightings to Butterflies and Moths of North America (BAMONA), eButterfly, and iNaturalist. Photographs of each species document sightings, but not all of these species are posted by the online databases.

The **Butterflies of the Greater Williamsburg Area: An Annotated List of Species** establishes a baseline of information about local butterflies and skippers. At present, 85 species are described as common, uncommon, or rare; three species are described as stray or aberrant (observed only once and not expected to originate in this region); and six species have no recent sightings but were found historically.

The annotated list is used as a workbook to record data and each succeeding draft provides an improved understanding of local butterfly species and their habitat needs. Early and late dates and peak counts are updated each year. Subsequent versions of the checklist will continue to refine data and improve the understanding of butterflies and skippers at the local level. It was intended that eventually the document will be used by a wider audience, for example to help landowners or park employees with guidance about planting and sustaining butterfly habitats.

Below are two examples of species descriptions contained in the annotated listing. The descriptions are written as a work in progress. If the document is to be distributed, then dates, locations, and observers will be removed.

The two examples below are both rare species. For this document, the definition of **rare** is very limited sightings, in limited locations, usually with low individual numbers; as compared to **common** that is defined as observed predictably in suitable habitat or **uncommon** as limited sightings, found in several locations, not found consistently from year to year.

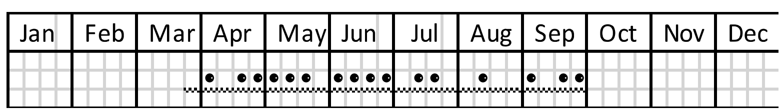
Harvester (*Feniseca tarquinius*) **Rare** **Broods:** Possibly 6 or more

Expected Flight Period: Late Mar. – Sep. (Mar. - Apr. – Sep.)

Reported Sightings:

Sight dates by quarter month •

Intermittent



Earliest: Apr. 8, 2012 (B. Taber, home) Latest: Sep. 26, 2018 (B. Taber, home)

Peak Count: Apr. 21, 2016 (B. Taber, home) # 2; Jun. 22, 2003 (T. Kain, home) # 2

Other Sightings: Apr. 20, 21, 30, 2013, 2015, Apr. 21-24, 2016, Apr. 22-27, 2019, May 5, 7-10, 12, 2019, May 11, 2013 (B. Taber, BAMONA), May 24, 2010, Jun. 5, 9 ,10, 2019 (B. Taber, home); Apr. 18, 2018 (A. Belden, G. Driscole, Debord); Apr. 18-19, 2018 (G. Driscole, A. Frank, Warhill); May 24, 2010, Jun. 6, 30, 1996, Jun. 22, 2003, Jul. 8-10, 1996, Jul. 21, 2014 (T. Kain, home); Jun. 11, 2019 (N. Barnhart, A. Frank, NOL, photo); Jun. 11, Jul. 21, 2019 (N. Barnhart, K. Lorenzen, B. Taber, NOL, photo); Sep. 19, 2017 (A. Frank, Debord Tract)

Habitat: Bottom or upland deciduous or mixed forests; usually near streams, ponds, or swamps with alder thickets.

Caterpillar Hosts: Wooly aphids that, in turn, feed on Smooth Alder (*Alnus serrulata*), American Beech (*Fagus grandifolia*), American Hornbeam (*Carpinus caroliniana*), and possibly other woody species. This is our only insectivorous caterpillar.

Notes: Adults never nectar, acquiring nutrients from moist soil along dirt roads and trails or along muddy stream banks near Smooth Alder (*Alnus serrulata*); also acquires nutrients from aphid honeydew, sap, dung, and carrion. Coloration can be bright reddish-orange or muted tan/brown. Can easily be mistaken for a moth when in flight.

Creole Pearly-eye (*Enodia creola*) **Rare** **Broods:** 2

Expected Flight Period: May – Sep. (May/Jun. – Jul./Aug. – Oct.)

Reported Sightings:

Sight dates by quarter month ●

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				●●	●●●	●●●●	●●●●	●●●●			

Earliest: May 16, 2019 K. Lorenzen +, NOL, photos) Latest: Sep. 29, 2018 (K. Lorenzen +, NOL)

Peak Count: Jul. 26, 2019 (K. Lorenzen +, NOL, photos) #21

Other Sightings: May 18, 21, 24, 28, 31, Jun. 4, 7, 9, 17, 21, Jul. 4, 7, 10, 17, 21, 26, 28, Aug. 6, 11, 16, 20, 22, 27, 29, Sep. 12, 2019 (K. Lorenzen +, NOL, photos); Aug. 9, 2017 (G. Driscole, A. Frank, K. Lorenzen, B. Taber, NOL); Aug. 15, 2016 (K. Lorenzen, NOL, photo); Aug. 15, 2017 (K. Lorenzen +, NOL, photo); Aug. 16, 20, 23, 25, 2018 (NOL, photos); Sep. 4, 6, 11, 16, 19, 25, 29, 2018 (NOL, photos)

Habitat: Usually on the periphery of dense, moist or wet bottomland woods and hardwood swamps with cane.

Caterpillar Hosts: Switch Cane (*Arundinaria tecta*).

Notes: Does not nectar on flowers; adults obtain nutrients from moist soil, dung, carrion and other putrefying matter. Males perch to await females. Aug. 15, 2016 was the first known sighting for this area.

Banisteria 54: N4–13

SHORTER CONTRIBUTIONS

SIX ROVE BEETLES (COLEOPTERA: STAPHYLINIDAE) NEW TO VIRGINIA

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ABSTRACT

Six species of rove beetles (Coleoptera: Staphylinidae), *Anotylus breviceps* (Casey), *Anotylus exiguus* (Erichson), *Anotylus insignitus* (Gravenhorst), *Homaeotarsus strenuus* (Casey), *Lithocharis nigriceps* (Kraatz), and *Stethusa spuriella* Casey are reported for the first time from Virginia. The specimens were captured by sampling white-tailed deer dung and in Malaise traps. All staphylinid taxa found in the dung of white-tailed deer are provided along with images of each new state record.

Keywords: Biodiversity, Fairfax County, national parks, new state records.

INTRODUCTION

Sampling dung from white-tailed deer (*Odocoileus virginianus* [Zimmerman]) in Great Falls Park, Fairfax County, Virginia, (a unit of the George Washington Memorial Parkway [GWMP]) uncovered four species of rove beetles (Coleoptera: Staphylinidae), *Anotylus breviceps*, *Anotylus exiguus*, *Anotylus insignitus*, and *Stethusa spuriella*, reported for the first time from the Commonwealth. Approximately 0.5–1.0 kg of dung was gathered on 25 October, and 1, 8, 15, 22, and 29 November 2019, and 15 January 2020. Each dung sample was placed in a 19 L bucket and 3.8 L of warm tap water was poured over the dung. The mixture was stirred and all beetles were collected and as they rose to the surface of the water. The beetles were represented by only two families, Staphylinidae and Scarabaeidae. Beetles were placed in a vial of 95% ethanol and later pinned. Scarabaeidae were saved for later study. Staphylinidae were represented by six species in four subfamilies (Aleocharinae [n=1], Omaliinae [n=1], Oxytelinae [n=3], and Paederinae [(n=1]). *Anotylus* was the most common genus, represented by 22 male specimens (representing three species) and 39 unidentified females. *Anotylus insignitus*, a non-native species of Palaearctic origin, was the most common species found in dung samples (n=15 ♂). In addition to the four new state records, two species previously documented from GWMP (Brattain et al., 2019) *Arpedium schwarzi* Fauvel (n=1) captured 25 October and *Scopaeus* sp. (n=1) captured 29 November were found in deer dung.

Continued sorting of Malaise trap samples (sensu Brattain et al., 2019) from Little Hunting Creek also added two staphylinids, *Homaeotarsus strenuous* and *Lithocharis nigriceps*, which are new state records. Data for these species are reported below.

All specimens were identified by microscopic examination, and for *Stethusa spuriella*, by dissection and examination of the male genitalia, using taxonomic keys provided in Downie and Arnett (1996) (*Anotylus* and *Homaeotarsus*), Assing and ScHülke (2011) (*Lithocharis*) and Gusarov (2003) (*Stethusa*). All specimens are curated in the collection maintained at the Turkey Run Park Headquarters in McLean, Virginia. State record determinations are based on a review of Brattain et al. (2019). The six species new to Virginia increase the number of rove beetles known from GWMP to 215 taxa (177 identified to species).

LIST OF SPECIES

VIRGINIA

Anotylus breviceps (Casey) (Fig. 1a–b) – Fairfax Co.: Great Falls Park, deer dung, 25 October 2019, M. Stirzaker and B. Steury, (GWMP, 1 ♂); same data except 15 November (1 ♂); same data except 22 November (2 ♂); same data except 15 January 2020 (2 ♂). **NEW STATE RECORD.**

This is the first record of this species from Virginia (Brattain et al., 2019). It represents a southern range extension from New York (Downie & Arnett, Jr., 1996).

Anotylus exiguus (Erichson) (Fig. 2a–b) – Fairfax Co.: Great Falls Park, deer dung, 25 October 2019, M. Stirzaker & B. Steury, (GWMP, 1). **NEW STATE RECORD.**

This species is documented from the District of Columbia but not Virginia (Brattain et al., 2019). It is also recorded from Indiana, Florida, and Texas (Downie & Arnett, Jr., 1996). Al Newton (pers. comm.) added Pennsylvania to the known range of this species based on two synonyms, *A. parvulus* (Melsheimer) and *A. pygmaeus* (Melsheimer). Makranczy (2006) recently transferred this species from the genus *Oxytelus*.

Anotylus insignitus (Gravenhorst) (Fig. 3a–b) – Fairfax Co.: Great Falls Park, deer dung, 25 October 2019, M. Stirzaker & B. Steury, (GWMP, 3 ♂); same data except 1 November (1 ♂); same data except 8 November (1 ♂), same data except 15 November (1 ♂); same data except 22 November (1 ♂), same data except 29 November (1 ♂), same data except 15 January 2020 (7 ♂). **NEW STATE RECORD.**

This species is documented from the District of Columbia but not Virginia or Maryland (Brattain et al., 2019). It is a non-native species of Palaearctic origin (Brattain et al., 2019) and was the most common staphylinid beetle found in the dung of native white-tailed deer. Downie & Arnett, Jr. (1996) state that it is a cosmopolitan species widespread over eastern North America, Mexico and Central and South America. In addition to the 15 male specimens cited above, 39 female *Anotylus* spp., probably *A. insignitus* or *A. breviceps*, were found in these deer dung samples.

Homaeotarsus strenuus (Casey) (Fig. 4a–b) – Fairfax Co.: Little Hunting Creek, Malaise trap, 5–19 May 2017, B. Steury, (GWMP, 1). **NEW STATE RECORD.**

This is the first record of this species from Virginia (Brattain et al., 2019). It represents a southeastern range extension from Ohio (Downie & Arnett, Jr., 1996).

Lithocharis nigriceps Kraatz (Fig. 5a–b) – Fairfax Co.: Little Hunting Creek, Malaise trap, 16–30 July 2018, B. Steury, (GWMP, 1 ♀). **NEW STATE RECORD.**

This is the first record of this European species from Virginia (Brattain et al., 2019). In North America it has been introduced in Québec, Canada, and in the United States in Arkansas, California, Florida, Georgia, Illinois, Kansas, Massachusetts, New Jersey, New York, Ohio, and South Carolina (Al Newton, unpublished pers. catalogue database, September 2020).

Stethusa spuriella (Casey) (Fig. 6a–b) – Fairfax Co.: Great Falls Park, deer dung, 25 October 2019, M. Stirzaker & B. Steury, (GWMP, 1 ♂). **NEW STATE RECORD.**

This is the first record of this species from Virginia or even nearby political regions of Maryland, or the District of Columbia (Brattain et al., 2019). It has been previously documented from scattered locations between New York and northern Florida and westward to Illinois (Gusarov, 2003).

