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EDITOR
Werner Wieland
Department of Biological Sciences
University of Mary Washington
Fredericksburg, VA 22401
Phone: (540) 654-1426

ACADEMY OFFICE
Executive Officer
Virginia Academy of Science
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Systematic Ichthyofaunal Surveys in Urban and Non-Urban Watersheds

Eugene G. Maurakis[1,2], David V. Grimes[3], Amanda Schutt[4], and Suzy Short[1]

[1]Science Museum of Virginia, 2500 W. Broad St., Richmond, VA 23220
[2]Biology Dept., University of Richmond, 28 Westhampton Way, Richmond, VA 23173
[3]Virginia Department of Environmental Quality, 13901 Crown Court, Woodbridge, VA 22193
[4]Virginia Commonwealth University, VCU Rice Center, 1000 W. Cary St., Richmond, VA 23284*

ABSTRACT

Objectives were to model fish species richness relative to natural and anthropogenic variables in Quantico Creek, a forested undisturbed stream environment, and Cameron Run, a highly disturbed urban stream environment in the lower Piedmont-Fall Line region of the Potomac River watershed. Species richness in all stream orders (e.g. avg. range=2.5-9.65 in 1st-3rd orders) of Quantico Creek were significantly higher than those (e.g. avg. range=2.1-7.6 in 1st-4th orders) of Cameron Run. Fish species richness in Quantico Creek watershed can be modeled by eight factors: season, stream order, elevation, river km, stream width and depth, watershed size, and percent of undeveloped land cover; and that in Cameron Run can be modeled with four factors: stream gradient, stream flow, water temperature, and percent undeveloped land cover. Therefore, it cannot be assumed that a model composed of one set of variables that represents species richness for a given watershed can be applied to a nearby watershed. Based on potential impacts of increased population growth and climate change in the area, coupled with a paucity of information on the extent of the use of the lower reaches of Quantico Creek as a spawning area for anadromous fishes, we propose that the national park, Prince William Forest Park, should be included as a freshwater protection area for the Quantico Creek watershed as proposed by the National Park Service for 50 other national parks in the country. Data and models generated in our study can serve as baselines in future comparative studies of mid-Atlantic streams relative to changes in system parameters (e.g. human population,

Corresponding author: emaurakis@smv.org
* Current address: Science from Scientists, 515 Beacon St., Boston, MA 02215

corresponding anthropogenic effects and climatic change predicted for the mid-Atlantic region).

Keywords: fish species richness modeling in watersheds

INTRODUCTION

Many lotic systems in the mid-Atlantic's Piedmont Region have been altered by human activities (e.g. agricultural, industrial and urban development), and few natural systems representing non-impacted conditions now exist. As such, discerning the effects of change in lotic systems is challenging due to the scarcity of baseline sites. However, a few mid-Atlantic Piedmont lotic systems have been preserved over the course of the past 50 to 100 years and as such provide a close approximation to baseline stream conditions. For example, the drainage basin of Quantico Creek is wholly within a national park (Prince William Forest Park) and a marine corps base (Quantico Marine Corp Base) where virtually no agricultural and urban development has occurred within the past 80 years. As such, Quantico Creek has been used as a benchmark control site for short-term environmental and ecological studies of watersheds in the mid-Atlantic's Piedmont region (2008 personal communication P. Petersen, Acting Chief Resource Manager, Prince William Forest Park).

Studies of fishes in freshwater streams have identified and quantified changes in fish distributions and species richness and diversity relative to natural changes in physical stream condition (e.g. elevation, gradient, and stream order) as well as anthropogenic perturbations (e.g. damming) (Azaele et al. 2009; Lotrich 1973; Maurakis and Grimes 2004; Maurakis et al. 1987; Mundy and Boschung 1981; Paller 1994). Accuracy of stream system modeling based on the accumulated data of historical studies has allowed more recent researchers (Argent et al. 2003) to use landscape-level physical variables in Geographical Information Systems to predict freshwater fish distributions in river drainages.

With 116 fish species, of which 86 are considered native (including one endemic, *Cottus cognatus*) and 30 as introduced, the Potomac River watershed has one of the richest ichthyofaunas in Chesapeake Bay drainage (Cummins 2006; Jenkins and Burkhead 1993). Historically, distributions of freshwater fishes in the Potomac River drainage have been presented for the entire drainage and used in biogeographic and aquatic impact studies. However, information on changes that may occur in species richness within discrete stretches (i.e., within the confines of a sub-watershed) relative to either natural or human induced changes in the environment in the Potomac River drainage is exiguous. Studies at the sub-watershed level have been typically focused on physical environmental variables and less on the modeling of the community structure of aquatic biota as a function of those variables. Studies of note for this research include Kelso et al. (2001), who investigated Quantico Creek's water and habitat quality relative to other sites in northern Virginia; Dawson (2010) who examined the ecological values and ecosystem services of Prince William Forest Park in northern Virginia; and Starnes et al. (2011) who examined fish occurrences in the vicinity of Plummers Island in the lower reaches of the Potomac River in vicinity of

Washington, DC. However, there have been no long-term monitoring studies conducted of fish populations at the sub-watershed level in the mid-Atlantic lower Piedmont and upper Coastal Plain regions to create a basis for understanding changes in community structure relative to natural and anthropogenic factors in the environment.

Objectives of this study were to model fish species richness relative to natural and anthropogenic physical variables in Quantico Creek, a forested undisturbed stream environment, and Cameron Run, a highly disturbed urban stream environment in the lower Piedmont-Fall Line region of the Potomac River watershed.

Study Area

The Quantico Creek watershed (approximately 4,778 ha) is 56 km S of Washington, DC. Its headwater tributaries and main stem above the fall line are entirely within Prince William Forest National Park and the Quantico Marine Corps Base. The watershed is predominantly piedmont forest that has had a minimal level of development since the close of World War II. Approximately 81 percent of the watershed is currently undeveloped land cover, and impervious cover in the watershed totals about 611 ha (12.8 %) (Maurakis et al. 2010). The population of approximately 3,500 people is concentrated in a small number of communities, the largest being located at or below the fall line. These watershed characteristics provided a low impact control site, which has been used in earlier studies in the region (Kelso et al. 2001).

The portion of the Cameron Run watershed included in this study is approximately 15 km South of Washington, DC, and did not include the area that drains into Lake Barcroft. The watershed area that was sampled is approximately 4,808 ha and lies within a highly developed urban and industrial environment with about 60 percent impervious cover. Undeveloped land cover is approximately 42 ha and the population is about 62.8 times greater (220,000) than that of the Quantico Creek study area (Maurakis et al. 2010).

MATERIALS AND METHODS

Fifteen sampling locations, representing stream orders 1, 2 and 3 were established in the Quantico Creek watershed and sampled monthly or bimonthly from November, 2008 through June, 2010. Seven sampling locations, representing stream orders 1, 2, 3, and 4 were sampled in the Cameron Run watershed during the same time period. Fishes were collected with a 12 or 24 Volt Smith-Root backpack electroshocker and dip-nets. Fishes were identified, counted and then returned to the stream except the invasive species *Channa argus* (Snakehead fish), which was saved and given to the VA Department of Game and Inland Fisheries.

