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EDITOR/BUSINESS MANAGER:

James H. Martin

Dept. of Biology - PRC

J. Sargeant Reynolds Community College

P.O. Box 85622

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Phone: (804)371-3064

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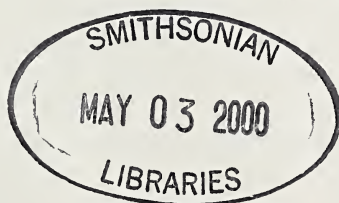
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The Fermat Point and The Steiner Problem

J.N. Boyd and P.N. Raychowdhury,

Department of Mathematical Sciences, Virginia Commonwealth
University, Richmond, Virginia 23284-2014

ABSTRACT

We revisit the convex coordinates of the Fermat point of a triangle. We have already computed these convex coordinates in a general setting. In this note, we obtain the coordinates in the context of the Steiner problem. Thereafter, we pursue calculations suggested by the problem.

INTRODUCTION

We came upon a lovely problem in Strang's outstanding calculus text (Strang, 1991). The problem, to which the author attaches the name of the great Swiss geometer J. Steiner, may be stated in the following manner:

Find the point F on the perimeter or in the interior of $\Delta V_1V_2V_3$ so that the sum of the distances from F to the three vertices of the triangle has its least possible value.

The problem is to minimize $d_1 + d_2 + d_3$ where d_1, d_2, d_3 are the distances from F to V_1, V_2, V_3 , respectively. The geometry of the problem is suggested by Figure 1.

We shall eventually show that the point F for which $d_1 + d_2 + d_3$ is a minimum is located in the interior of $\Delta V_1V_2V_3$ in such a way that $\angle V_1FV_2 = \angle V_2FV_3 = \angle V_3FV_1 = 120^\circ$ provided that the largest of the three angles of the triangle ($\angle V_1, \angle V_2, \angle V_3$) has a measure less than 120° . If one of these three angles equals or exceeds 120° , then the point F is located at the vertex of that angle. We shall confine our discussion and calculations to triangles in which each angle is less than 120° .

Now let us suppose that three equilateral triangles have been constructed in the exterior of $\Delta V_1V_2V_3$ with each equilateral triangle having its base upon one of the sides of $\Delta V_1V_2V_3$ as shown in Figure 2. Then the three lines determined by the three vertices of $\Delta V_1V_2V_3$ and the corresponding remote vertex of the opposite equilateral triangle are concurrent. The point of concurrence is the equiangular point of $\Delta V_1V_2V_3$ and is called the Fermat point. These matters have been demonstrated in elegant fashion by Posamentier (Posamentier, 1984), and we have found the convex coordinates of this point (Boyd, Lees, and Raychowdhury, 1990).

When each angle of $\Delta V_1V_2V_3$ is less than 120° , the Fermat point is also the point F which minimizes $d_1 + d_2 + d_3$. In this present note, we take advantage of the solution of the Steiner problem to provide an alternative method for computing the convex coordinates of the Fermat point.

THE CONVEX COORDINATES

We shall postpone the solution of the Steiner problem until the last section of our paper and, for the present, assume that we have in hand the distances d_1, d_2, d_3 from

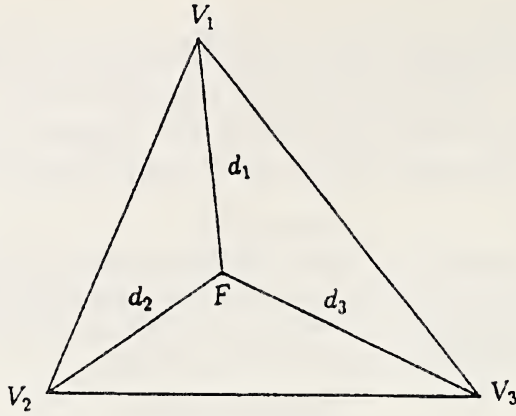


FIGURE 1. Point F in $\Delta V_1V_2V_3$.

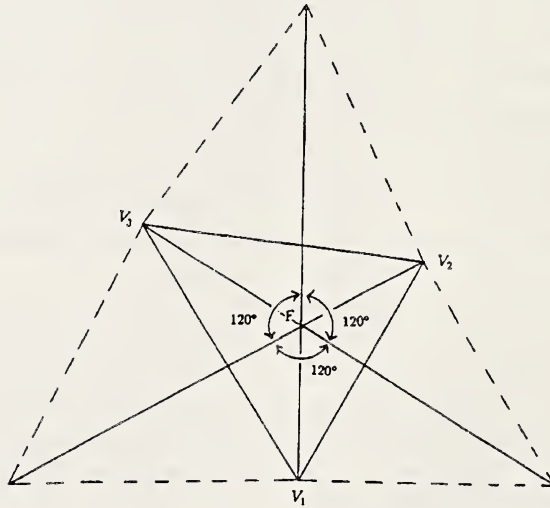


FIGURE 2. The Equiangular Point is the Fermat Point.

F to V_1, V_2, V_3 , respectively. These are the distances which minimize $d_1 + d_2 + d_3$ for all points of $\Delta V_1V_2V_3$ when all angles of $\Delta V_1V_2V_3$ are less than 120° .

The convex coordinates of a point P in the closed triangular region $V_1V_2V_3$ are three nonnegative numbers $\alpha_1, \alpha_2, \alpha_3$, such that $\alpha_1 + \alpha_2 + \alpha_3 = 1$. We say that α_i is the convex coordinate of P with respect to V_i for $i = 1, 2, 3$. The convex coordinates of V_i are $\alpha_i = 1, \alpha_j = 0$ for $j \neq i$.

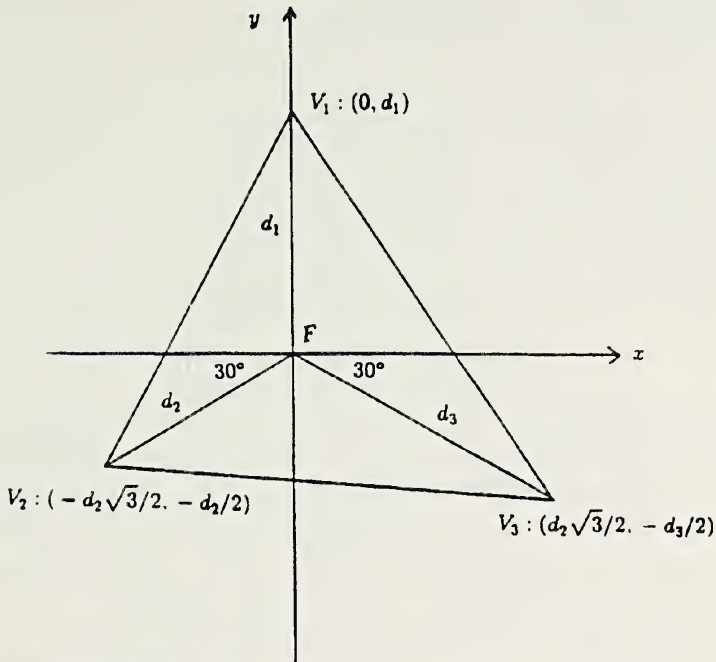


FIGURE 3. $\Delta V_1V_2V_3$ in the Cartesian Plane.

Let us suppose that the plane of $\Delta V_1V_2V_3$ is the Cartesian plane and that the coordinates of V_i are (x_i, y_i) . Let us denote the Cartesian coordinates of P by (x, y) . Then the property of convex coordinates which will advance our calculations is that

$$\left. \begin{aligned} x &= \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \\ y &= \alpha_1 y_1 + \alpha_2 y_2 + \alpha_3 y_3 \end{aligned} \right\} \quad (1)$$

Thus the Cartesian coordinates of P may be regarded as a convex combination of the Cartesian coordinates of the vertices (Boyd and Raychowdhury, 1987).

Let us choose the Cartesian coordinates of F and V_1 to be $(0, 0)$ and $(0, d_1)$, respectively. Then the Cartesian coordinates of V_2 are $(-d_2 \cos 30^\circ, -d_2 \sin 30^\circ) = (-d_2 \sqrt{3}/2, -d_2/2)$ and the Cartesian coordinates of V_3 are $(d_3 \cos 30^\circ, -d_3 \sin 30^\circ) = (d_3 \sqrt{3}/2, -d_3/2)$ as shown in figure 3.

Equations 1 and the fact that convex coordinates sum to unity yield three linear equations for the convex coordinates of the Fermat point F :

$$\left. \begin{aligned} -(d_2 \sqrt{3}/2)\alpha_2 + (d_3 \sqrt{3}/2)\alpha_3 &= 0 \\ d_1 \alpha_1 - (d_2/2)\alpha_2 - (d_3/2)\alpha_3 &= 0 \\ \alpha_1 + \alpha_2 + \alpha_3 &= 1 \end{aligned} \right\} .$$

Application of Cramer's rule quickly yields

$$\left. \begin{aligned} \alpha_1 &= \frac{d_2 d_3}{d_1 d_2 + d_1 d_3 + d_2 d_3} , \\ \alpha_2 &= \frac{d_1 d_3}{d_1 d_2 + d_1 d_3 + d_2 d_3} , \\ \text{and } \alpha_3 &= \frac{d_1 d_2}{d_1 d_2 + d_1 d_3 + d_2 d_3} , \end{aligned} \right\} \quad (2)$$

THE ISOSCELES TRIANGLE

Let us denote the length of the side opposite to V_i in $\Delta V_1 V_2 V_3$ by ℓ_i , $i = 1, 2, 3$. Then let $\Delta V_1 V_2 V_3$ be isosceles with $\ell_2 = \ell_3 = \ell$ and $\angle V_1 < 120^\circ$. It should be clear that $\angle FV_2 V_3 = \angle FV_3 V_2 = 30^\circ$ and that symmetry implies that d_2 and d_3 must have the same value which we denote by d . Figure 4 indicates the geometry for the isosceles triangle.

We see that $\ell_1 = 2 d \cos 30^\circ = d \sqrt{3}$ and $d = \ell_1 / \sqrt{3}$. Applying the law of cosines to $\Delta V_1 V_2 F$, we obtain $\ell^2 = d^2 + d_1^2 - 2d d_1 \cos 120^\circ$. Therefore,

$$d_1^2 - d d_1 + (d^2 - \ell^2) = 0$$

and

$$d_1 = \frac{-d + \sqrt{d^2 - 4(d^2 - \ell^2)}}{2}.$$

We take the positive sign in applying the quadratic formula since $d^2 - \ell^2 < 0$ and $d_1 > 0$. Substituting $d = \ell_1 / \sqrt{3}$ into the last equation, we find that

$$d_1 = \frac{\sqrt{12\ell^2 - 3\ell_1^2} - \ell_1}{2\sqrt{3}}.$$

Substituting d_1 , $d_2 = d$, and $d_3 = d$ into Equation 2 yields the convex coordinates. As a check upon our work, we let $\ell_1 = \ell_2 = \ell_3 = 1$. Then the triangle becomes equilateral with $d_1 = d_2 = d_3 = \frac{1}{\sqrt{3}}$ and $\alpha_1 = \alpha_2 = \alpha_3 = \frac{1}{3}$ as expected.

As a further example, let $\ell_1 = 1$ and $\ell_2 = \ell_3 = 2$. Then $d_1 = (3\sqrt{5} - 1) / (2\sqrt{3}) \approx 1.6478$ and $d_2 = d_3 = 0.5882$. It follows from Equation 2 that $\alpha_1 \approx 0.1514$, $\alpha_2 \approx 0.4243$, and $\alpha_3 \approx 0.4243$ for Fermat point F in the triangle defined by the lengths

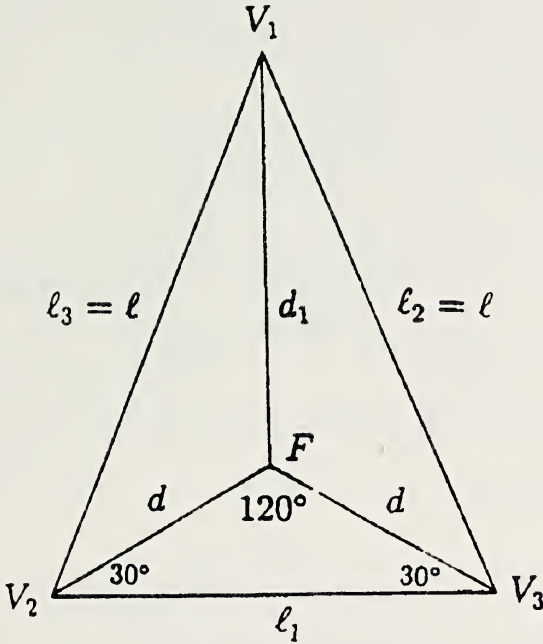


FIGURE 4. $\Delta V_1V_2V_3$ is Isosceles.

of the three sides as listed.

THE SCALENE TRIANGLE

It would seem much more natural to begin the investigation of a triangle with known sides rather than with given values of d_1, d_2, d_3 . We shall now show how to compute d_1, d_2, d_3 when $\Delta V_1V_2V_3$ is scalene. That is, we begin our computation under the assumption that $l_1 \neq l_2, l_1 \neq l_3,$ and $l_2 \neq l_3$.

We apply the law of cosines to subtriangles $V_2FV_1, V_1FV_3,$ and V_3FV_2 as shown in Figure 5 to obtain the following equations:

$$l_1^2 = d_2^2 + d_3^2 + d_2d_3, \tag{3.1}$$

$$l_2^2 = d_1^2 + d_3^2 + d_1d_3, \tag{3.2}$$

and
$$l_3^2 = d_1^2 + d_2^2 + d_1d_2. \tag{3.3}$$

Equations 3.1, 3.2, and 3.3 possess pleasing symmetry and, as quadratic equations in $d_1, d_2, d_3,$ are solvable in terms of square roots when the given sides satisfy the

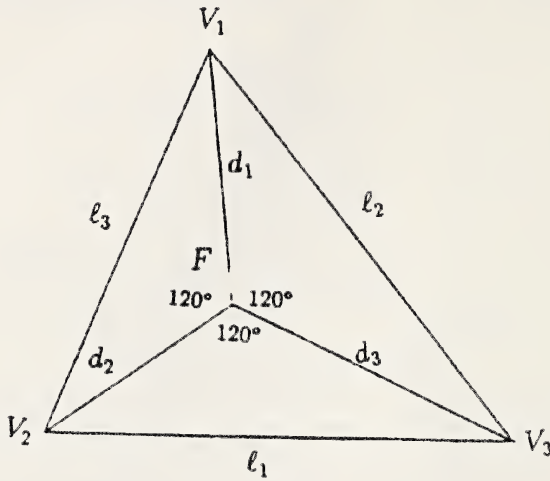


FIGURE 5. The Scalene Triangle.

triangle relations $l_1 < l_2 + l_3$, $l_2 < l_1 + l_3$, and $l_3 < l_1 + l_2$.

Multiplying Equations 3.1, 3.2, and 3.3 by $d_3 - d_2$, $d_1 - d_3$, and $d_2 - d_1$, respectively, yields three other equations:

$$l_1^2(d_3 - d_2) = d_3^3 - d_2^3,$$

$$l_2^2(d_1 - d_3) = d_1^3 - d_3^3,$$

and

$$l_3^2(d_2 - d_1) = d_2^3 - d_1^3.$$

Adding these three equations and performing algebraic simplification yield a fourth equation which we will find useful:

$$(l_2^2 - l_3^2)d_1 + (l_3^2 - l_1^2)d_2 + (l_1^2 - l_2^2)d_3 = 0 \quad (3.4)$$

For the sake of convenience, we adopt the notation

$$\left. \begin{aligned} A_1 &= l_2^2 - l_3^2, \\ A_2 &= l_3^2 - l_1^2, \\ \text{and } A_3 &= l_1^2 - l_2^2 \end{aligned} \right\} . \quad (4)$$

Then Equation 3.4 may be written as

$$A_1d_1 + A_2d_2 + A_3d_3 = 0$$

which implies that

$$d_3 = -\left(\frac{A_1d_1 + A_2d_2}{A_3}\right).$$

We now substitute this expression for d_3 into Equation 3.1. We then perform straightforward algebraic operations to obtain

$$A_3^2\ell_1^2 = (A_3^2 + A_2^2 - A_2A_3)d_2^2 + A_1^2d_1^2 + (2A_1A_2d_1 - A_1A_3d_1)d_2. \quad (5)$$

We next rewrite Equation 3.3 as

$$0 = d_1^2 + d_1d_2 + (d_2^2 - \ell_3^2)$$

and note that $d_2^2 - \ell_3^2 < 0$.

Then

$$d_1 = \frac{\sqrt{4\ell_3^2 - 3d_2^2} - d_2}{2}.$$

Substitution of this expression for d_1 into Equation 5 yields a most complicated equation in the single variable d_2 :

$$\begin{aligned} & (A_1^2 - 2A_1A_2 + A_1A_3)d_2\sqrt{4\ell_3^2 - 3d_2^2} = \\ & (-A_1^2 + 2A_2^2 + 2A_3^2 - 2A_1A_2 - 2A_2A_3)d_2^2 + (2A_1^2\ell_3^2 - 2A_3^2\ell_1^2). \end{aligned} \quad (6)$$

We simplify this equation by letting

$$\left. \begin{aligned} P &= A_1^2 - 2A_1A_2 + A_1A_3, \\ Q &= -A_1^2 + 2A_2^2 + 2A_3^2 - 2A_1A_2 - 2A_2A_3 + A_1A_3, \\ \text{and } R &= 2A_1^2\ell_3^2 - 2A_3^2 - 2A_3^2\ell_1^2. \end{aligned} \right\} \quad (7)$$

With the substitutions of P , Q , and R into Equation 6, we obtain

$$Pd_2\sqrt{4\ell_3^2 - 3d_2^2} = Qd_2^2 + R.$$

Squaring both sides of this equation, followed by algebraic manipulation, yields

$$(3P^2 + Q^2)d_2^4 + (2QR - 4\ell_3^2P^2)d_2^2 + R^2 = 0.$$

Application of the quadratic formula then yields

$$d_2^2 = \frac{4\ell_3^2 P^2 - 2QR \pm \sqrt{(2QR - 4\ell_3^2 P^2)^2 - 4(3P^2 + Q^2)R^2}}{2(3P^2 + Q^2)}.$$

Next we wrote a simple computer program in Quick BASIC to evaluate d_2^2 . It was a simple matter to enter ℓ_1 , ℓ_2 , and ℓ_3 and then to compute A_1, A_2, A_3, P, Q , and R from Equations 4 and 7. We evaluated $d_2^2(-)$ by taking the "-" sign of the " \pm " combination. If $d_2^2(-)$ turned out to be negative, it was rejected; and we computed $d_2^2(+)$ for the "+" sign. We took the positive square root of $d_2^2(+)$ to obtain d_2 . Our program then turned to Equation 3.1 to find d_3 .

Rewriting Equation 3.1 as

$$d_3^2 + d_2 d_3 + (d_2^2 - \ell_1^2) = 0,$$

we noted that $d_2^2 - \ell_1^2 < 0$. We were immediately able to conclude that

$$d_3 = \frac{\sqrt{d_2^2 + 4(\ell_1^2 - d_2^2)} - d_2}{2} > 0.$$

We then substituted our values for d_2 and d_3 into Equation 3.4 to obtain d_1 .

If $d_2^2(-)$ was positive, we then had to decide between $d_2(-)$ and $d_2(+)$ for the correct value of d_2 . To do this, we used $d_2(-)$ to find possible values of d_3 and d_1 . We then checked $d_2(-)$, d_3 and d_1 in the three triangle inequalities

$$d_2(-) + d_3 > \ell_1, \quad d_1 + d_3 > \ell_2, \quad \text{and} \quad d_1 + d_2(-) > \ell_3.$$

If all three inequalities were satisfied, then we had found d_1, d_2 , and d_3 .

If all three inequalities were not satisfied, we substituted $d_2^2(+)$ for $d_2^2(-)$ and repeated the calculations to find the correct values of d_1, d_2 , and d_3 .

In Table 1, we display the results of five runs of our program. Each triple d_1, d_2 , and d_3 may be shown to satisfy Equations 3.1, 3.2, and 3.3.

TABLE 1. Five Solutions for d_1 , d_2 , and d_3 .

ℓ_1	ℓ_2	ℓ_3	d_1	d_2	d_3
3	4	5	3.388521	2.354003	1.023908
4	7	8	6.083282	2.978962	1.567617
5	6	9	5.690160	4.685959	5.778656
7	9	10	6.816284	4.663640	3.385508
8	11	14	9.573575	6.494169	2.44232

As a last calculation, we return to Equation 2 for the convex coordinates of the Fermat point in the right triangle with $\ell_1 = 3$, $\ell_2 = 4$, $\ell_3 = 5$. We find that $\alpha_1 = 0.173947$, $\alpha_2 = 0.250392$, and $\alpha_3 = 0.575661$.

AN INEQUALITY

In the course of our computations, we discovered an inequality which was not obvious to us when we first wrote Equations 3.1, 3.2, and 3.3 which hold true for all triangles whether isosceles or scalene. In this section, we shall derive that inequality.

Adding the three equations to which we have just referred, we see that

$$\ell_1^2 + \ell_2^2 + \ell_3^2 = 2d_1^2 + 2d_2^2 + 2d_3^2 + d_1d_2 + d_2d_3 + d_1d_3.$$

Dividing both sides above by 2, we obtain

$$\frac{\ell_1^2 + \ell_2^2 + \ell_3^2}{2} = d_1^2 + d_2^2 + d_3^2 + \frac{d_1d_2}{2} + \frac{d_2d_3}{2} + \frac{d_1d_3}{2} = (d_1 + d_2 + d_3)^2 - \frac{3}{2}(d_1d_2 + d_2d_3 + d_1d_3).$$

Since d_1 , d_2 , and d_3 are positive, we may conclude that

$$\sqrt{\frac{\ell_1^2 + \ell_2^2 + \ell_3^2}{2}} < d_1 + d_2 + d_3. \tag{8}$$

We may also write that

$$\begin{aligned} \ell_1^2 + \ell_2^2 + \ell_3^2 &= d_1^2 + d_2^2 + d_3^2 + \left(\frac{d_1^2 + d_2^2}{2} + d_1 d_2 \right) \\ &+ \left(\frac{d_2^2 + d_3^2}{2} + d_2 d_3 \right) + \left(\frac{d_1^2 + d_3^2}{2} + d_1 d_3 \right) \\ &> d_1^2 + d_2^2 + d_3^2 + 2d_1 d_2 + 2d_2 d_3 + 2d_1 d_3 = (d_1 + d_2 + d_3)^2. \end{aligned}$$

Therefore,

$$d_1 + d_2 + d_3 < \sqrt{\ell_1^2 + \ell_2^2 + \ell_3^2}. \quad (9)$$

Taken together, inequalities 8 and 9 imply that

$$\sqrt{\frac{\ell_1^2 + \ell_2^2 + \ell_3^2}{2}} < d_1 + d_2 + d_3 < \sqrt{\ell_1^2 + \ell_2^2 + \ell_3^2}.$$

THE STEINER PROBLEM

By solution of the Steiner problem, we mean a demonstration that each of the angles, $V_1 F V_2$, $V_2 F V_3$, and $V_3 F V_1$ (see Figure 5) has measure 120° . Posamentier gives an elegant geometrical argument that, if and only if $d_1 + d_2 + d_3$ is a minimum, then the three angles around point F are congruent. The drawback to such a proof is that it is unlikely that even a very good mathematician who does not teach Euclidean geometry would know how to start on his own. Therefore, we shall sketch Strang's solution in which an exercise of ingenuity is not required at the start but is postponed until later. Posamentier presents the result as one of a sequence of theorems and does not associate Steiner's name with it.