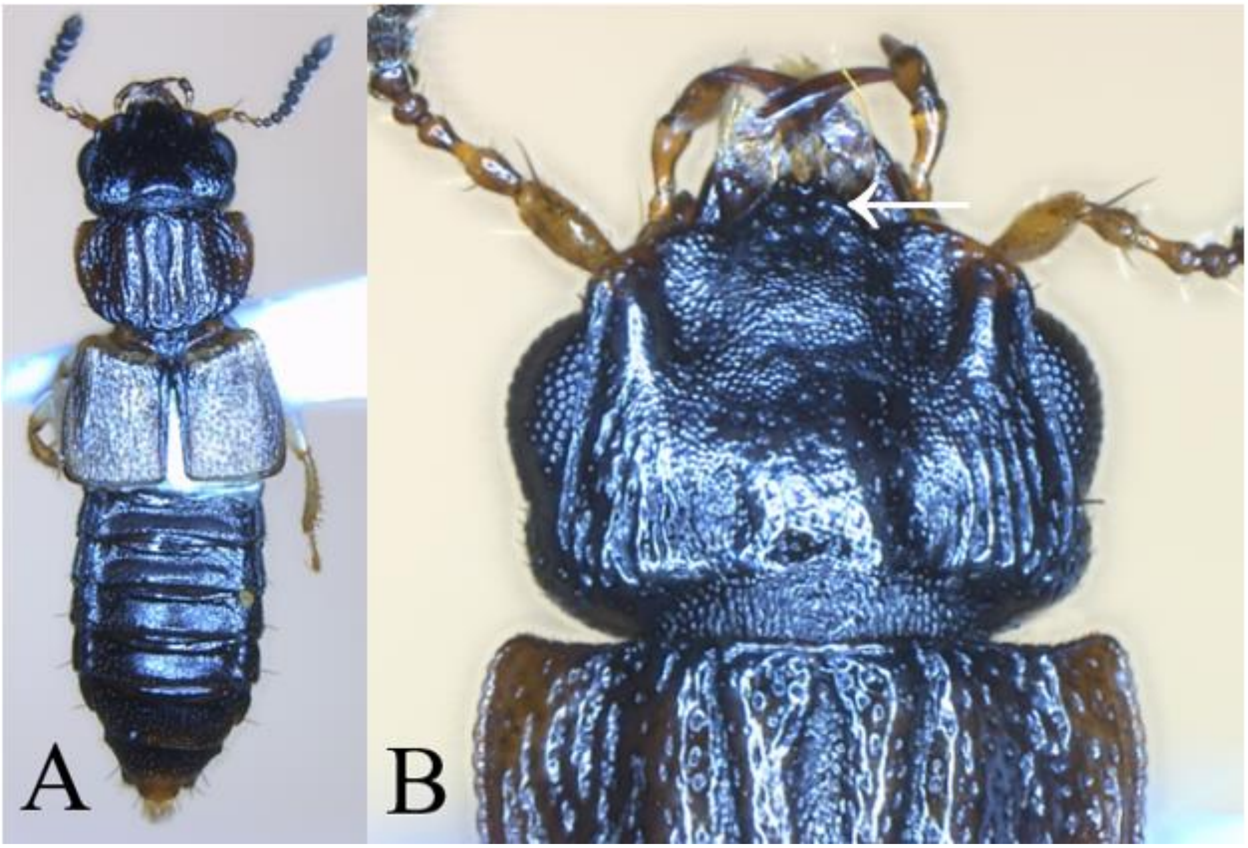

Figure 1. A) *Anotylus breviceps*, male, dorsal view. B) Close-up of head of same specimen with white arrow showing diagnostic bifurcate rostrum. The specimen was captured in the dung of white-tailed deer found in Great Falls Park, Fairfax County, Virginia, during 25 October 2019. Body length 3.1 mm.

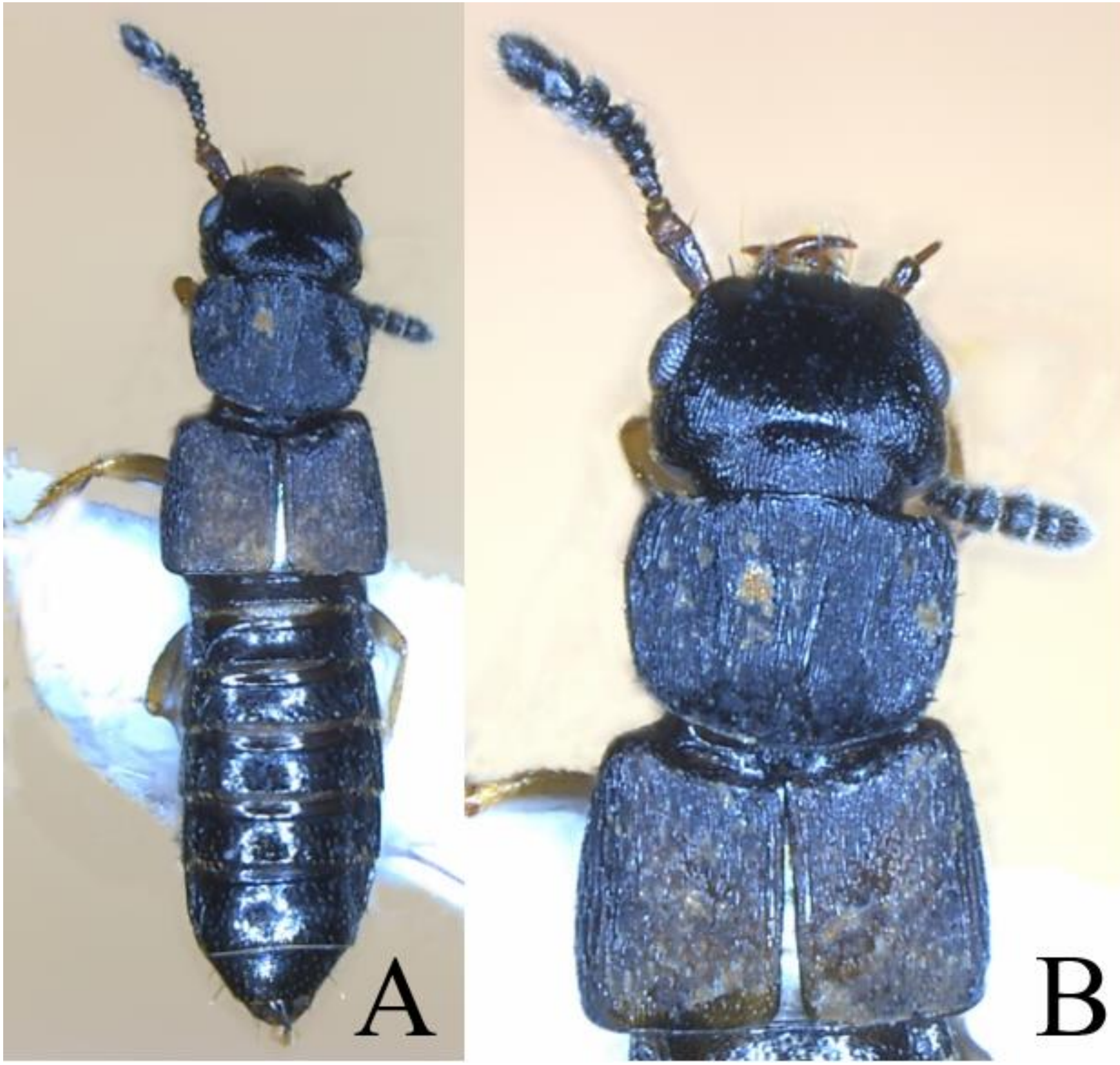

Figure 2. A) *Anotylus exiguus*, dorsal view. B) Close-up of head of same specimen showing diagnostic strigose pronotum and elytra. The specimen was captured in the dung of white-tailed deer found in Great Falls Park, Fairfax County, Virginia, during 25 October 2019. Body length 1.9 mm.

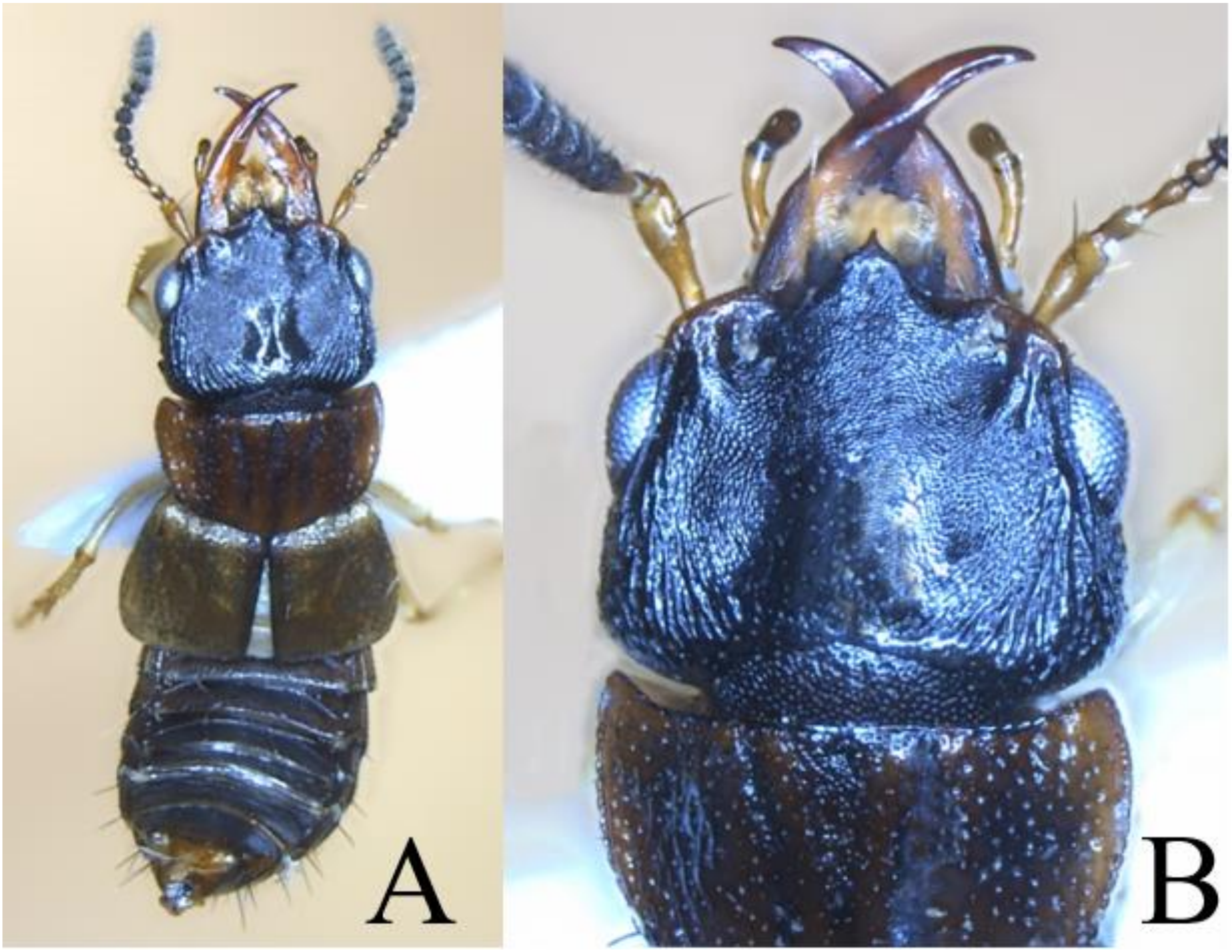

Figure 3. A) *Anotylus insignitus*, dorsal view. B) Close-up of head showing acuminate rostrum. Specimens were captured in white-tailed deer dung found in Great Falls Park, Fairfax County, Virginia, during 25 October 2019 (A) and 15 November 2019 (B). Body length 3.7 mm.

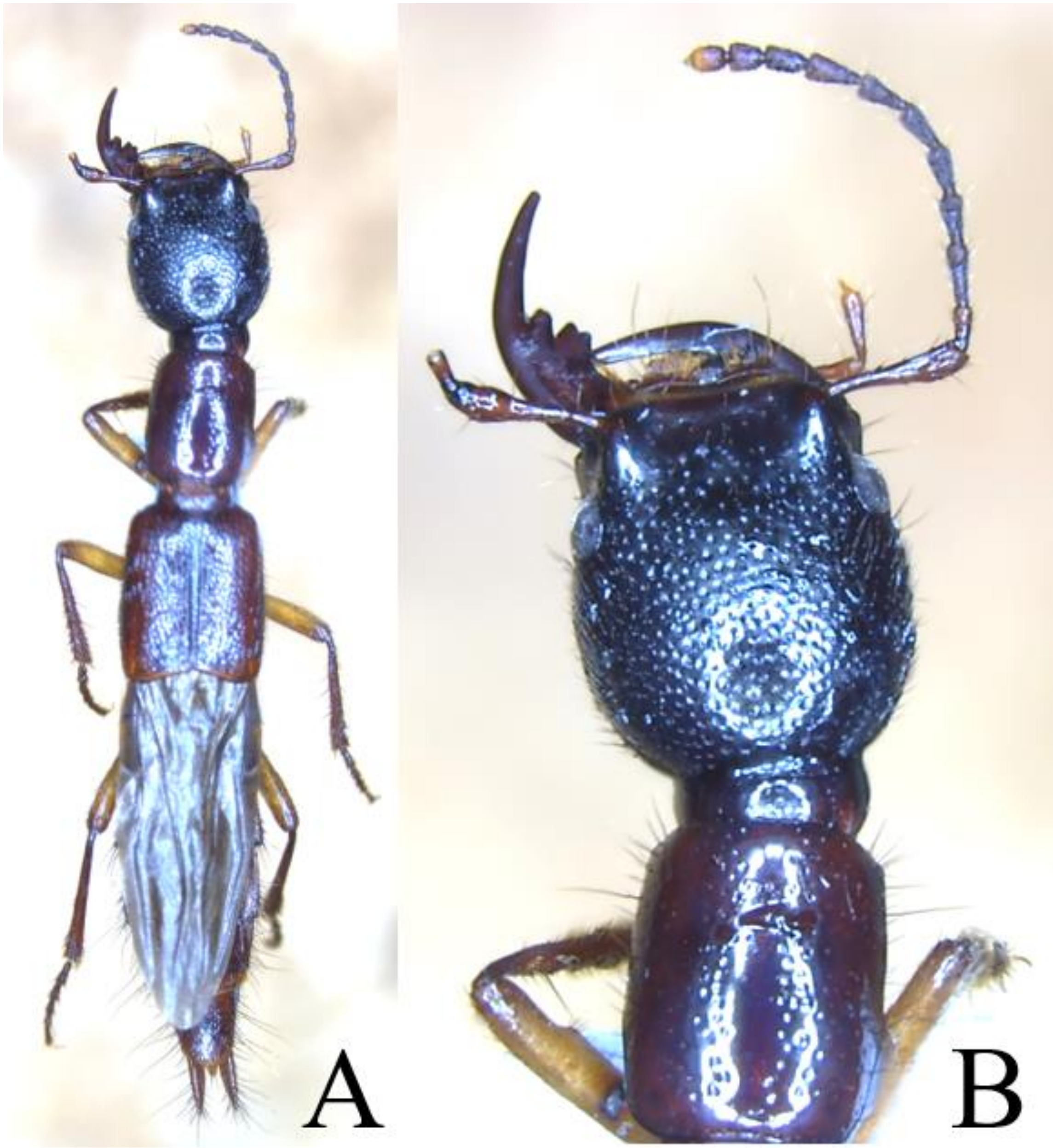

Figure 4. A) *Homaeotarsus strenuus*, dorsal view. B) Magnified view of the head and pronotum of the same specimen. Collected at Little Hunting Creek in a Malaise trap set during 5–19 May 2017. Body length 14 mm.