Latitude, longitude, stream order, elevation (m), stream width and depth (m), gradient (m/km), river kilometer (distance from the mouth of the river to a collection point (km), water temperature (C), water velocity (m/sec), water flow (m^3/sec), and pH were recorded at each sampling station. The Horton method (1945) was used to assign stream order with the exception that intermittent streams were not classified as first order. Stream order was determined by tracing drainages on USGS Topographic maps (1:250000 scale) and verified through a GIS hydrology analysis. Map contours were used to determine gradients (m/km) for each collecting location. Elevation (m) was determined from a Garman Oregon 550t GPS receiver, and USGS topographic maps (1:125,000). Stream width (m) and stream depth (m) were measured with a meter stick, and water temperature (C°) with a hand held thermometer. River kilometer (km) was determined using USGS topographic maps (scale) and tracing the distance between a collecting location in a stream and the mouth of its parent river with a planimeter. Watershed and sub-watershed populations were determined from US census data, and watershed development (percents of impervious cover and vegetated land cover) was determined from GIS analysis of digital land cover maps from the University of Maryland's RESAC project.

Fish species richness was calculated using the raw number of species collected at each location. The Jaccard Coefficient of Similarity was used to determine taxa similarity between stream orders.

Detailed methods for GIS analyses are presented in Maurakis et al. (2010). Base maps were developed on 1:24k topographic maps of the study area (USGS 2006, 2010a-c). Collection stations for the study area were imported to the base map as x, y data using latitudes and longitudes collected in the field using a Garmin Oregon 550t GPS receiver. Polygons of the Quantico Creek and Cameron Run study area watersheds were was developed for use in sub-watershed analyses. The Cameron Run study area watershed did not include the portion of the watershed above the Lake Barcroft dam as it was assumed the lake would attenuate flows from that portion of the watershed. Sub-watersheds associated with each collection station were developed through a hydrology analysis of 30 m gridded Digital Elevation Models (ESRI 2008, 2010; USGS 2006, 2010a-c) using a flow accumulation weight of 400. Total population denisty, percent impervious surface and percent vegetated land cover were determined for each sub-watershed using the 2000 U.S. Census Block Group numbers and the 2000 RESAC land cover data (USDC 2009; RESAC 2000 CBW Impervious Surface Product – Version 1.3, CBW Land Cover – Version 1.5).

Correlation analyses (SAS 2009) were performed to determine significant relationships among biotic and physical parameters for each watershed. A General Linear Model followed by Duncan's Multiple Range Test (SAS 2009) was used to determine significant differences for each parameter. Multiple stepwise regression ($p=0.15$, SAS 2009) was used to determine factors accounting for significant variation in species richness in each watershed.

RESULTS

A total of 210 collections of fishes and physio-chemical parameters were made at 15 locations (stream orders, 1, 2, and 3) in Quantico Creek watershed; and 98 collections at seven locations (stream orders 1, 2, 3, and 4) in Cameron Run watershed from November, 2008 to June, 2010. Data and analyses are available upon request. Results are presented within watersheds and then between watersheds.

Quantico Creek watershed: A total of 29 fish species (representing 10 families) were collected in Quantico Creek (Table 1). The most frequently collected species were

TABLE 1. Presence (1) and absence (blank) of fish species collected in Quantico Creek and Cameron Run, VA from November, 2008-June, 2010.

	Quantico Creek Stream Order			Cameron Run Stream Order			
Species	**1**	**2**	**3**	**1**	**2**	**3**	**4**
Lampetra aepyptera			1				
Petromyzon marinus			1				
Anguilla rostrata	1	1	1			1	1
Esox niger		1	1				
Cyprinidae		1					
Clinostomus funduloides	1	1	1		1	1	1
Semotilus atromaculatus	1	1	1	1	1		1
Rhinichthys atratulus	1	1	1	1	1	1	1
Luxilus cornutus	1	1	1				
Exoglossum maxillingua	1	1	1				
Notropis procne		1	1			1	1
Semotilus corporalis		1	1				
Cyprinella analostana			1			1	1
Notropis hudsonius			1				1
Notemigonus crysoleucas		1	1				
Hybognathus regius			1				
Pimephales notatus						1	1
Catostomus commersoni		1	1	1	1	1	1
Erimyzon oblongus	1	1	1		1		1
Noturus insignis		1	1			1	
Ameiurus natalis			1		1	1	1
Ameiurus nebulosus			1		1		1
Fundulus diaphanus			1			1	1
Fundulus heteroclitus						1	1
Lepomis auritus	1	1	1			1	1
Lepomis gibbosus	1	1	1			1	1
Lepomis cyanellus	1	1	1		1		
Lepomis microlophus		1	1				
Lepomis macrochirus	1	1	1	1	1	1	1
Micropterus salmoides			1		1		1
Etheostoma olmstedi	1	1	1		1	1	1
Channa argus			1				
Total	12	20	29	4	11	15	19

Rhinichthys atratulus (12.3%), *Etheostoma olmstedi* (9.1%), *Lepomis auritus* (9.0%), *Clinostomus funduloides* (7.2%), *Semotilus atromaculatus* (6.1%), *Exoglossum maxillingua* (5.7%), *Semotilus corporalis* (5.6%), *Catostomus commersoni* (5.6%), *Lepomis cyanellus* (5.6%), *Notropis procne* (5.5%), *Noturus insignis* (5.5%) and *Erimyzon oblongus* (5.0%), which accounted for 82.2 % of occurrences of all fishes during the study period (Table 1). Six species (i.e., *N. procne*, *S. corporalis*, *Notemigonus crysoleucas*, *N. insignis*, *L. microlophus*, and *Esox niger*) were common in 2nd and 3rd order streams but not present in 1st order streams. Ten species (i.e., *Cyprinella analostana*, *Notropis hudsonius*, *Hybognathus regius*, *Ameiurus natalis*, *Ameiurus nebulosus*, *Fundulus diaphanus*, *Micropterus salmoides*, *Channa argus*, *Lampetra aepyptera*, and *Petromyzon marinus*) occurred in 3rd order streams only (Table 1).

Total species richness (12, 19, and 29 species) increased with increasing stream order from 1st, 2nd and 3rd order streams, respectively in Quantico Creek (Table 1). Average species richness (9.6) in stream order 3 was significantly greater than those (6.3 and 2.5 species) in stream orders 2 and 1, respectively (Table 2). Similarity of species composition between 1st and 2nd order streams was 60 percent (12 species in common); that between 2nd and 3rd order streams was 63 percent (19 species in common) (Table 3).

Fish species richness was positively correlated with stream order, stream width, depth, and current, stream flow, watershed size, human population, impervious cover, undeveloped land cover and water temperature, and negatively correlated to stream gradient (Table 4). Stream order was positively correlated with stream width, stream depth, stream current, watershed size, human population, impervious cover, undeveloped land, and stream flow; and negatively correlated with elevation, river km, and stream gradient. Percent undeveloped land cover was inversely correlated with human population ($r=-0.3071; p<0.0001$) and impervious cover ($r=-0.2454; p=0.0006$). The fish species richness model for Quantico Creek is composed of eight variables (Tables 5):

Fish species richness = 0.51449+(0.43460*Season) + (1.73006*Stream Order) + (0.04152*Elevation) + (0.25609*River km) + (0.23222*Stream Width) + (2.00873*Stream Depth) + (0.00081546*Sub-Watershed Size) + (-0.08121*Percent Undeveloped Land Cover)

Cameron Run watershed: A total of 21 species (representing seven families of fishes) were collected in the Cameron Run watershed (Table 1). The most frequently collected species were *R. atratulus* (17.8%), *S. atromaculatus* (10.8%), *C. commersoni* (10.4%), *C. analostana* (7.0%), *A. natalis* (7.6%), *E. olmstedi* (7.6%), *N. procne* (6.7%), and *L. auritus* (6.5%), which accounted for 74.4 % of all occurrences of species during the study period (Table 1). Three species (i.e., *R. atratulus*, *C. commersoni*, and *Lepomis macrochirus*) occurred in all four stream orders. Three species (i.e., *C. funduloides*, *A. natalis*, and *E. olmstedi* occurred only in stream orders 2, 3, and 4. Eight species (i.e., *N. procne*, *C. analostana*, *P. notatus*, *A. rostrata*, *Fundulus heteroclitus*, *F. diaphanus*, *L. auritus*, and *Lepomis gibbosus*) were collected only in stream orders 3 and 4. *Notropis hudsonius* occurred only in stream order 4. Similarity of species composition was low (36 and 30%) between 1st and 2nd order streams and

TABLE 2. Results of Duncan's Multiple Range test (SAS, 2009) of mean values of species richness by stream order in Quantico Creek and Cameron Run watersheds, VA from November, 2008 – June, 2010. Underscored means do not differ significantly at p=0.05.