Let the Cartesian coordinates of V_1 , V_2 , V_3 be (x_1, y_1) , (x_2, y_2) , (x_3, y_3) , respectively, and let those of point P in the interior of $\Delta V_1 V_2 V_3$ be (x, y) . The distance from P to V_1 is

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$

for $i = 1, 2, 3$. We seek the point P having coordinates which minimize

$$g(x, y) = d_1 + d_2 + d_3.$$

To determine these critical coordinates, we let $\nabla g(x, y) = \nabla d_1 + \nabla d_2 + \nabla d_3 = \vec{0}$.

Since $d_i^2 = (x - x_i)^2 + (y - y_i)^2$, we may write that

$2d_i \nabla d_i = 2(x - x_i)\hat{x} + 2(y - y_i)\hat{y}$ where \hat{x}, \hat{y} are unit vectors in the x, y -directions, respectively. Therefore

$$\nabla d_i = \frac{(x - x_i)\hat{x} + (y - y_i)\hat{y}}{d_i}$$

and $|\nabla d_i| = 1$. Thus each gradient $\nabla d_i, i = 1, 2, 3$, is a unit vector directed from vertex V_i toward point P . Denoting these unit vectors by \hat{u}_i , we write the gradient of $g(x, y)$ as

$$\nabla g(x, y) = \hat{u}_1 + \hat{u}_2 + \hat{u}_3 = \vec{0}.$$

We also note that the discontinuities of the gradient occur at vertices V_1, V_2 , and V_3 . Since the sum of the three unit vectors is the zero vector, it follows that the angle between each two of these unit vectors must be 120° .

The point P of the interior of $\Delta V_1 V_2 V_3$ is precisely F , the equiangular point with which we have been concerned all along. The condition that $\nabla g(x, y) = \vec{0}$ at $P = F$ is necessary if $d_1 + d_2 + d_3$ is to be a minimum value, but it is not sufficient. That the gradient of $g(x, y)$ is the zero vector at $P = F$ implies only that we have found a

stationary point for $g(x, y)$. Since the geometry presented by Posamentier makes it clear that $d_1 + d_2 + d_3$ takes its least value at F , we dispense with the tests with the higher partial derivatives of $g(x, y)$ which may be employed to complete Strang's argument. Strang also fails to test the minimum.

If one of the angles of $\Delta V_1 V_2 V_3$ is permitted to equal or exceed 120° the vertex of the largest angle is the point of the closed triangular region for which $d_1 + d_2 + d_3$ is a minimum. (Recall that $\nabla g(x, y)$ does not exist at the vertices.)

A PHYSICAL SOLUTION OF STEINER'S PROBLEM

Let us draw or imagine drawing a triangle of convenient size upon the smooth plane surface of a plywood lamina. The triangle will represent the general triangle of interest in our work. That is, each angle of the triangle should be less than 120° .

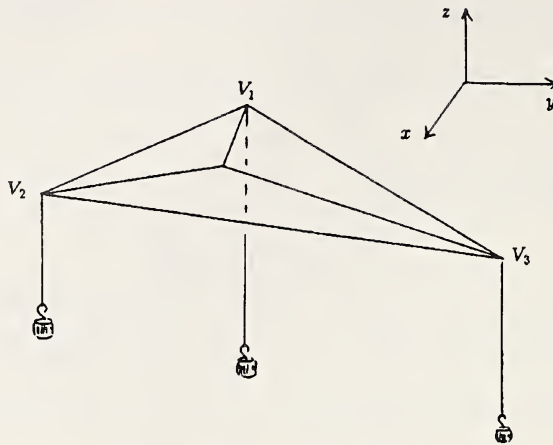


FIGURE 6. The Physical Interpretation of the Steiner Problem.

Then we need to drill a small hole through the lamina at each vertex.

Next, we take three strings and tie their ends together (one end from each string) in a single knot. We then thread the free ends of the strings through the three holes (one string through each hole). We obtain three masses of equal weight and attach one to the free end of each string (Figure 6).

If we turn the lamina so that the smooth surface and triangle are upward and horizontal, the system of weights will find its equilibrium configuration with the knot at the equiangular point of the triangle.

The reason is that the tension in each string is equal to the weight that it supports. Since the weights are the same, the three tensions are equal in magnitude. Since the vector sum of the tensions at the knot must be $\vec{0}$ under equilibrium conditions, the angles between the strings must be 120° . (The reasoning is precisely the same as that which justified $\nabla g(x, y) = \hat{u}_1 + \hat{u}_2 + \hat{u}_3 = \vec{0}$ in the preceding section. Of course, we have ignored any frictional effects exerted on the strings as they pass through their holes. We have already assumed the surface of the lamina to be smooth.)

Now, displace the knot horizontally. When the system was in equilibrium with the knot at the equiangular point of the triangle, the value of the gravitational potential energy of the system was minimum, subject to the geometrical constraints of the lengths of the strings. Moving the knot must increase the gravitational potential energy of the system. Thus the center of mass of the three weights below the lamina must rise. When that occurs, the total length of string below the lamina must have been shortened. Since our strings do not stretch, the new position of the knot requires that there now be a greater total length of string from the knot to the three vertices

than before the knot was moved.

We may conclude that the equiangular point is the point which solves the Steiner problem.

LITERATURE CITED

- Boyd, J.N., Lees, J.J., and P.N. Raychowdhury. 1990. The Convex Coordinates of the Fermat Point. *Virginia Journal of Science* 41:487-491.
- Boyd, J.N. and P.N. Raychowdhury. 1987. Convex Coordinates, Probabilities, and the Superposition of States. *The College Mathematics Journal* 18:186-194.
- Posamentier, A.S. 1984. *Excursions in Advanced Euclidean Geometry*. Addison-Wesley, Reading, MA.
- Strang, G. 1991. *Calculus*. Wellesley-Cambridge Press, Wellesley, MA.

Comparison of Larval Myomere Counts Among Species of *Nocomis* in Virginia (Actinopterygii: Cyprinidae)

Terre D. Green and Eugene G. Maurakis, Science Museum of Virginia, 2500 West Broad Street, Richmond, VA 23220, and Department of Biology, University of Richmond, Richmond, VA 23173

ABSTRACT

Larval myomere counts of *Nocomis platyrhynchus* were made using a dissecting light microscope equipped with polarizing filters, and then compared to those of the three other species of *Nocomis* (*Nocomis leptocephalus*, *Nocomis micropogon*, and *Nocomis raneyi*) found in Virginia. Average preanal myomere counts for *N. platyrhynchus* (26.9) were significantly different from those of the other three species (*N. raneyi* = 28.7; *N. micropogon* = 26.0; and *N. leptocephalus* = 25.9). This is especially important as larvae of *N. leptocephalus*, the only other species of *Nocomis* syntopic with *N. platyrhynchus* in the upper New River drainage, can now be distinguished from those of *N. platyrhynchus*. Larvae of *N. raneyi* also can be distinguished from those of other species of *Nocomis* in Virginia based on preanal myomere counts. However, larvae of *N. platyrhynchus* and *N. raneyi* cannot be distinguished from each other based on total myomeres (42.0 versus 41.7). Larvae of *N. platyrhynchus* can be distinguished from those of three of its nest associates (*Lythrurus ardens*, *Notropis rubellus*, and *Phoxinus oreas*), but not from *Campostoma anomalum* and *Luxilus chrysocephalus* using myomere counts.

INTRODUCTION

Nocomis (Cyprinidae) is composed of seven species in three species-groups: *Nocomis biguttatus* with *Nocomis asper* and *Nocomis effusus*; *Nocomis leptocephalus*; and *Nocomis micropogon* with *Nocomis platyrhynchus* and *Nocomis raneyi* (Lachner and Jenkins, 1971; Maurakis et al., 1991). Of these, four species (*N. leptocephalus*, *N. micropogon*, *N. platyrhynchus* and *N. raneyi*), representing two species-groups, are found in Virginia. *Nocomis leptocephalus* occurs in the New, Potomac, Rappahannock, York, James and Roanoke River drainages. *Nocomis micropogon* is distributed in the Potomac, Rappahannock, York and James River drainages. *Nocomis platyrhynchus* is endemic to the New River drainage, and *N. raneyi* occurs in the James and Roanoke River drainages in Virginia (Jenkins and Burkhead, 1994) (Table 1).

Total, preanal, and postanal myomeres of larval *N. leptocephalus*, *N. micropogon*, and *N. raneyi* have been counted and compared by Maurakis et al. (1992). Currently, however, there is no information on the numbers of myomeres of larvae of *N. platyrhynchus*. The objective of this study is to present information on myomere counts of larval *N. platyrhynchus*, and compare them to counts of the other three species of *Nocomis* in Virginia, as well as nest associates of *N. platyrhynchus*.

TABLE 1. Rivers of Virginia containing *Nocomis leptcephalus*, *Nocomis micropogon*, *Nocomis platyrhynchus*, and *Nocomis raneyi*.

Species	River					
	New	Potomac	Rappahannock	York	James	Roanoke
<i>leptocephalus</i>	X	X	X	X	X	X
<i>micropogon</i>		X	X	X	X	
<i>platyrhynchus</i>	X					
<i>raneyi</i>					X	X

MATERIALS EXAMINED

The state, drainage, larvae (L), eggs (E), collection number (ANSP, Academy of Natural Sciences of Philadelphia; and EGM, Eugene G. Maurakis), locality, and collection date for *N. leptcephalus*, *N. micropogon*, *N. platyrhynchus*, and *N. raneyi* are:

Nocomis leptcephalus. Georgia: Savannah, (L), ANSP 140977, Columbia Co., Reed Cr., Rt. 28, 3.4 km N of jct. with Co. Rt. 26 near Martinez, 26 June 1976. North Carolina: Savannah, (L), EGM-NC-210, Jackson Co., Horsepasture R., U.S. Rt. 64, 2.2 km NE of Cashiers, 10 June 1988. Virginia: Roanoke, (L), ANSP 134421, Montgomery Co., Roanoke R. at Elliston, 13 June 1975.

Nocomis micropogon. Virginia: Potomac, (L), EGM-VA-254, Loudoun Co., Caectin Dr., Co. Rt. 633, 0.2 km from Co. Rt. 665 jct. near Lovettsville, 25 May 1990.

Nocomis platyrhynchus. Virginia: New, (L), EGM-VA-416, Montgomery-Floyd Co. line, Little R., 1 km upstream of State Rt. 8 bridge on dirt road, 16 May 1998. New, (E), EGM-VA-417, Montgomery Co., Little R., Co. Rt. 693 and 613 junction, about 8 km W of Riner, 16 May 1998.

Nocomis raneyi. Virginia: James, (L), EGM-VA-260, Craig Co., Johns Cr., Co. Rt. 632 at Maggie, 13 June 1990.

MATERIALS AND METHODS

Naturally-spawned eggs were collected with an aquarium dipnet from spawning areas of active nests of each of the four *Nocomis* species. Eggs were transported in tagged plastic jars to the laboratory where they were reared at room temperature (22°C) to fully scaled juveniles. Larvae were sampled at each of three larval stages (protolarval, mesolarval, and metalarval) following terminology in Fuiman (1982), and preserved in Bouin's fixative.

Preanal and postanal myomeres of larvae of each of the four species of *Nocomis* were counted using a dissecting light microscope equipped with polarizing filters. A vertical line was drawn at the posterior end of the anus, and any myomere that intersected this line was counted as preanal according to methods in Fuiman (1982). Total myomeres were calculated by adding preanal and postanal myomeres of each specimen. Eggs of *Nocomis platyrhynchus* were measured using a metric rule under the microscope.

Differences in average numbers of each of preanal, postanal, and total myomeres of larvae among the four species were determined with a General Linear Model and Duncan's Multiple Range Test (SAS, 1985).

TABLE 2. Average (range) preanal, postanal, and total myomeres of *Nocomis leptocephalus*, *Nocomis micropogon*, *Nocomis raneyi* and *Nocomis platyrhynchus*. Underscored means do not differ significantly ($p = 0.05$).

Myomere	Mean (range)				F value	Pr > F
	<i>leptocephalus</i> (n = 21)	<i>micropogon</i> (n = 24)	<i>platyrhynchus</i> (n = 53)	<i>raneyi</i> (n = 25)		
Preanal	<u>25.86 (24-28)</u>	<u>26.04 (24-28)</u>	26.88 (25-29)	28.72 (27-31)	42.69	0.0001
Postanal	<u>12.24 (11-13)</u>	<u>12.50 (11-14)</u>	15.09 (14-18)	13.00 (11-15)	78.52	0.0001
Total	<u>38.10 (36-41)</u>	<u>38.54 (36-41)</u>	<u>41.96 (40-45)</u>	<u>41.72 (39-44)</u>	73.97	0.0001

TABLE 3. Preanal myomere modes and means of *Nocomis leptocephalus*, *Nocomis micropogon*, *Nocomis platyrhynchus*, and *Nocomis raneyi*.

Species	Mode							\bar{x}	
	24	25	26	27	28	29	30		31
<i>leptocephalus</i>	2	5	9	4	1	-	-	-	25.86
<i>micropogon</i>	2	4	10	7	1	-	-	-	26.04
<i>platyrhynchus</i>	-	2	17	22	10	2	-	-	26.88
<i>raneyi</i>	-	-	-	4	6	9	5	1	28.72

When myomere counts were unavailable (e.g. *Lythrurus ardens*), an adjusted vertebral count (total minus one vertebrae) was used as a prediction of myomeres using methods of Fuiman (1982). Vertebral counts of *Phoxinus oreas* were determined from radiographs and were not adjusted as our counts of both myomeres and vertebrae included final elements. Specimens were exposed at 30kV and 5mA for 45 seconds.

RESULTS

Average total myomere counts of *N. leptocephalus* (\bar{x} = 38.10) and *N. micropogon* (\bar{x} = 38.54) are significantly lower than those for *N. raneyi* (\bar{x} = 41.72) and *N. platyrhynchus* (\bar{x} = 41.96) (Table 2). Preanal as well as postanal counts of *N. raneyi* (\bar{x} = 28.72, 13.00) and *N. platyrhynchus* (\bar{x} = 26.88, 15.09) differ significantly from those of *N. leptocephalus* (\bar{x} = 25.86, 12.24) and *N. micropogon* (\bar{x} = 26.04, 12.50) (Table 2). The modal preanal and total myomere counts for all four species are consistent with their respective mean values (Tables 3 and 4). Eggs of *N. platyrhynchus* averaged 2.1 mm in diameter, ranging = 2.0-2.2 mm.

TABLE 4. Total myomere modes and means of *Nocomis leptocephalus*, *Nocomis micropogon*, *Nocomis platyrhynchus*, and *Nocomis raneyi*.

Species	Mode										\bar{x}
	36	37	38	39	40	41	42	43	44	45	
<i>leptocephalus</i>	4	2	7	5	2	1	-	-	-	-	38.10
<i>micropogon</i>	1	5	5	8	3	2	-	-	-	-	38.54
<i>platyrhynchus</i>	-	-	-	-	7	11	18	13	2	2	41.96
<i>raneyi</i>	-	-	-	1	3	7	6	7	1	-	41.72

TABLE 5. Actual and predicted preanal, postanal, and total myomeres of larvae of nest associates of *Nocomis platyrhynchus*.

	Preanal	Postanal	Total
<i>Campostoma anomalum</i>	26-29	11-14	37-43
<i>Luxilus chrysocephalus</i>	26-27	12-14	38-41
<i>Lythrurus ardens</i> *	18-20	17-20	36-40
<i>Notropis rubellus</i>	19-23	15-18	34-41
<i>Phoxinus oreas</i> *	21-23	17-19	38-41
\bar{x}	22.1	17.4	39.5

* Myomere counts of *L. ardens* predicted from vertebral counts of Snelson (1972) using methods in Fuiman (1982), and myomeres predicted for *P. oreas* from our vertebral radiographs.

DISCUSSION

Nocomis platyrhynchus can be distinguished from other species of *Nocomis* in Virginia based on preanal, postanal, and total myomere counts with one exception. This is especially significant as *N. leptocephalus* is the only *Nocomis* species that occurs with *N. platyrhynchus* in the New River. *Nocomis platyrhynchus* cannot be separated from *N. raneyi* with total myomere counts. That larvae of *N. raneyi* also can be distinguished from those of *N. leptocephalus* and *N. micropogon* based on preanal and postanal myomere counts is consistent with results reported by Maurakis et al. (1992). Myomere counts of larval *N. platyrhynchus* are consistent with those of vertebrae (\bar{x} = 40.6, range = 39-42, mode = 41) in adults reported by Lachner and Jenkins (1971).

Larvae of *N. platyrhynchus* can be distinguished from those of some of its nest associates (i.e., species that congregate and may spawn over a nest but do not contribute to its construction) by myomere counts (Table 5). Lobb and Orth (1988) and Maurakis (1999) reported *Campostoma anomalum*, *Luxilus chrysocephalus*, *Lythrurus ardens*, *Notropis rubellus*, and *Phoxinus oreas* as nest associates of *N. platyrhynchus*. Larvae of *N. platyrhynchus* can be separated easily from those of *L. ardens* based on preanal myomeres as *N. platyrhynchus* has 25 to 29, and Snelson (1972) reported precaudal vertebra counts for *L. ardens* to be 18-20. *Notropis rubellus* can be distinguished from *N. platyrhynchus* based on preanal myomeres (range = 19-23,

Fuiman and Heufelder, 1982). Larvae of *P. oreas* may be differentiated from *N. platyrhynchus* by preanal myomeres as adult *P. oreas* have precaudal vertebra counts of 21-23. *Nocomis platyrhynchus* cannot be distinguished from *C. anomalum* on the basis of myomere counts. However, they can be distinguished by egg diameter (*N. platyrhynchus*, \bar{x} = 2.1 mm; range = 2.0-2.2; n = 10; *C. anomalum*, range = 2.3-2.4 mm, Auer, 1982), as well as by their spawning location. *Nocomis platyrhynchus* spawns in a trough on the upstream slope of the nest whereas *C. anomalum* spawns in pits on this slope. Larvae of *L. chrysocephalus* cannot be distinguished from those of *N. platyrhynchus* based on numbers of preanal, postanal and total myomeres of Fuiman and Heufelder (1982) or egg diameter (range = 2.0-2.3 mm) reported by Auer (1982).

Maurakis et al. (1992) indicated that the increased resolutions of scanning electron microscopy and compound light microscopy are superior to that of dissecting light microscopy for identification and enumeration of actual numbers of myomeres in larvae. They proposed that myomere counts made with dissecting light microscopy alone are not accurate where the actual number of myomeres is required. However, in this study, due to the great divergence in preanal, but particularly total myomere means and modes in *N. leptocephalus* and *N. platyrhynchus*, dissecting light microscopy is adequate for distinguishing larvae of the two species in the New River drainage.

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LITERATURE CITED

- Auer, N. A. (ed.). 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, Ann Arbor, MI 48105. Special Pub. 82-3:744 pp.
- Fuiman, L. A. 1982. Correspondence of myomeres and vertebrae and their natural variability during the first year of life in yellow perch, pp. 56-59. In C. F. Bryan, J. V. Conner, and F. M. Truesdale (eds.). The 5th Ann. Larval Fish Conf. La. Coop. Fish. Res. Unit and School of Forestry and Wildl. Mgt. La. St. Univ., Baton Rouge, LA.
- Fuiman, L. A. and G. R. Heufelder. 1982. Family Cyprinidae, carps and minnows. pp. 242-249, 270-276. In N. A. Auer (ed.). 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, Ann Arbor, MI 48105. Special Pub. 82-3:744 pp.
- Jenkins, R. E. and N. M. Burkhead. 1994. Freshwater Fishes of Virginia. Amer. Fish. Soc. Bethesda, MD. 1079 p.
- Lachner, E. A. and R. E. Jenkins. 1971. Systematics, distribution, and evolution of the chub genus *Nocomis* Girard (Pisces, Cyprinidae) of eastern United States, with descriptions of new species. Smiths. Contr. Zool. 85: 1-97.
- Lobb, M. D. and D. J. Orth. 1988. Microhabitat use by the Bigmouth chub *Nocomis platyrhynchus* in the New River, West Virginia. Am. Midl. Nat. 120(1):32-40.

- Muraklis, E. G., W. S. Woolcott, and M. H. Sabaj. 1991. Reproductive-behavioral phylogenetics of *Nocomis* species-groups. *Am. Midl. Nat.* 126: 103-110.
- Muraklis, E. G., W. S. Woolcott, G. P. Radice, and W. R. McGuire. 1992. Myomere counts in larvae of three species of *Nocomis* (Pisces: Cyprinidae).
- SAS Institute, Inc. 1985. SAS User's Guide: statistics. Version 5. SAS Institute, Cary, NC. 956 p.
- Snelson, F. F., Jr. 1972. Systematics of the subgenus *Lythrurus*, genus *Notropis* (Pisces: Cyprinidae). *Bull. Florida State Mus.* 17(1):1-92.

Feeding Habits of Young-of-Year Striped Bass, *Morone saxatilis*, and White Perch, *Morone americana*, in lower James River, VA

Paul J. Rudershausen, Tarpon Bay Environmental Laboratory, 900
A Tarpon Bay Road, Sanibel, FL 33957 and

Dr. Joseph G. Loesch, Virginia Institute of Marine Science, College
of William and Mary, P.O. Box 1346, Gloucester Point, VA 23062

ABSTRACT

A total of 188 young-of-year (YOY) striped bass, *Morone saxatilis*, and 199 YOY white perch, *Morone americana*, were collected by pushnet, seine and trawl during 24-hour periods from June through August, 1992 in lower James River, Virginia. The purpose was to identify prey and temporal and spatial feeding habits. Copepods were the most numerous prey of both species. Fishes and mysids comprised the largest volumetric percentage of diets of striped bass and white perch, respectively. Using an index of relative importance, leptodoridae and copepods were the most important prey of striped bass and white perch, respectively. Both species shifted from planktonic to epibenthic foods with increasing length. Diets of striped bass and white perch captured by seine were significantly more diverse than those captured by trawl. No temporal or spatial differences in feeding success were found for striped bass. White perch captured at twilight and by pushnet fed more successfully than conspecifics captured at day, or by seine or trawl, respectively. Spearman correlation coefficient, Horn's index and Shannon-Weaver index indicated that diets between striped bass and white perch were significantly correlated, highly overlapping and equally diverse, respectively. With the exception of one temporal and one spatial comparison, interspecific comparisons of feeding success were not significantly different. Results indicate that young of both species feed opportunistically. Abiotic factors appear to have little direct relationship with YOY striped bass and YOY white perch feeding success.