Figure 5. A) *Lithocharis nigriceps*, female, dorsal view. B) Magnified view of the head, pronotum and elytra of the same specimen Collected at Little Hunting Creek in a Malaise trap set during 16–30 July 2018. Body length 4.0 mm.

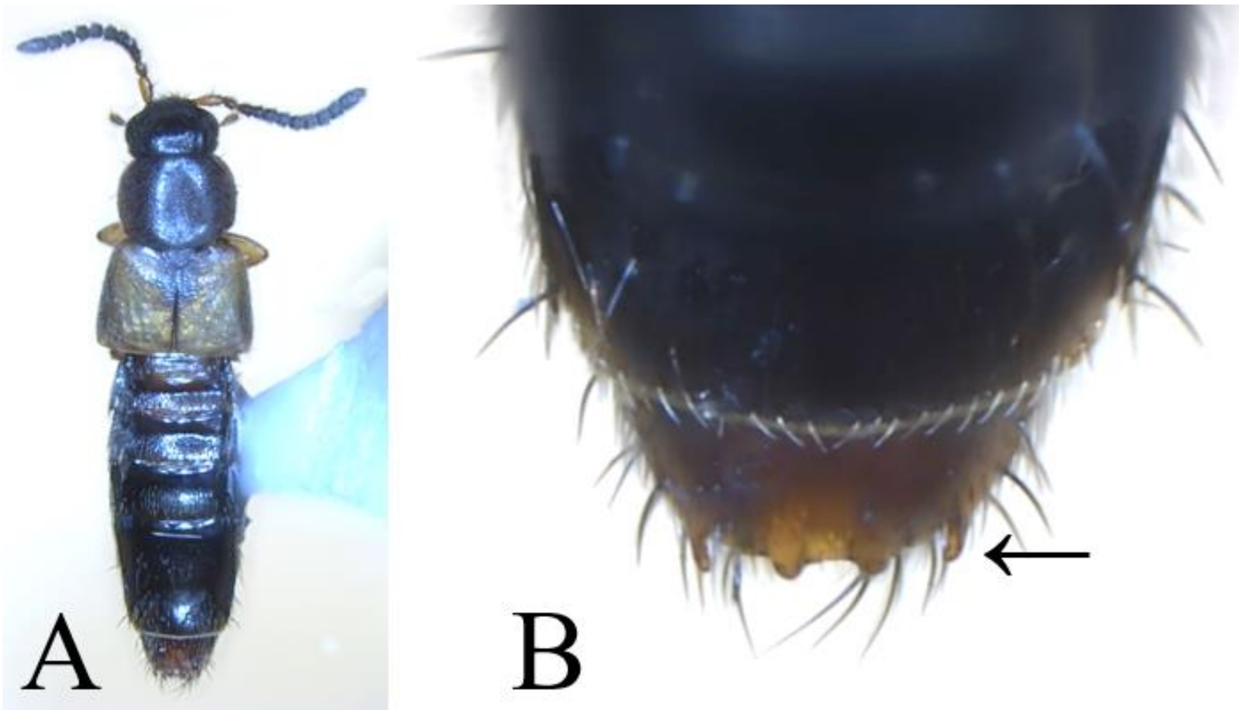

Figure 6. *Stethusa spuriella*, male, dorsal view. B) Eighth tergite of same specimen with arrow showing distinctive spinulose armature at the apex. Collected at Great Falls Park from deer dung during 25 October 2019. Body length 2.8 mm.

ACKNOWLEDGEMENTS

Much appreciation is extended to Mireya Stirzaker, Evan Costanza, Austin Davis, Hugh Davis and Richard Stirzaker for collecting deer dung samples from Great Falls Park. Alfred F. Newton, Field Museum of Natural History, identified the specimen of *Lithocharis nigriceps* from the image in Figure 5. E. Richard Hoebeke, University of Georgia, identified the specimen of *Stethusa spuriella*.

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Banisteria 54: N14–22

SHORTER CONTRIBUTIONS

PARASITE LOADS AND AGING TECHNIQUES ASSESS THE CONDITION OF A BOBCAT (*LYNX RUFUS*) KITTEN IN VIRGINIA

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ABSTRACT

On 7 September 2020, the Southwest Virginia Wildlife Center of Roanoke admitted a Bobcat (*Lynx rufus*) kitten from a patron in Bedford County, Virginia. Despite the best efforts of the staff, the 1030-g kitten succumbed to its maladies on 10 September 2020. We discuss the Center's attempts to remove the parasites, and our subsequent collective efforts to quantify and identify them through DNA barcoding. We identified a number of internal (*Toxocara cati* and *Giardia*) and external (Lone Star Tick, *Amblyomma americanum*) parasites, and quantified the external parasite load (644 ticks across all 3 life stages). In comparing the kitten's intake weight to multiple aging techniques, we determined that this Bobcat was approximately 12 weeks old and showed multiple signs of severe malnourishment. Because Bobcats in the wild are expected to be capable of withstanding a high parasite load, we believe other unidentified ailments led to this kitten's lethargy. Its demise was likely hastened when the hard ticks overwhelmed and anemiated the kitten. We present this case study not only to document illnesses affecting a young Bobcat kitten (to our knowledge, the youngest kitten to be examined in depth for maladies) but also to alert other wildlife rehabilitation specialists about roadblocks to treating Lone Star Tick infestations.

Keywords: *Amblyomma americanum*, dental eruption, DNA barcoding, ectoparasite, endoparasite, *Giardia*, Lone Star Tick, roundworm, serous fat atrophy, *Toxocara cati*.

BACKGROUND

On 7 September 2020, the Southwest Virginia Wildlife Center of Roanoke (hereafter, SWVA Wildlife Center) admitted a Bobcat (*Lynx rufus*) kitten from a patron in the city of Thaxton in Bedford County, Virginia. The kitten was on their back porch on 6 September, and was assumed to have been attracted by cat food.

When the kitten arrived at the SWVA Wildlife Center, it was sexed as a female, described as emaciated, weak, and infested with a "tremendous" number of ticks (Fig. 1A). Its recorded weight was 1030g. It had loose stool, a low body temperature, and was listed as anemic. Immediate efforts included warming it with a heating pad. Co-author Garvin described larval or nymph-stage ticks on or around the live Bobcat while it was in the Center's care - with ticks visibly crawling on the carrier, on the towels, and more. On this first day, staff applied Adams Plus topical flea and tick spray for dogs (Adams Corp., Phoenix, AZ), but this treatment did not appear to encourage the ticks' detachment from the Bobcat kitten.

A standard fecal analysis on 8 September 2020 determined that the Bobcat kitten was infected with roundworms and *Giardia* (cysts discovered). The kitten was offered canned cat food, given 40 cc (subcutaneous) and then 100 cc (bolus) of Lactated Ringers Solution (LRS). At the direction of advising veterinarian, Dr. E. Dominguez (formerly of The Wildlife Center of Virginia, Waynesboro, VA), it was administered pyrantel pamoate (prescribed 6.5 ml [Q every 24 h] x 5 days) to treat *Giardia* and roundworms. Beef liver paste (pureed and diluted with water) was fed to the kitten during evening hours. Staff also topically applied Revolution Plus for cats (Zoetis, Kalamazoo, MI) as a second attempt to remove the ticks. This tick medication appeared to have no immediate effect.

By 9 September 2020, the kitten was less responsive, but treatments continued. This Bobcat was administered 40 cc (bolus) of LRS. At the direction of advising veterinarian Dr. K. Thomason (retired, Blue Ridge Veterinary Hospital, Floyd, VA), staff administered 1 cc of injectable Iron Dextran (100 mL iron; Vedco Inc., Saint Joseph, MO) for anemia, 1 cc of B-12 complex, and an additional 100 cc of LRS (bolus). The kitten also was force-fed 35 cc of pureed chicken liver. By the end of the day, the kitten was unresponsive.

On 10 September 2020, the Bobcat kitten was catheterized, and an LRS IV was started. Unfortunately, it succumbed to its multiple illnesses on this date.

PARASITE EXTRACTION

The deceased Bobcat was frozen and transferred to co-author Powers on 12 September 2020. Over the next several weeks, co-authors Marshall and Van Meter removed ticks from the carcass and sorted by stage: larva (<1 mm, 6 legs), nymph (1.5-2.5 mm, 8 legs), and adult (3-4 mm, 8 legs; Holderman & Kaufman, 2013). Ticks were preserved and remained separated by life stage: larva catalogued as RU 14554, nymphs catalogued as RU 14555, adults catalogued as RU 14556 (Fig. 1B). Nearly every tick was fully engorged; multiple exoskeletons also were recovered, but not counted in the totals.

Following the extraction of ticks from the carcass, co-author Powers prepared the Bobcat as a museum specimen, RU 14525. Once the internal organs were accessible post-taxidermy, co-author Sheehy investigated intestinal parasites. Six ascarid worms were located in the large intestine, and none in the small intestine. This location suggests that the pyrantel pamoate was effective, and the roundworms were exiting the kitten. Two of the worms were preserved (RU 14553; Fig. 1C).

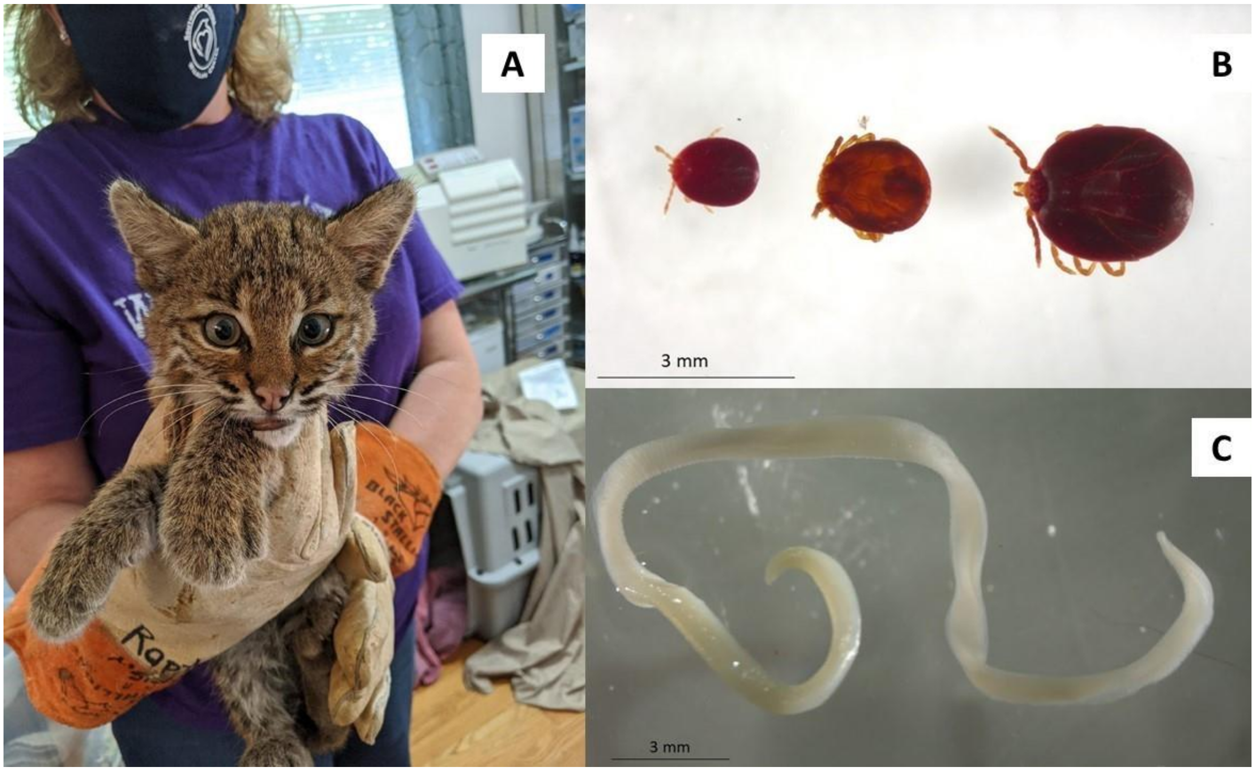

Figure 1. Images of a Bobcat (*Lynx rufus*) kitten and its parasites: A) Bobcat at time of admission to the Southwestern Virginia Wildlife Center of Roanoke on 7 September 2020; B) Lone Star Ticks (*Amblyomma americanum*; L-to-R: larva, nymph, adult) found on the pelage, and C) roundworm (*Toxocara cati*) found in the large intestine.

SPECIES IDENTIFICATION

We used DNA barcode analysis to identify the Bobcat's parasites to the species level. We collected tissue from four tick specimens (two adults and two nymphs; legs only, to avoid contamination with Bobcat blood), one roundworm specimen and the Bobcat itself (liver sample). Roundworm sections, tick legs and Bobcat liver samples (ca. 5-25 mg) were homogenized using disposable micropestles.

We extracted DNA from homogenized tissue using *Qiagen* DNeasy® Blood and Tissue kit (Qiagen Inc., Valencia, CA). Extracted DNAs served as templates for polymerase chain reaction (PCR) amplification of a 709-bp fragment of the mitochondrially-encoded COI gene. We included both positive and negative controls for each set of amplifications.