Quantico Creek Stream Order	1	2	3	
Mean	2.53	6.30	9.65	
F = 107.1, p>F = <.0001				
Cameron Run Stream Order	1	2	4	3
Mean	2.11	5.32	7.59	8.08
F = 42.6, p>F = <.0001				

between 2nd and 3rd order streams, respectively; and 70 percent between 3rd and 4th order streams (Table 3).

Total species richness increased with increasing stream order (i.e., 1st order=3 species; 2nd order=11 species; 3rd order=15 species; and 4th order=19 species) in Cameron Run (Table 1). Average species richness values (avg. range=7.6-8.1) in 4th and 3rd stream orders, respectively, were significantly higher than those (avg. range=2.1-5.3) in 1st and 2nd stream orders, respectively (Table 2).

Fish species richness was positively correlated with stream order, stream width, stream current, stream flow, water temperature, watershed size, human population, impervious cover, and undeveloped land cover; and negatively correlated with elevation and river km (Table 4). Stream order was positively correlated with stream width, current, flow, and water temperature; sub-watershed size, human population, impervious cover, and undeveloped land cover; and negatively correlated with elevation, river km, and gradient (Table 4). Sub-watershed size and human population were correlated with impervious cover ($r=0.999$; $p<0.0001$ and $r=0.984$; $p<0.0001$, respectively), undeveloped land cover ($r=0.993$; $p<0.0001$ and $r=0.966$; $p<0.0001$, respectively), and stream flow ($r=0.354$; $p=0.0004$ and $r=0.414$; $p<0.0001$, respectively). The fish species richness model for Cameron Run is composed of four variables (Table 5):

Fish species richness = 10.10139 + (-0.62161*Gradient) + (0.11283*Water Temperature) + (0.18116*Stream Flow) + (-0.03953*Percent Undeveloped Land Cover)

TABLE 3. Number of species per stream order, species in common and unique in stream orders, and Jaccard Coefficient of Similarity of Species in Quantico Creek and Cameron Run watersheds, VA from November, 2008 – June, 2010.

Watershed	Stream order	Total # species	Stream order comparison	# species in common	Species unique to lower order	Species unique to higher order	Jaccard Coefficient of Similarity x 100
Quantico	1	12	1 and 2	12	0	8	60
	2	20	2 and 3	19	1	10	63
	3	28					
Cameron	1	4	1 and 2	4	0	7	36
	2	11	2 and 3	6	5	9	30
	3	15	3 and 4	14	1	5	70
	4	19					

TABLE 4. Relevant significant (>0.05) correlation results of fish species richness and physiochemical parameters in Quantico Creek and Cameron Run watersheds from November, 2008-June, 2010. Blanks indicate non-significant correlations.

	Quantico Creek		Cameron Run	
	Richness	Order	Richness	Order
Order	0.743		0.716	
Width	0.544	0.756	0.640	0.690
Depth	0.364	0.330		
Water current	0.149	0.272	0.346	0.368
Stream flow	0.254	0.265	0.372	0.409
Sub Watershed size	0.541	0.776	0.562	0.874
Human population	0.483	0.581	0.656	0.894
Impervious cover	0.339	0.384	0.565	0.871
Undeveloped land cover	0.543	0.788	0.561	0.902
Water Temp	0.165		0.438	0.203
Gradient	-0.448	-0.519		-0.831
Elevation		-0.309	-0.831	-0.916
River km		-0.160	-0.574	-0.734

Interdrainage comparisons

GIS Parameters: Human population (103,728) in the 4th order Cameron Run sub-watershed was significantly greater than those (avg. range=0-44,811) in all Cameron Run and Quantico Creek sub-watersheds (Table 6). Impervious cover (3,428.4 ha) in the 3rd and 4th order sub-watersheds of Cameron Run were significantly greater than those (avg. range=12.4-1,412.2 ha) in all other sub-watersheds of both Cameron Run and Quantico Creek (Table 6). Percentage (avg. range=83.35-94.39) of hectares of undeveloped land cover in 1st, 2nd, and 3rd sub-watersheds of Quantico Creek were significantly greater than those (avg. range=26.67-48.22) in 1st, 2nd, 3rd, and 4th order sub-watersheds of Cameron Run (Table 6).

TABLE 5. Results of stepwise multiple regression for fish species richness in Quantico Creek and Cameron Run watersheds, VA from November, 2008 – June, 2010.

Quantico Creek Variable	Parameter Estimate	F Value	Pr > F
Intercept	0.51449	0.11	0.7361
Season	0.4346	12.7	0.0005
Stream order	1.73006	16.97	<.0001
Elevation (m)	0.04152	21.85	<.0001
River Km	0.25609	31.75	<.0001
Stream width (m)	0.23222	3.32	0.0703
Stream depth (m)	2.00873	3.5	0.0633
Watershed size (ha)	0.00081546	8.74	0.0036
% Undeveloped land cover	-0.08121	31.89	<.0001

Cameron Run Variable	Parameter Estimate	F Value	Pr > F
Intercept	10.10139	117.04	<.0001
Stream gradient (m/km)	-0.62161	145.77	<.0001
Stream flow (m3/sec)	0.18116	4.12	0.0463
Water Temperature (C)	0.11283	23.98	<.0001
% Undeveloped land cover	-0.03953	6.99	0.0102

Fish species richness and composition: Overall, nine species (i.e., *L. cornutus*, *E. maxillingua*, *S. corporalis*, *N. crysoleucas*, *Hybognathus regius*, *Lepomis microlophus*, *Channa argus*, *Lampetra aepyptera*, and *Petromyzon marinus*) present in Quantico Creek were not collected in Cameron Run watershed (Table 1). Nine species (i.e., *C. funduloides*, *L. cornutus*, *E. maxillingua*, *E. oblongus*, *A. rostrata*, *L. auritus*, *L. gibbosus*, *L. cyanellus*, and *E. olmstedi*) were present in 1st order streams of Quantico

TABLE 6. Results of Duncan's Multiple Range Test (SAS, 2009) among watershed size (ha), human population, impervious cover (ha), undeveloped land cover (ha), and % undeveloped land cover in Quantico Creek and Cameron Run watersheds, VA. Underscored means do not differ at p=0.05.