INTRODUCTION

The striped bass, *Morone saxatilis* (Walbaum), and white perch, *Morone americana* (Gmelin), are recreationally, commercially and ecologically important species that use lower reaches of Chesapeake Bay tributaries as spawning and nursery grounds. Striped bass occur sympatrically with white perch over part of the range of white perch (Woolcott, 1962) with juveniles of both species utilizing similar estuarine habitats and niches (Rinaldo, 1971). White perch constitute a large part of the resident ichthyofauna of Chesapeake Bay tributaries (St. Pierre, 1971) and, as such, are important for cycling nutrients within estuarine food webs and contributing to the diet of larger fishes such as striped bass (Bath and O'Conner, 1982).

A low abundance of striped bass in the past has been partially attributed to habitat loss and declining in food production, which reduces survivability (Kelley, 1982). Feeding analyses on these two species are important because inadequate quantity and

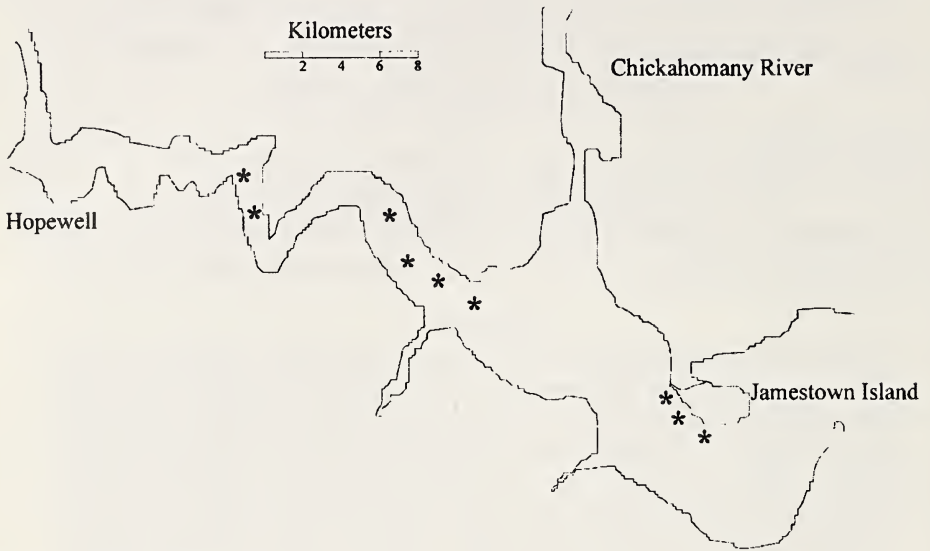


FIGURE 1. James River sampling sites.

quality of food may be contributing factors to year-class variability and poor year-class success (Rulifson, 1985). Additionally, feeding studies of fingerlings may be more accurate than similar studies on ichthyoplankton because the former assessment is conducted at a life history stage closer to that of the fishable stock (Boynton et al., 1977).

Food availability plays an important role in regulating juvenile striped bass growth (Dey, 1981). Additionally, food availability and foraging success may be major factors in habitat preference and movement of young-of-the-year moronids within nursery areas (Boynton et al., 1977).

Food and feeding patterns of YOY striped bass and YOY white perch are important in analyzing how natural or artificial changes in an estuary may affect year-class success and stock abundance. Food availability as measured by average stomach fullness is thought to play a major role in controlling both growth and mortality of YOY striped bass (Kline, 1990). The same may be true for YOY white perch.

Objectives of this study were to: identify prey items of striped bass and white perch; measure intra- and interspecific diet similarity, correlation and overlap; compare and contrast intra- and interspecific spatial and temporal feeding patterns; and determine the relationship between feeding success of each species and physical parameters that included light, temperature, salinity, and current speed.

METHODS

Field sampling took place over nine 24 hr periods between 20-21 June and 19-20 August, 1992 in James River, VA. Sample sites ranged from 56-90 km above the river mouth (Figure 1). Samples were taken within the same river km during each 24 hr period. Each 24-hr period consisted of either eight or nine 3 hr sampling blocks, depending on weather conditions. Although little information is available on residence

times of foods in stomachs of juvenile moronids, digestion appears to be rapid in larval striped bass stomachs, with some foods entering the intestine $\frac{1}{2}$ hr post-feeding (Chu and Ozkizilcik, 1999). Young (ages 0 and 1) largemouth bass (*Micropterus salmoides*) had an average of 31.6 % of their meal remaining 2.5 hours after being fed 2% of their body weight in live minnows at 26°C (Hayward and Bushmann, 1994). We felt that a 3 hr interval between sampling blocks was sufficient enough to allow feeding activity to be partitioned between three times of day but short enough in duration to help increase sample size.

At the beginning of each block, samples were taken in a randomly selected order, by three gears deployed in four habitats to detect temporal and spatial feeding patterns. A 15.2 m long, 1.2 m deep seine with 6.4 mm mesh was deployed in the nearshore zone perpendicularly to shore and swung down-current back to the beach. A 2.25 m² pushnet (Kriete and Loesch, 1980) that had 20 mm mesh at the mouth and 12 mm mesh at the cod end was affixed to the front end of a twenty-one foot skiff and used to sample channel near-surface and shoal near-surface habitats. A 4 m semi-balloon otter trawl with 30 mm mesh at the mouth and 13 mm mesh at the cod end was also affixed to the boat for bottom sampling in the river channel. Vessel-deployed gear was fished countercurrent for five minutes at a speed of roughly 3.5 km/hr. Seventy-seven samples each were collected with the beach seine, shoal pushnet and otter trawl. Sixty-nine samples were collected with the channel pushnet.

Physical parameters were recorded with each sampling block. Current was visually estimated as fast, medium, slow or zero for each collection. Surface temperature and salinity were recorded for each sampling block. Light readings at 0.5 m below the surface were recorded for each sampling block. Daytime collections were considered those when light exceeded 25.0 $\mu\text{E}/\text{m}^2/\text{sec}$; twilight between 0.1 $\mu\text{E}/\text{m}^2/\text{sec}$ and 25.0 $\mu\text{E}/\text{m}^2/\text{sec}$; and night less than 0.1 $\mu\text{E}/\text{m}^2/\text{sec}$.

Captured YOY striped bass and white perch were fixed in a 5 % buffered formalin solution for 48 hr after capture and then transferred to a 70 percent ethanol solution. Fork length (FL) and total length (TL) of each specimen were measured to the nearest mm.

For this study, stomach contents were removed from the base of the esophagus to the first major curve of the small intestine. Stomach contents were identified to the lowest practical taxon and enumerated. An ocular micrometer was used to measure the volume of each food item by first measuring the item's length and width, and then turning the food item on its side to measure its depth.

An index of relative importance (Pinkas et al., 1971) was used to estimate contributions of major food groups to diets of both species. Index of relative importance (IRI) is defined as: $\text{IRI} = F(N+V)$ where F is percent frequency of occurrence of a food group, N is numerical percentage of the food group and V is volumetric percentage of the food group. Frequency of occurrence of food items was determined relative to total number of stomachs, regardless of whether they were full or empty. IRIs were computed for all specimens and 5 size classes (TL) of each species: 30 mm or less; 31-40 mm; 41-50 mm; 51-60 mm; and 61 mm and above.

Measure of intra- and interspecific similarity were calculated by applying Spearman rank correlation coefficients to percent frequency of occurrence of food groups. This is done by calculating the percent frequency of occurrence of each food group,

ranking the food groups in descending order of their frequency of occurrence, and then applying the Spearman rank correlation coefficient, r_s . Unlike the parametric correlation coefficient, the Spearman coefficient is distribution-free, a condition that was not met for either species for the data on frequency of occurrence.

Comparisons of intra- and interspecific diet overlap were made with Horn's index (R) of overlap (Horn, 1966), where R ranges from 0 (no overlap) to 1 (complete overlap). Intra- and interspecific comparisons of dietary diversity of striped bass and white perch were performed using Shannon-Weaver diversity index (Shannon, 1948).

A gravimetric index of relative fullness (IRF) was measured for each specimen and used to test for temporal and spatial differences in feeding success (food consumption). IRF is defined as the quotient of dry weight of stomach contents of a specimen divided by dry weight of a specimen after its stomach has been removed, multiplied by 100 (Smyly, 1952). Parametric tests could not be used to test for differences in mean fullness because assumptions were violated before and after the data was transformed. Subsequently, the Wilcoxon signed-rank test (Wilcoxon, 1945) was used to make pairwise tests for differences in mean fullness. Intraspecific temporal comparisons of feeding success were performed using only specimens captured by seine and using only specimens captured by trawl. For each species, channel pushnet and shoal pushnet catches were combined due to low catches in the channel pushnet. Intraspecific spatial comparisons of feeding success were performed between: pushnet and seine specimens; pushnet and trawl specimens; and seine and trawl specimens.

Feeding success of striped bass and white perch was examined for interspecific differences between: all striped bass and white perch; specimens captured at day, twilight, and night, respectively; seine specimens; trawl specimens; and specimens captured by both pushnets. Interspecific feeding comparisons were also performed for: seine catches at day, twilight and night; and trawl catches at day, twilight and night.

For each species, linear multiple regression was performed to examine relationships between abiotic factors and striped bass and white perch feeding success. A regression model for feeding success was developed using light, temperature, salinity and current speed as independent variables. For the model, dummy variables were used by assigning a value of one to the current speed at which the specimen was caught, and zero values to the other three estimates of current speed. The dependent variable, feeding success, was measured with IRFs. Each regression model was run with a minimum tolerance of 0.10.

RESULTS AND DISCUSSION

A total of 188 striped bass and 199 white perch were captured in 300 collections (Table 1).

Striped bass and white perch captured by seine were significantly longer than those captured by trawl ($t=15.04$; $p<0.0005$ and $t=19.94$; $p<0.0005$, respectively).

A total of 6,402 food items were found in striped bass stomachs. Adult copepods were the most numerous food item found in striped bass. Fish comprised the largest volumetric percentage of striped bass food items. Leptodorida cladocerans (leptodoridae) were found in the greatest percentage of striped bass. Five striped bass stomachs were empty. Using an index of relative importance, the five most important striped bass food groups, in descending order of importance, were leptodoridae, copepods, insect pupae, fish and insect larvae. The percent frequency of occurrence,

TABLE 1. Catches of striped bass and white perch by gear and time of day.

	Day	Twilight	Night
Striped bass			
haul seine	45	15	14
channel pushnet	1	1	2
shoal pushnet	13	13	2
otter trawl	38	22	22
White perch			
haul seine	43	6	17
channel pushnet	0	1	0
shoal pushnet	1	60	0
otter trawl	30	25	16

numerical percentage, volumetric percentage, and indices of relative importance of major striped bass food groups are presented in Table 2.

A total of 11,278 food items were found in white perch stomachs. Adult copepods were the most numerous food item found in white perch. Mysids comprised the largest volumetric percentage of white perch food items. Adult copepods were found in the greatest percentage of white perch. Four white perch stomachs were empty. The five most important white perch food groups, in descending order of relative importance, were copepods, leptodoridae, insect larvae, bosminids and insect pupae. The percent frequency of occurrence, numerical percentage, volumetric percentage and indices of relative importance of major white perch food groups are presented in Table 3.

Diets of larger striped bass and white perch shifted to larger food items. Tables 2 and 3 summarize the shifts in dietary preferences (as measured by indices of relative importance) of striped bass and white perch, respectively.

The Spearman rank correlation coefficient, R_s , between striped bass and white perch diets was 0.86 and highly significant ($p < 0.001$). Horn's index of overlap, R_o , between striped bass and white perch diets was 0.77. To perform the Shannon-Weaver analysis, food items of both striped bass and white perch were divided into twelve categories. The diversity of striped bass diets was not significantly different from the diversity of white perch diets ($t = 1.24$; $0.2 < p < 0.5$).

Diets of striped bass captured by the two most successful gears, seine and trawl, were compared. Using the Spearman rank correlation coefficient for tied ranks, they were not significantly correlated with each other ($R_s = 0.47$; $0.1 < p < 0.2$). Horn's index of overlap, R_o , between these two groups of striped bass was 0.64, although this relatively high value is attributable to the consumption of fish by two trawl striped bass. Had these two specimens not consumed fish, R_o would have been 0.151. The diets of striped bass captured by seine were significantly more diverse than the diets of striped bass captured by trawl ($t = 8.90$; $p < 0.0005$).

Diets of white perch captured by seine and trawl were also compared. The Spearman coefficient found that the diets of white perch captured by seine and trawl

TABLE 2. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of major food groups for five size classes of striped bass.

Striped bass ≤ 30 mm							
Food group	#bass	#eaten	vol.(mm ³)	F	N	V	IRI
copepods	50	1175	18.73	83.3	71.6	36.7	9021.4
leptodorids	50	242	29.87	83.3	14.8	58.6	6114.2
bosminids	17	153	1.32	28.3	9.3	2.6	336.8
copepod nauplii	17	45	0.33	28.3	2.7	0.7	94.8
Striped bass 31-40mm							
Food group	#bass	#eaten	vol.(mm ³)	F	N	V	IRI
leptodorids	37	653	71.90	74.0	40.4	62.1	7585.0
copepods	29	660	9.42	58.0	40.8	8.1	2836.2
insect pupae	6	19	14.42	12.0	1.2	12.5	164.4
insect larvae	7	62	7.04	14.0	3.8	6.1	138.6
Striped bass 41-50mm							
Food group	#bass	#eaten	vol.(mm ³)	F	N	V	IRI
leptodorids	23	1262	149.98	57.5	65.5	73.1	7965.5
copepods	23	295	4.68	57.5	15.3	2.3	1012.0
insect larvae	13	126	20.49	32.5	16.5	10.0	536.3
insect pupae	7	65	13.49	17.5	3.4	6.6	175.0
Striped bass 51-60mm							
Food group	#bass	#eaten	vol.(mm ³)	F	N	V	IRI
copepods	7	385	6.67	33.3	40.8	1.8	1418.6
mysids	5	142	151.35	23.8	15.0	40.2	1314.3
fish	4	8	151.18	19.1	0.8	40.2	781.1
insect larvae	11	44	21.42	52.4	4.7	5.7	544.8
Striped bass > 60 mm							
Food group	#bass	#eaten	vol.(mm ³)	F	N	V	IRI
insect pupae	9	162	56.52	52.9	59.6	14.2	3907.0
fish	6	7	266.74	35.3	2.6	67.2	2463.9
insect larvae	5	39	20.29	29.4	14.3	5.1	570.4
mysids	1	31	32.85	5.9	11.4	8.3	115.8
All striped bass							
Food group	#bass	#eaten	vol.(mm ³)	F	N	V	IRI
leptodorids	119	2186	255.18	63.3	34.1	22.3	3570.1
copepods	113	2526	39.68	60.1	39.5	3.5	2584.3
insect pupae	36	271	104.43	19.1	4.2	9.1	254.0
fish	11	16	424.57	5.9	0.2	37.1	220.1
insect larvae	37	272	69.36	19.7	4.2	6.1	202.9

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TABLE 3. Percent frequency of occurrence (F), numerical percentage (N), volumetric percentage (V), and relative importance (IRI) of major food groups for five size classes of white perch.

White perch ≤ 30 mm							
Food group	#perch	#eaten	vol.(mm ³)	F	N	V	IRI
copepods	75	3295	53.80	90.4	81.5	47.6	11670.6
leptodoridae	67	404	52.80	80.7	1.0	46.8	4583.8
copepod nauplii	34	167	1.07	41.0	4.1	1.0	206.8
bosminids	23	117	1.01	27.7	2.9	0.9	105.0
White perch 31-40mm							
Food group	#perch	#eaten	vol.(mm ³)	F	N	V	IRI
copepods	31	1975	34.30	67.4	83.7	35.8	8054.3
leptodoridae	18	219	31.12	39.1	9.2	32.5	1630.5
insect larvae	6	15	7.66	13.0	0.6	8.0	112.7
copepod nauplii	17	61	0.36	37.0	2.6	0.4	110.1
White perch 41-50mm							
Food group	#perch	#eaten	vol.(mm ³)	F	N	V	IRI
copepods	21	1478	22.28	70.0	68.6	15.4	5876.5
leptodoridae	11	254	24.63	36.6	11.8	17.0	1053.3
mysids	5	53	58.16	16.6	2.5	40.2	708.2
insect larvae	12	35	10.38	40.0	1.6	7.2	352.0
White perch 51-60mm							
Food group	#perch	#eaten	vol.(mm ³)	F	N	V	IRI
insect larvae	24	243	101.74	77.4	13.5	40.8	4202.0
insect pupae	21	138	65.81	67.7	7.7	26.4	2308.6
copepods	22	431	6.60	71.0	23.9	2.6	1881.5
bosminids	12	644	4.51	38.7	35.8	1.8	1455.5
White perch >60mm							
Food group	#perch	#eaten	vol.(mm ³)	F	N	V	IRI
mysids	3	82	62.89	33.3	8.9	72.1	2697.3
bosminids	2	680	4.88	22.2	74.1	5.6	1769.3
insect larvae	5	30	7.59	55.5	3.3	8.7	666.0
ostracods	2	9	0.29	22.2	1.0	0.3	29.1
All white perch							
Food group	#perch	#eaten	vol.(mm ³)	F	N	V	IRI
copepods	151	7183	117.03	75.9	63.7	17.0	6125.1
leptodoridae	109	1024	113.22	54.8	9.1	16.4	1397.4
insect larvae	50	326	127.89	25.1	2.9	18.5	537.1
bosminids	48	1458	10.57	24.1	12.9	1.5	347.0
insect pupae	32	161	79.39	16.1	1.4	11.5	207.7

were not significantly correlated with each other ($R_s=0.08$; $0.5 < p$). Horn's index of overlap, R_o , between these two groups of white perch was 0.27. The diets of white perch captured by seine were significantly more diverse than the diets of white perch captured by trawl ($t=12.51$; $p < 0.0005$).

Striped bass and white perch captured by trawl had diets that largely consisted of zooplankton, with copepods, leptodoridae, and bosminids the three most important foods. These three groups of zooplankton comprised 98.1% and 98.5% of the sum of IRIs across all food groups of striped bass and white perch respectively, captured by trawl. The importance of zooplankton to striped bass and white perch captured by seine decreased as insect larvae, insect pupae, mysids and fish became substantial dietary components. For moronids captured by seine, the same three groups of zooplankton comprised 55.0% and 46.6% of the sum of IRIs for striped bass and white perch respectively, captured by seine.

Feeding success (as measured by IRFs) was independent of time or location of capture for striped bass (Table 4).

Feeding success was associated with time of capture for white perch. White perch captured at twilight had a significantly greater mean IRF than those captured at day ($Z=2.093$; $p=0.036$). Feeding success of white perch was also associated with location of capture, as white perch captured by pushnet had a significantly greater mean IRF than those captured by seine ($Z=2.492$; $p=0.013$) or by trawl ($Z=2.251$; $p=0.024$). Temporal and spatial comparisons of feeding for white perch are presented in Table 5.

For interspecific comparisons of feeding, white perch captured at twilight had a significantly greater mean IRF than striped bass captured at twilight ($Z= 2.325$; $p=0.020$). Additionally, white perch captured by pushnet had a significantly greater mean IRF than striped bass captured by pushnet ($Z=3.216$; $p=0.001$). Interspecific feeding comparisons are presented in Table 6.

For the regression examining striped bass feeding success, salinity and fast current speed were found to be significantly and positively related to feeding success at $\alpha=0.05$ with an $r^2=0.164$. The fitted equation was $Y = 0.183 + 0.294 S + 0.276 FCS$ where Y was the fitted IRF value, 0.183 was the constant α , and 0.294 and 0.276 were the regression coefficients, β_1 's, for salinity, S , and fast current speed, FCS , respectively. The values for the t-statistic were 0.340, 4.948 and 2.468 for α , β_1 , and β_2 , respectively.

For the regression examining white perch feeding success, a fast current speed had a significant, positive relationship with feeding success at $\alpha=0.05$. The r^2 was 0.284. The fitted equation was $Y = -0.487 + 0.805 FCS$ where Y was the fitted IRF value, -0.487 was the constant α , and 0.805 was the partial regression coefficient, β , for fast current speed, FCS . The values for the t-statistic were -0.784 and 7.809 for α and β , respectively.

The low catches of YOY striped bass in James River in this study are consistent with YOY striped bass population data collected by Colvocoresses et al. (1993), who caught fewer than the average numbers of striped bass in James River in 1992. Additionally, steadily decreasing catches of striped bass throughout the summer in this study parallels typical seasonal findings by the Virginia Institute of Marine Science juvenile striped bass seining survey (Colvocoresses, 1990).

TABLE 4. Temporal and spatial index of relative fullness (IRF) comparisons for striped bass.

comparison	mean IRF	Z	p
day	0.378	0.572	0.567
twilight	0.481		
day	0.378	-1.256	0.209
night	0.312		
twilight	0.481	-1.559	0.119
night	0.312		
pushnets	0.348	-1.309	0.191
seine	0.455		
pushnets	0.348	-0.075	0.940
trawl	0.350		
seine	0.455	-0.916	0.360
trawl	0.350		
day seine	0.414	1.533	0.125
twilight seine	0.656		
day seine	0.414	-0.282	0.778
night seine	0.374		
twilight seine	0.656	-1.161	0.245
night seine	0.374		
day trawl	0.382	0.406	0.685
twilight trawl	0.368		
day trawl	0.382	-0.438	0.661
night trawl	0.275		
twilight trawl	0.368	-0.698	0.485
night trawl	0.275		

A combination of several factors may have led to relatively low catches of striped bass and white perch in this study (and others) in James River in 1992. These factors include patchiness (McGovern and Olney, 1988), gear avoidance, downstream drift or dispersal from the sampling area (Raney, 1952; Calhoun, 1953; Sasaki, 1966; Markle and Grant, 1970; Rinaldo, 1971; Turner and Chadwick, 1972; Boynton et al., 1977; Kernehan et al.

The most plausible explanation of low catches of striped bass is relatively poor year-class success in James River in 1992. Potential patchiness may have been rectified at least for striped bass if sampling had been expanded outside of the historical center of YOY striped bass abundance in James River. Although patchiness may have

TABLE 5. Temporal and spatial index of relative fullness (IRF) comparisons for white perch.

comparison	mean IRF	Z	p
day twilight	0.359 0.582	2.093	0.036
day night	0.359 0.190	-0.393	0.694
twilight night	0.582 0.190	-1.831	0.067
pushnets seine	0.727 0.314	2.492	0.013
pushnets trawl	0.727 0.292	2.251	0.024
seine trawl	0.314 0.292	-0.144	0.886
day seine twilight seine	0.367 0.174	-1.153	0.249
day seine night seine	0.367 0.228	0.284	0.776
twilight seine night seine	0.174 0.228	-0.734	0.463
day trawl twilight trawl	0.352 0.311	-0.283	0.778
day trawl night trawl	0.352 0.154	0.284	0.776
twilight trawl night trawl	0.311 0.154	-0.734	0.463

contributed to low catches, the intensity of this study's sampling (300 collections) over a nine week period should have minimized the effects of patchiness. Gear avoidance by larger YOY striped bass and white perch as well as downstream drift by both species may have contributed to reduced catch rates, particularly as summer progressed.