We amplified this fragment of the COI gene using M13 tailed primers. We used primers M13F-LCO 1490 and M13R-HCO 2198 modified from Folmer et al. (1994) to amplify DNA extracted from roundworm and tick samples. The Bobcat DNA template was amplified using primers VF1d_t1 and VR1d_t1 (Ivanova et al., 2006). Both the invertebrate primers and the vertebrate primers amplify the Folmer region of the COI gene - the standard mitochondrial region used in DNA barcoding. Both strands of PCR products were sequenced by Sanger Dideoxy sequencing performed by GeneWiz Inc. (www.genewiz.com). Assembly of forward and reverse sequences and manual trimming of primer sequences were performed using Codon Code Aligner (CodonCode Corporation, www.codoncode.com).

Consensus of forward and reverse COI sequences were compared with sequences in the nucleotide sequence database at NCBI using MegaBLAST (Zhang et al., 2000; Morgulis et al., 2008) with default settings. We also used the consensus sequence as a search query using the identification tool provided by *Barcode of Life Data Systems* (Ratnasingham & Hebert, 2007; www.boldsystems.org). We searched both databases using data available on 3 November 2020.

DNA barcoding identified each of the four ticks as Lone Star Ticks, *Amblyomma americanum*, with a 100% match to other members of this species in the database. Barcoding of the roundworm identified it as *Toxocara cati* with its DNA sequencing matching other sequences in the database with 99.5% similarity. The closest alternate taxon in the database, *Toxocara canis*, demonstrated 92.6% similarity and solidified our confidence in the identification. The DNA barcode sequence of the Bobcat matched other Bobcat entries in the database showing 99.85% sequence similarity; it does, however, contribute to the database by representing only the second sample from the United States.

ECTOPARASITE ANALYSES

Lone Star Ticks from the Bobcat carcass totaled 644 individuals: 342 larvae, 294 nymphs, and 8 adults. Co-author Garvin estimated an equal number removed from or recovered from around the kitten while in the Center's care. Ticks were especially concentrated inside the ear (e.g., 37 larvae were removed from an area of approximately 0.5 x 0.5 cm), all fully engorged. Lone Star Ticks are recognized as generalist ticks, able to jump among mammalian and avian hosts (Stafford, 2007). Indeed, when the Bobcat was kept in semi-isolation, ticks jumped from the Bobcat to a Red-tailed Hawk (*Buteo jamiacensis*) in the same triage room.

Lone Star Ticks typically are three-host ticks, feeding on a different host during each stage. They are aggressive pursuit ticks and will actively travel relatively long distances to find a host and will release pheromones to attract other Lone Star Ticks to the host (White & Gaff, 2018), and could likely explain the multiple life stages attached to the kitten. Once attached, larvae will blood-feed for 7-10 days. When engorged, the larvae drop off and digest the blood meal away from a host. They molt and reach the nymph stage. Nymphs will find and attach to a new host (via the same methods as larvae), feed for 10-18 days, disassociate from the second host, and molt into an adult. Adults attach to a third host to feed and mate. Adults may remain on the hosts up to 18 days (Holderman & Kaufman, 2013). Despite finding tick exoskeletons on the Bobcat kitten, there are no reports of Lone Star Ticks staying on the same host across life stages. The exoskeletons recovered were likely those that died (via failure to latch or hyperparasitism) on the Bobcat rather than actual molts (H. Gaff, Old Dominion University, personal communication).

This hard tick species will cause anemia but not exsanguination of the host (Goddard & Varela-Stokes, 2009). This Bobcat kitten's anemia may have been partly a result of the initial tick infestation, making it lethargic; this lethargy enabled the parasitism by additional ticks of multiple stages. Further, the presumed failure of tick treatments may have been an artifact of this hard tick species' behavior; Lone Star Ticks are more likely to die attached than to drop off the host (H. Gaff, personal communication).

Tick parasitism of Bobcats has been reported, but only quantified for adults. Wehinger et al. (1995) reported three tick species (99% in the adult stage) in 85 Bobcats in Florida: *Ixodes scapularis* (Deer Tick; prevalence rate: 71.7%), *Ixodes affinis* (no common name; prevalence rate: 12.9%), and *Dermacentor variabilis* (American Dog Tick; prevalence rate: 65.9%). Surprisingly, *Amblyomma americanum* and *Amblyomma maculatum* (Gulf Coast Tick) made up less than 1% of all ticks collected (Wehinger et al., 1995), despite being ranked as a high-density state for *A. americanum* (Shock et al., 2011). Although not quantified, *A. americanum* has been documented on adult and juvenile Bobcats in multiple studies (e.g., Shock et al., 2011; Zieman et al., 2017) often associated with the tracking of a protozoan parasite, *Cytauxzoon felis*. Lone Star Ticks are the primary tick to transmit this protozoan parasite that causes cytauxzoonosis, otherwise known as Bobcat fever (Glenn et al., 1983). If this Bobcat was infected by this protozoan, paralysis (Persky et al., 2020) and death (Nietfeld & Pollock, 2002) could have resulted within 24 h of infection. However, other publications suggest higher rates of infection in the wild (e.g., Zieman et al., 2017: 70.6% of 125 Bobcats in Illinois; Shock et al., 2011: 79% of 39 Bobcats in Missouri) with no apparent symptoms exhibited by the adult or juvenile Bobcats.

Gaff (personal communication) did suggest infection with *Rickettsia* (documented in Bobcats by Guzmán-Cornejo et al., 2019) as a possible underlying cause for the mortality of this kitten. Tissue samples have been preserved for testing at a later date.

ENDOPARASITE ANALYSES

Past endoparasitic studies of adult Bobcats included the presence of several roundworm species, including *Toxocara cati* and *Toxascaris leonina*. Of 146 Bobcats examined in the western United States, Carver et al. (2012) reported that 14 were parasitized by these roundworms. In a study of 50 Bobcats, Rollings (1945) reported a 36% prevalence rate of *Toxocara cati*. One adult Bobcat in the study was infested with 44 individual worms. Despite this high intensity parasite load, Rollings (1945) reported no obvious health effects. Hiestand et al. (2014) examined 67 Bobcats (52 adults, 15 juveniles) and found no significant difference in endoparasitic infection rates between age groups. Within this study, Bobcats in both age groups were infected by *Taenia releyi* (70% of the individuals), *Alaria marcianae* (42%), and *Toxocara cati* (25%).

The endoparasites we documented are Bobcat or generic felid specialists (Hiestand et al., 2014). Further, none of these publications suggest compromised health from the roundworms. It is unlikely that roundworms were the ultimate cause of the kitten's death.

Giardia is a protozoan parasite that causes infections not expected to be lethal. Carver et al. (2012) found that in some survey locations in Colorado, more than half the Bobcat fecal samples contained *Giardia* cysts or trophozoites. They discovered a greater number of cysts or trophozoites (in fecal matter) of *Giardia* at locations closer to areas of high densities of humans. Therefore, it is not surprising that this kitten (picked up in a suburban neighborhood in Bedford County) was infected. Although adult Bobcats are slightly more likely than juveniles to be infected with *Giardia,* the differences in prevalence were not significant (Carver et al., 2012).

VISUAL METRICS TO ESTIMATE BOBCAT AGE AND FURTHER ASSESS CONDITION

At the time of taxidermy, standard body measures were taken: total length = 430 cm, tail length = 70 cm, hind foot length = 103 cm, ear length = 45 cm, weight = 1250g. The weight suggested that efforts to rehydrate and feed the Bobcat added ca. 21% to its intake weight.

In order to determine if the Bobcat was medically underweight, we used several features to estimate its age, including tooth eruption patterns and comparison to published growth rate charts for kittens. First, an examination of the teeth revealed that its full complement of baby teeth had erupted, and it was missing one upper incisor (I1) and one lower incisor (I2). Using Jackson et al.'s (1988) chronological description of eruption and tooth replacement in young Bobcats, eruption patterns suggest the Bobcat was markedly older than 9 weeks old (when its full complement of baby teeth have erupted) but less than 16-18 weeks old (when the first and second adult incisors erupt; Jackson et al., 1988). After sharing dental photos with this lead author, Miller (née Jackson) estimated that the kitten was ca. 12 weeks old (D. Miller, University of Tennessee-Knoxville, personal communication). Second, we extrapolated growth rates from a kitten growth chart by Stys & Leopold (1993), presuming the published linear growth rates from Bobcats aged 0-7 weeks held true in subsequent weeks. Our total body and ear lengths suggested this kitten would be 13 weeks old, while the hind foot length suggested 12 weeks, and the tail length suggested 14 weeks. Were assumed that if Bobcats followed an asymptotic growth pattern, our age estimate would have been skewed higher.

The intake weight corresponded to a wild kitten weight of about 9 weeks (Stys & Leopold, 1993). Furthermore, Miller (personal communication) remarked that the skull presented visible serous fat atrophy. Such atrophy is a measure of the nutritional state of wild animals; muscle and bone marrow in severely malnourished individuals would appear gelatinous (Hooser et al., 2006). Although several vet schools can quantify bone marrow atrophy for this malady, the effort currently is cost-prohibitive; the long bones of this kitten will remain frozen, if future analyses are possible. This combination of metric evidence and visible serous fat atrophy supports our theory that the kitten was severely malnourished.

CONCLUSION

Despite the documentation of a number of parasites and a number of maladies, we cannot point to one ultimate cause of death. Although the combination of ticks, *Giardia*, and roundworms could have debilitated the animal, we presume that a still-undefined underlying condition may have been present. Once the kitten was lethargic, it was likely susceptible to increased tick infestation. The anemia was a result of or was enabled by the engorged Lone Star Ticks. The roundworm parasitism and *Giardia* infections were not unexpected or presumed life-threatening.

We present this case study as a way to document the numerous parasitic threats to a Bobcat kitten in the wild. To our knowledge, this kitten is the youngest to be examined in detail for parasites in published literature. We document the efforts to address myriad problems with said parasites, so that other wildlife rehabilitation professionals may learn what was successful and, more importantly, what was not. When wildlife rehabilitation centers receive these “worst” cases, it is sometimes too late for the animal to recover; this was certainly the case for the severely malnourished Bobcat kitten. Our research to determine the ultimate cause of death will continue, and the SWVA Wildlife Center will continue to collaborate with knowledgeable veterinarians on cases like this in the future.

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CITIZEN SCIENCE

PEARLY-EYE BUTTERFLIES (LEPIDOPTERA: NYMPHALIDAE) OF COLONIAL NATIONAL HISTORICAL PARK, VIRGINIA

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ABSTRACT

During an August 2016 butterfly survey conducted in Colonial National Historical Park, VA, a single Creole Pearly-eye (*Enodia creola*) and 12 Northern Pearly-eyes (*E. anthedon*) were documented in an area of the park known as Neck of Land. During a second butterfly survey conducted in the same area one year later, two more Creoles and three Northerns were documented. Finding Creole Pearly-eye butterflies represented a new record for James City County and with permission from the National Park Service, a study of pearly-eye butterflies in the Neck of Land area was conducted during 2018-2019. Pearly-eye numbers, distribution, caterpillar feeding, and timing of broods were documented. During the study, three Southern Pearly-eye butterflies (*E. portlandia*) also were documented, representing another new James City County record. Ranges for both the Creole and Southern Pearly-eye butterflies appear to have extended northward along the Atlantic Seaboard.

Keywords: Creole Pearly-eye, *Enodia creola*, Northern Pearly-eye, *Enodia anthedon*, Southern Pearly-eye, *Enodia portlandia*, Satyrinae, Switch Cane, *Arundinaria tecta*, Japanese Stiltgrass, *Microstegium vimineum*, Neck of Land, Jamestown Island, James City County, county record.

INTRODUCTION

Pearly-eyes belong to a group of butterflies known as satyrs (Lepidoptera: Nymphalidae: Satyrinae). There are estimated to be over 2,400 species of satyrs found world-wide, including almost 50 species in the United States (US) and Canada. Fifteen species of satyrs are found in the eastern US, three of which are sibling species called pearly-eyes: the Northern Pearly-eye (*Enodia anthedon*), the Southern Pearly-eye (*E. portlandia*), and the Creole Pearly-eye (*E. creola*). Butterfly names used herein are based on Cassie et al. (2001).

These three satyrs are categorized as woodland satyrs because they prefer the dark interiors of forests and tend to remain close to the ground. Adult pearly-eyes do not nectar on flowers, instead obtaining nutrients from sap, moist soil, dung, carrion, and decaying organic matter. All three pearly-eye species overwinter as late-instar caterpillars.

On 15 August 2016, in preparation for a US National Park Service (NPS) BioBlitz to be held in Colonial National Historical Park, VA, a survey was conducted by volunteers from the Historic Rivers Chapter of Virginia Master Naturalists (HRCVMN) and the Coastal Virginia Wildlife Observatory (CVWO) to assess butterfly activity and identify butterfly species observed at various NPS locations along the Colonial Parkway (Parkway) between Yorktown and Jamestown. In an area of the park known as Neck of Land (NOL), near Jamestown Island, a single Creole Pearly-eye and 12 Northern Pearly-eye butterflies were observed in the forest near the end of Back River Trail. This was the first known sighting of a Creole Pearly-eye in James City County and appears to be an extension northward of the range for this species on the Atlantic Seaboard.