Watershed size

Habitat	Quantico-1	Cameron-1	Quantico-2	Cameron-2	Cameron-3	Quantico-3	Cameron-4
Mean	71	152	581	605	2011	3371	4808

F = 7.17, p>F = 0.0009

Human population

Habitat	Quantico-1	Quantico-2	Quantico-3	Cameron-1	Cameron-2	Cameron-3	Cameron-4
Mean	0	240	1250	2342	10957	44811	103728

F = 69.12, p>F =<.0001

Impervious cover

Habitat	Quantico-1	Quantico-2	Cameron-1	Quantico-3	Cameron-2	Cameron-3	Cameron-4
Mean	12.4	41.0	91.3	188.8	287.8	1412.2	3428.4

F = 16.19, p>F =<.0001

Undeveloped land cover

Habitat	Cameron-1	Quantico-1	Cameron-2	Quantico-2	Cameron-3	Cameron-4	Quantico-3
Mean	59.0	67.8	291.2	550.3	809.5	1599.5	3059.5

F = 7.40, p>F = 0.0008

% Undeveloped land cover

Habitat	Cameron-1	Cameron-4	Cameron-3	Cameron-2	Quantico-2	Quantico-3	Quantico-1
Mean	26.7	33.3	41.6	48.22	83.4	93.0	94.4

F = 12.90, p>F =<.0001

Creek but not collected from 1st order streams of Cameron Run. In a comparison of 2nd order streams, *L. cornutus*, *E. maxillingua*, *N. procne*, *S. corporalis*, *N. chrysoleucas*, *N. insignis*, *A. rostrata*, *F. diaphanus*, *L. auritus*, *L. gibbosus*, and *L. microlophus* were present in Quantico Creek 2nd order streams but not in those of Cameron Run. A total of 14 species (i.e., *L. cornutus*, *E. maxillingua*, *S. corporalis*, *N. hudsonius*, *N. chrysoleucas*, *H. regius*, *E. oblongus*, *A. nebulosus*, *L. cyanellus*, *L. microlophus*, *M. salmoides*, *C. argus*, *L. aepyptera*, and *P. marinus*) occurred in 3rd order streams of Quantico Creek but were absent from 3rd order streams of Cameron Run (Table 1). In contrast, only two species (i.e., *Pimephales notatus* and *Fundulus heteroclitus*) occurred in both 3rd and 4th order streams of Cameron Run but not in any stream orders of Quantico Creek (Table 1).

Species richness (avg.=9.65) in 3rd order Quantico Creek was significantly higher than those (avg. range=7.6-8.1) in 3rd and 4th orders in Cameron Run (Table 7). Species composition similarity in Quantico Creek 1st and 2nd order streams (60 %) and that between 2nd and 3rd order streams (63 %) were about twice those in Cameron Run 1st-2nd order (36 %) and Cameron Run 2nd-3rd order (30 %). Cameron Run species composition similarity (70 %) between 3rd and 4th order streams was comparable to that (63 %) for Quantico Creek 2nd-3rd order (Table 3).

DISCUSSION

Long-term studies of discrete stream segments or stream orders are crucial to understand and predict changes in fish communities that may result from changes in system parameters. The present investigation resulted in establishing a broad scope of baseline data for fish communities, and creating models for fish species richness in two mid-Atlantic stream systems, lower Piedmont forest (Quantico Creek) and urban (Cameron Run) watersheds. The current study's baseline data and models are requisite for future comparative studies of these mid-Atlantic streams relative to changes in system parameters (e.g. human population, corresponding anthropogenic effects, and climatic changes that have been modeled for the mid-Atlantic region). For example, the population in the Cameron Run watershed has been projected to increase by 100 percent or more by 2050 (CARA 2006). The high human population and impervious cover in the Cameron Run watershed were significant factors accounting for reduced species richness compared to that in Quantico Creek watershed (Table 6). These results suggest that the forecasted population growth has the potential to significantly impact fish communities in the Cameron Run watershed. Our study's predictive model captures this relationship, which can be applied in determining alterations in fish communities relative to these and other forecasted changes in this urban watershed. The use of this predictive model in the land planning process can facilitate the environmental impact avoidance and minimization analysis of proposed development plans in a watershed that is already significantly impacted relative to the nearby forested Quantico Creek watershed. Studies of plant species richness by Tilman (2001) and Tilman et al. (1997, 2006) and those of aquatic food webs by Steiner et al. (2005) have demonstrated that more species diverse communities are more resilient to environmental changes than those with fewer species. Higher degrees of biodiversity

TABLE 7. Results of Duncan's Multiple Range Test (SAS, 2009) of fish species richness by stream order in Quantico Creek (QC) and Cameron Run CR) watersheds, VA from November, 2008 – June, 2010. Underscored means do not differ at p=0.05.

Habitat	CR-1	QC-1	CR-2	QC-2	CR-4	CR-3	QC-3
Mean F=61.51, p>F=<.001	2.11	2.53	5.32	6.30	7.59	8.08	9.65

in a community or in an ecosystem give the systems stability (Tilman 1997). A worthwhile research project in the future will be to determine if the already compromised fish communities in each of the stream orders of Cameron Run will be able to sustain themselves relative to the projections of increased human population and concomitant impacts (e.g. additional stream pollutants, habitat alteration, and potential decreases in remaining forest cover), and hydrologic changes that may be associate with climate change modeled for the area. In a report on the effects of climate change in the Champlain Basin, Stager and Thill (2010) indicated that rising temperatures may also exacerbate late-summer low flows by increasing evapotranspiration through vegetation and evaporation from land and water surfaces, warmer and less oxygenated tributaries in summer, changes in the timing of spawning, increased erosion and siltation, and physical disruption of streambeds.

The variability in terrestrial and aquatic features that defines discrete segments in watersheds is crucial to take into account when making comparisons between ichthyofaunas in different watersheds. Of particular note is the trenchant difference between the parameters that comprise the mathematical models for the forested Quantico Creek watershed and the urbanized Cameron Run watershed. Fish species richness in Quantico Creek watershed currently can be modeled by eight factors: season, stream order, elevation, river km, stream width and depth, watershed size and percent of undeveloped land cover (Table 5). That in Cameron Run can be modeled with three different factors (stream gradient, stream flow, and water temperature), and one (percent undeveloped land cover) also used in the Quantico Creek model (Table 5). Therefore, it cannot be assumed that a model composed of one set of variables that represents species richness for a given watershed can be applied to a nearby watershed. As a result, researchers should evaluate species richness by discrete segments within a given watershed as the abiotic and biotic features defining these segments cannot be assumed to be comparable within or between watersheds. We caution that direct applications of our two species richness models to other watersheds are limited because they are unique to watersheds we studied.

Anthropogenic effects have been demonstrated to impact species richness independently of stream order as was observed in Cameron Run. For example, Schlosser (1987) stated that species richness tended to increase from modified to natural upstream areas. Based on the differences in species richness models between Quantico Creek and Cameron Run watersheds, we propose that stream order and its other correlated factors used to model species richness in forested watersheds where human disturbance is minimal, are not appropriate for streams in highly modified urban environments such as those in the Cameron Run watershed. For example, total species richness (4 and 11) in 1st and 2nd order streams of Cameron Run were lower than those (12 and 20) in 1st and 2nd order streams of Quantico Creek, respectively, and those (range=15-22 in 1st order; range=17-33 in 2nd order streams) in the lower Piedmont and upper Coastal Plain provinces of the Rappahannock River drainage reported by Maurakis et al. (1987). The low species richness in 1st and 2nd order streams in the urbanized Cameron Run is not unlike those of harsh environments (e.g. streams in desert and boreal environments) summarized by Hutchinson (1993). Likewise, species richness in 2nd and 3rd order streams in Quantico Creek watershed were significantly higher than those in 2nd, 3rd, and 4th order streams in the Cameron Run watershed (Table 1), which reflects the differences in habitat characteristics (stream widths and depths, water temperature, human population, impervious cover, and percent undeveloped land cover between the forested Quantico Creek and urbanized Cameron Run watersheds (Table 6).