Although striped bass and white perch captured by seine were significantly longer, respectively, than those captured by trawl, it is not clear whether these intraspecific size differences were due to a true shoreward migration, avoidance of the trawl, or a combination of these factors. As larvae, striped bass and white perch are planktonic and appear to exhibit a shoreward migration as they become nektonic juveniles (Boynton et al., 1977). In the Potomac River, Boynton et al. (1977) found that YOY

TABLE 6. Interspecific index of relative fullness (IRF) comparisons.

comparison	mean IRF	Z	p
all striped bass	0.391	0.497	0.619
all white perch	0.435		
day bass	0.378	-0.199	0.842
day perch	0.359		
twilight bass	0.481	2.325	0.020
twilight perch	0.582		
night bass	0.312	-0.509	0.611
night perch	0.190		
trawl bass	0.350	-0.464	0.643
trawl perch	0.292		
seine bass	0.455	-1.747	0.081
seine perch	0.314		
pushnet bass	0.348	3.216	0.001
pushnet perch	0.727		
day trawl bass	0.382	-0.751	0.453
day trawl perch	0.352		
twilight trawl bass	0.368	-0.666	0.506
twilight trawl perch	0.311		
night trawl bass	0.275	0.724	0.469
night trawl perch	0.154		
day seine bass	0.414	-0.350	0.726
day seine perch	0.367		
twilight seine bass	0.656	-1.572	0.116
twilight seine perch	0.174		
night seine bass	0.374	-0.910	0.363
night seine perch	0.228		

striped bass were more abundant at nearshore sights and had higher feeding success (weight of food items per individual) at these nearshore sights. Additionally, Dey (1981) found in the Hudson River that post-larval and juvenile striped bass moved shoreward and onto shoal areas. Kernehan et al. (1981) found that progressively larger striped bass were taken closer to shore in upper Chesapeake Bay nursery areas. White perch may use nearshore areas for similar reasons as striped bass.

The Shannon-Weaver index found that striped bass and white perch captured by seine had significantly more diverse diets, respectively, than those captured by trawl. Older, more mobile striped bass and white perch begin to consume larger prey

presumably to more efficiently meet greater nutritional requirements (Elrod et al., 1981). The finding that striped bass and white perch fed to a large extent on epibenthic prey is consistent with other research on YOY striped bass feeding (Markle and Grant 1970; Bason, 1971) and YOY white perch feeding (Hildebrand and Schroeder, 1928; Elrod et al., 1981; Bath and O'Conner, 1985; Weisberg and Janicki, 1990). These dietary changes may have also been related to seasonal abundance and availability of specific food items (Calhoun, 1953; Thomas, 1967).

While no significant differences in mean IRFs were found among groups of striped bass, two significant differences were found among white perch. Only four collections yielded all 61 white perch captured at twilight by pushnet. The much greater average IRF (0.728) for white perch captured at twilight by pushnet than the average IRF (0.435) for all other white perch accounts for the only significant differences in IRFs among conspecifics and congeners in this study. Consistent with this study, Webster (1942) found that young white perch taken from freshwater fed most heavily early in the evening and much less later into the night or early in the morning. Although our findings suggest that young white perch feed heavily prior to sunset, further inquiry is needed before a definitive conclusion may be reached.

Few stomachs of either species were either gorged or empty. The majority of striped bass and white perch stomachs were partially full, which suggests that a moderate level of feeding had taken place prior to capture, and that young of both species forage and feed in widely varying habitats and light levels. The ability of juvenile striped bass and white perch to feed at night suggests that senses other than light are important for prey detection.

Once striped bass become nektonic they predominantly inhabit nearshore areas rather than move shoreward on a daily basis (Boynton et al., 1981; Dey, 1981; Kernehan et al., 1981). The lack of a daily movement would increase the importance of analyzing within-gear catches to detect temporal feeding patterns. Yet striped bass and white perch captured by seine and trawl showed no significant intraspecific within-gear feeding trends. These findings support the widely held view that YOY striped bass and white perch feed whenever food becomes available (Bigelow and Welsh, 1925; Scofield, 1931; Raney, 1952; Boynton et al., 1981; Elrod et al., 1981).

The similarity in feeding niches between young striped bass and white perch is shown by a high Horn's index, a highly significant Spearman rank coefficient, and similar Shannon-Weaver indices. Although Rinaldo (1971) found that striped bass greater than 19 mm in the Pamunkey River had more diverse diets than similarly sized white perch, the Shannon-Weaver index indicated no significant interspecific differences in dietary diversity in this study. Additionally, with exception of specimens capture at twilight, or by pushnet, there were no significant interspecific differences in feeding success. The similarity in feeding niches, feeding success and habitats of YOY striped bass and white perch indicates that interspecific competition may occur, which could be critical should food items become limited (Rinaldo, 1971). However, YOY white perch exhibit less downstream drift than YOY striped bass (Rinaldo, 1971), which may help to reduce interspecific niche overlap and competition for food as summer progresses.

An inverse relationship has been found between first year growth and cohort abundance for both striped bass (Chadwick, 1964) and white perch (Mansueti, 1961). The findings of an inverse relationship between growth and abundance underscore the

ramifications of intra- and interspecific competition for food when large numbers of young of one or both species are produced. It has been suggested that fish community density rather than population density of any one species is most important to the growth of individuals of any particular species (Boisclair and Leggett, 1989). A pertinent topic of future research would be to compare feeding success and condition factors of striped bass and white perch between years of high and low abundances.

Greater salinity being positively related to striped bass feeding success is attributed to mysids in the diets of striped bass collected at higher salinities. Mysids were 66.9% of the total volume of food items consumed by striped bass at the four stations with measurable salinities. Striped bass that had eaten mysids had an average IRF of 1.176, compared to the average IRF for all striped bass of 0.391.

Although a positive relationship was found between fast current speed and white perch feeding success, the low adjusted r^2 for striped bass and white perch regressions indicates that using a linear regression model, only a small percentage of the total variation in striped bass and white perch IRFs can be accounted for. It would appear that striped bass and white perch feeding success is directly due to the availability of food (Calhoun, 1953; Thomas, 1967), which is indirectly determined by a combination of abiotic environmental factors (Boynton et al., 1981).

Both species shifted towards consumption of mysids with greater salinity. Similarly, Markle and Grant (1970) found in the James River that due to the unavailability of mysids at low salinity sites, insect larvae became the most frequent food item of striped bass 25-100 mm in length. Mysids and decapods would have likely comprised a much larger numeric and volumetric percentage of prey of both species in this study if more sampling was conducted at higher salinities.

The wide array of food items consumed by juvenile striped bass and white perch suggests that an unselective, opportunistic feeding strategy is employed. Such a feeding strategy by juvenile striped bass has been suggested by other authors (Bigelow and Welsh, 1925; Scofield, 1931; Raney, 1952; Boynton et al., 1981; Elrod et al., 1981). Such a strategy likely allows juvenile striped bass and white perch to adjust to variable environmental conditions (Boynton et al., 1981).

Striped bass were captured in only 64 of 300 collections and white perch were captured in only 52 of 300 collections. Greater catches would have increased the power of statistical tests and may have led to the detection of movements and feeding patterns that were otherwise undetected in this study.

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LITERATURE CITED

- Bason, W.H. 1971. Ecology and early life history of striped bass, *Morone saxatilis*, in the Delaware Bay estuary. Prog. Rep. 3 (Part IV). Ichthyological Assoc., Ithaca, NY.
- Bath, D.W. and J.M. O'Conner. 1982. The biology of the white perch, *Morone americana*, in the Hudson River estuary. N.Y. Fish Game J. 80(3):599-610.

- Bath, D.W. and J.M. O'Conner. 1985. Food preferences of white perch in the Hudson River estuary. N.Y. Fish Game J. 32(1): 63-70.
- Bigelow, H.B., and W.W. Welsh. 1925. Fishes of the Gulf of Maine. Bull. U.S. Bur. Fish. 40. Part 1, 567 p.
- Boisclair, D. and W.C. Leggett. 1989. Among population variability of fish growth: Influence of fish community. Can. J. Fish. Aquat. Sci. 46: 1539-1550.
- Boynton, W.R., T.T. Polgar, and H.H. Zion. 1981. Importance of juvenile striped bass food habits in the Potomac estuary. Trans. Am. Fish. Soc. 110: 56-63.
- Boynton, W.R., E.M. Setzler-Hamilton, K.V. Wood, H.H. Zion, M. Homer and J.A. Mihursky. 1977. Potomac River Fisheries Program: Ichthyoplankton and juvenile investigations. Final Rep. MD Dept. Nat. Res. Ches. Biol. Lab. Ctr. Env. Studies, Univ. MD Ref. No. UMCEES 77-169 CBL: 248 p.
- Calhoun, A.J. 1953. Distribution of striped bass fry in relation to major water diversions. Cal. Fish Game 39(3): 279-299.
- Chadwick, H.K. 1964. Annual abundance of young striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. Cal. Fish Game 50(2): 69-99.
- Chu, F-L.E. and S. Ozkizilcik. 1999. Acceptability of complex microencapsulated diets by striped bass (*Morone saxatilis*) larvae. J. Exp. Mar. Biol. Ecol. 237(1): 1-9.
- Colvocoresses, J.A. 1990. Striped bass research, Virginia. Estimation of juvenile striped bass relative abundance; Annual Report, 1989. Va. Inst. Mar. Sci, Glouc. Pt., VA.
- _____, A.D. Estes, and D.M. Seaver. 1993. Striped bass research, Virginia. Estimation of juvenile striped bass relative abundance; Annual Report, 1992. Va. Inst. Mar. Sci, Glouc. Pt., VA
- Dey, W.P. 1981. Mortality and growth of young-of-the-year striped bass in the Hudson River estuary. Trans. Am. Fish. Soc. 110: 151-157.
- Elrod, J.H., W.D.N. Busch, B.L. Griswold, C.P. Schneider and D.R. Wolfert. 1981. Food of white perch, rock bass and yellow perch in eastern Lake Ontario. N.Y. Fish Game J. 28(2): 191-201.
- Hayward, R.S. and M.E. Bushmann. 1994. Gastric evacuation rates for juvenile largemouth bass. Trans. Am. Fish. Soc. 123(1): 88-93.
- Hildebrand, S.F. and W.C. Schroeder. 1928. Fishes of the Chesapeake Bay. Bull. U.S. Bur. Fish. (1927) 43(1): 247-250.
- Horn, H.S. 1966. Measurement of "overlap" in comparative ecological studies. Am. Nat. 100: 419-424
- Kelley, D.W. 1982. The striped bass decline in the San Francisco Bay-Delta estuary. An analysis by the striped bass working group for the California State Water Resources Control Board, Sacramento, 58 p.
- Kernehhan, R.J., M.R. Hendrick, and R.E. Smith. 1981. Early life history of striped bass in the Chesapeake and Delaware Canal and vicinity. Trans. Am. Fish. Soc. 110: 137-150.
- Kline, L.L. 1990. Population dynamics of young-of-the-year striped bass (*Morone saxatilis*) populations, based on daily otolith increments. Doctoral dissertation. Va. Inst. Mar. Sci., College of William and Mary, Glouc. Pt., VA, 253p.
- Kriete, W.H. and J.G. Loesch. 1980. Design and relative efficiency of a bow-mounted pushnet for sampling juvenile pelagic fishes. Trans. Am. Fish. Soc. 109: 649-652.

- Mansueti, R.J. 1961. Movements, reproduction and mortality of the white perch, *Roccus americanus* in the Patuxent estuary, Maryland. Ches. Sci. 2(3-4): 142-205.
- Markle, D.F. and G.C. Grant. 1970. The summer food habits of young-of-the-year striped bass in three Virginia rivers. Ches. Sci. 11(1): 50-54.
- McGovern, J.C. and J.E. Olney. 1988. Potential predation by fish and invertebrates on early life stages of striped bass in the Pamunkey River, Virginia. Trans Am. Fish. Soc. 117: 152-161.
- Pinkas, L., M.S. Oliphant, and I.L.K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. Cal. Dept. Fish Game Fish. Bull. 152: 1-105.
- Raney, E.C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull. Bigham Oceanog. Collect. 14(1): 1-97.
- Rinaldo, R.G. 1971. Analysis of *Morone saxatilis* and *Morone americanus* spawning and nursery areas in the York-Pamunkey River, Virginia. Masters thesis. VA Institute Marine Science, College of William and Mary, Gloucester Pt., VA, 56 p.
- Rulifson, R.A. 1985. Food and feeding of young striped bass in western Albermarle Sound, North Carolina. N.C. Dept. Nat. Res. Communic. Devel., Div. Mar. Fish: Compl. Rep. Contract No. C-1366 (ICMR Tech Rep. 84-07), 47 p.
- St. Pierre, R.A. 1971. Age, growth and mortality of the white perch, *Morone americana* (Gmelin) in the James and York Rivers, Virginia. Masters thesis. VA Institute Marine Science, College of William and Mary, Gloucester Pt., VA, 27 p.
- Sasaki, S. 1966. Distribution of juvenile striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. Pp 59-67 in Ecological studies of the Sacramento-San Joaquin Delta: Part II. Fishes of the Delta. J.L. Turner and D.W. Kelley (compilers): Cal. Dept. Fish Game Bull. No. 130.
- Scofield, E.C. 1931. The striped bass of California (*Roccus lineatus*). Bull. Cal. Fish Game 29: 1-82.
- Shannon, C.E. 1948. A mathematical theory of communication. Bell Sys. Tech. J. 27: 379-423, 623-656.
- Smyly, W. J. P. 1952. Observations on the food of fry of perch (*Perca fluviatilis* Linneatus) in Windermere. Proceed. Zool. Soc. London 122:407-416.
- Thomas, J.L. 1967. The diet of juvenile and adult striped bass (*Roccus saxatilis*) in the Sacramento-San Joaquin River system. Cal. Fish Game 53: 49-62.
- Turner, J.L. and H.K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin estuary. Trans. Am. Fish. Soc. 101: 442-452.
- Webster, D. A. 1942. Food progression in young white perch, *Morone americana* (Gmelin) from Bantam Lake, Connecticut. Trans. Am. Fish. Soc. 72: 136-144.
- Weisberg, S.B. and A.J. Janicki. 1990. Summer feeding patterns of white perch, channel catfish and yellow perch in the Susquehanna River, Maryland. J. Freshwater Ecol. 5(4): 391-405.
- Wilcoxon, F. 1945. Individual comparisons by ranking methods. Biometrics Bull. 1: 80-83.
- Woodhead, P.M.J. 1966. The behavior of fish in relation to light in the sea. Oceanog. Mar. Biol: Ann. Rev. 4: 337-403.
- Woolcott, W.S. 1962. Intraspecific variation in the white perch, *Roccus americanus* (Gmelin). Ches. Sci. 3: 94-113.

Binding of Pb and Zn to Aluminium Oxide and Proton Stoichiometry

Wing H. Leung and A. Kimaro, Department of Chemistry,
Hampton University, Hampton, Virginia 23668

ABSTRACT

The interaction of Pb and Zn with Al_2O_3 in aqueous solution was studied as a function of pH and metal ion concentration. Results indicated the complexation of metal ions by oxide surfaces is strongly pH dependent; the extent of adsorption is a function of pH with an abrupt change within approximately 2 pH units. The adsorption of Pb and Zn on aluminium oxide can be interpreted in terms of a surface complexation formed by association with one surface AlOH group, thus releasing one bound hydrogen ion. $-AlOH + M^{2+} = -AlOM^+ + H^+$. It is suggested that the major surface reaction is the formation of a monodentate inner-sphere complex.

INTRODUCTION

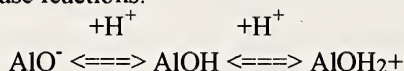
Metallic oxides and silicas are abundant components of the earth's crust. Adsorption of metals from aqueous solution onto oxide surfaces is considered to be an important process in natural environments and in many industrial systems. Examples include the interactions between sediments and the water column, the mobility and transportation of trace metals in natural waters, leaching of metals from landfills, and the use of adsorption for removal or recovery of trace metals in wastewater and water treatment operations. It is therefore of practical and theoretical interest to obtain a detailed understanding of the sorption process at the oxide-water interface. This understanding hinges to a great extent upon elucidation of the nature of particulate surface, and the effects of pH, ionic strength, and metal concentrations. pH is probably the single most important factor influencing metal behavior in aqueous systems. Typically adsorption of metals on oxides increases from near zero to nearly 100% as pH increases through a critical range of 1-2 units wide (Lion et al., 1982; Benyahya and Garnier, 1999).

The mobility of metal ions in aquatic environment is often characterized by a distribution coefficient K_d defined as the ratio of the concentration of metal adsorbed on the solid phase (Γ) to that in solution at equilibrium (C_f). High values of K_d indicate that the metal has been retained by the solid through sorption reactions, while low values of K_d indicate that most of the metal remain in solution where it is available for transportation and geochemical reactions. Trace metal ion adsorptions at oxide/natural waters interfaces are often better described by a distribution coefficient, since their concentrations in natural aquatic systems are usually low.

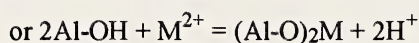
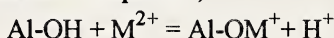
Several mechanisms and models have been developed for metal ion adsorption reactions at the oxide-water interface. (1) James and Healy (1972) proposed an ion-solvent interaction model, which considers electrostatic, solvation, and specific chemical energy interactions as the ion approaches the interface and which implies that a lowering of the ionic charge of the metal species (e.g., by hydrolysis) decreases the ion-solvent interaction which presents a barrier to close approach of multiple

charged ions to the surface. The pH at which adsorption of metal ions becomes significant is the pH at which the dissolved cations undergo hydrolysis to hydroxy complexes. It is because the hydrolyzed species do not have a strongly held hydration shell to prevent adsorption. (2) The ion exchange model suggested by Dugger (1964), according to which metallic cations upon adsorption on the hydrous oxide surface replace protons from hydroxyl groups $-AlOH$. And (3) Schindler-Stumm surface complex formation model (Stumm et al., 1970; Huang et al., 1973; Schindler et al., 1987; Hohl et al., 1976; Schindler, 1981) hypothesizes that complexes are formed at the surface of the oxide, which is composed of a hydroxyl species bound to a central cation. In this model the hydrous oxide surface groups, $-AlOH$, $-AlO^-$, or $-Al-OH_2^+$ are treated similar to amphoteric functional groups in polyelectrolytes, as complex forming species. The fundamental concept is that adsorption takes place at defined coordination sites (the surface hydroxyl groups are present in finite number). The surface complexation model permits us to handle adsorption equilibria in the same way as equilibria in solution; adsorption is thus closely analogous to complex formation in solution, and can be described by similar equations.

Accordingly, we interpret our results of adsorption of metal ions (M^{2+}) on Al_2O_3 in terms of this latter model and characterize the amphoteric and complex forming properties by the acid-base reactions:



and the following coordination reactions, (thus leading to the formation of either monodentate or bidentate surface complexes.)



where M^{2+} is either Pb^{2+} or Zn^{2+} in this study.

Competitive complex formation equilibria (metal ion versus H^+ , or anion versus OH^-) explain the strong dependence of metal ion (as well as anion) binding on pH.

Hence uptake and release of H^+ ions in solution can be described by the acidity constants. Similarly, adsorption equilibria involving metal ion are conveniently characterized by stability constants for the formation of surface complexes. According to the above equations, we assume that among other species in solution at the pH studied only free cations (Pb^{2+} or Zn^{2+} , and not another species such as $PbOH^+$ or $ZnOH^+$) form surface complexes (i.e. adsorbed) and that the pH-dependence of the association of metal ions can be explained by the pH-dependence of the surface concentration of the AlO^- group and the affinity of this group to the free metal ion.

Although experimental studies on adsorption conducted to date represents a considerable increase in knowledge, a quantitative application of this knowledge to natural aqueous environments is still inadequate. The binding stoichiometry of metal ions to the solid and suspended phase is not yet resolved satisfactorily. The focus of this study was (1) to study the effect of pH on the adsorption of metal ions (lead and zinc) on aluminium oxide, and (2) evaluate quantitatively the interaction of these cations with the surface hydroxyl group on aluminium oxide in terms of proton stoichiometry.

MATERIALS

A commercial product, Aluminium Oxide C (Fumed Alumina), supplied by Degussa Corporation (N.J.) was used without further treatment. The surface properties of this sample have been reported previously (Hachiya et al., 1979). It has a pH_{zpc} of 8.3 and a specific surface area of $100 \text{ m}^2/\text{g}$, with a particle size smaller than $1 \mu\text{m}$ and apparently uniform.

All chemicals used were reagent grade, and together with the reference standard solutions of Pb and Zn for atomic absorption were purchased from Fisher Scientific (N.J.). Solutions of 0.1 M NaOH and HCl were prepared and used in adjusting the pH of the experimental samples.

METHODS

Our study is aimed at: (1) The extent of cation (Pb and Zn) interactions with the Al_2O_3 surface at various pH evaluated from direct measurements of the cation uptake by the surface. And (2) the studies of proton release and stoichiometry at aluminium oxide/water interface during metal ion adsorption through a titration of suspended aluminium oxide particles with cation (lead and zinc), and the plots of K_d versus pH. Pb or Zn bound to the surface is calculated from the difference between the total Pb or Zn added to the system and that remaining in solution using AAS (Atomic Absorption Spectrophotometer, SpectrAA 20, Varian Instrument) for the measurements. The pH of the suspension is monitored as cations are titrated with the suspension of aluminium oxide using an Orion research digital ionalyzer (Model 701A) with an Orion Combination electrode.

(1) Adsorption of Lead and Zinc on Aluminium oxide - Effect of pH

(a) In the first set of adsorption runs, 0.1 g of aluminium oxide was weighed into a 250mL polycarbonate erlenmeyer flasks containing 100mL of lead of concentration 1.0 - 14 mg/L or 0.4 - 4.0 mg/L of zinc. The pH was adjusted to the required value. pH values of 5-8 were studied. Samples were sealed in nitrogen, and then shaken overnight in a shaker at 150 revolutions per minute and 25°C . After this period the pH of the samples was readjusted, equilibrated and then filtered. The filtrate was retained for metal analysis. The difference between the initial and final concentration was taken as the amount adsorbed.