Creoles are the least abundant of the three pearly-eye species (Glassberg, 1999; Cech & Tudor, 2005), being uncommon to rare throughout their range, and where populations do occur, they tend to be very localized. According to NatureServe (2020), the Global Conservation Status Ranks for the three pearly-eye species are G5, G4, and G4 for the Northern, Southern, and Creole, respectively. This means all three species appear to be secure globally with a low risk of extirpation. At the national and state (Virginia) levels, Northerns and Southerns both have Conservation Status Ranks of N4 and S4, respectively, meaning these two species are apparently secure with a low risk of extirpation. Creoles are ranked N3N4 nationally, and S3S4 in Virginia and are considered vulnerable with a moderate risk of extirpation. Host plant loss due to habitat fragmentation, degradation, or total destruction continues to be a serious risk factor for this species.

In August 2017, HRCVMN and CVWO volunteers returned to the location where pearly-eye butterflies had been observed the previous year but found none. The search was continued in other NOL areas and two Creole and three Northern Pearly-eye butterflies were observed along Old Jamestown Road Trail.

Finding Creole Pearly-eye butterflies during NOL surveys conducted in August of 2016 and 2017 suggested the presence of a previously unknown population of the species, so a citizen science project to document Creole Pearly-eyes in the NOL area was prepared and submitted to the NPS. Included in the study would be further documentation of Northern Pearly-eyes and a search for Southern Pearly-eyes.

Concurrently, the James River Association (JRA) was negotiating with the NPS to occupy the vacant Neck of Land Contact Station in order to use the building and surrounding property for educational outreach programs. An agreement was reached and JRA occupied the building in late 2017. Shortly thereafter, the NPS issued a permit for this study and both the NPS and JRA granted access to the NOL area.

The first objective of the project was to search the NOL area for native cane (*Arundinaria sp.*), host plants for Creole and Southern Pearly-eyes. Wagner (2005), Opler & Krizek (1984), and Opler & Malikul (1998) state that Creole Pearly-eye caterpillars feed only on Switch Cane (*A. tecta*), while Cech & Tudor (2005) and Opler & Malikul (1998) state that Southern Pearly-eye caterpillars feed on both Switch Cane and Giant Cane (*A. gigantea*). Taxonomists are undecided about the status of native canes, with some considering *A. tecta* to be a subspecies of *A. gigantea*. Cech &Tudor (2005) state that Northerns use a variety of woodland grasses (Family Poaceae) to host their caterpillars and a survey of NOL vegetation would be conducted to search for known and potential host plants. Other objectives were to document the species, number, and distribution of pearly-eye butterflies in the NOL area, determine the number and timing of pearly-eye broods, and document pearly-eye caterpillar feeding.

METHODS

The search for *Arundinaria* was conducted in three locations: 1) the NOL area and along the Parkway and in the forests on both sides of the Parkway extending to approximately 1.5 km east of the NOL area; 2) along the Parkway from the west end of the Powhatan Creek bridge to the Historic Jamestowne Visitor Center on Jamestown Island; and 3) on Jamestown Island via the island's Loop Drives. Roadside searches were conducted by automobile; the NOL area and forests on both sides of the Parkway east of the NOL area were searched by foot.

To document the number of pearly-eye butterflies and the number and timing of broods, weekly surveys were begun on 18 April 2018. Initially, surveys were conducted only in those areas where pearly-eyes had been observed in 2016 and 2017 (the Back River and Old Jamestown Road Trails). By 29 July, having sighted only a single Northern near the location where pearly-eye butterflies were observed in 2016, search parameters were changed. The number of surveys was increased to twice per week and the search area was expanded to include all of NOL (henceforth called the Study Area, Fig. 1). From 5 August to 17 October 2018, and from 16 May to 27 September 2019, these new parameters were followed.

Figure 1. Google Earth 2020 view of the Neck of Land and Jamestown Island regions of Colonial National Historical Park. The Study Area is outlined.

Due to the close similarity in appearance of the three pearly-eye species, each observer attempted to photograph every pearly-eye butterfly sighted. When an approaching observer caused a pearly-eye to take flight, the observer remained still and watched until the butterfly settled in a new location. Then the observer moved slowly to a position within a few meters of the butterfly where it could be viewed through binoculars and photographed. During 2018, locations where each pearly-eye butterfly was first sighted were approximated and marked on a map. During 2019, observers used hand-held GPS devices to pinpoint pearly-eye locations.

Other data recorded during surveys included: start and stop times, number of observers, general weather conditions, number and species of pearly-eye butterflies sighted, and number, stage of growth, and location of any pearly-eye caterpillars found. Temperatures and wind were measured with a hand-held device and recorded at the beginning and end of each survey. GPS readings and photographs of pearly-eye butterflies were downloaded and saved in a computer database. All other data recorded during each survey was entered into the same database and saved for future analysis.

RESULTS AND DISCUSSION

Switch Cane

During the search for Switch Cane a total of eight stands were found (Fig. 2): two stands on the north side of the Parkway at the northwest edge of the Study Area; one stand at the intersection of

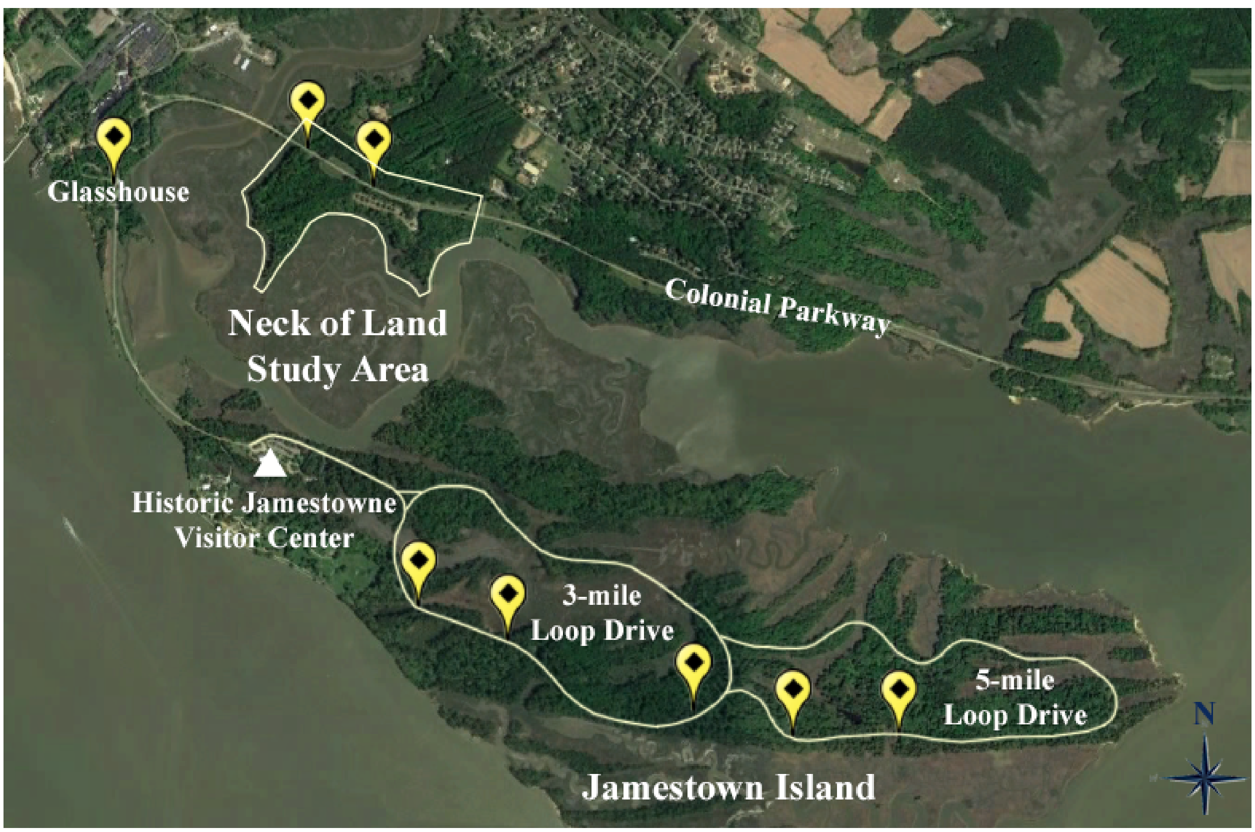

Figure 2. Google Earth 2020 view of the Neck of Land and Jamestown Island regions of Colonial National Historical Park. The Study Area is outlined; stands of Switch Cane are indicated by yellow markers.

the Parkway and the entrance to the Jamestown Glasshouse site; and five stands on Jamestown Island itself, all on the south side of the Island Loop Drives.

Habitat

Pearly-eyes prefer the dark interiors of dense, bottomland woods, usually near marshes or swamps, with *Arundinaria* present in the case of Southerns and Creoles. The habitat in parts of NOL and Jamestown Island fit these conditions very well (Fig. 3). Patterson (2008) classified the forests of these regions as "Coastal Plain Loblolly Pine–Oak Forest". Trees commonly seen in the Study Area included Sweetgum (*Liquidambar styraciflua*), American Holly (*Ilex opaca*), Red Maple (*Acer rubrum*), Southern Red Oak (*Quercus falcata*), and Loblolly Pine (*Pinus taeda*), along with common vines and shrubs like Muscadine Grape (*Vitis rotundifolia*), Japanese Honeysuckle (*Lonicera japonica*), Yellow Crownbeard (*Verbesina occidentalis*), and Chinese Privet (*Ligustrum sinense*). Japanese Stiltgrass (*Microstegium vimineum*) was pervasive throughout the Study Area, but other commonly seen species included Common Woodreed (*Cinna arundinacea*), Virginia Wild Rye (*Elymus virginicus*), Broomsedge (*Andropogon virginicus*), and Soft Rush (*Juncus effusus*).

Figure 3. Typical forest habitat in the Neck of Land and Jamestown Island areas. Japanese Stiltgrass is the prevalent groundcover.

Patterson (2008) classified the surrounding wetlands as “Tidal Freshwater Marsh”. Commonly seen species included Big Cordgrass (*Spartina cynosuroides*), Smooth Cordgrass, (*S. alterniflora*), Bitter Panic Grass (*Panicum amarum*), Bottlebrush Sedge (*Carex comosa)*, and Broom Sedge (*Carex scoparia)*.

Caterpillars

The Alabama Butterfly Atlas (2020) states that Creole Pearly-eye caterpillars chew “a squared notch into cane leaves, which is typical of the satyrs.” Ogard & Bright (2010) state that most satyr caterpillars “chew distinctive squared-off indentations into host leaves, creating deeper, more extensive notches as they grow.” No images were provided, but during the search for *Arundinaria*, observers inspecting leaves for pearly-eye caterpillar feeding evidence found patterns matching those descriptions in all but one of the stands of Switch Cane (Fig. 4).

Figure 4. Notch in Switch Cane leaf resulting from pearly-eye caterpillar feeding. Brown edges of the chewed section indicate older activity.

While examining Switch Cane leaves for pearly-eye caterpillars, observers sometimes encountered individual leaf blades rolled lengthwise and bound by silk, or multiple leaf blades bound together lengthwise by silk. Inside the individually-rolled leaves were single caterpillars of the Lace-winged Roadside Skipper (*Amblyscirtes aesculapius*). Where several leaves had been bound together, multiple caterpillars of a Crambid snout moth (*Crocidophora pustuliferalis*) were found. Feeding damage caused by other herbivores (*e.g.*, grasshoppers and katydids) also was encountered.

Despite finding presumed pearly-eye caterpillar feeding evidence on cane leaves, no pearly-eye caterpillars were found during 2018. During 2019, feeding evidence continued to be found but caterpillars remained elusive until 28 June. After inspecting a cane plant with fresh-looking feeding evidence on several leaves (the edges of chewed areas were still green, as opposed to having turned brown) but finding no caterpillars, a search of the leaf litter at the base of the plant was conducted. During this search, a single fourth instar pearly-eye caterpillar was discovered.

Following this discovery, the plant was carefully re-examined and a single third instar pearly-eye caterpillar was found on the underside of a leaf blade, near the tip. With its cryptic coloration and long, slender body, it was very difficult to see. Observers learned to look for caterpillars on leaves of young plants (further discussion below), and more importantly, turn leaves over and look closely near the tips of the blades. Once this technique was adopted, finding caterpillars became much easier. During the next survey on 4 July, two more third instar caterpillars were found. Then, no caterpillars were found until 22 August when a cluster of six first instar caterpillars was discovered. Between 22 August and 3 September, five different clusters of first instar caterpillars totaling 30 individuals were found (Table 1), each cluster numbering five to seven individuals (Fig. 5). No first instar caterpillars were found singly, while second and third instar caterpillars were found singly, in pairs, or sometimes mixed together in groups of three (Fig. 6). Several more leaf litter searches were conducted during 2019 but no additional late instar pearly-eye caterpillars were found.

Table 1. Number and growth stage of pearly-eye caterpillars found during Study Area surveys conducted in 2019.

Survey Date	Instar					Total Found
	1st	2nd	3rd	4th	5th	
28 Jun	—	—	2	1	—	**3**
4 Jul	—	—	3	—	—	**3**
22 Aug	6	—	—	—	—	**6**
27 Aug	—	2	4	—	—	**6**
29 Aug	11	2	5	—	—	**18**
3 Sep	13	—	5	—	—	**18**
10 Sep	—	2	—	—	—	**2**
12 Sep	—	—	2	—	—	**2**
27 Sep	—	—	2	—	—	**2**
Total	**30**	**6**	**23**	**1**	**0**	**60**

Almost all first and second instar caterpillars were found on leaves of young cane plants no more than about 60 cm tall, or on leaves of young stems of similar height arising from the base of mature cane plants. Third instar caterpillars were found on the leaves of plants up to about 120 cm tall. No pearly-eye caterpillar feeding evidence was observed on the highest leaves of the tallest plants (1.8 to 2.1 m high). All pearly-eye caterpillars were found on the underside of cane leaves, almost always near the tips. The pinkish to reddish horns on the heads and tails of pearly-eye caterpillars likely contribute to camouflage (along with their coloration and body shape), making it possible for caterpillars to blend in with the tip of a leaf blade no matter which way they face (Fig. 6).