Lawrence et al. (2011) assessed the representation of freshwater fish diversity provided by the National Park Service (NPS) and the potential for parks to serve as freshwater protected areas (FPA) in the United States. They identified 50 national parks that could serve as a comprehensive system of freshwater protected areas in the country as 62 % of native fishes reside in national parks. Prince William Forest Park, however, was not designated as a FPA in the assessment by Lawrence et al. (2011). However, the potential impacts of increased population growth and climate change in the area, coupled with a paucity of information on the extent of the use of the lower reaches of Quantico Creek as a spawning area for anadromous fishes, we propose that the national park, Prince William Forest Park, should be included as a freshwater protection area for the Quantico Creek watershed, now wholly contained within the Prince William Forest Park, and the upper undisturbed areas in the US Quantico Creek Marine Base.

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The Small Mammals of Two Dune Communities in Southeastern Virginia

Robert K. Rose[1] and Justin L. Sweitzer

Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529

Tetra Tech, 451 Presumpscot Street, Portland, ME 04103

ABSTRACT

Small mammals were surveyed using live and pitfall traps between the primary and secondary dunes at two locations on the shores of the Chesapeake Bay near the Atlantic Ocean: Little Creek Amphibious Base in Norfolk and Joint Expeditionary Base Fort Story in Virginia Beach, Virginia. Captures were dominated by house mice (*Mus musculus*) in interdunal habitats with sparse grass, whereas white-footed mice (*Peromyscus leucopus*) were found primarily in shrubby live-oak thickets on the tops of dunes. Hispid cotton rats (*Sigmodon hispidus*) were present only at Fort Story, and then only in patches of dense herbaceous vegetation just above the wrack line.

INTRODUCTION

Relatively little research has been conducted of small mammals in dune communities of the Atlantic Coast (e.g., Shure 1970), and even less is known of the biota of estuarine dunes (Varnell et al. 2010). Dunes are dynamic landforms that are subject to rapid changes in size, shape, and vegetation due to weather events such as hurricanes and nor'easters (Cowles 1899). Even a strong prevailing wind can bury a plant in sand in a day (pers. obs.). The result is that the quality of dune communities is constantly changing. Further, the soils of dunes typically are sandy, porous, and low in nutrients, and therefore unsuitable for plants not adapted to such conditions. Plant communities of dunes from southern New Jersey to northern North Carolina have few species and often are dominated by *Ammophila breviligulata* (American beachgrass) and *Panicum amarum* var *amarum* (bitter panic grass; Day et al. 2001, Leonard and Judd 2011).

Perhaps because dune systems are ever-changing, many dune organisms are colonizing species and adapted to disturbed conditions. Colonizing species often are the first to arrive in newly formed environments and they reproduce quickly, expanding their populations rapidly to exploit resources before other species arrive. Among small mammals, house mice (*Mus musculu s*) and white-footed mice (*Peromyscus leucopus*) are the major colonizing species in disturbed or emerging habitats in eastern North America (e.g., Courtney and Fenton 1976, DeLong 1978, Mehlhop and Lynch 1978).

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[1] Corresponding author: brose@odu,edu

We studied small mammals inhabiting the plant communities between primary and secondary dunes of the lower Chesapeake Bay estuary. Our objectives were to learn what small mammals were present in the interdunal communities of two relatively undeveloped beaches, those at the Little Creek Amphibious Base in Norfolk (hereafter, Little Creek) and at the Fort Story Joint Expeditionary Forces Base in Virginia Beach, Virginia (hereafter, Fort Story).

Our study is the only published information describing small mammal communities in estuarine dune habitats in the mid-Atlantic region.

MATERIALS AND METHODS

Little Creek was surveyed from 6-11 February 2012, using 90 Fitch live traps (Rose 1994) and 59 pitfall traps set in 15 transects along 4.1 km of beach. Pitfall traps were made from #10 cans set into the ground so the top of the can was level with the surface. Fitch traps were placed 10 m apart in each transect, near grasses or other plant cover, when possible. The six live traps in each transect were baited with a mixture of wild bird seed and sunflower seeds and polyfill was added for insulation. Both kinds of traps were marked with surveyors' flags, which proved helpful because one day sand carried by a persistent 40-mph wind buried several traps of both types within 24 hours. The location of each transect was recorded with a GPS device, and the dominant plants were noted. Fort Story was surveyed from 7-12 February, using 90 Fitch traps and 30 pitfall traps in 15 transects along 4.3 km of beach, with methods similar to those used at Little Creek.

Traps were checked daily, providing 894 trap-nights at Little Creek and 720 trap-nights at Fort Story. Small mammals caught in live traps were evaluated for sex and reproductive condition, and were weighed with a Pesola® pencil scale before being released at the point of capture. Approximately half of rodents were given numbered ear tags to learn whether we were recapturing animals (mostly we caught different ones each day). For reproductive status of males, we recorded the location of the testes (descended or abdominal). We noted whether females were pregnant or had perforate vaginae, the relative size of nipples and condition of the pubic symphysis (closed, slightly open, open). Because our study was conducted in mid-winter, we expected minimal, if any, evidence of reproduction.

Our field methods followed the guidelines of the American Society of Mammalogists as outlined in Sikes, Gannon et al. (2011). A wildlife collecting permit for this study (No. 043768) was issued to the junior author by the Virginia Department of Game and Inland Fisheries. Specimens from the pitfall traps that were of scientific value were prepared as museum specimens to be deposited in the collection of a research museum. A small series of skins, skeletons and tissues of white-footed mice was deposited at the National Museum of Natural History (Smithsonian) in Washington, D. C. Pending verification by genetic analysis, they have been catalogued as *Peromyscus leucopus easti*.

RESULTS

We caught only 17 small mammals at Little Creek but 103 at Fort Story (Table 1). White-footed mice were the most frequently captured species at Little Creek, whereas house mice were most numerous at Fort Story. Five species of small mammals were captured during the six days of trapping (Table 1). We only caught three small

TABLE 1. Small mammals of the dune communities at Little Creek (Norfolk) and Fort Story (Virginia Beach), Virginia, February 2012. *Mus musculus* = *M.m.*, *Peromyscus leucopus* = *P.l.*, *Sigmodon hispidus* = *S.h.*, *Reithrodontomys humulis* = *R.h.*, *Blarina carolinensis* = *B.c.*

	M.m.	*P.l.*	*S.h.*	*R.h.*	*B.c.*
Little Creek	4	12	0	1	0
Fort Story	59	28	15	0	1

mammals in pitfall traps, in part because blowing sand often filled the traps. Thus, our traps caught 3 rodent species at each location, but eastern harvest mice were caught only at Little Creek and hispid cotton rats were present, and fairly common, in dense grassy habitats only at Fort Story. We also caught 3 Song Sparrows (*Melospiza melodia*) in the live traps at Little Creek.

At Fort Story, almost all (54; 92%) house mice were taken in traps set in grassy habitat, with the remaining 5 taken in shrub thicket (Fig. 1). By contrast, 24 white-footed mice were trapped in shrub thickets at Fort Story, with 1 in grassy habitat and 2 at the grass-shrub edge. The majority of hispid cotton rats (12 of 15) were captured in grassy habitats, often ≤2 meters of bare beach, but always in dense grassy vegetation dominated by American beachgrass and sea oats (*Uniola paniculata*).