(b) In the second set of adsorption runs, the adsorption edges (the pH region in which adsorption increases rapidly) of lead and zinc on aluminium oxide were determined. A suspension containing 0.5 g/L of the adsorbent (aluminium oxide) was placed in a 500mL flask and equilibrated for 1 hour under nitrogen atmosphere at pH 2 where no adsorption was anticipated. After 1 hour a 50mL aliquot was removed as a blank, and then 10 mg/L lead or 6 mg/L zinc was added. A 50mL aliquot containing the adsorbate was removed and transferred to a clean 250mL polycarbonate erlenmeyer flask. Then the pH was adjusted upward (2-11), 50mL aliquots being drawn at each pH. Samples were sealed under nitrogen, and then shaken overnight in a shaker at 150 revolutions per minute and 25°C . After this period the pH of the samples was readjusted, equilibrated and then filtered. The filtrate was retained for metal analysis.

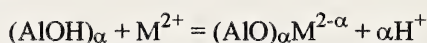
(2) Proton Release and Stoichiometry during adsorption of metal ions:

(a) Titration - proton release during adsorption

Suspended particles were titrated with cations (lead and zinc) while pH change as a result of titration was measured. 0.1 g of aluminium oxide was weighed into a 250mL flask containing 100mL of distilled deionized water. The solution of metal ion whose pH was adjusted to the same as that of the aluminium oxide suspension was introduced through a burette while the suspension was stirred using a Teflon-coated magnetic stirrer. The pH change of the suspension was measured using a glass electrode as the cations were titrated with the suspension. A blank titration containing no metal ion was performed for comparison.

(b) Proton stoichiometry estimated from the plots of K_d versus pH.

We assume that surface complexation is the major interaction during adsorption. The association of aluminium oxide with metal ions (M^{2+}) can be represented in a general form as follows:



where M^{2+} is a divalent aqueous metal ion such as Pb^{2+} or Zn^{2+} in this study. α is the number of hydrogen ions replaced from surface hydroxyl groups. This equation implies generally that one metal ion can associate with one or more surface AlOH groups, where $(AlO)_\alpha M^{2-\alpha}$ denotes bound metal ion. The value of α can be obtained from the equilibrium of the mass action law reaction.

$$K = ((AlO)_\alpha M^{2-\alpha})(H^+)^\alpha / ((AlOH)_\alpha)(M^{2+}) \quad (1)$$

where K is the equilibrium constant of the surface interaction. And

$$K_d = ((AlO)_\alpha M^{2-\alpha}) / (M^{2+}) = \Gamma / C_f \quad (2)$$

where Γ is the amount of adsorbate adsorbed per gram of adsorbent, and C_f is the equilibrium solution concentration. K_d is, therefore, equal to the slope of a straight line on a Γ versus C_f plot. As seen in the Fig. 1 and 2, the plots of Γ versus C_f are nearly linear in the portion where the concentrations of metal ions (C_f) in solution are low. Thus, K_d values at various pH can be derived by linear regression from the measurements made at low concentrations.

Therefore,
$$K = K_d(H^+)^\alpha / (AlOH)_\alpha$$

$$\log K_d = \alpha pH + \log(K(AlOH)_\alpha) \quad (3)$$

From the above equation a plot of $\log K_d$ versus pH should give a positive slope α .

RESULTS AND DISCUSSION

In all cases, the data represent a measurement precision of ± 2 relative standard deviation.

(1) Effect of pH on Adsorption of Lead and Zinc

As seen from Figures 1-3, adsorption of lead and zinc is strongly pH dependent; adsorption increased markedly as pH increased. For the pH range (5-8) studied the adsorption of Pb (Fig. 1) and Zn (Fig. 2) was highest at pH 8.

The pH region in which adsorption increases rapidly (the "adsorption edge") for lead and zinc is demonstrated in Fig. 3. The abscissa is the pH of the suspension and

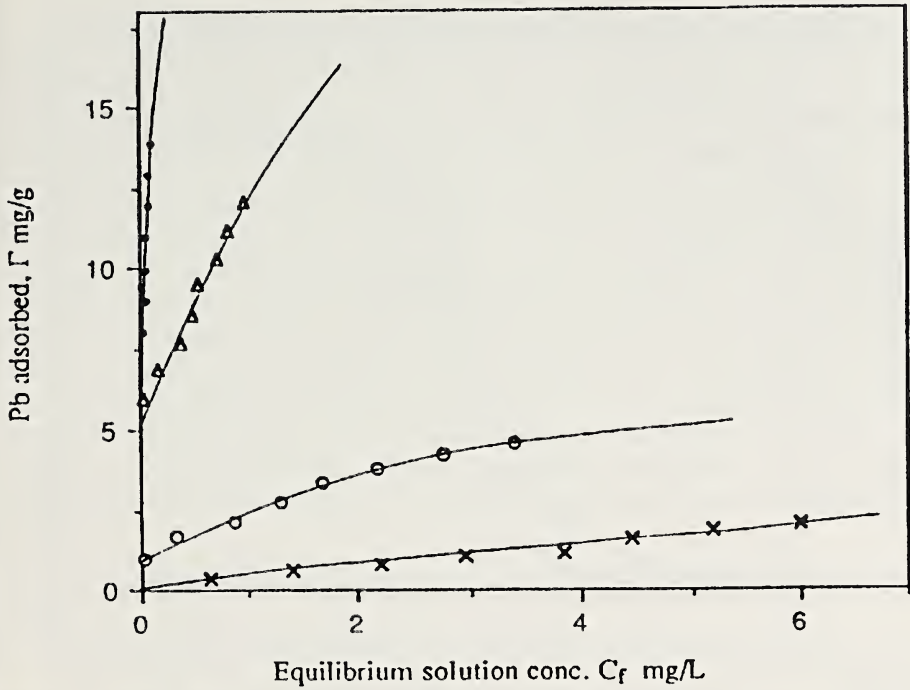


FIGURE 1. Plot of Γ versus C_f for the adsorption of Pb on aluminium oxide at pH 5 (x), pH 6 (o), pH 7 (Δ) and pH 8 (\cdot) at 25°C.

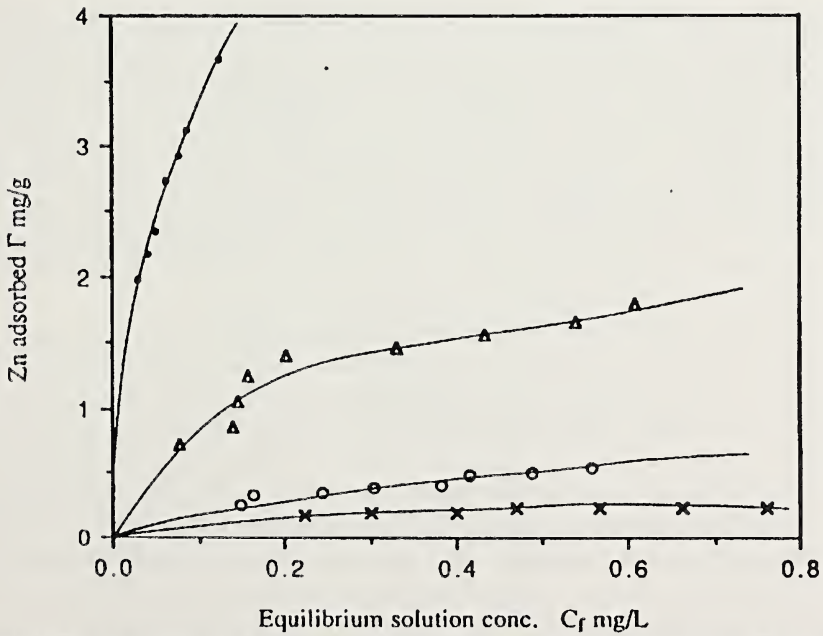


FIGURE 2. Plot of Γ versus C_f for the adsorption of zinc on aluminium oxide at pH 5 (x), pH 6 (o), pH 7 (Δ) and pH 8 (\cdot) at 25°C.

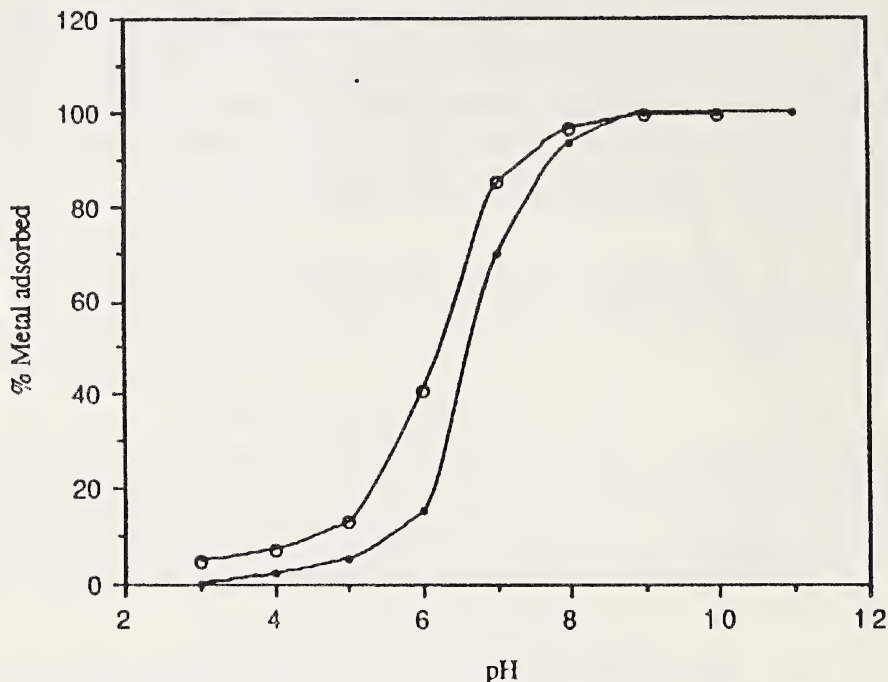


FIGURE 3. Plot of % metal adsorbed versus pH of the suspension for the adsorption of Pb (o) and Zn (.) on aluminium oxide at 25°C. The initial concentration of Pb used was 10 mg/L and that of Zn was 6 mg/L.

the ordinate is the percentage metal (lead or zinc) adsorbed. From Fig. 3 adsorption of lead increased from about 7% at pH 4 to almost 98% at pH 8, while it increased markedly between pH 5 and 7. At approximately pH 6.2 the adsorption of lead on aluminium oxide was 50%. Adsorption of zinc increased from about 4% at pH 4 to nearly 95% at pH 8, while a marked increase occurred between pH 6 and 8. At approximately pH 6.5 the adsorption of zinc on aluminium oxide was 50%. Both results show the bulk of the adsorption occurring over a relatively narrow pH range of approximately 2 unit wide where fractional adsorption increases from near nil to near 100%, and are in good agreement with literature results (Lion et al., 1982; Benyahya and Garnier, 1999; Johnson, 1990; Tewari and Lee, 1975).

These results conform with the trend of increasing adsorption with increased pH and suggest further that adsorption of metal ions on oxides is pH dependent. This dependence can be attributed to the properties of both, the oxide surface (charge, potential, and/or surface composition) and the solution composition (e.g. metal ion speciation) change with pH. In aquatic environments, oxides and oxide minerals are covered with surface hydroxyl groups, AlOH . The presence of two lone electron pairs and a dissociable hydrogen ion indicates that these groups are ampholytes. As mentioned above, depending on the pH of the system, the surface of the oxide exists in the following forms.



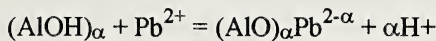
The pH dependent charge of a hydrous oxide results from proton transfer at the surface. The zero point of charge (pzc) of the aluminium oxide used in this study is 8.3 as stated above. At pH values well below the pzc, the majority of the surface sites will be positively charged (AlOH_2^+). As the pzc is approached, increasing numbers will be neutralized, forming AlOH , and a small number will acquire a negative charge, forming AlO^- before the pzc is reached. At higher pH values, the number of available active sites for metals increases. Given that the adsorbed species are positively charged, lead and zinc adsorption will occur most readily on neutral and negatively charged sites. However, cations of Pb and Zn can be strongly adsorbed against electrostatic repulsion as illustrated in this study, whereby adsorption of lead and zinc occurred at the pH of solution even below the pH_{pzc} . Therefore, the interactions of metal ions with aluminium oxides cannot be explained by electrostatic interaction only; specific interactions have been interpreted in recent years in terms of surface coordination with surface functional groups, $-\text{AlOH}$, whose acid-base and other coordinative properties are similar to their counterparts in soluble compounds. Adsorption of metal ions is therefore considered as competitive complex formation involving one or more surface hydroxyls.

(2) Proton Release and Stoichiometry during Metal Adsorption on Aluminium Oxide.

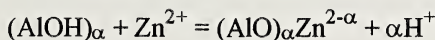
(a) Results from titration of aluminium oxide suspension with metal ions.

In this study surface complexation process in aluminium oxide is investigated through a titration of suspended aluminium oxide particles with metal ions (lead and zinc). The pH of the suspension is monitored as the suspension is being titrated.

A plot of pH versus cumulative volume of the cations is shown in Fig. 4, which reflects the interactions of Pb and also Zn with the Al_2O_3 surface. From Fig. 4 it can be seen the pH of the aluminium oxide suspension decreased as lead or zinc solution was added through a burette. The decreasing pH of the suspensions indicated that a process occurred which decreased the pH (increased H^+), as compared with the blanks containing no metal ions, which remained essentially at the same initial pH during titration. The results support the interpretation that lead and zinc adsorption on aluminium oxide can be represented in terms of a surface complexation formed by association of Pb or Zn ion with a number of surface AlOH groups thus replacing one or more bound H^+ ions (α).



and



(b) Plots of K_d versus pH - Proton Stoichiometry

The resulting plots of $\log K_d$ versus pH (Eq. 3) are shown in Fig. 5. The slope of these curves demonstrated that α which give the equivalent number of H^+ released per metal ion adsorbed was determined and found to be close to unity. This suggests that for each metal ion adsorbed, approximately one H^+ is released, indicating that the major

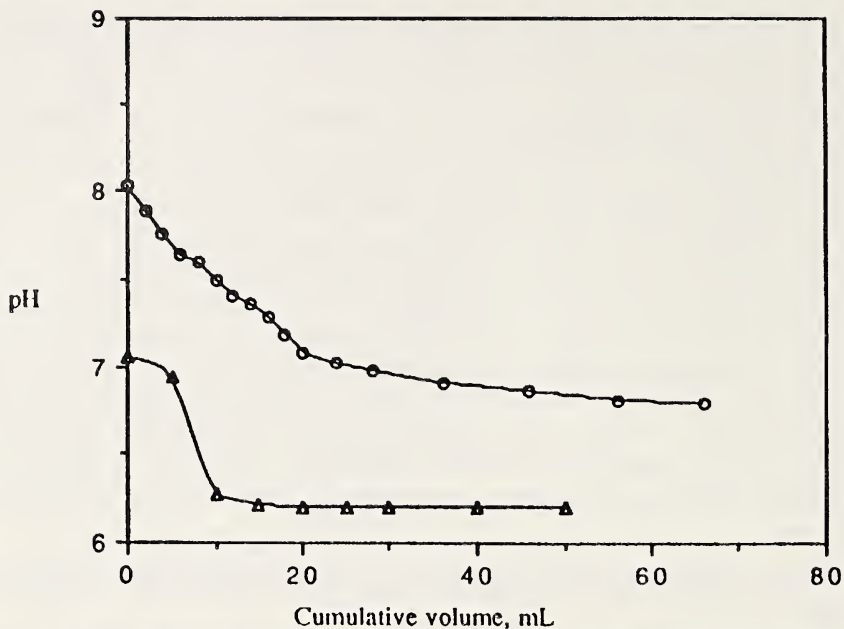
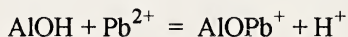


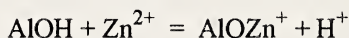
FIGURE 4. Plot of pH versus cumulative volume for the titration of 10 mg/L Pb(○), 2 mg/L Zn (Δ) with aluminium oxide suspension at 25°C.

surface reaction is the formation of monodentate inner-sphere complex over the experimental pH range.

Therefore the adsorption of lead and zinc on aluminium oxide in general can be represented:



and



This is a surface complexation formed by association of one surface AlOH group, thus replacing one bound H^+ ion. A similar mass action approach to adsorption equilibria is outlined in Kurbatov, et al. (1951), and also described for the distribution coefficient of trace metals on soils in Anderson and Christensen (1988). Based on the investigation of Pb(II) complexes at the Al_2O_3 /water interface, using X-ray absorption spectroscopy, Chisholm-Brause et al. (1990) demonstrated that Pb(II) bonded directly to the Al_2O_3 surface as an inner-sphere complex and the adsorption site is monodentate, which is in direct support of our results.

As suggested by Benjamin and Leckie (1981), over a wide pH range extending at least ± 3 pH units from the point of zero charge, the surface proton density is 1.0 ± 0.1 proton per surface site on oxides. In other words $-\text{AlOH}$ is the most abundant site for adsorption over this wide pH range. Thus, if all surface sites are equivalent under the condition of low surface coverage, on the average one surface proton would be released per site occupied when a trace metal adsorbs. Thus, bidentate or multidentate com-

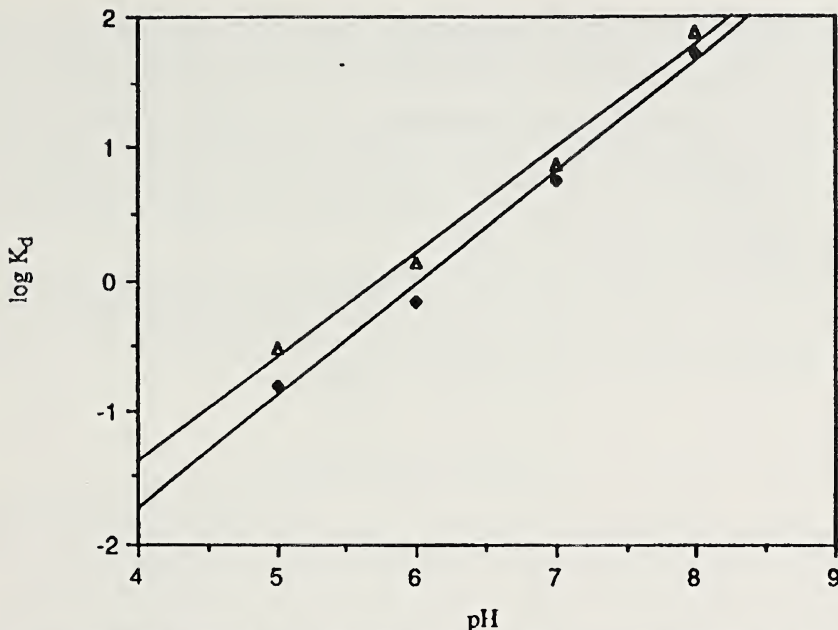


FIGURE 5. Plot of $\log K_d$ versus pH for the adsorption of Pb (Δ) and Zn (o) on aluminium oxide at 25°C.

plexes which can not be ruled out are formed only to a very small extent in comparison to the 1:1 complexes.

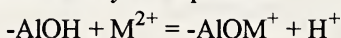
Honeyman (1984) discussed the limitations of this approach, including the requirement for an excess of surface binding sites and the dependence of proton release on system pH. As we have seen from the above plotted isotherms, K_d is better described at low adsorption density where unoccupied sites are in great excess, but not at high surface coverage. Below some sufficiently low adsorption density there must exist a condition where unoccupied sites of all types are in excess. Under these conditions the adsorption density (Γ) should be a linear function of equilibrium dissolved adsorbate concentration. In the region where the surface coverage is high, the tendency for a metal ion to adsorb decreases because of three possible reasons (Schindler and Stumm, 1987; Benjamin and Leckie, 1981): (1) the coulombic attraction between the solid and the adsorbate decreases as the metal ions adsorb, because the surface charge becomes more positive. (2) There are unfavorable interactions between adjacent adsorbed species. (3) There are a variety of site types on the solid, of varying affinity for the adsorbate. As suggested by Chisholm-Brause et al. (1990), while Pb(II) surface complexes on Al_2O_3 were predominantly monodentate, some Pb was sorbed as small multinuclear complexes and the number and size of these complexes apparently increased with increasing surface coverage.

CONCLUSIONS

The experimental results obtained in this study provide some understanding of the nature and extent of adsorption of metal ions (lead and zinc) on aluminium oxide at different values of pH. It is interesting to note that the adsorption edges of Pb and Zn

occur approximately in the pH range of natural water (pH 5-8). This means that a small shift in pH in aqueous system, as may occur in rivers and estuaries, causes a sharp increase or decrease in dissolved metal levels. For most natural surfaces, the electrostatic state of the interface is determined primarily by the pH of the solution. High pH facilitated the adsorption of lead and zinc. This is in agreement with the pH dependent charge characteristics of oxide surface. As the pH decreases, surface protonation will create a positively charged entity and thereby allow electrostatic interaction to take place in addition to the specific reaction.

Significant adsorption of Pb and Zn on to hydrous aluminium oxide from aqueous solutions is observed even at pH values far below the zero point of charge. The specific binding of Pb or Zn on Al_2O_3 in aqueous solution is interpreted as surface complex formation, which can be quantified by the equation:



ACKNOWLEDGEMENTS

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LITERATURE CITED

- Anderson, P.R., and Christensen, T.H., 1988. Distribution coefficients of Cd, Co, Ni, and Zn in soils. *J. Soil Sci.* 39, 15-22.
- Benjamin, M.M. and Leckie, J.O. 1981. Multiple-site adsorption of Cd, Cu, Zn, and Pb on amorphous iron oxyhydroxide. *J. Colloid Interface Sci.*, 79, 209-221.
- Benyahya, L. and Garnier, J.M. 1999. Effect of salicylic acid upon trace-metal sorption (Cd^{II} , Zn^{II} , Co^{II} and Mn^{II}) onto alumina, silica, and kaolinite as a function of pH. *Environ. Sci. Technol.* 33, 1398-1407
- Chisholm-Brauser, C.J., Hayes, K.F., Roe, A.L., Brown, Jr., G.E., Parks, G.A., Leckie, J.O. 1990. Spectroscopic investigation of Pb(II) complexes at the g- Al_2O_3 /water interface. *Geochim. Cosmochim. Acta*, 54, 1897-1909.
- Dugger, D.L., Stanton, J.H., Irby, B.N., McConnell, B.L., Cummings, W.W., and Maatman, R.W. 1964. The exchange of twenty metal ions with the weakly acidic silanol group of silica gel. *J. Phys. Chem.* 68, 757-760.
- Hachiya, K., Ashida, M., Sasaki, M., Inoua, T., and Yasunaga, T. 1979. Study of the kinetics of adsorption-desorption of Pb^{2+} on a g- Al_2O_3 surface by means of relaxation techniques, *J. Phys. Chem.* 83, 1866-1871.
- Hohl, H. and Stumm, W. 1976. Interaction of Pb^{2+} with hydrous g- Al_2O_3 . *J. Colloid Interface Sci.* 55, 281-288.
- Honeyman, B.D. 1984. Cation and anion adsorption at the oxide-solution interface in systems containing binary mixtures of adsorbents: An investigation of the concept of adsorptive additivity. Ph.D. Thesis, Stanford University, Stanford, CA, U.S.A.
- Huang, C.P., and Stumm, W. 1973. Specific adsorption of cations on hydrous g- Al_2O_3 . *J. Colloid Interface Sci.* 43, 409-

- James, R.O., and Healy, T.W. 1972. Adsorption of hydrolyzable metal ions at the oxide-water interface. III Thermodynamic model of adsorption. *J. Colloid Interface Sci.* 40, 65-81.
- Johnson, B.B. 1990. Effect of pH, temperature, and concentration on the adsorption of cadmium on goethite. *Environ. Sci. Technol.* 24, 112-118.
- Kurbatov, M.H., Wood, G.G., and Kurbatov, J.D. 1951. Isothermal adsorption of cobalt from dilute solutions, *J. Phys. Chem.* 55, 1170-1182.
- Lion, L.W., Altmann, R.S. and Leckie, J.O. 1982. Trace-metal adsorption characteristics of estuarine particulate matter: evaluation of contributions of Fe/Mn oxide and organic surface coatings. *Environ. Sci. Technol.* 16, 660-666.
- Schindler, P.W. In adsorption of inorganics at solid-ligand interface; Anderson, M.A., Rubin, A.J., Eds.; Ann Arbor Science Publishers Inc.; Ann Arbor, Michigan, 1981; pp 1-49.
- Schindler, P.W. and Stumm, W. 1987. "The surface chemistry of oxide, hydroxide, and oxide minerals." in *Aquatic surface chemistry*, Ed. by Werner Stumm, John Wiley and Sons, New York.
- Stumm, W., Huang, C.P., and Jenkins, S.R., 1970. Specific chemical interaction affecting the stability of dispersal systems. *Croatica Chem. Acta*, 42, 223-245.
- Tewari, P.E., and Lee, W. 1975. Adsorption of Co(II) at the oxide-water interface. *J. Colloid Interface Sci.*, 52, 77.