Figure 5. First instar pearly-eye caterpillars, each approximately 5 mm long, at the tip of a Switch Cane leaf blade.

Figure 6. Second and third instar pearly-eye caterpillars near the tip of a Switch Cane leaf blade.

According to Lotts & Naberhaus (2020), Creole Pearly-eye caterpillars feed at night and spend the day hiding at the base of cane plants. Ogard & Bright (2010) state that pearly-eye "caterpillars often feed at night." Based on observations made during this study, young caterpillars (first through third instars) appear to remain on cane leaves both day and night to feed, while older caterpillars (fourth and fifth instars) descend cane stems to spend the day concealed in leaf litter on the ground, then ascend cane stems to feed on cane leaves during the night. The timing of these movements is not known.

Both Creole and Southern Pearly-eyes use Switch Cane as a host plant but since only three Southerns were found during this study, the majority of pearly-eye caterpillar feeding evidence observed must have been caused by Creole Pearly-eye caterpillars. Since caterpillars of both species look identical, it is impossible to know how many Southern Pearly-eye caterpillars may have been present among the 60 caterpillars found during 2019.

Pearly-eye Butterfly Surveys

During each survey, observers walked in unison along a loosely-defined route through the Study Area, spacing themselves approximately five meters apart in a line perpendicular to the survey route. Observers adjusted their individual positions as needed when encountering obstacles, difficult terrain, or to follow a pearly-eye butterfly. The route for each subsequent survey was adjusted to the left or right of the last line traversed in order to cover as much of the Study Area as possible over time. Observers had to re-establish their search line numerous times during each survey. When five to seven observers were present for a survey, two groups were formed and each group searched a different section of the Survey Area. Observers always inspected the two stands of Switch Cane in the Study Area for evidence of pearly-eye caterpillar feeding and the presence of pearly-eye caterpillars.

During 2018, a total of 35 butterfly surveys were conducted. No surveys were possible during the weeks of 13 May and 22 July due to inclement weather. During 2019, a total of 36 surveys were conducted. Only one survey per week was possible during the weeks of 28 July, 4 August, 1 September, and 15 September due to inclement weather; surveys conducted on 31 July and 13 August were curtailed by rain.

Except as noted above, weather conditions were generally good during surveys, with clear to partly cloudy skies and calm or light winds. In 2018, survey temperatures averaged 30.2 C (range = 21 to 34 C). In 2019, survey temperatures averaged 28.3 C (range = 20 to 33 C). Humidity was not measured, but conditions were muggy throughout most of June through September each year.

The number of observers participating in a survey was typically two to four, but ranged from as few as one to as many as seven. The average time spent per survey during 2018 was 1.9 h (range = 45 min to 3.5 h), with observers collectively spending 134.7 h conducting surveys. During 2019, the average time spent per survey was 2.6 h (range = 1.5 to 4.25 h), with observers collectively spending 347.4 h conducting surveys. The 2018 data reflect the much smaller area of NOL surveyed during 18 April to 29 July.

Surveys were conducted at varying times of the day, depending on the availability of observers and the weather. Some surveys began as early as 9:00 AM while other surveys began as late as 4:00 PM. Surveys conducted during 2018 had an average start time of 1:30 PM and an average end time of 3:30 PM. Surveys conducted during 2019 had an average start time of 10:45 AM and an average end time of 1:40 PM.

Most of the pearly-eye butterflies encountered by observers were concealed in Japanese Stiltgrass, the predominant forest undergrowth, taking flight only when observers neared their resting places. Disturbed butterflies usually re-settled quickly in the Stiltgrass or on a tree trunk or branch within several meters of their previous perch. However, some flew up to 10 m or more and in several cases, observers lost sight of them before they could be viewed through binoculars and photographed.

During 2018, 116 pearly-eyes were sighted, of which 106 were photographed. Careful examination of these photographs revealed 24 individuals had been photographed more than once during a survey, resulting in 28 duplicate images. The duplicates were eliminated, leaving 78 photographed sightings. Five of those could not be identified to species and the remaining 73 were identified as 55 Northern, 17 Creole, and one Southern Pearly-eye. The 10 unphotographed sightings were visually identifiable only as pearly-eyes.

Fig. 7 shows the approximate locations where pearly-eye butterflies were first sighted

Figure 7. Google Earth 2020 view of the Survey Area showing approximate locations where pearly-eye butterflies were sighted in 2018. Pink markers represent Creoles; green markers represent Northerns. Sites 1, 2, and 3, indicated by red markers, represent locations where Creoles were sighted during 2016-2018.

during surveys conducted in 2018. Creoles were observed only in the vicinity of Sites 2 and 3; Northern sightings were more widespread. Fig. 8 shows the number of Creoles and Northerns observed during surveys conducted in 2018. Only one brood for each species is indicated because the areas later found to have the most butterflies were not surveyed during 18 April to 29 July when a first brood would be expected.

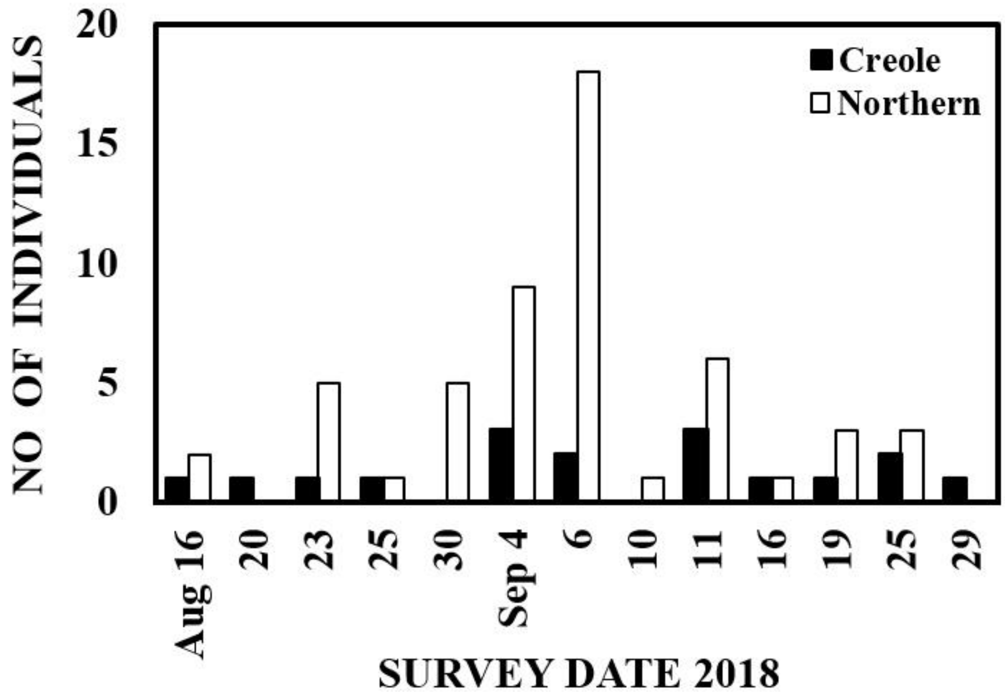

Figure 8. Number of Creole and Northern Pearly-eye butterflies sighted during 2018.

A single Southern Pearly-eye was observed near Site 3 on 4 September 2018 and represents the first known sighting of this butterfly in James City County. It also appears to be an extension of their range northward. This discovery was not unexpected because Creoles and Southerns have very similar ranges, often occur together in similar habitats, and both use Switch Cane as a caterpillar host plant (Glassberg, 1999; Cech & Tudor, 2005; Alabama Butterfly Atlas, 2020). Two more Southerns were documented during 2019: the same individual on 16 and 18 May near Site 4, and a second individual on 10 July between Sites 3 and 4.

During 2019, a total of 913 pearly-eye sightings were recorded, of which 745 were photographed. Careful examination of these photographs revealed 126 individuals had been photographed more than once during a survey, resulting in 173 duplicate images. The duplicates were eliminated, leaving 572 photographed sightings. Seven of those could not be identified to species and the remaining 565 were identified as 413 Northern, 149 Creole, and two Southern Pearly-eyes. The 168 unphotographed sightings were visually identifiable only as pearly-eyes.

According to Opler & Krizek (1984) and Opler & Malikul (1998), Virginia has two broods of both Creole and Northern Pearly-eyes from approximately May to September. The number of Creole and Northern Pearly-eye butterflies observed during 2019 are shown in Figs. 9 and 10, respectively, and as expected, two broods are clearly shown for both species within the reported

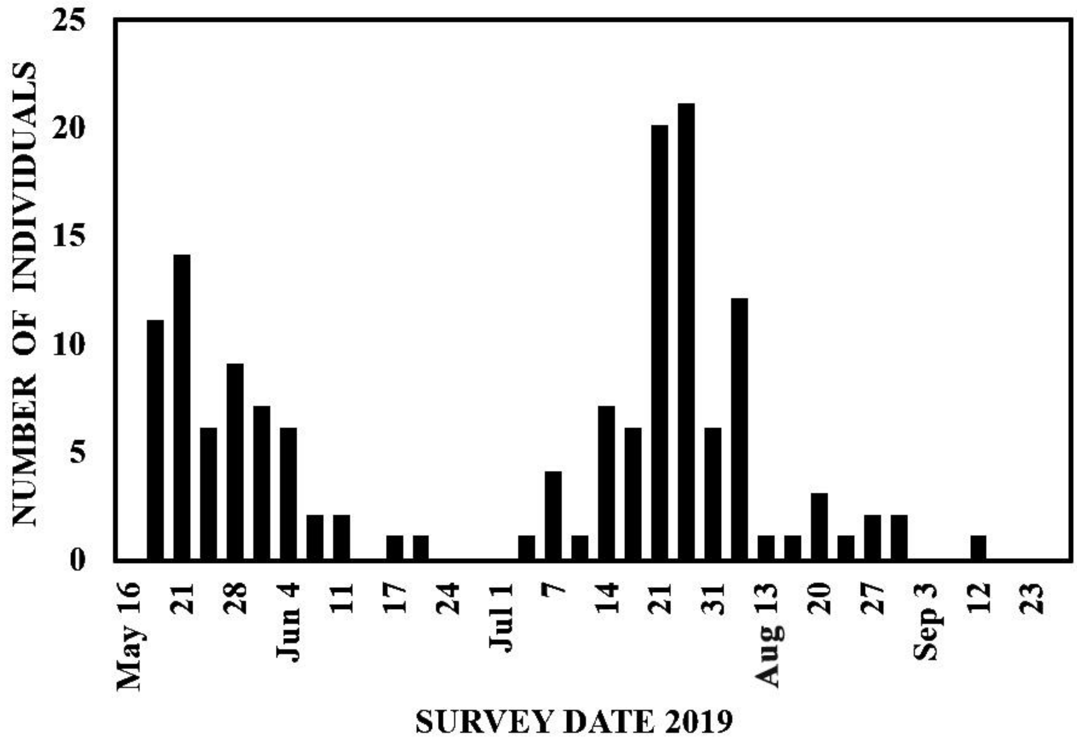

Figure 9. Number of Creole Pearly-eye butterflies sighted during 2019.

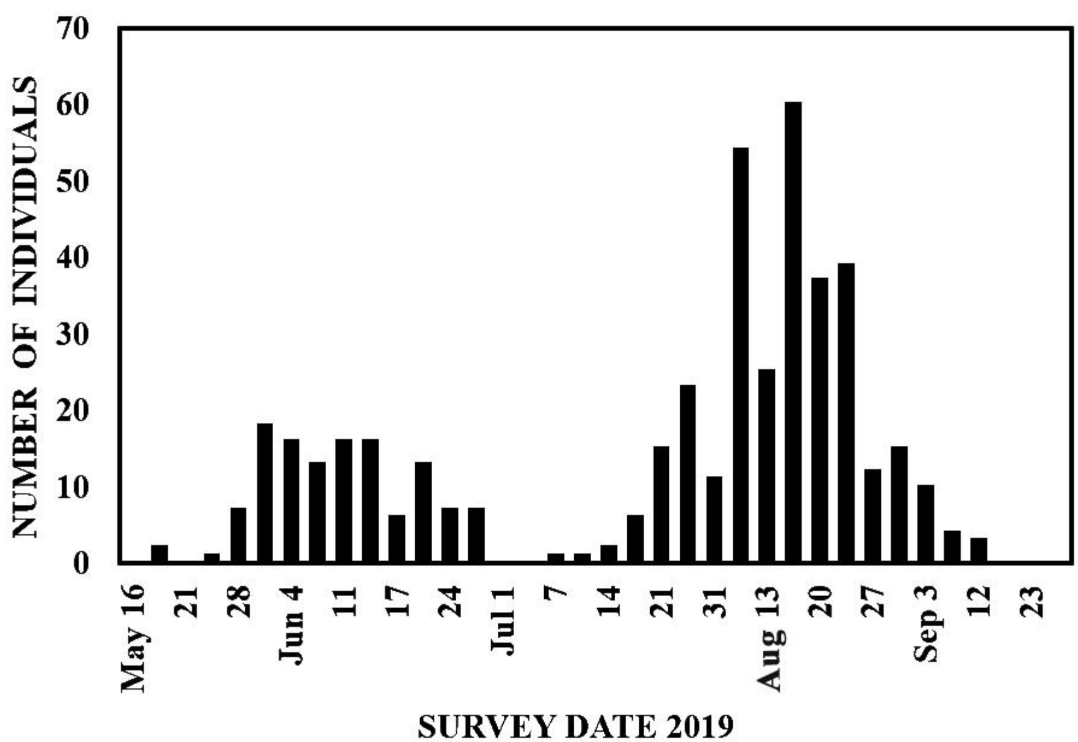

Figure 10. Number of Northern Pearly-eye butterflies sighted during 2019.

time frame. Having sighted only three Southerns during this study, it is not possible to say how many broods of Southern Pearly-eyes occur in the NOL area. However, the timing of Southern sightings (May, July, and September) certainly suggests the possibility of three broods. This would be consistent with the above authors reporting three broods for Southerns.