Habitat associations were such that a given habitat tended to have a single species (Table 2). At Little Creek, white-footed mice were caught at four transects, three of which yielded only *Peromyscus leucopus*. Similarly, most of the 59 house mice caught at Fort Story were taken on transects yielding only that species. House mice were the one species associated with another species of small mammal outside of its typical grassy habitat (Table 2).

Evidence of Reproduction

None of the house mice or hispid cotton rats showed signs of reproduction. All females had non-perforate vaginae and males had abdominal testes. However, three of the house mice were tiny (6-7 g), indicating they were juveniles born within recent weeks. By contrast, the white-footed mice showed evidence of current reproduction, with some large males having descended testes, a good predictor of fertility (McCravy and Rose 1992). Further, some females had medium-large nipples, indicating recent lactation, and two small white-footed mice had gray pelage, indicative of young animals. Additionally, male white-footed mice that were retained for genetic analysis had convoluted epididymides, confirming the presence of mature sperm, and one female had 3 embryos.

Multiple captures

In eight instances the Fitch live traps had multiple captures, always of conspecifics. Two house mice were observed in a trap five times, two white-footed mice were captured together once, two cotton rats once, and one trap yielded three house mice.

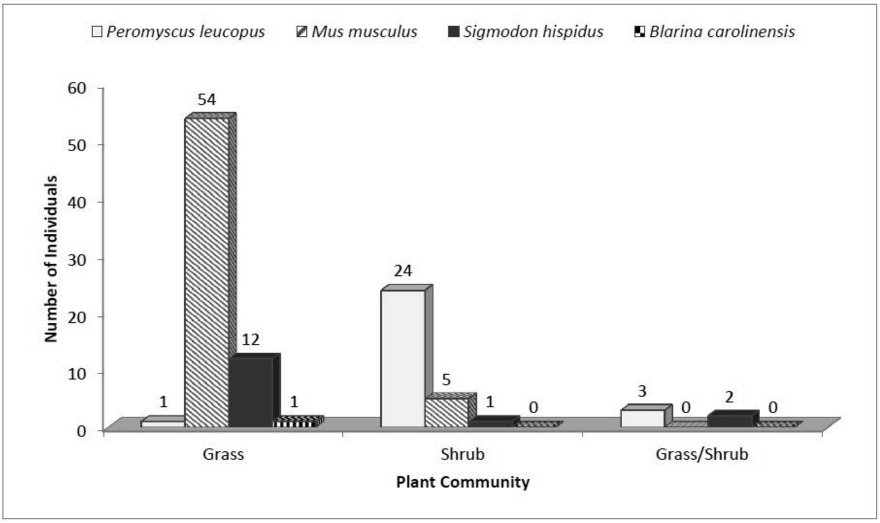

FIGURE 1. The relationship between habitat and numbers of small mammals captured at Fort Story. Most transects were either all grass or all shrub thicket.

TABLE 2. Associations among species at the 15 transects at Little Creek and Fort Story. "Nothing" means 9 transects at Little Creek yielded no small mammals. The column headings with species names show the numbers of transects yielding only that species; the last two columns show the number of transects yielding two species. *M.m*. = house mouse, *P.l.* = white-footed mouse, *S.h*.. = hispid cotton rat.

Site	Nothing	M.m.	P. l.	S.h.	M.m. & P.l.	M.m. & S.h.
Little Creek	9	2	3	0	1	0
Fort Story	0	6	2	2	1	4

Thus, traps with multiple captures yielded more than 10 percent of total captures in our short field study.

DISCUSSION

The numbers of small mammals taken in pitfall and live traps differed greatly between the two locations, despite similar numbers of live traps and transects at each. Furthermore, almost half (7) of the 15 transects at Little Creek yielded no small mammals, but at Fort Story all transects produced at least one small mammal. This difference in capture success may have been due to differences in habitat quality; at Fort Story, all dunes (except one place) appeared to be fairly intact, but primary dunes at Little Creek often were absent or poorly formed. For example, a dune near a shooting range at Little Creek was perhaps 10 m tall and had been previously enhanced with earth-moving machinery. This tall dune was stabilized with thickets of mixed shrubs and grasses consisting of bayberry (*Morella pensylvanica*), live oak (*Quercus virginiana*), common persimmon (*Diospyros virginiana*), trumpet honeysuckle (*Lonicera sempervirens*), and coastal little bluestem (*Schizachyrium littorale)* and yielded the highest number (9 of 12) of white-footed mice at Little Creek. Likewise, the tallest dunes at Fort Story, some perhaps also made taller during dune restoration activities, yielded most of the white-footed mice; 26 of 28 (93%) captures were from adjacent tall dunes, separated by a paved road leading to the beach and each vegetated with live oak thickets and some maritime forest. Thus, tall and well-vegetated dunes at both sites were prime habitats and locations where most of white-footed mice were found. No house mice were captured on the tall dunes.

A strong relationship was observed between habitat type and the species of small mammal present. Presence of white-footed mice was associated with thickets, whereas house mice were most numerous in sparse grasses. Patches of tall dense grass often yielded hispid cotton rats. House mice and white-footed mice were only captured in the same transect when those transects possessed both habitat types. Shure (1970), who studied small mammals of a New Jersey barrier beach, also found white-footed mice had a strong affinity for woody thickets or heath, whereas house mice were found in grassy areas. Scott and Dueser (1992), in their studies on Assateague Island, Virginia, demonstrated in reciprocal removal experiments of these two species that each species remained only in its preferred habitat even in the absence of the other. For example, *Mus* did not move into thickets when white-footed mice had been removed. Similar strong associations between *Mus* and grassy habitats and between *P. leucopus* and woody habitats have been reported by Cranford and Maly (1990), from dune communities on Assateague Island, Virginia, and Kirkland and Fleming (1990) on Wallops Island, Virginia. (The northern distribution of the hispid cotton rat on the Atlantic coast ends at Fort Story, located at the southern rim of the Chesapeake Bay, so they are not present on the Eastern Shore.)

Some transects in shrub thickets or maritime forest had numerous acorns on the ground, but such places yielded no white-footed mice, despite acorns being a major food source (Batzli 1977, Wolff et al. 1985). The presence of unexploited acorns suggested that although resources were available, the habitat was otherwise unsuitable for white-footed mice. At both Little Creek and Fort Story, white-footed mice were densely packed in a few locations (with no acorns), such as on transects 6 and 7 at Fort Story. Five traps on a transect on the tallest dune yielded five white-footed mice on two occasions, suggesting the use of multiple traps at a trapping point would have yielded even more *P. leucopus*. The densities of white-footed mice we observed in the thickets of these tall dunes appear to be much greater than those reported for the species in hardwood forests of the eastern US (e.g., Batzli 1977). Shure (1970) also found white-footed mice had higher abundances in maritime vegetation than those reported in mainland studies.

The grassy areas where house mice dominated appeared to be highly variable in their structure and percentage of ground cover. We estimated grassy interdunal swales to be 20-40 percent vegetated, with the majority of the ground surface being bare sand. Such habitats are the equivalent of early successional stages and may be ideal for house mice to colonize and occupy. Because the dense ground cover required by native herbivorous small mammals, such as meadow voles, never develops in these sandy places, populations of house mice likely persist free from competition for resources by other species. Other studies show that once populations of native rodents become established, house mice disappear (e.g., Lidicker 1966, Caldwell and Gentry 1965).