JEFFRESS RESEARCH GRANT AWARDS

The Allocations Committee of the Thomas F. and Kate Miller Jeffress Memorial Trust has announced the award of Jeffress Research Grants to the institutions listed below to support the research of the investigator whose name is given. The Jeffress Trust, established in 1981 under the will of Robert M. Jeffress, a business executive and philanthropist of Richmond, supports research in chemical, medical and other natural sciences through grants to non-profit research and educational institutions in the Commonwealth of Virginia. The Jeffress Research Grants being announced here have been awarded in 1999.

The Jeffress Memorial Trust is administered by Bank of America. Additional information about the program of the Trust may be obtained by writing to: Advisor, Thomas F. and Kate Miller Jeffress Memorial Trust, Bank of America, Private Bank, P. O. Box 26688, Richmond, VA 23261-6688.

Samuel A. Abrash, University of Richmond. Photochemistry of Complexes of Hydrogen Sulfide with Acetylene and Ethylene and Hydrogen Halides with Propyne and Propylene in Argon Matrices. \$15,000 (one year renewal).

Bao Ling Adam, Eastern Virginia Medical School. Identification and Characterization of Prostate Cancer Associated Proteins. \$29,500. (one year).

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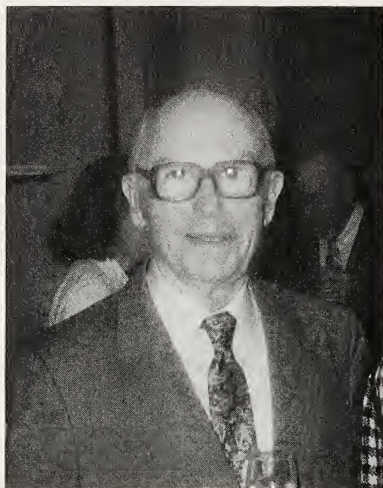
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NECROLOGY

**Blanton Mercer Bruner**

The Academy is saddened to announce to its members the death of Blanton Bruner. Those of us who knew and worked with him as our Executive Secretary-Treasurer, knew of him as a thoughtful, meticulous and skillful force in the Academy. We truly missed him when he retired from Academy service. The following is the Richmond Times-Dispatch news obituary from, Thursday, February 3, 2000, page B3, By Jenifer V. Buckman, Times-dispatch Staff Writer (Reproduced by Permission, Richmond Times-dispatch)

A memorial service for Blanton Mercer Bruner, former executive secretary of the Virginia Academy of Science, will be held Thursday at 2 p.m. at St. Stephen's Episcopal Church, 6004 Three Chopt Road. Burial will be private.

Mr. Bruner, also a retired American Tobacco Co. executive, died Saturday at the age of 95.

Mr. Bruner, a Richmond native, joined the tobacco firm's department of research and development in 1928. That year he also became a member of the Virginia Academy of Science. He worked for American Tobacco for 31 years and at his retirement was director of technical information and community relations coordinator.

In that role, Mr. Bruner served as a director of the National Tobacco Festival and led the company's civic involvement in the local Red Cross, the March of Dimes and the American Heart Association. He was also a former director of the Richmond Thanksgiving Festival.

After his retirement, he began a second career with the Virginia Academy of Science in 1967 as business manager of the Virginia Journal of Science and later as Executive Secretary-Treasurer. He served in that post until 1996 and retired at the age of 91.

He was named a Fellow of the Academy and was given the Distinguished Service Award from the Virginia Junior Academy of Science. In 1992, the 14,000 (sic) member academy, awarded him its highest honor, the Ivey F. Lewis Distinguished Service Award.

A 1926 graduate of the College of William and Mary, Mr. Bruner, a chemist, was a member of numerous professional organizations including The American Chemical Society, The Virginia State Chamber of Commerce, Richmond Chamber of Commerce and Richmond Public Relations Association.

Mr. Bruner was the widower of Alice Massey Bruner, who died in 1980. Survivors include two daughters; Sandra Bruner Hague and Carol Bruner Fleet, both of Richmond; a sister, Elizabeth Bruner Smith of Roanoke; four grandchildren; and four great-grandchildren.

NECROLOGY



Irving Gordon Foster
“Iggy”

July 15, 1912 -- January 11, 2000

Iggy Foster was the Academy's 32nd President (1954-55) and a former chair of its Astronomy, Mathematics and Physics Section. Born in Lynn, Massachusetts, he received his B.S. degree in Electrical Engineering from Virginia Military Institute in 1935 and a Master of Philosophy from the University of Wisconsin in 1937. He was a “Beams man”, receiving his Ph.D. from the University of Virginia in 1948. He was a member of Phi Beta Kappa and Sigma Xi. His teaching career began in 1937 at V.M.I. as Instructor of Physics with the rank of Captain, rising to Professor and Colonel in 1950, the first member of his department to hold a doctorate.

In research, he was a consultant to Honeywell and in 1951 he began a summer research program at V.M.I. doing contract work for the Harry Diamond Laboratories of the National Bureau of Standards. His contracts involved accelerometers and fuze timing mechanisms and for the next decade provided both “moonlighting” income and professional stimulation for undergraduate faculty in physics, mathematics and electrical engineering as well as for some Washington and Lee University faculty and led to the establishment of the V.M.I. Research Laboratories in 1963.

“The Ig”, as he was nicknamed by the Keydets of the fifties, was one of the chief architects of the physics major program initiated in 1949 and one of the primary influences in the design of Mallory Hall which has housed physics since 1952. In his classes he insisted on rigor and designed his course in theoretical physics to prepare

seniors for graduate school. In professional societies he was partial to both the Academy and the Southeastern Section of the American Physical Society where he served on the Executive Committee and as meeting chair. He attended both almost every year, serving as a role model for younger faculty and cadets in presenting papers and serving in various leadership capacities. Iggy was a deacon and later an elder in the Lexington Presbyterian Church and a regular teacher of the Stonewall Jackson Bible Class.

In 1960 he moved to St. Petersburg, Florida, to become a founding faculty member of Florida Presbyterian College, later named Eckerd College. In 1966-67 he was a Fulbright Fellow in Sri Lanka. He was a leader in the Florida Academy of Science and an active elder in the First Presbyterian Church of St. Petersburg, where his adult Sunday School class was frequently "standing room only." He retired from Eckerd in 1977 but remained active in college affairs for another two decades.

His wife of 62 years, Dorothy, survives him along with three children; Jeanne Foster Kearley, Chula Vista, California; two sons, Dr. David E. Foster, Waukeg, Iowa, and Gordon H. Foster, Crystal River, Florida; a sister, Barbara Prince, San Anselmo, California; six grandchildren and two great-grandchildren.

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EDITOR/BUSINESS MANAGER:

James H. Martin

Dept. of Biology - PRC

J. Sargeant Reynolds Community College

P.O. Box 85622

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**Abstracts of Papers Presented at the
Seventy-eight Annual Meeting, Virginia Academy of Science
May 23 - 26, 2000, Radford University, Radford, VA**

Aeronautical and Aerospace Sciences

THE RADFORD UNIVERSITY RADIO JOVE PROJECT. K. C. St. Clair, Jason B. Shelton, Leigh A. Kitts, Rian Q. Everett, Joseph M. Waugh & Rhett B. Herman, Radford University. The Physics program at Radford University has recently constructed a radio telescope as part of NASA's Radio Jove Project educational initiative. This telescope, the components of which were provided in kit form by NASA, consists of a double-dipole half wave antenna and a radio receiver tuned to a frequency of 20.1MHz. This frequency is characteristic of radio emissions from processes involving the magnetospheres of Jupiter and its satellite Io, and is fortuitously situated in a relatively radio-quiet region of the spectrum. This frequency is also emitted by certain processes in stellar atmospheres, and thus provides a venue for studying various processes present in our sun. This antenna was built by students in the Electromagnetic Theory class at Radford, presenting them not only with a practical application of the theory from the class, but also giving them experience in building and troubleshooting complex electronics. This project will allow Radford University to join the national network of radio astronomers monitoring Jovian and solar activity.

NUMERICAL INVESTIGATION OF ETHYLENE COMBUSTION IN SUPERSONIC AIR STREAMS WITH PILOT-HYDROGEN INJECTION. Sudendra N. Tiwari, Ahmed A. Taha & Taj O. Mohieldin, Dept. of Mechanical Eng., Old Dominion Univ., Norfolk, VA 23529. Mixing and combustion characteristics of ethylene fuel in supersonic air streams are investigated numerically. The configuration used features the existence of a generic rearward-facing step in the upper longitudinal wall. The effect of the injected sonic pilot ethylene on the combustion of the gaseous sonic ethylene fuel, that is injected normal to the incoming supersonic air stream, is investigated. The existence of a wedge downstream of the rearward-facing step and upstream of the main normal ethylene injection forms a cavity-like configuration that showed a good potential towards enhancing the fuel-air mixing in addition to helping initiate and stabilize the main flame. The current work is still underway to complete studying the combustion flowfield of the normal injection of the sonic gaseous ethylene with sonic pilot hydrogen. This will lead to a comprehensive study to address the feasibility of using hydrocarbon fuels in the mid-speed range of the hypersonic flight.

NONGRAY RADIATIVE INTERACTIONS OF MOLECULAR GASES IN INCOMPRESSIBLE FLOWS. S. B. Pidugu & S. N. Tiwari, Dept. of Mechanical Engineering, Old Dominion University, Norfolk, VA 23529. Nongray radiative interactions have been investigated under local thermodynamic (LTE) and non local thermodynamic conditions (NLTE). The specific problem considered in this study is a fully developed laminar incompressible flow between two parallel plates. The plates are maintained at uniform surface heat flux and are assumed to be black. The governing equations describing the physical problem along with the boundary conditions are solved numerically by employing the technique known as method of undermined parameters. Results are obtained for two diatomic gases (NO, OH) and one triatomic gas (H₂O). Results are obtained under different pressure (0.1 to 10 atm.) and temperature (300 to 2000 K) conditions. The spacing between plates is varied from 0.01 to 1.0 meters. The results under LTE and NLTE conditions are compared at different temperatures and pressures. The variation of bulk temperature with plating spacing is plotted for different gases under both LTE and NLTE conditions. Results indicate that, in general, the radiative ability of the gases increase with the increase in temperature, pressure and plate spacing. The NLTE effect becomes significant at lower temperatures and pressures. Among the gases, OH shows least radiative effect while H₂O shows the highest radiative interactions under both LTE and NLTE conditions.

SCIENCE FAIR MENTORING PROGRAM: UNIVERSITY VOLUNTEERS HELPING SCIENCE FAIR STUDENTS SUCCEED. Mary E. Manning & Adam Possner, College of Arts and Sciences, University of Virginia, Charlottesville, Va. 22904. In 1998, students at the University of Virginia founded a mentoring program to help elementary, middle and high school students succeed in science fair by uniting them with the guidance of undergraduates, graduates and professors at U.Va. This novel program has engaged over 80 mentors in aiding students from diverse socioeconomic backgrounds in the completion of a science fair project. Working in partnership with local schools, mentors visit with students once a week to encourage innovative ideas, refine concepts, answer questions, and help develop procedures. Personalized attention and encouragement from mentors who have successful academic careers gives younger students confidence in their studies and enthusiasm for scientific research. Over 90 percent of student participants completed a science fair project with their mentor, and several competed in higher level competitions. Run entirely by student volunteers, this program could serve as a useful model for launching a volunteer mentoring organization at a college or university or in the community at large.

NUMERICAL STUDY OF CHARACTERISTICS OF TWO DIMENSIONAL PLANE PARALLEL JETS. S. N. Tiwari, T. O. Mohieldin & T. M. Abdel-Salam, Department of Mechanical Engineering, Old Dominion University, Norfolk, VA 23508. Effect of various parameters on the characteristics of two dimensional turbulent plane parallel jets were numerically studied. Flow geometry under consideration is a two parallel plane jets of 4mm width each. Effects of nozzle spacing (D/a) and nozzle exit velocity (U) on both merging and combined points are investigated using an existing CFD code "FLUENT". Six different values of D/a are used ranging between 8 to 18. Also, nine different jet velocities have been examined corresponding to Reynolds number of 8,000 to 36,000. The results provide acceptable agreement in comparison with the experimental results. It is noted that the ratio D/a linearly affect the location of the merging and the combined points, while velocity plays no role in their location.

SIMULATION OF THE GLOBAL POSITIONING SYSTEM (GPS) TO COMPUTE THE GEOMETRIC DILUTION OF PRECISION (GDOP). Abdul Ghafoor Al-Shehabi, Aero. Dept., Old Dominion Univ., Norfolk, VA, 23529. GPS is the latest technology in navigation and location determination. The principal behind GPS is the measurement of ranges between the receiver and the satellites. Due to the relative motion of satellites, the distances and geometry of the visible satellites are time dependent. A measure of the geometry is the Geometric Dilution of Precision (DOP) factor. Deriving equations that give the user's position, calculating GDOP factor and investigating how this factor is affected by the geometry of visible satellites are goal of this research. GDOP factor and other factors related to GDOP are introduced by linearizing the pseudorange equation, this linearization represents the changes in user position and time bias. An algorithm by which, the receiver can determine the visible satellites and which is the best set of four satellites of many satellites in view is developed, the best set is that which gives us the optimal GDOP. The optimum configuration is used to perform the position calculation. To achieve this goal, a powerful aerospace analytic software tool called (STK) developed by Analytical Graphic, is used to get the required trajectory data necessary as input to exercise, test and run our navigation algorithms for calculating the GDOP factor.

AERODYNAMIC CHARACTERISTICS OF AN AIRPLANE CONFIGURATION WITH SEVERAL BODY ARRANGEMENTS. M. Leroy Spearman, Systems Analysis Branch, NASA-Langley Research Center, Hampton, VA 23681 & Jill C. Harper, Aerospace and Ocean Engineering Dept, Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. A review has been made of some existing wind-tunnel data for the purpose of assessing the aerodynamic behavior of airplane designs having various multiple body arrangements. The use of multiple bodies rather than conventional single bodies provides a means of increasing volume without undesirable increases in body length and diameter. In addition, multiple body arrangements provide for various alternate locations of the wing lifting surface and the stabilizing and control surfaces. The review indicates that multiple body arrangements, in comparison to single centerbody arrangements, might have a positive effect in some areas such as weight reduction, longitudinal, lateral, and directional stability, utilization of interference flow fields, and reduction of wing tip vortex strength.

STUDIES OF THE AERODYNAMICS OF THE INBOARD WING CONCEPT. Matthew Orr, Samantha Magill, James Marchman, William Mason, Joseph Schetz, & Bernard Grossman, Aerospace and Ocean Engineering Dept. Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. This investigation examines a new concept in airliner configurations. This concept proposes mounting the fuselages at the tips of a low aspect ratio wing. The motivation for this configuration is to provide an increase in the number of passengers carried with no increase in span or length over conventional designs. An additional motivation is the change in the wake flow of the wing due to the fuselages and vertical tails. This may reduce the effect of the trailing vortex on trailing aircraft. This investigation used two models of different size that provided measurement of the forces, moments, and flow properties in the wake. These data were used to aid in the validation of numerical models of the flow around and behind the configuration. The L/D values found for the non-optimized configuration were modest compared to those for conventional transports. The vertical tails were shown to act as winglets, reducing drag and increasing L/D. One important result in the wake was that the maximum swirl velocities were less than for the plain wing of the same span, chord, and total lift. All of these results suggest areas for substantial improvements in aerodynamic performance.

AEROELASTIC FORMULATIONS OF LIFTING SURFACES IN VARIOUS FLIGHT SPEED REGIMES FOR FLUTTER AND RESPONSE ANALYSES: INDICIAL FUNCTION APPROACH. Piergiovanni Marzocca & Liviu Librescu, E.S.M Dept., Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24061. This paper deals with the generation and the use of new indicial functions towards the aeroelastic formulation of two-dimensional lifting surfaces, in the subsonic compressible and supersonic flight speed regimes. The indicial function approach enables one to treat in a unified way, i.e. in the time and frequency domains the various problems of the aeroelasticity of lifting surfaces. Such an approach yields the proper aerodynamic loads necessary to the study of the subcritical response of the open/closed loop aeroelastic systems, and of flutter of lifting surfaces, respectively. Counterparts of Theodorsen's and Wagner's functions extended in the subsonic compressible and supersonic flight speed regimes enable one to express correspondingly the aerodynamic lift and moment in the frequency and time domains, respectively. Validation of the model, closed form solutions and aerodynamic derivatives for different flight speed regimes are obtained, graphical representations and results displaying the aeroelastic response to blast loads are presented and pertinent conclusions are outlined. The first author gratefully acknowledges the support by the Centro Studi per la Dinamica dei Fluidi of the Italian National Research Council (CNR).

PROPELLER SLIPSTREAM EFFECTS ON THE AERODYNAMICS OF UAVS AT LOW REYNOLDS NUMBERS. Ehab A. Elsaadawy & Colin P. Britcher, Department of Aerospace Engineering, Old Dominion University, Norfolk, VA, 23529. Aiming to develop aeronautical technologies that will lead to a new family of Unmanned Aerial Vehicles (UAVs), a number of groups are developing atmospheric science aircraft to fly at extreme altitudes, up to 100,000 ft. Many of these aircrafts are propelled by turbocharged piston engines driving tractor or pusher propellers. The effect of the propeller slipstream (wake) on the aerodynamic performance of the airframe, wings and air inlets, at low Reynolds numbers is the subject of this study. Propeller slipstream is known to affect the transition location, and the laminar separation bubble extent, consequently, drag forces and heat transfer on the wing. Through this study, a laminar flow and 2-D inlet airfoil are used as models to generate different types of boundary layers. The laminar flow airfoil is used as a benchmark case and the results obtained are compared with computations by the MSES code, a widely used code for 2-D single element and multi-element airfoils. Results show a laminar-turbulent-reverse transitional behavior in the boundary layer that emphasizes the fact that the propeller slipstream does not cause a total loss of the laminar boundary layer as was previously postulated.

Agriculture, Forestry, and Aquaculture

TOCOPHEROL (VITAMIN E), POLYUNSATURATED FATTY ACIDS INTERACTIONS: EFFECTS ON CHOLESTEROL AND TRIGLYCERIDES. A. I. Mohamed¹ and A. S. Hussein², ¹Agricultural Research Station, Virginia State University, Petersburg, VA 23806, ²United Arab Emirates University, El-Ein, United Arab Emirates. The effects of feeding menhaden fish, olive or coconut oil at three different levels of Vit. E (100, 300, and 600 IU) on serum and liver total cholesterol (TC), HDL cholesterol (HDL-C), triglycerides (TG), phospholipids (PL), total lipids (TL) and fatty acid pattern of male Sprague-Dawley rats were studied. Diets were fed for 28 days to 6 individually caged rats in a factorial designed experiment. In serum, means were 38.2, 64.2, 67.0 for TC; 32.5, 53.8, 75.4 for TG; and 25.7, 48.0, 48.6 mg/dL for HDL-C for rats fed menhaden fish, olive and coconut oil, respectively at three different levels of Vit.E. In the liver, means were 5.7, 7.6, 4.6 for TC; 46, 55, 69 for TG and 5.7, 3.0, 4.7, for PL for the same treatments. Statistical analyses indicated that F value of the means of the measured parameters were significant ($P < 0.0001$) for oil treatment; but were not significant for Vit. E treatments. Interactions between Vit. E and oils were not significant. Pearson's correlation coefficient were 0.655 ($P < 0.0001$) between serum TG and TC, 0.568 ($P < 0.0003$) between serum TG and HDL -C, 0.731, ($P < 0.0001$) between serum TC and HDL- C, and 0.923 ($P < 0.0001$) between liver TG and liver TL.

AGRONOMIC AND NUTRITIONAL EVALUATION OF VEGETABLE SOYBEAN. T. Mebrahtu, T. Andebrhan, & A. L. Mohamed, Virginia State University, P. O. Box 9061 Petersburg, Va. In addition to oil and soyfoods, soybean may be produced as a vegetable. The importance of consuming soybean for the prevention of chronic diseases, such as heart diseases and cancer has motivated soybean breeders to investigate the nutritional attributes of vegetable soybean. Thirty-one vegetable soybean genotypes from Maturity Groups (MGs) III to VI were planted at Randolph Farm, Agricultural Research Station of Virginia State University, Petersburg, Virginia. The genotypes were analyzed for lipid, protein, fatty acid profile and isoflavones contents, at immature green pod stage. The significant genotype differences for the seed traits studied suggested that genetic variation exist among the genotypes for selection and improvement. The associations of plant height with fatty acid ratio, total, and protein were significant and negative. On the other hand, the association of number branches/plant, nodes/branch, nodes/stem, and pods/plant with ratio and total fatty acids and protein were significant and positive. These results suggest the architectural traits could be used an indicator to predict genotypes with high protein, fatty acid ratio and total. Selection for genistein, daidzein, and total isoflavone should focus on early MG genotypes. Recognizing soybean isoflavones constitute a powerful tool in quest for healthy life, further research is needed to identify and develop superior genotypes that fit into special niche markets.