After finding the two stands of Switch Cane in the Study Area, observers expected to regularly encounter Creole and possibly Southern Pearly-eye butterflies in or near one or both stands. However, none were observed there during surveys conducted in 2018, and while four pearly-eyes were observed in the east stand of cane during 2019, three of them were Northerns. The fourth was a Creole, which appeared to be very fresh, likely recently eclosed. Instead, Creoles and Southerns were observed well away from both stands of cane, the majority in the forest across the Parkway from the west stand of cane (Fig. 11).

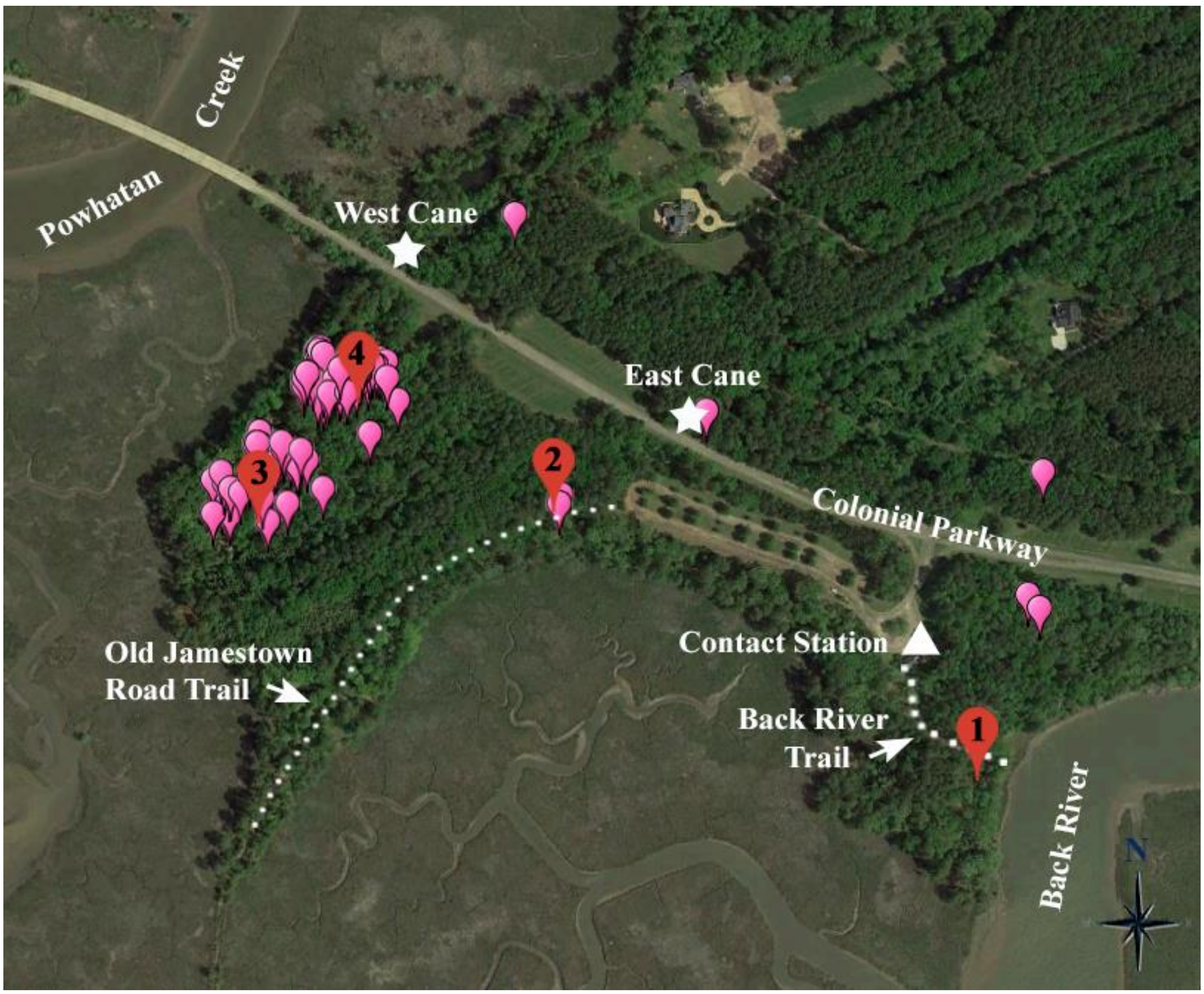

Figure 11. Google Earth 2020 map showing locations where Creole Pearly-eye butterflies were sighted in 2019; Sites 1, 2, 3, and 4, indicated by red markers, represent locations where Creoles were sighted during 2016-2019.

All three pearly-eye species are reported to be most active during late afternoon or twilight hours, or on cloudy days (Opler & Krizek 1984; Tveten & Tveten 1996; Cech & Tudor 2005; Belth 2013; Butterflies of Massachusetts 2020). In 2018, two surveys were conducted during the hours of 9:30 AM to 12:30 PM under completely overcast conditions, but no pearly-eye butterfly activity was observed (butterflies taking flight after being disturbed by the approach of an observer was not considered active flight). In 2019, three surveys were conducted under completely overcast conditions. One was conducted during the hours of 9:00 AM to Noon, the other two during the hours of 1:30 PM to 4:30 PM. No pearly-eye activity was observed during the morning survey, but observers did encounter pearly-eye butterflies actively flying during both afternoon surveys. These observations suggest that pearly-eyes are not active all day on cloudy days, but become active only later in the day.

The activity observed appeared to be territorial behavior associated with mating, viz, perched males waiting for the opportunity to mate with a passing female or chase off rival males or other intruders. In an area roughly 20 m in diameter, eight to 10 pearly-eye butterflies were observed actively flying near the ground, while two other pearly-eyes were observed perched head down approximately two meters above ground on different tree trunks; perched individuals were identified as Northerns and were assumed to be males; actively flying butterflies were identifiable visually as pearly-eyes but the species could not be determined. Observers stood in the area and watched as a perched individual left its vantage point to investigate a passing butterfly, often pursuing that individual in tight circles for several seconds or more. Then the first individual ceased its pursuit and returned to a tree trunk (often the same one) to resume its vigil. Sometimes three pearly-eyes became involved in these short-lived pursuits. Even a passing black morph Eastern Tiger Swallowtail (*Papilio glaucus*) was chased by one of the perched Northerns. This behavior was witnessed multiple times as observers watched for about 10 min during each of the two overcast afternoon surveys.

The absence of adult Creoles and Southerns in or near the two stands of Study Area cane, as well as their presence in two fairly specific locations (Sites 3 and 4, Fig. 11) is a mystery. Both stands of cane are located adjacent to the Parkway with their southern edges exposed, so it would seem natural following eclosure for butterflies to fly away from the Parkway and toward the darker forest interior. However, they did not do this, choosing instead to fly across the open Parkway and into the forest well away from their host plants, influenced by factors not apparent to observers.

Northern Pearly-eyes were sighted throughout the Study Area (Fig. 12), although there were three locations where they were sighted in greater numbers: between Sites 3 and 4, west of the Contact Station, and across the Parkway northeast of the Contact Station. An obvious benefit of such concentrations is that both sexes are present in higher numbers and opportunities for successful matings are greatly increased. When different pearly-eye species occupy the same habitat, there may be a natural predilection, perhaps even a pheromonal component, for comingling. Thus, the presence of large numbers of Northerns in the vicinity of Sites 3 and 4 may have been a factor attracting Creoles and Southerns to that area, or perhaps better food resources were available, attracting all three species.

According to Porter (2016), finding all three pearly-eye species together is a rare event. Upon finding all three pearly-eye species at the same time in the Tallassee Forest in Athens-Clarke County, Georgia, he commented: “The presence of three virtually indistinguishable, but genetically distinct, species at the same time and in the same place is almost unheard of outside the tropics.” Pyle (2010) reported finding all three pearly-eye species at the same time on a farm in southern Illinois, and Cech & Tudor (2005) state that all three pearly-eye species can be found together in parts of Arkansas.

As mentioned previously, Northern Pearly-eyes use a variety of woodland grasses as host plants for their caterpillars. According to Virginia Botanical Associates (2020), several of these grasses [Bearded Shorthusk (*Brachyelytrum erectum*), White Cutgrass (*Leersia virginica*), Bitter Panic Grass (*Panicum amarum*), and Velvet Panic Grass (*Dichanthelium scoparium*)] occur in James City County, but only the latter two were found in the Study Area. While it is possible that some Northerns use these plants as hosts, none were found in numbers large enough to support the population of Northerns encountered in the Study Area.

The Maryland Biodiversity Project (2020) and NABA-NJ (2020) indicate that Northern Pearly-eyes in Maryland and New Jersey have adapted to using Japanese Stiltgrass as a host plant. Based on survey results, it appears that Northern Pearly-eyes in the Study Area also have adapted to using Stiltgrass as a host plant because those sections of the Study Area with the highest number of Northern sightings also had the greatest abundance of Stiltgrass (Fig. 12).

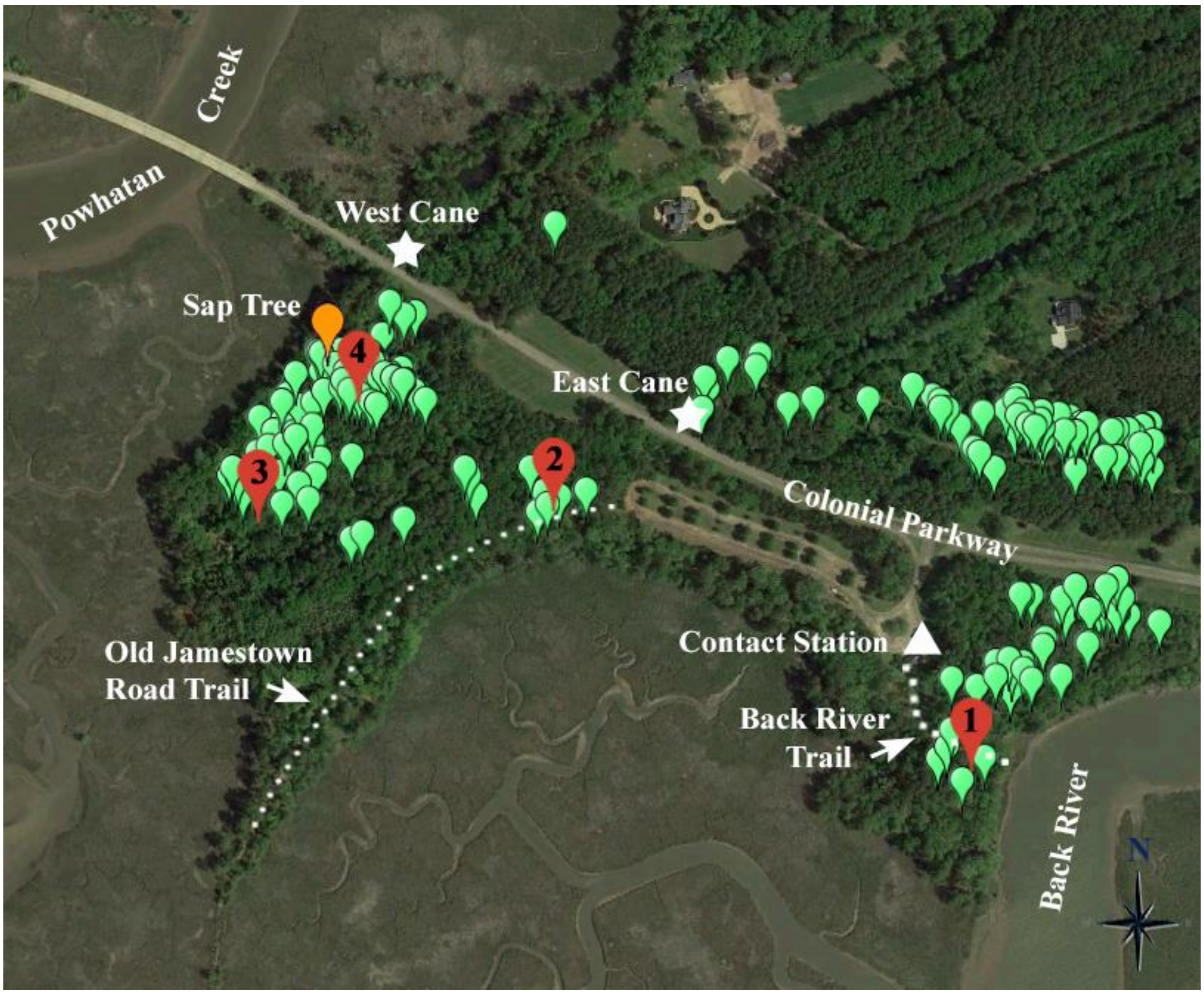

Figure 12. Google Earth 2020 map showing locations where Northern Pearly-eye butterflies were sighted in 2019; Sites 1, 2, 3, and 4, indicated by red markers, represent locations where Creoles were sighted during 2016-2019.