The absence of one species, eastern harvest mouse, was unexpected at Fort Story; one was caught at Little Creek. The eastern harvest mouse is a versatile small mammal in eastern Virginia. Although found at highest densities in grassy oldfields (Cawthorn and Rose 1991), it is often present in a wide range of habitats, including pine forests, hardwood forests, roadsides, i.e., places lacking the vegetation structure of grassy oldfields. One 6-g female was caught on a Little Creek transect dominated by grasses. Harvest mice often are associated with hispid cotton rats (Cameron and Kincaid 1982), but none was caught at Fort Story, where cotton rats were taken at 6 different transects (Table 2). Harvest mice eat seeds and some insects (Kincaid and Cameron 1985), a diet similar to that of house mice.

In conclusion, the rodents of the interdunal communities in eastern Virginia are predictable. White-footed mice occupied shrub thickets, house mice were found in sparse grasses, and hispid cotton rats, when present, were found in patches of tall dense grasses.

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Virginia Academy of Science, 2013, Fall Undergraduate Research Meeting

The Fall Undergraduate Research Meeting, sponsored by the Virginia Academy of Science, was held at J. Sargeant Reynolds Community College, in Richmond, Virginia, on October 26, 2013. Undergraduate students and mentors from 12 different colleges and universities in Virginia, submitted 31 proposals and presented posters at the annual event. Each year the attendance and number of colleges participating in the Undergraduate Research Meeting has increased. This year 76 attendees enjoyed a luncheon and lecture by Dr. Michael Fine, Professor of Biology, at Virginia Commonwealth University, *The Evolution of Talking Fish*.

Dr. Michael Fine, Professor of Biology, Virginia Commonwealth University, Richmond, Virginia

The first Fall Undergraduate Research Meeting was held in 2001. This particular research meeting is held to give undergraduate student researchers, working with Virginia Academy of Science mentors, the opportunity to develop a research proposal and present it using a poster presentation format. Students must submit grant applications as research proposals, develop their posters outlining their research plan, and present them to judges at the meeting. Several judges volunteer to spend time reviewing both the grant proposals and the posters with the student researchers, asking them questions, to evaluate their work. Five students, with the highest scores, are awarded research grants of up to $500 each, to conduct their research throughout the year. In addition to the monetary award, each student receives a one-year VAS membership and are required to attend the Annual Meeting in the spring to report on the results of their research.

This years invited speaker was Dr. Michael Fine, a fish neurobiologist at Virginia Commonwealth University. Dr. Fine has spent much of his professional career studying acoustic communication in the oyster toadfish, catfish, and sciaenid fishes.

The VAS gives a special thank you to our volunteer judges for the Fall Undergraduate Research Meeting:

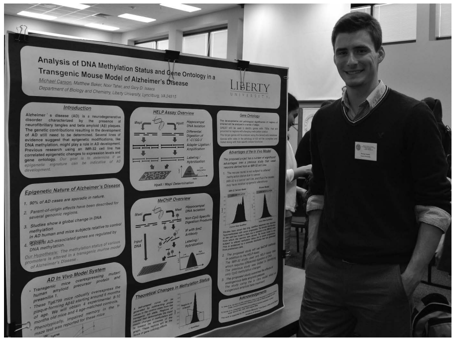
Participating Institutions

Christopher Newport University
Ferrum College
George Mason University
Liberty University
Longwood University
Norfolk State University
Old Dominion University
Virginia Commonwealth University
Virginia State University
Virginia Tech
Virginia Wesleyan College
Washington and Lee University

Judges

Dr. David W. Crosby, Cooperative Extension, Virginia State University
Dr. Chris Catanzaro, College of Agriculture, Virginia State University
Dr. Louis Landesman, Cooperative Extension, Virginia State University
Dr. Yixiang Xu, Agricultural Research Station, Virginia State University
Brandon Lind, Dept. of Biology, Virginia Commonwealth University
Lynn VanderWielen, Dept of Health Administration, Virginia Commonwealth University
Alex Enurah, School of Medicine, Virginia Commonwealth University
Dr. Deborah O'Dell, Dept of Biological Sciences, University of Mary Washington
Dr. Patrick Young, Senior Research Associate, Dupont.

VAS - Winners - Fall 2013 Undergraduate Research Awards



Michael Carson, Department of Biology and Chemistry, Liberty University
Faculty Advisor: Gary D. Issocs

Project title: **Analysis of DNA Methylation Status and Subsequent Gene Ontology of a Transgenic Mouse Model of Alzheimer's Disease**. Research suggests that changes in DNA methylation status contribute to the development and pathology of Alzheimer's Disease (AD). This study will use HELP assay and microarray hybridization data from a transgenic mouse model of AD to identify regions of interest for gene ontology analysis using online genomics tools (GREAT and GeneCodis).

Randl Dent, Eliza Parrot, and Kingsley Schroeder (not pictured), Department of Psychology, Washington & Lee University
Faculty Advisor: Meghan Fulcher

Project title: **Fighting and Makeup: What Children Learn from Playing with Gender-amplified Dolls**. Children use dolls as models to construct their perceptions of themselves and their world. The current study investigates how playing with dolls that have an amplified focus on gendered body will affect gender typicality of play and influence a child's feelings of efficacy for future gendered skills and tasks.

Betty R. McConn, Dept. of Animal & Poultry Science, Virginia Tech
Faculty Advisor: Mark R. Cline

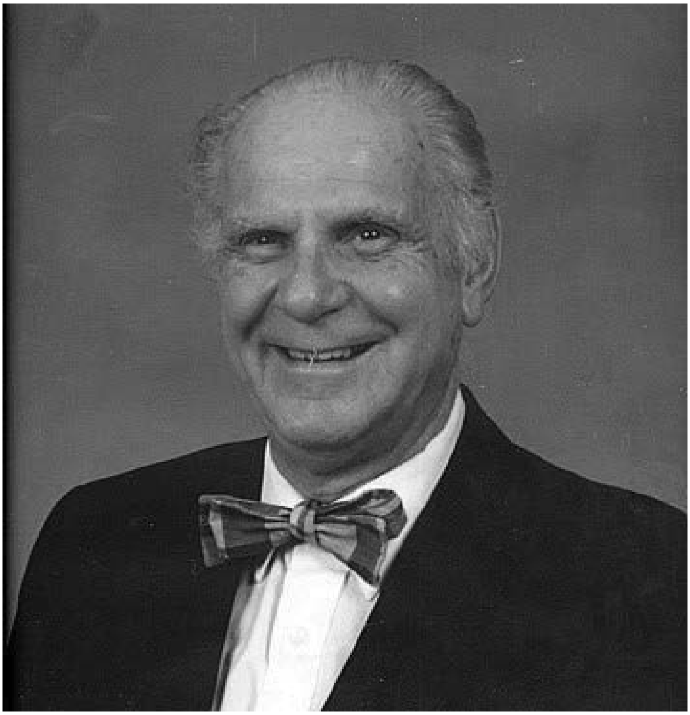
Project Title: **Elucidating the Mechanism of Gonadotropin-inhibitory Hormone Stimulation of Hunger**. The purpose of the proposed research is to elucidate the brain mechanisms where gonadotropin-inhibitory hormone (GnIH) mediates the perception of hunger. Study in this area is highly warranted because only a few neurotransmitters stimulate hunger. With this knowledge we can devise a model of the molecular mechanism of GnIH.

Keaira Thornton (on right), Department. of Biology, Norfolk State University
Faculty Advisor: Ashley Haines

Project title: **Phylogenetic Analyses of *Streptococcus parauberis* form Fish and Cattle**. This project will analyze the phylogeny of *Streptococcus parauberis* from fish and cattle using nucleic and amino acid sequences of multiple housekeeping genes. This analysis will clarify whether *S. parauberis* is more closely related to *S. iniae* (a fish pathogen) than to *Streptococcus uberis* (a cattle pathogen).