SPECIES EFFECTS ON PERIPUBERTAL SPERM RESERVES IN SMALL RUMINANT MALES. B.L. Sayre & S. Wildeus, Virginia State University, Petersburg 23806. Sperm reserves were evaluated in peripubertal, co-raised ram lambs (Katahdin & Barbados Blackbelly; 5/breed) and bucklings (Myotonic, Nubian, Pygmy, and Spanish; 5/breed). Scrotal content was collected at necropsy at 6 mo of age. Testicular and epididymal segments were processed for sperm concentrations. Testicular sperm reserves were greater ($P < .05$) in hair sheep than meat goats (515.3 and 336.1 million sperm, respectively), while epididymal sperm reserves were greater ($P < .05$) in meat goats than hair sheep (108.4 vs. 47.6; 194.7 vs. 121.0 million sperm for caput and cauda sections respectively). Differences in testicular sperm production per gram of tissue were not evident between species. Age was positively correlated (.35; $P < .05$) with epididymal sperm reserves and scrotal circumference was positively correlated to testicular (.66; $P < .001$) sperm reserves. Sperm reserves did not differ among breeds of meat goats or hair sheep. Data indicated differences in sperm reserves between species. However, differences in testicular sperm reserves can be explained by differences in testicular size. All animals were capable of producing sperm and most had adequate reserves available for breeding. Thus, hair sheep and meat goat males are capable of breeding by six months of age.

EXPRESSION OF CONFORMATIONAL DIFFERENCES IN MYOTONIC AND SPANISH GOATS THROUGH LIVE ANIMAL MEASUREMENTS. Michaela P. Dismann and S. Wildeus, Virginia State University, Agricultural Research Station, Petersburg, VA 23806. The Myotonic goat is considered an endangered breed, with significant production potential by the National Animal Germplasm Program. Since there is a need to determine conformational traits in this breed, live linear measurements were taken in young and mature Myotonic and Spanish goats of both sexes (n=5 per group). Measurements were taken with scissor-type calipers and ruler, with animals restrained in a natural standing position and right lateral recumbency. The data were analyzed in a model with breed, age and sex as main effects and body weight as covariate. Mature Myotonic (45.6 kg) were smaller ($P<0.001$) than Spanish (61.2 kg) goats. This difference was reflected in a smaller ($P<0.001$) wither height (60.9 vs. 70.8 cm), and reduced ($P<0.001$) leg bone (radius, metacarpus, tibia and metatarsus) length, as well as a smaller ($P<0.05$) hip-wither length (44.0 vs. 52.1 cm). However, hip width was not ($P>.1$) affected by breed. Data indicate distinct skeletal differences between breeds in height and length, but not width; hence the appearance of a greater width in the Myotonic breed may be associated with heavier muscling.

MONITORING INSECT PESTS TO REDUCE PESTICIDE APPLICATION IN SWEET CORN. Mark E. Kraemer and Carl E. Niedziela, Jr. Agricultural Research Station, Virginia State University, Petersburg, VA 23806. Sweet corn production is one of several alternatives to tobacco production in Virginia and is important to new farmers' markets established by the State. Our objective was to evaluate an integrated pest management (IPM) strategy that relies on timing pesticide applications to population levels of the most economically significant pest, the corn earworm, *Helicoverpa zea* (Boddie). Two pheromone traps monitored the moth population from tassel to harvest maturity. Plot size was 6 corn rows of 50 feet in length. Each treatment was replicated 4 times. Warrior® was applied with a drop-down sprayer at intervals of 3 days, 5 days, and according to the IPM threshold values. Moderate to low numbers of moths were present during most of the critical period and the IPM plots were treated with pesticide every four days, except towards the end when very low moth populations allowed a 6 day interval. All spray treatments had at least 95% of corn ears with no corn earworm damage and 90% free of all insect damage. The control treatment had 90% of ears damaged by insects, 76% by corn earworm. The IPM spray schedule reduced pesticide application by at least one spray application without increased insect damage.

PROJECTING GROWTH OF LOBLOLLY PINE UNDER CHANGING ENVIRONMENTAL CONDITIONS. James A. Westfall & Harold E. Burkhart, Dept. of Forestry, Va. Polytechnic Inst. & State Univ., Blacksburg VA 24061. Growth and yield models are capable of projecting tree growth over a range of stand conditions. Process models have the ability to account for how environmental conditions affect tree growth processes. A linked system composed of a growth and yield model (PTAEDA2) and a process model (MAESTRO) was developed. This system incorporates effects of stand structure and changing environmental conditions into loblolly pine growth projections. The basis of this linkage is an equation that modifies site index, a key driver variable in PTAEDA2. The adjustment to site index is based upon changes over a given time period in net photosynthesis (NPS), which is an output of MAESTRO, and in stand density. The equation was evaluated using long-term data from 100 unthinned plots across the Southeast. CO₂ levels were adjusted in MAESTRO to reflect the ambient concentrations present during plot growth. The mean predicted site index change was +0.278 ft./yr. This site index adjustment was incorporated into PTAEDA2 and growth simulations were performed for each of the 100 plots. The use of the site index modifier resulted in a mean predicted plot volume that was not significantly different than the mean observed plot volume ($p = 0.92$).

WINTER EFFECTS UPON HYBRID STRIPED BASS PRODUCTION IN VIRGINIA. Scott H. Newton and Ali Mohamed, Agriculture Research, Virginia State University, Petersburg, VA 23806. Hybrid striped bass produced in ponds are generally harvested for market sales during the fall of their second growing season. As the industry grows, there may be the need for spreading fish harvests and sales into the following spring when prices may be better due to less fish available. Market-size bass were held in a pond at Virginia State University from December to May to observe possible changes during this period in net yield and individual fish condition. A loss in fish yield occurred due to a 10% mortality toll and a net loss in fish weight, even with winter-feeding during this period. Individual fish lost an average of 2% of their mesenteric fat during the 5 month winter period. For economic reasons, the present recommendation is to sell hybrid striped bass when they reach market size to avoid profit losses by attempting to hold them over winter for spring sales.

BLOOD CHEMISTRY OF CAGE-REARED CATFISH AND RAINBOW TROUT IN VIRGINIA. David Crosby, Cooperative Extension, PO Box 9081, Virginia State University, Petersburg, VA 23806. Serum blood chemistry (total protein, glucose, and calcium) was taken from rainbow trout and channel catfish held in cages. The primary objective of the study was to establish the baseline parameters of the blood chemistry for fish in cages. Rainbow trout were sampled monthly from December 1998 to April 1999 and catfish were sampled nine times from June 1998 to August 1999 with each sample consisting of ten fish for each species. The over-all blood chemistry averages for rainbow trout were 3.23 g/dl (sample averages ranged from 2.74 to 3.89 g/dl) for protein, 117.28 mg/dl (sample averages ranged from 78.09 to 124.71 mg/dl) for glucose, and 8.86 mg/dl (sample averages ranged from 3.17 to 12.92 mg/dl) for calcium. The over-all averages for catfish were 3.96 g/dl (sample averages ranged from 3.11 to 5.27 g/dl) for protein, 82.44 mg/dl (sample averages ranged from 38.48 to 124.36 mg/dl) for glucose, and 9.25 mg/dl (sample averages ranged from 10.29 to 13.05 mg/dl) for calcium. Generally, blood chemistry parameters fell within published values for catfish and rainbow trout.

ECONOMIC ANALYSIS OF POND MONOCULTURE OF FRESHWATER SHRIMP IN VIRGINIA. Brian L. Nerrie & Debra Prior, School of Agriculture, Science and Technology, VA State Univ., Petersburg, VA 23806. The tropical freshwater shrimp, *Macrobrachium rosenbergii*, has successfully been cultured at research facilities in the temperate region of the United States. An enterprise budget was estimated based on results from initial private sector shrimp culture efforts and simulated commercial production in research ponds. Stocking density was 12,500 shrimp per acre. Shrimp were fed a 32% protein sinking catfish pellet during the 120-150 day growing season from May to October. Minimum water temperature for growth of tropical shrimp is 20° C. Harvest was by seine and complete drainage of ponds. Shrimp were marketed on ice at pond bank or through local seafood retail outlets. Returns to land and management varied from \$400 to \$900 per acre based on survival. More than 50% of total cost was due to purchase and delivery of juveniles. Substantial savings could be achieved by establishment of local hatchery.

PRELIMINARY RESULTS FROM SUMMER FLOUNDER (*Paralichthys dentatus*) GROWN ON COMMERCIAL FEEDS IN RECIRCULATING AQUACULTURE SYSTEMS. Ryan W. Cool, M. Schwarz, M. Jahncke, J. Koo & R. Lane, Virginia Seafood Agricultural Research and Extension Center (VSAREC), 102 S. King Street, Hampton, VA 23669. Recirculating aquaculture has become a key focus of seafood research at the VSAREC. We have been working with summer flounder (*Paralichthys dentatus*) since June 1998. Summer flounder are a new species to the aquaculture industry and pioneer research is needed to create a viable aquaculture species. We receive our fish at ~2-4 grams and hold them in a quarantine/isolation facility for at least 90 days. These fish are weaned on commercial feeds, rich in protein and lipids, which are essential for enhanced fish growth. Water quality and fish behavior are monitored daily to maintain an optimal, stress-free environment. Our fish have been very successful thus far with over 50% survival, increased growth over time and a Food Conversion Ratio (FCR) between 0.78 and 1.27. From the isolation system, the fish move to a larger, air-driven recirculating system. This system was designed to reduce operating costs and possible catastrophic pump failures. Our first batch of flounder received in June 1998 are currently averaging over a pound, with some fish over three pounds.

Archaeology

THE JOHN SMITH MAP AND NATIVE AMERICAN REGIONAL SOCIETY. Mike Klein (MWC), Martin Gallivan (W&M), and Josh Duncan (MWC). Situating contact between Europeans and Native Americans within an evolving regional system reorients our view of the Contact Era away from specific historical details toward underlying processes. John Smith's remarkably accurate *Map of Virginia* serves as the primary cartographic documentation of early seventeenth-century regional social relations in the southern Middle Atlantic region. Since Smith's map provides village location during the two-year period when Smith explored Virginia, and documents the majority of villages located along the Coastal Plain rivers, this map overcomes problems of contemporaneity and preservation that often plague settlement pattern analysis. This analysis indicates that 1) the position of the lower Rappahannock within the Chesapeake Bay exchange system explains the concentration of villages along the north shore of the Rappahannock River; and 2) that the collapse of the regional exchange system contributed to the late seventeenth-century abandonment of the Northern Neck by many Native Americans.

THE BONE TOOLS RECOVERED FROM THE LATE WOODLAND PERIOD TRIGG SITE (44MY3), MONTGOMERY COUNTY, VIRGINIA: TYPOLOGY, SYMBOLISM, AND SYMMETRY. Michael B. Barber, George Washington & Jefferson National Forests. During the excavations of the Trigg site in the early 1970s, a large number of modified animal bones were recovered. Although associated with a salvage effort and with a loss of provenience of many artifacts due to a fire, 982 bone tools survived and were included in the current analysis. Ninety-five different tool types were identified with the most frequently recovered categories being turkey wing digit beads, cylindrical bird bone beads, turkey tarsometatarsal awls, antler drifts, blunted bear fibula weaving tools, and box turtle shell cups. Specific cultural issues were discussed concerning the implications of bone tools with regard to the sacred and the mundane, shamanism, clan affiliation, site relationships, the deer skin trade, gender, and symmetry and world view. Future research directions were discussed.

CONCORDANCE OF SKELETAL AND DOCUMENTARY EVIDENCE: SELECTED EXAMPLES FROM HISTORIC VIRGINIA CEMETERY POPULATIONS. Donna C. Boyd, Radford University. Since the 1970s, there has been a significant increase in the number of historic cemeteries unearthed in North America, often with associated documentary evidence. A direct comparison of this documentary evidence with the osteological information derived from an analysis of the skeletal remains from these cemeteries is the primary focus of this paper. Using examples from two historic Virginia cemeteries (the Marshall Tract Burial Ground and the Jones Cemetery), the degree of concordance of these two types of data is investigated. This comparison involves a discussion of the implications for concordance and discordance of skeletal and documentary evidence, a critical evaluation of the validity of both types of evidence, as well as an assessment of the advantages, problems, and limitations when these approaches are combined. It is seen that when multiple lines of evidence are investigated and correlated, we can understand the lives and deaths of past peoples interred in historic cemeteries.

ARCHAEOLOGICAL FIELDWORK AT A CIVIL WAR EARTHWORK AND CAMPGROUND: THE CARRIESBROOK SITE (44FK66). Matt Webster (MWC) and Mike Klein (MWC). During the 1960s and 1970s, historical archaeologists placed themselves at the center of debates about method and theory. As historical archaeology became widely accepted as a legitimate field of inquiry, the need to justify excavation by reference to the service it provided prehistorians evaporated. However, as deforestation, expanding transportation networks, warfare, and political consolidation force Hunter-Gatherers off even marginal lands, and expanding highway systems lead to the loss farmland and forest to suburban sprawl, it appears time to further explore the potential contribution of historical archaeology to the development of archaeological method and theory. The ongoing analysis of the Carriesbrook Site, located near Winchester, Virginia, forms the basis for an exploration of issues common to the archaeology of both Civil War encampments and the sites produced by mobile foragers, specifically: 1) the problems of locating and characterizing low-density, dispersed scatters of artifacts archaeologically; and 2) the potential contribution of Civil War archaeology to an understanding of the relationship between intended and actual length of stay and assemblage and feature diversity and density.

LOCATION, LOCATION: TESTING PREHISTORIC SETTLEMENT MODELS IN SHENANDOAH NATIONAL PARK. Carole L. Nash, James Madison University. A recent cultural resources survey in Shenandoah National Park has led to the reconsideration of previously developed predictive models for prehistoric settlement in the Blue Ridge. Phase I testing of seven areas predicted by the models as “high probability” for significant prehistoric sites found that such sites were located in only four of these. While the four sites offer evidence of repeated occupation as small base camps (through a wide variety of artifacts types and vertical separation of strata), the fifth and sixth locations offered evidence of only ephemeral occupation and the seventh was bereft of cultural materials. By assessing the variables commonly used to predict “high probability” mountainous locations (distance to water, slope, elevation, the sheltered nature of the locale, access to high quality raw material), the current study found that an additional variable may be needed to refine the predictive model: access to a perennial stream hollow. The four site areas share this variable while the three evidencing minimal occupation do not. The study suggests that stream-based travel routes connecting the uplands and lowlands were

MULTIDISCIPLINARY RESEARCH ON 19TH CENTURY MILITARY AND INDUSTRIAL SITES IN SALTVILLE, VIRGINIA: A PRELIMINARY REPORT. Cliff Boyd, Robert Whisonant, Bernd Kuennecke, Loretta LeMay, Brendan Cox & Ryan Murley, Radford University. Geology, Geography, and Anthropology students and faculty from Radford University are currently conducting a multi-year project to investigate nineteenth-century military and industrial sites in Saltville, Virginia. This NASA-funded project has focused on using archival and oral history data as well as remote-sensing data provided by infrared imaging, electromagnetic induction, and other methods to locate sites. Two sites were intensively tested in 1999 and 2000 by the senior author and Radford University archaeology students. The investigation of these two salt furnace sites—used for the production of salt from locally available brine—is described and the various methods of remote sensing used are evaluated.

A JASPER QUARRY AND WORKSHOP (44RB323) IN ROCKBRIDGE COUNTY, VIRGINIA: WHAT WAS GOING ON THERE? Eugene B. Barfield, U.S.D.A. Forest Service, (Ret). This Quarry and workshop site has produced thousands of artifacts with intermittent Native American occupation beginning ca. 10,000 years ago. Most of the artifacts are expedient rather than formal tools and are morphologically indicative of use for certain tasks. Sixty percent of these tools working edges or points are heat treated even though research has shown that this procedure reduces tensile strength of the jasper lithic by 50%. There are advantages to heat treating prepared cores in the normal reduction sequence of micro and cryptocrystalline lithics. The majority of tools found here are, however, expedient and not intentionally reduced to the normally symmetrical and finely finished formal stone tools seen at most other sites. The reasons or cognitive processes of these inhabitants for heat treating their tools are therefore a mystery. Photomicroscopy and scanning electron microscopy are used to view lithic topography in areas of high use-wear and damage in an attempt to determine what materials were worked upon. Results were compared to previous research from cognitive archaeologists. Prehistoric behavior such as butchering, hide-working, and modifying bone and wood to tools or weapons were determined.

Astronomy, Mathematics, and Physics

USE OF WEB-BASED RESOURCES FOR THE PHYSICS CLASSROOM: WEBASSIGN AND WEBDEMO. William W. McNairy, Dept. of Physics, Duke University, Box 90305, Durham, NC 277080305. At North Carolina State University two Web-based programs have recently been developed that can significantly improve physics courses. WebAssign (<http://webassign.net/info/>: marketed the NCSU Physics Education group) aims to deliver homework problems to students via Web browsers. A wide variety of problem types (either from a large database linked to physics texts or those created by the instructor can be assigned to students.) Analysis of students' performance can then be used to focus classroom discussions (see the Just in Time Teaching method by Gregor Novak et al. In addition, the Keith Warren at NCSU has developed a database of demonstrations accessible from the Web (see <http://demoroom.physics.ncsu.edu/>). WebDemo uses the PIRA classification scheme to sort classroom demonstrations for use by faculty who are generally unfamiliar with available demonstrations. A team from Duke is assisting in the development of a version of WebDemo that can be readily used at other institutions. Web access to the demonstration collection makes it more readily available (and more used!) by faculty across the curriculum. WebDemo permits the linking of key features of each demonstration: images, movies, links to published articles, source references and other invaluable information. Additionally, WebDemo can be used as a scheduler and can track the frequency of use of each demonstration.

AN INEXPENSIVE LAPTOP-BASED MULTI-LEAD SEISMIC ARRAY. Rhett B. Herman, Radford University. Seismic studies constitute one of the most important areas of study in undergraduate geophysics courses. Yet purchasing such equipment from commercial vendors is typically prohibitively expensive for most undergraduate institutions. In this talk, a method is presented for constructing an eight-lead seismic array whose cost is more than an order of magnitude less than that of the most basic commercial arrays. The geophones were acquired as surplus equipment at zero cost from a commercial geophysical prospecting company. The seismic cables are constructed from Category 5 computer network cable, hardware-store springs and claw clamps, and shrink wrap tubing. The data is collected and analyzed using the program LabView® and a 68-pin connector block, both available from National Instruments. The data collected with this array is comparable to that acquired by commercial arrays.

ANALYZING THE STABILITY OF PHOTOMULTIPLIER TUBES. Jason C. Mace & Kevin L. Giovanetti, Department of Physics, James Madison University, Harrisonburg, VA 22807. All detector systems have active components that change over time. A system has been installed in the forward calorimeters for the CLAS detector at Thomas Jefferson National Accelerator Facility to monitor photomultiplier tube drifts. Data was acquired during a data-recording period for the CLAS detector using a Laser Calibration System the analysis of this data and future plans for the use of the Calibration System will be discussed. This work is supported by the National Science Foundation.

KILLER ASTEROID 3200 BC. Joseph W. Rudmin Physics Dept, James Madison U. Evidence for the destruction of Ur in Sumer, c. 3200 BC is presented. The evidence includes sulfates deposited in the Greenland ice cap, statistical support from impact frequency vs. energy, archeological evidence from the excavations at Ur, a literary account from The Epic of Gilgamesh written c. 2600 BC, and astroblems at various places (Australia, India, and Saudi Arabia) which were created in that century.

PREPARATION AND CHARACTERIZATION OF TRANSPARENT OXIDE CONDUCTING THIN FILMS. Timothy J. Nagle¹, Gerald R. Taylor¹, John Stenger², David Lawrence², ¹Physics Dept., ²ISAT, James Madison Univ., Harrisonburg, VA 22807. Transparent conductive thin films are in high demand due to their potential for use in liquid crystal displays, photovoltaic cells, space applications, and other electro-optical devices. Zinc oxide (ZnO) is of particular interest for these applications due to its relative low cost compared with more commonly used indium tin oxide (ITO) thin films. Transparent ZnO thin films were deposited on glass substrates using spin-coating techniques. Properties of the films including electrical resistivity, Hall coefficient, and carrier concentration have been measured. Experimental techniques and measurements will be presented. Also, surface properties measured using atomic force microscopy (AFM) will be discussed.

HOW TO MAKE SINGING RODS SCREAM. D. Rae Carpenter, Jr., Richard B. Minnix & William W. McNairy, Virginia Military Institute, Virginia Military Institute, Duke University. The singing rod has long been a favorite of physics demonstrators. Longitudinal vibrations are easily excited for mode numbers $n=1$ and $n=2$ for shorter rods and even higher mode numbers for rods about a meter in length or greater. Aluminum is favored because of its higher Q , or tendency to maintain its resonance with a minimum of damping. Occasionally one finds by chance that an aluminum rod screams when one of the transverse modes becomes coupled to the longitudinal mode as a result of an integer ratio between a natural frequency of the longitudinal and transverse frequencies. Computer software is now available to analyze the various waves emanating from a rod and read out the numerical value of the frequencies. This has made it possible to measure the multiplicity of frequencies present when coupling occurs. In such cases a good comparison between the theoretical and experimental values is possible. Demonstrations, with accompanying data on frequencies and mode numbers, will be provided for rods of both circular and square cross section. Rods of other cross sections are also being investigated.

CAN WORMHOLES BE SUPPORTED BY QUANTIZED FIELDS? Brett E. Taylor, Radford University. Wormhole spacetimes were introduced as solutions to the Einstein field equations in 1988 by Morris and Thorne. This initial work created a burst of work focused on attempting to solve difficulties that were inherent in these spacetimes. In particular, the spacetimes required exotic material to maintain the geometry of the wormholes. This material is considered exotic because at least some observers would see this material having a negative energy density and, in addition, there would need to be a very large tension associated with this material. This talk will focus on determining whether quantized scalar fields might be able to act as this exotic matter.

TIME TRAVEL PHYSICS Tsunefumi Tanaka, Radford University. Time travel is a very popular theme in science fiction shows because it gives twists to otherwise boring story lines. Is it actually possible to go back in time? Many people will say "no" if they are asked, because of apparent paradoxes caused by time travel. However, from a physicist's standpoint, we need to show whether time travel violates any laws of physics before answering the question. Being able to go back in time means that there exist closed timelike curves (CTCs) in a spacetime. Some solutions of the Einstein field equations contain CTCs. CTCs can also appear in spacetimes with nontrivial topology. Examples of spacetimes with CTCs are described. Some physical mechanisms that might prevent us from going back in time are described. They include the weak energy condition, metric back reaction on the spacetime geometry, quantum fluctuations, and quantum gravity. However, our best answer to the original question is, "We don't know." This is because these mechanisms work in some cases but not in others. The real physical mechanism that prevents the formation of CTCs is expected to be applicable in all cases.