During the initial 2018 search for *Arundinaria*, it was noted that Stiltgrass was present in the forests on both sides of the Parkway east of the Study Area. The plant was not widespread in the forest on the south side of the Parkway, but considerably more was growing in the forest on the north side of the Parkway (although not as extensively as in the Study Area). This suggested that Northern Pearly-eyes might be present in one or both forests, but no pearly-eyes were sighted in either forest during foot searches conducted on 29 June, 25 July, and 21 August 2019. During the Jamestown Island search for cane, a single Creole and a single Northern Pearly-eye butterfly were sighted near the first stand east of where the 3-mile Loop Drive splits off from the 5-mile Loop Drive (Fig. 2).

Pearly-eye Butterfly Identification

After examining many hundreds of pearly-eye photographs, one thing became very clear: there is a lot of variation within and between characters and no single character can be relied on for identifying any pearly-eye species. This includes the "diagnostic" orange antennal clubs of Southern Pearly-eyes. Northerns and Creoles have black antennal clubs with orange tips, so this would seem to be a foolproof method for identifying as a Southern any pearly-eye with orange antennal clubs. However, this proved not to be the case. Of the 638 pearly-eye photographs taken during this study (excluding duplicates and those not identifiable to species), images of 308 Northerns, 131 Creoles, and three Southerns clearly showed both antennae. Among the Creole images was one individual with two orange antennal clubs and another individual with one orange antennal club and one "normal" antennal club. Whether rare genetic anomalies or a sign of interbreeding, this demonstrates the need to consult multiple resources and use a combination of characters to properly identify pearly-eye butterflies. It also stresses the importance of taking good photographs to help with identification.

ACKNOWLEDGEMENTS

The following individuals and organizations are gratefully thanked for their assistance with this project: Dorothy Geyer, US National Park Service Natural Resource Specialist, approved this study and issued permits granting access to NPS property in the Neck of Land and Jamestown Island areas; Emily Hinson, Lower James Regional Outreach Manager for the JRA, granted access to JRA facilities in the Neck of Land area, and Ryan Walsh, Lower James Restoration Coordinator for the JRA, participated in several Study Area surveys. The following volunteers from the Historic Rivers Chapter of Virginia Master Naturalists and the Coastal Virginia Wildlife Observatory assisted with the search for Switch Cane or participated in Study Area surveys, or both: Adrienne Frank, Gary Driscole, Brian Taber, Nancy Barnhart, Jan Lockwood, Shirley Devan, and Lester Lawrence. Adrienne Frank and Gary Driscole identified plants and trees in the Study Area, and Helen Hamilton identified grasses, sedges, and rushes in the Study Area. Allen Belden provided valuable comments and guidance throughout this study. Photographs are by the author.

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Errata

Steury, B. W. 2020. Land snails and slugs from a suburban yard in Fairfax County, Virginia. Banisteria 54: 19-30.

All references to *Triodopsis juxtidens* (Pilsbry) should be amended to *Triodopsis hopetonensis* (Shuttleworth). This emendation has been confirmed by Timothy A. Pearce, Curator of Collections, Section of Mollusks, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania.

Reports

1. **Minutes of the Executive Committee of the Virginia Natural History Society** (Virtual) Meeting held on October 31, 2020.

The 2020 meeting of the Executive Committee of the Virginia Natural History Society was called to order by President Nancy Moncrief at 10.04 a.m. on October 31, 2020. In attendance were Nancy Moncrief, Kal Ivanov, Karen Powers, Paul Marek, Michael Lachance, Todd Fredericksen, Art Evans, and Curt Harden

The minutes were approved from the November 2, 2019 Executive Committee Meeting by unanimous consent.

Moncrief asked for ratification of an April 2020 vote via email that changed *Banisteria* to an open-access journal; the change had been approved by majority in the email vote as follows: Evans, no; Fredericksen, yes; Harden, yes; Ivanov, no; Lachance, yes; Marek, yes; Powers, yes. The email vote was ratified by unanimous consent.

A question was raised by Evans regarding the function of the VMNH Foundation. Moncrief and Ivanov responded that VMNH Foundation does critical paperwork and accounting.

Moncrief inquired if late October is as a good time for Executive Committee Meeting, and those present responded, yes.

Topics:

Membership Report (Moncrief): As of September 16, 2020, there are two student members, 56 regular members, and one group member (i.e., Friends of Dyke Marsh). Libraries have discontinued subscriptions because the journal is open access. Due to the SARS-CoV-2 global pandemic, the VNHS Annual Member's meeting was suggested to be an online-only meeting in 2021.

Treasurer Report (Moncrief and Ivanov): Society total funds balance as of September 24, 2020 is $ 16,639. The costs for printing and mailing *Banisteria* numbers 52 and 53 were $3,053.09. The dues, contributions, and payments for back issues since 2 November 2019 was $ 2141.13. The fees to be paid for website services as follows: $0 for virginianaturalhistorysociety.org (this domain and hosting was discontinued in 2020 as a result of discussions at November 2019 meeting), $32.98 for the domain, virginianaturalhistory.com (paid in 2019, assuming equal or greater charge for 2020), $0 for hosting virginianaturalhistory.com (this hosting has been paid through 2021). The fees paid to VMNH Foundation for managing VNHS accounts is $250 per year.

Newsletter and Webmaster Report (Marek): Newsletter for 2020 was sent out to members by email in April 2020. It was stated that the email with the newsletter attached failed to successfully send to numerous members' addresses; it was identified that these email addresses may have been invalid.

In 2020, accepted articles in *Banisteria* were sent to the webmaster by the editor and were posted on the VNHS website as open-access. As of October 31, 2020, there are 10 published articles in issue 54 (2020) of *Banisteria*. It was noted that is about double the number of articles that would normally be published in (non-open-access/paper) issues over the past several years. It was suggested that social media notifications announcing new papers should continue and ideally include photographs representative of the material published.

The webmaster indicated that the website is operational and serving its proper function. While there are ostensibly minor issues with security (it is http and not https) and functionality, the underlying hand-built HTML code by the previous webmaster is robust and loads quickly. While it was suggested that there is availability of a web-builder at the VMNH, committee members and the webmaster concluded that a website rebuild was not needed at this time.

Editor report (Fredericksen): As of October 31, 2020, there are 10 published articles in issue 54 (2020) of *Banisteria*. The webmaster recently received the 11th accepted article, which will be posted in early November 2020. Executive committee member discussion concluded that a compiled issue 54 be assembled as a single PDF at the end of 2020, and posted to the *Banisteria* website. This should include items of the Society's business (such as minutes of the Executive Committee meetings) published in past (paper) versions. Editor Fredericksen recommended participation by associate editors. The Society agreed to continue to charge a fee of $50 for papers for non-members.

Councilor Evans suggested format modifications to the current online open-access articles to make them more consistent with previously published papers. Marek suggested consistent font usage: including changing the page number font to match the body font and changing hyperlinks and email links to black font and not underlined blue font. Fredericksen will implement these changes and email the next accepted article as a PDF to the Executive Committee for format review.

Vice President Ivanov raised the opportunity to have a monthly online member meeting through the software Zoom. Powers recommended that the event be live for members, and therefore allow participation, and be recorded for non-members. Committee discussion broadly accepted that this event would be beneficial to engage younger members. Subsequently a discussion of engagement of members ensued. Marek re-suggested a prior recommendation by Eckerlin of a small grant program. Evans suggested including Virginia Master Naturalists. It was agreed that purchasing a Zoom subscription would not be needed due to its availability elsewhere.

Moncrief raised the need for an election for Vice President and Councilor. The webmaster will receive biographies and produce and deploy a ballot through email distribution. Currently there are two positions. Powers will run for Vice President and is unopposed. Jason Gibson and Jackson Means will run to fill the remainder of Powers' term as Councilor. The timeframes are as follows: Vice Presidential term is January 2021 – December 2022, and Councilor term is January 2021 – December 2021. The election will be open for two weeks for voting; after which the votes will be tallied.

The meeting was adjourned at 12:05 p.m.

Respectfully submitted,
Paul E. Marek, Secretary and Webmaster

2. **President's Report**

The minutes of the VNHS Executive Committee meeting held on 31 October 2020 are included in this issue. That meeting included ratification of a 2020 April vote by a majority of the Executive Committee to change *Banisteria* to an electronic-only, open-access journal.
The Committee also discussed holding the third general meeting of the Society as an online-only conference during the Fall of 2021. We hope to be able to return to in-person meetings in 2022.

We will announce details of the digital meeting as soon as possible, probably in the late Spring of 2021.

As I noted in my report last year, Number 53 was the last printed issue of *Banisteria*. As of this writing, 10 articles have already been published in 2020 and are available on the VNHS website. Also, as I noted last year, most or all of the Society's business (e.g., announcements, ballots, dues notices) have transitioned to an electronic format.

Members should visit the VNHS website frequently to read recently published articles and announcements as they are posted. I also encourage members to contact the VNHS Business Office to confirm that it has their current e-mail address.

Respectfully submitted,
Nancy D. Moncrief, VNHS President

3. **Treasurer's Report**

As of 24 September 2020, there was a funds balance of $16,639. Also, as of 24 September 2020, a total of $3,053.09 had been paid (all expenses were costs for printing and mailing *Banisteria* number 52 and 53). The following expenses have not been paid yet, but are due in 2020: 1) approximately $33 for fees related to domain hosting of virginianaturalhistory.org and 2) a total of $500 for fees charged by VMNH Foundation for managing VNHS accounts ($250 per year for 2019 and 2020).

Respectfully submitted,
Nancy Moncrief and Kal Ivanov, VNHS Co-Treasurers

4. **Editor's Report**

Volume 54 is the first issue of *Banisteria* to be published online. Papers received this year were published individually online after acceptance and were compiled together in this year-end volume. This will be the plan going forward – immediate online publishing and one year-end volume compilation. This year, we also expanded our editorial board with six new associate editors who have expertise in a wide array of subject areas within the field of natural history. I thank each of them for their service. Papers submitted to the journal are now divided into four sections: regular papers, field notes, citizen-science contributions, and book reviews. Prospective authors should discuss with me their preference for assignment to one of these categories.

Finally, I would like to thank the following reviewers for Volume 54: Chris Bloch, Don Chandler, Ray Dueser, Ralph Eckerlin, Art Evans, Mike Ferro, Curt Harden, Kal Ivanov, Clyde Kessler, Alexander Konstantinov, Chekka Lash, Jeff Nekola, Toni Peppin, Kathryn Perez, Karen Powers, Steve Powers, Dana Price, Ed Riley, and Bob Rose.

Respectfully submitted,
Todd Fredericksen, Editor

Virginia Natural History Society

http://virginianaturalhistorysociety.com/

General Information

The Virginia Natural History Society (VNHS) was formed in 1992 to bring together persons interested in the natural history of the Commonwealth of Virginia. The VNHS defines natural history in a broad sense, from the study of plants, animals, and other organisms to the geology and ecology of the state, to the natural history of the native people who inhabit it. The goals of the VNHS are to promote research on the natural history of Virginia, educate the citizens of the Commonwealth on natural history topics, and to encourage the conservation of natural resources.

Dissemination of natural history information occurs through publication of the society's journal *Banisteria* and an annual newsletter. The first issue of *Banisteria*, named in honor of John Banister (1650-1692), the first university-trained naturalist to work in Virginia, was published in 1992. Articles cover a wide array of subjects, and prospective authors are encouraged to submit manuscripts on any aspect of natural history in Virginia; papers may pertain to Virginia or regional archaeology, anthropology, botany, ecology, zoology, paleontology, geology, geography, or climatology. Biographies, obituaries, and historical accounts of relevance to natural history in Virginia are also welcomed. Manuscripts are peer-reviewed for suitability and edited for inclusion in the journal.

The society's website contains detailed instructions for prospective authors and PDF reprints of all *Banisteria* articles that are more than two years old. *Banisteria* is indexed by Zoological Record and is available through EBSCO and the Biodiversity Heritage Library.

Memberships

The VNHS is open to anyone with an interest in natural history and welcomes participation by all members in society activities and efforts to promote education and conservation. Membership includes a subscription to *Banisteria* and invitation to an annual meeting. Annual dues for members are $20 (per calendar year); library subscriptions are $40 per year. Payments may be made online or via a check or money order sent to the Treasurer. Copies of most back issues of *Banisteria* are available for sale at a reduced price. The VNHS is a tax-exempt, nonprofit, society under Section 501(C)3 of the IRS. We welcome donations to support our mission in Virginia.

Virginia Natural History Society

Application for Membership

Name ________________________________

Address________________________________

____

____

Zip Code ______________________________

Phone ________________________________

Email ________________________________

Area(s) of Interest _________________________

ANNUAL DUES AND SUBSCRIPTIONS TO *BANISTERIA*

- ☐ $500.00 Life (not annual)
- ☐ $300.00 Benefactor
- ☐ $100.00 Patron
- ☐ $50.00 Supporting
- ☐ $40.00 Institutional
- ☐ $25.00 Family
- ☐ $20.00 Regular
- ☐ $5.00 Student (see below)
- ☐ Contribution in addition to membership dues $______

The special student rate is applicable only when accompanied by the following certification signed by a faculty advisor (**students are also eligible for a 1-year free membership** if an advisor's nomination is approved by the society's Executive Committee; see nomination guidelines in *Banisteria*).

Institution ___________________________

Advisor ______________________________

Date_________________________________

Online membership registration and payments may be made at this website:

https://www.virginianaturalhistorysociety.com/membership/membership.html

If paying by mail, send membership form and dues (check or money order payable to Virginia Natural History Society) to:

Dr. Nancy Moncrief, VNHS Treasurer
Virginia Museum of Natural History
21 Starling Avenue
Martinsville, VA 24112