Alison M. Washington, Department of Chemistry, Virginia Wesleyan College
Faculty Advisor: Kevin Kittredge

Project title: **Kinetics of Release of Dyes and Pigments in Thermally Cured Poly(allylamine)/Poly(acrylic acid hydrochloride) Thin Films**. Hyperbranched poly(acrylic acid hydrochloride) (PAA/PAH) films have been synthesized in a layer-by-layer fashion. The films may be intercalated with a dye molecule and the rates of release can be measured by UV-Visible spectroscopy. We plan to examine the kinetics for releasing this dye from the films under physiological conditions.



Donald R. Cottingham, Sr.

Academy Fellow and Patron, Don Cottingham passed away on September 4, 2013 after a short illness. Don was volunteer Director of the Virginia Junior Academy of Science (1991-2001) and chaired the Academy's Junior Academy of Science Committee. He was awarded the VJAS Distinguished Service Award in 1998.

Born in Cicero, Illinois on July 12, 1924, Don received his associate degree from J. Sterling Morton Junior college in Illinois, prior to his entry into the Navy, and his BS and MS degrees from Old Dominion University in 1966 and 1971 respectively. He served as a U.S. Navy officer in WWII, Korea, and into the early Vietnam War years, retiring in 1965 after a distinguished military career of 23 years. Don then changed to his second career as a beloved and accomplished teacher of Chemistry and General Sciences. Schools where he taught with great success and service to students were Norview Junior High, Norfolk Academy, and Maury High, where he was Chair of the Science Department until his retirement in 1991. A longtime member of First Presbyterian church, Don was a member of the Session there for 24 years and a Deacon for eight years. In recent years Don became a member of Royster Presbyterian church.

Don's honors as a teacher are many, including Norfolk Teacher of the Year 1981, Outstanding Teacher of the National Academy of Sciences, and a personal recognition award from President Reagan for Outstanding Science Teacher Leadership in 1985. He will be long remembered and cherished for mentoring so many successful students over his many years of teaching and his advocacy for science education in Virginia and nationally through the National Association of Academies of Science and the American Junior Academy of Science.

Don is survived by his faithful, longtime love and devoted caregiver, Martha S. Greenwood, son Donald Richard Cottingham, Jr., daughters by heart, Martha Suzanne Tice and husband Tom, Elizabeth A. Jernigan and husband Perry, sons by heart Larry J. Tice and wife Susan, Steven N. Tice and wife Debbie, Joseph L. Greenwood III and wife Becky, grandchildren, Teri Cottingham Ramey and husband, Charles R. Cottingham, grandchildren by heart, Jessica Duggan and husband Steve, Amber Greenwood, Charles L. Tice II, James V. Jernigan, Davis J. Versprille, Hannah M. Jernigan, Delaney E. Versprille, Brooke C. Jernigan, Wade M. Jernigan, and sister-in-law, Norma Demmin and husband Les, and numerous nieces and nephews.

Special thanks are given to Edward B. Cummings, his CNA, Joan Burt, and his ICU nurse, Ami, at DePaul Hospital who all took such special care of him.

Published in the Virginian Pilot on September 8, 2013

Dorothy Crandall Bliss

Academy Fellow Dorothy Bliss, 97, of Lynchburg, died Monday, October 14, 2013. She was the wife of the late Paul Dayton Bliss. Dorothy was born February 20, 1916, in Westerly, Rhode Island, a daughter of the late Frank H. Crandall and the late Alice Arnold Crandall. Dorothy received her Ph.D. in Botany from the University of Tennessee in Knoxville.

Dorothy was a member of the faculty of Randolph College (formerly Randolph Macon Women's College) in Lynchburg, Virginia from 1949 to 1983, serving as Assistant Professor, Professor and Department Head for the Biology Department. Upon her retirement she was named Professor Emeritus. In 2008, Randolph College dedicated the Botanic Garden at the college as the Dorothy Crandall Bliss Botanic Garden.

Dorothy was a founding member of Peakland Baptist Church, a member of the Virginia Academy of Science (VAS), the Appalachian Trail Club, the Virginia Native Plant Society (VNPS) and the Blue Ridge Wildflower Society (BRWS). She was an active member of the VAS Botany Section serving on the Virginia Flora Committee and was elected as a VAS Fellow. An early supporter of the Foundation of the Flora of Virginia Project (FFVP), she served on the FFVP Flora Advisory Committee. Dorothy was a charter member of BRWS and served as one of the first Botany Chairs of VNPS. While serving as Botany Chair, she organized the VNPS Registry Program which seeks to work with landowners to protect native plants. Dorothy's lifelong interest and passion for education, native plants, and nature was an inspiration to her students, colleagues, and friends. The Randolph College Dorothy Crandall Bliss Botanic Garden and the VNPS Registry Program are part of her living legacy.

She is survived by her stepdaughter, Dorothy Bliss Raines of Franklin, Tenn.; a brother, Frank Crandall of Rhode Island; a sister, Ruth C. Greenhalgh of Florida; seven nieces and nephews, all of Rhode Island; two step-grandchildren, six step great-grandchildren and her husband's niece, Laura Bliss of Westminster Canterbury. In addition to her husband and parents, she was preceded in death by a brother, Charles Crandall; and two sisters, Eleanor C. Thayer and Marguerite C. Purnell.

Instructions to Authors

All manuscripts and correspondence should be sent to the Editor (wwieland@umw.edu). The Virginia Journal of Science welcomes for consideration original articles and short notes in the various disciplines of engineering and science. Cross-disciplinary papers dealing with advancements in science and technology and the impact of these on man and society are particularly welcome. Submission of an article implies that the article has not been published elsewhere while under consideration by the Journal.

Submit manuscripts in electronic form as an MS Word OR WordPerfect file. Tables and figures should NOT be embedded within the body of the manuscript. Place tables and figures after the Literature Cited. Authors should submit names of three potential reviewers. All manuscripts must be double-spaced. **Do not** use special effects such as bold or large print.

The title, author's name, affiliation, address and e-mail should be placed on a cover page. An abstract (not to exceed 200 words) summarizing the text, particularly the results and conclusions, is required. The text should follow the general format used by professional journals in the author's discipline and the Virginia Journal of Science has an on-line style manual. In-text references should follow the name-year format: (McCaffrey and Dueser 1990) or (Williams et al. 1990). In the Literature Cited section at the end of the article, each reference should include the full name of the author(s), year, title of article, title of journal (do not abbreviate), volume number and first and last page of the article. For a book, include author(s), year, title, pages or number of pages, publisher and city of publication. Examples:

McCaffrey, Cheryl A. and Raymond D. Dueser. 1990. Plant associations of the Virginia barrier islands. Va. J. Sci. 41:282-299.

Spry, A. 1969. Metamorphic Textures. Pergamon Press, New York. *350* pp.

Each figure and table should be mentioned specifically in the text. All tables, figures and figure legends should be on a separate pages at the end of the text.

Multiple author papers are required to have a statement in the acknowledgments indicating the participation and contribution of each author.

After revision and prior to final acceptance of an article, the author will be required to furnish publication-quality files in TIFF or JPEG format of all figures. Keep in mind the page size of the journal, 6 x 9 in (152 x 228 mm), in constructing tables and figures. An error-free copy of the manuscript in acceptable format is also required.

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