A PROTOTYPE ELECTRONIC NETWORK SUPPORTING SCIENCE EDUCATION – THE VIRGINIA SCIENCE RESOURCE NETWORK AND ADVISORY COUNCIL. Gerald R. Taylor, Jr.,¹ Patricia Fishback² and David Hagan², ¹James Madison University, Harrisonburg, VA, 22807, ²Science Museum of Virginia, Richmond, VA 23220. The Science Museum of Virginia and the Virginia Academy of Science are partners in developing the Virginia Science Resource Network (VSRN) to help increase the science education of every middle school and high school student in the Commonwealth. A goal of VSRN is to stimulate and facilitate connections between teachers, students and science and engineering experts in Virginia. The Virginia Science Resource Network Advisory Council has been established to review and recommend best practices for VSRN. An overview of VSRN and its new website, VSRN.org, will be presented. Members of the scientific community in universities and industry are encouraged to sign-on to VSRN.org, register and share their enthusiasm for science with teachers and elementary, middle and high school students throughout Virginia.

μ + LIFETIME: PAST AND FUTURE MEASUREMENTS. Kevin Giovanetti, Physics Department, James Madison University, Harrisonburg, VA 22807. Improved theoretical calculations of the relationship between the muon lifetime, τ_μ , and the Fermi coupling constant, G_F , allow the extraction of G_F from measurements of the positive muon lifetime with a greatly reduced error. Because G_F is a fundamental constant new measurements of the muon lifetime have been proposed. A review of the challenges associated with a lifetime measurement will be given with examples from past and newly proposed experiments.

Biology

CHARACTERIZING THE FUNCTIONAL AND STRUCTURAL DOMAINS IN *ARABIDOPSIS* CHALCONE ISOMERASE. Chris Dana & Brenda Winkel, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 25061. Enzyme complexes are groups of two or more enzymes that interact to catalyze related metabolic reactions. The flavonoid biosynthetic pathway of *Arabidopsis* has been developed as a model system for the study of multi-enzyme complexes. The aim of this research project is to characterize the interactions between the first two enzymes of this pathway, chalcone synthase (CHS) and chalcone isomerase (CHI), and to model these interactions in three dimensions. A series of N- and C-terminal truncations of CHI will be used in affinity chromatography experiments with plant extracts to identify domains through which CHI interacts with other flavonoid enzymes. In addition, we have already determined a theoretical model of wild-type and mutant alleles of *Arabidopsis* CHS by homology modeling. We propose to purify, crystallize and solve the crystal structure of CHI for modeling its interactions with CHS. Applying this data to a three-dimensional model of CHI and CHS, we may be able to show how these enzymes work together in a complex. More importantly, the results from these experiments will give us a better perspective on how enzymes work together within the cell.

EFFECTS OF POLLUTANT CHEMICALS ON THYROID HORMONE EXCRETION IN BIRDS. Ryan J. R. McCleary¹, F. M. Anne McNabb¹ & Keith A. Grasman², ¹Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061 and ²Dept. of Biological Sciences, Wright State University, Dayton, OH 45435. Studies in lab rodents suggest some PCBs and dioxins reduce thyroid function by increasing T₄ glucuronidation and excretion. However, little is known of PCB effects on thyroid function in birds, although wild birds often are exposed to these pollutants in the environment. To assess PCB effects on avian thyroid function, we dosed chicken eggs with PCB 126 (a coplanar, dioxin-like PCB congener) at concentrations of 0, .0512, .128, .32, .48, .64 or .80 ng/g egg prior to incubation. Embryos were sampled at day 20. Plasma T₄ was determined by RIA, and hepatic uridinediphosphate-glucuronosyltransferase (UDP-GT) activity to phenolic compounds was determined by a *para*-nitrophenol assay validated for use with avian tissue. Neither plasma T₄ concentrations nor hepatic UDP-GT activities were significantly different from controls in any dosed group, indicating that thyroid function in chicken embryos was not altered by PCB 126 exposure throughout development. Before generalizing about PCB effects on thyroid function, more research is needed to elucidate possible effects of other PCB congeners, different exposure times and different developmental ages. Supported by EPA grant #R 827400-01-0.

PHYSICALLY COMPLEX HABITAT AND BENTHIC INVERTEBRATE COMMUNITY PARAMETERS: MATHEMATICAL RELATIONSHIPS IN THE JAMES RIVER. T. W. Stewart, T. Shumaker, & T. Radzio, Dept. of Natural Sciences, Longwood College, Farmville, VA 23909. Physical structure generally stimulates increased organism abundance and diversity by providing refuges from disturbance. However, mathematical relationships (i.e., linear or nonlinear) between physical structure abundance and organism abundance and diversity are poorly described. We show evidence that freshwater bottom-dwelling invertebrates respond positively to physical structure, and present preliminary results from an investigation of mathematical relationships between physical structure abundance and invertebrate abundance and diversity. Contrary to our hypotheses that high densities of physical structure are required to elicit a biological response, invertebrate abundance and diversity were greater at low levels of physical structure (10% of cement block covered with stones) than when no structure was present ($p \leq 0.05$). Our results will contribute to an improved understanding of biological community responses to changes in physical structure abundance that is needed to predict effects of habitat loss or gain on biological diversity.

CLONING AND ANALYSIS OF TRANSCRIPTIONAL REGULATION OF THE 5'NUCLEOTIDASE GENE IN *DICTYOSTELIUM DISCOIDEUM*. Can M. Eristi & Charles L. Rutherford, Dept. of Biology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. A 5'AMP-degrading activity appears during the time course of cell differentiation in *Dictyostelium discoideum* and the activity becomes restricted to a narrow band of cells that form the interface between the two differentiated cell types. The gene is referred as 5' *nucleotidase* or 5'NT. The expression of this gene occurs during the formation of the multicellular slug stage. The sorting of specific cells expressing 5'NT to form a boundary between the prespore and prestalk zones suggests that this activity is essential to positional differentiation of the two cell types. An understanding of the regulation of the expression of this protein is required before an accurate model of the mechanisms that regulate morphogenesis can be constructed. A genomic fragment containing a part of the 5'NT coding as well as an upstream flanking region has been cloned. Promoter deletions have been generated using an exonucleaseIII-mung bean nuclease system. Regulatory elements responsible for the cell-specific expression of this gene will be defined by use of the luciferase reporter gene system. Gel mobility shift assays will also be performed to identify trans-acting factor(s) that bind specifically to those elements.

SPERM COMPETITION AS A MECHANISM FOR SEXUAL SELECTION IN THE LIZARD, *ANOLIS CAROLINENSIS*. Kelly M. Passek, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. Sperm competition is one mechanism by which competition over mates occurs. It has been defined as competition between the sperm of two or more males to fertilize the eggs of a female during one reproductive cycle. Given the life history characteristics of the lizard, *Anolis carolinensis*, sperm competition is a plausible mechanism for sexual selection. Sperm competition can be evidenced through the occurrence of multiple paternity. Does a resident male father all of the hatchlings born to females whose territory he patrols? Resident males, females from within their territories and neighboring males were collected. One to two eggs collected from each female were incubated until hatching. Paternity analysis using RAPD-PCR was performed to determine the paternity of each hatchling. Using the presence of diagnostic bands as an indicator of paternity, I found evidence of neighboring males fathering six of 18 hatchlings. In light of this documentation of multiple paternity, I am interested in determining if male territory size or location of resident females within a male's territory influences the occurrence of multiple paternity.

EFFECT OF INTERLEUKIN-10 ON THE FREQUENCY OF PREGNANCY LOSS INDUCED BY LIPOPOLYSACCHARIDE INJECTION IN CD-1 MICE. Kristin L. Hrinak¹, Carolyn M. Conway², & Arthur F. Conway¹, ¹Dept. of Biol., Randolph-Macon Coll., Ashland, VA 23005 & ²Dept. of Biol., VCU, Richmond, VA 23284. Pregnant female CD-1 mice were injected intraperitoneally with 2.5 µg recombinant mouse interleukin-10 (IL-10) twelve hours prior to lipopolysaccharide (LPS) injections, injected intravenously with 5 µg LPS on day 9 of gestation (plug = day 1), and sacrificed on day 12 of gestation. Control females were injected with phosphate-buffered saline (PBS) in place of IL-10 and/or LPS. IL-10 treatment significantly decreased the frequency of pregnancy loss in LPS-treated females. A second set of mice were left untreated, injected with PBS, or injected with LPS as above and sacrificed six hours later for ELISA analysis of IL-10 concentrations in maternal serum and in implantation sites from LPS-treated mice. Although IL-10 concentrations in maternal serum were increased in LPS-injected mice, no changes in IL-10 concentrations were observed in the regions sampled in implantation sites. These results indicated that although injecting IL-10 in excess of normal levels can inhibit LPS-induced pregnancy loss, no changes in intrinsic IL-10 concentrations in implantation sites were associated with the early stages of LPS-induced pregnancy loss.

MODULATING FLAVONOID BIOSYNTHESIS IN TRANSGENIC *ARABIDOPSIS*. Michael C.O. Santos & Brenda S.J. Winkel, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg VA 24061. We are testing the feasibility of altering a metabolic pathway in transgenic plants by using antibodies that recognize the pathway's key enzymes. Thus, we have attempted to overexpress antibodies in the single-chain fragment format (ie scFv) that recognize either of the first two enzymes of the flavonoid biosynthetic pathway (ie chalcone synthase: CHS, chalcone isomerase: CHI) in *Arabidopsis*. Our efforts have resulted in a minimum of 10 independent transgenic lines per unique anti-CHS or -CHI scFv. We are now screening all homozygous lines for scFv-expression by immunoblot analysis. In addition, we are looking at flavonoid composition by HPLC analyses of methanolic extracts from transgenic plants grown on flavonoid metabolism-inducing medium. Thus far, we have identified a low-level anti-CHS scFv expressor that has a significantly altered profile for glycosylated kaempferol and quercetin, flavonoid compounds detectable at 255 nm. These preliminary results are, to our knowledge, the first to demonstrate that scFv-expression is a potentially useful strategy for *in vivo* modulation of metabolism in transgenic plants.

CHANGES IN GUT MORPHOLOGY AND PHYSIOLOGY OF TWO *MICROTUS* SPECIES UNDER DIFFERING PHOTOPERIODS AND DIETARY FIBER LEVELS. Scott Buchanan & Jack A. Cranford, Dept. of Biology, Virginia Polytechnic Institute and State University, Blacksburg, VA 25061. We subjected meadow voles (*Microtus pennsylvanicus*) and prairie voles (*M. ochrogaster*) to high (50% NDF) and low (5% NDF) dietary fiber levels and long (16L:8D) and short (8L:16D) photoperiods for 20 days. Animals were then euthanized and dissected and the mass, length, and content mass of the stomach, caecum, and small and large intestine were measured. Food intake rate and feces produced increased significantly ($p < 0.01$) and digestive efficiency percentage decreased significantly on high-fiber treatments for both species. Retention time did not vary significantly between trials. GI tract mass decreased under short photoperiod for prairie voles, but not for meadow voles. There were no differences in gut mass between species on long and short photoperiod regardless of dietary fiber level. We assert that voles may compensate for low-quality diets by increasing intake rate and decreasing digestive efficiency in order to maintain retention time.

THE EFFECTS OF PHOSPHATE DEFICIENT MEDIUM ON CELL SIZE, CYANOPHYCIN GRANULE FORMATION, NITROGENASE ACTIVITY, PHOTOSYNTHETIC PIGMENT FORMATION, AND GENOME ARRANGEMENT DURING AKINETE DIFFERENTIATION IN *ANABAENA AZOLLAE*. Stephanie M. Carter, Dept. of Biology, Virginia State University, Petersburg, VA 23806 & Robert W. Fisher, Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284. The purpose of this research was to identify the structural, biochemical and genetic changes that occur during vegetative cell differentiation to akinete cells in the cyanobacterium *Anabaena azollae* Stras. Results were determined through a series of experiments: 1. Structural changes were studied by calculating the surface area of cells and changes in cyanophycin granule accumulation; 2. Biochemical changes were observed through monitoring phycobiliprotein and chlorophyll *a* concentrations and by monitoring nitrogen fixation by using the Acetylene Reduction Assay (ARA); and 3. Genetic changes were monitored through DNA isolation and characterization. The end results showed that granule accumulation and cell size increased while phycobiliprotein and chlorophyll *a* concentrations declined. Nitrogenase activity gradually decreased due to the lack of heterocyst differentiation. Supported in part by NIH grant # 1E25GM56620-01.

IMMUNOLocalIZATION OF TWO FLAVONOID ENZYMES IN *ARABIDOPSIS*. David Saslowsky & Brenda Winkel, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. The enzymes of certain metabolic pathways, such as glycolysis and the citric acid cycle, have been shown to function as multicatalytic complexes, or metabolons. Such organization offers a number of potential advantages with respect to metabolic efficiency, kinetics, and regulation. The research interest of our laboratory is to determine if the enzymes of the flavonoid biosynthetic pathway exist as a cytosolic enzyme complex, and how such organization impacts metabolic regulation. Immunolocalization of the first and second flavonoid enzymes, chalcone synthase (CHS) and chalcone isomerase (CHI), respectively, is being used to determine if a flavonoid metabolon exists in *Arabidopsis*. In wild type (Landsberg) seedling roots, CHS and CHI exhibit cell type-specific co-localization around vacuoles and at the endoplasmic reticulum (ER). In a mutant (*tt7*) devoid of a pathway integral membrane protein (F3'H), CHS and CHI display tissue-specific localization patterns distinct from that of wild type, although subcellular localization patterns seem to be unaffected. Localization near the vacuole is logical as flavonoid end products are transported into this organelle.

ANALYSIS OF cAMP INDUCED NEUROENDOCRINE DIFFERENTIATION IN HUMAN PROSTATIC ADENOCARCINOMA CELL LINE LNCaP USING mRNA DIFFERENTIAL DISPLAY. Jeremy L. Goodin & Charles L. Rutherford, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. Prostate cancer is the second leading cause of cancer related death among men and the most commonly diagnosed cancer in the Western world. It has been demonstrated that LNCaP prostate cancer cells can be induced to differentiate from a growing epithelial morphology to a growth arrested neuroendocrine (NE) state by increased levels of intracellular cAMP. Elucidation of those genes that are differentially expressed between growing epithelial cells and LNCaP cells that have been induced to NE differentiation may present new insights for the early detection of prostate cancer and/or targets for effective gene therapy. In order to determine the molecular events underlying the effects of cAMP on these prostate cancer cells, we have used a new and powerful technique called Differential Display PCR to identify a number of differentially expressed genes. To date, eleven PCR products have been confirmed by northern blot analysis to be differentially expressed. The differentially expressed PCR products have been cloned and sequenced. Resultant sequences have been tested for homology to known sequences in public databases. Expression of the genes for HRS3A protein and ATP synthase subunit g were found to be down regulated in NE cells and may play an important role in prostate cancer progression.

EFFECT OF INDOMETHACIN TREATMENT ON PROSTAGLANDIN E_2 AND F_{2A} CONCENTRATIONS IN MATERNAL SERUM AND PERI-EMBRYONIC TISSUES OF IMPLANTATION SITES IN CONTROL AND LIPOPOLYSACCHARIDE-TREATED CD-1 MICE. James E. Urban¹, Carolyn M. Conway², & Arthur F. Conway¹, ¹Dept. of Biol., Randolph-Macon Coll., Ashland, VA 23005 & ²Dept. of Biol., VCU, Richmond, VA 23284. Mice were given 6 μ g/ml indomethacin (IND) or plain drinking water from day 7 to day 9 of gestation (plug = day 1), then injected with lipopolysaccharide (LPS) or with phosphate-buffered saline (PBS) or left untreated on day 9 of gestation. Mice were sacrificed 6 hours after day 9 treatment and implantation sites were frozen for ELISA analysis of prostaglandins $F_{2\alpha}$ (PGF_{2 α}) and E_2 (PGE₂). IND treatment reduced both PGE₂ and PGF_{2 α} concentrations in maternal serum and in all regions sampled in implantation sites and resulted in a reduction in the ratio of PGE₂ to PGF_{2 α} , but LPS treatment had no effect. The reduction in PGF_{2 α} concentration was consistent with IND treatment preventing pregnancy loss in LPS-treated mice by inhibition of inflammatory prostaglandin synthesis, but the failure to observe elevation (relative to control mice) of PGF_{2 α} concentrations in LPS-treated females not treated with IND argued strongly against involvement of increased PGF_{2 α} concentrations in LPS-induced pregnancy loss.

SURVIVAL AND PHENOTYPES OF HATCHLING LIZARDS. Daniel A. Warner & Robin M. Andrews, Dept. of Biology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. Environmental conditions during egg incubation affect phenotypes of hatchling reptiles. However, the ecological significance of incubation induced phenotypes is poorly known. We investigated such effects for hatchlings of the lizard *Sceloporus undulatus*. Eggs from 28 clutches were incubated under two moisture regimes (-150 kPa and -530 kPa) at a constant 28 C. Yolk was removed from eggs to manipulate hatchling body size in a third treatment. After hatching, snout-vent length, mass, tail length, growth rate, thermal preference, running performance, and desiccation rate were measured for each hatchling. Hatchlings were then released at the field site near Blacksburg, Virginia and monitored for 12 weeks. In both the laboratory and field, most variation in hatchling phenotype was explained by clutch; treatment had no affect after correcting for body size. For example, survival was related to clutch, and variation in survival was associated with growth rate. Hatchlings that survived longer than six weeks grew slower than those that did not survive to six weeks. If rapid growth is associated with high activity, the more rapidly growing hatchlings may be more conspicuous to predators. In general, our observations demonstrate the importance of maternal contributions to offspring fitness.

DIOXIN-INDUCED ALTERATION OF THYROID HORMONE METABOLISM IN MICE. J. E. Baumgartner, F. M. A. McNabb, I. A. Camacho & M. Nagarkatti, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. The effects of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) on uridinediphosphate-glucuronosyltransferase (UDP-GT) were studied in C57BL6^{+/+} mice, a TCDD-sensitive species. In rats, TCDD increases thyroxine (T₄) glucuronidation and excretion, but the effects of TCDD on UDP-GT in mice have not been investigated. We measured hepatic UDP-GT spectrophotometrically at 400 nm as the decolorization of *para*-nitrophenol substrate. The assay was validated by establishing conditions that gave linearity with reaction time and with tissue concentration. UDP-GT activity did not change after one day of exposure to a single dose of any TCDD amount used (.1, 1.0, 10 or 50 µg/kg body weight vs. corn oil injected controls). At 5 days of exposure, UDP-GT activity increased linearly with TCDD dose when compared to controls. Responses of males and females did not differ. Hepatic UDP-GT was increased significantly above controls at 14 and 21 days of TCDD exposure but activity was highest at 5 days after injection with the 50 µg/kg dose. These results show that TCDD induces a dose dependent increase in UDP-GT activity, which should result in increased T₄ glucuronidation and excretion. If T₄ production is insufficient to balance increased excretion this could result in decreased circulating T₄ and a hypothyroid state. Supported by EPA grant #R 827400-01-0.

SEASONAL VARIATIONS IN THE PHYTOPLANKTON COMMUNITIES OF AN EPHEMERAL SINKHOLE COMPLEX, YORK COUNTY, VIRGINIA. Michelle R. Kokolis, Dept. of Biological Sciences, Old Dominion University, Norfolk, VA 23529. The Grafton Ponds Natural Area is a 374 acre preserve in York County, Virginia, approximately 14 miles north of the City of Newport News. The preserve contains over 40 ephemeral ponds, which are filled seasonally by precipitation and groundwater discharge. These ponds are typically wet from late fall through late spring or early summer. Pond size varies from 0.1 ha to 2 ha, and depths range from 4 cm to 3 meters. The first phase of this study was to examine the physical and chemical characteristics of several of these ponds, including pond size and depth, canopy openness, inundation period, water temperature, and pH. The second phase was to examine the phytoplankton assemblages of the selected ponds, and correlate differences in the phytoplankton assemblages to the varying physical and chemical characteristics of the ponds. Analysis indicates the occurrence of spring and early fall Chlorophyte and Cyanobacteria blooms and a winter Dinoflagellate bloom. Diatoms are a secondary component of the phytoplankton community.

MONITORING ENZYME-ENZYME INTERACTION IN THE PLANT FLAVONOID BIOSYNTHETIC PATHWAY USING FLUORESCENCE RESONANCE ENERGY TRANSFER. Anna M. Leung & Brenda S.J. Winkel, Dept. of Biology, Virginia Polytechnic Institute & State University, Blacksburg, Va 24061. The flavonoid biosynthetic pathway of *Arabidopsis* is being used as a model system for the study of enzyme complexes. My project involves studying the interaction between chalcone synthase (CHS) and chalcone isomerase (CHI), the first two enzymes in this pathway. We are exploring the feasibility of using fluorescence resonance energy transfer (FRET) to detect these interactions, first in *Escherichia coli* and eventually in live *Arabidopsis* plants. FRET is a process where an excited fluorophore transfers excitation energy to a light-absorbing molecule. FRET occurs only if distance and mutual orientations of the proteins are suitable. FRET was used to detect interactions between CHS and CHI by fusing these enzymes to enhanced cyan fluorescence protein (ECFP) and enhanced yellow fluorescence protein (EYFP). These fusion proteins were placed into bacterial expression vectors and then coexpressed in *E. coli* strain BL21 (DE3). FRET was not detected in preliminary experiments due to a variety of external factors. Additional experimentation will be needed before conclusive results can be obtained.

EFFECTS OF CHRONIC UNPREDICTABLE STRESS ON LEVELS OF INNATE AND IMMUNE DEFENSE COMPONENTS IN UNSTIMULATED AND LIPOPOLYSACCHARIDE-STIMULATED RATS. Melissa D. Derr¹, Kelly G. Lambert², & Arthur F. Conway¹, ¹Dept. of Biol. & ²Dept. of Psych., Randolph-Macon Coll., Ashland, VA 23005. The effects of chronic stress on innate and immune components were studied in Long-Evans rats by exposing the rats to an eleven-day stress protocol, then injecting the rats subcutaneously with 50 µg of bacterial lipopolysaccharide (to simulate a Gram-negative bacterial infection) or with phosphate-buffered saline, and then sacrificing the rats approximately six hours after injection. Chronically stressed rats gained significantly less weight than control rats and had significantly smaller adrenal glands, indicating that the stress protocol was sufficient to cause physical changes. Thymus and spleen weights, serum IgG and TNF alpha concentrations, and percentages of lymphocytes, monocytes, and neutrophils among white blood cells were not significantly altered by chronic stress. Chronic stress significantly inhibited the increases in percentages of basophils and eosinophils among white blood cells which occurred in response to lipopolysaccharide, suggesting that innate responses to protistan and helminth parasites might be compromised in stressed animals.

THE NEANDERTAL'S ROLE IN HUMAN HISTORY. Wendy L. Skinner & David A. DeWitt, Dept. of Biology & Chemistry, Liberty University, Lynchburg, VA 24502. MtDNA has been used to infer migration patterns and establish dates of divergence of common ancestors in human evolution. Such results have promoted the 'Out of Africa' model whereby early modern humans evolved in Africa and then migrated to Europe replacing the Neandertals. Recent reports yielding the sequence of HVRI and HVRII mtDNA regions from fossil Neandertals have been interpreted to support this model and as evidence that Neandertals were outside the range of modern human variability. However, these regions are known to have an extremely high rate of mutation. Further, 12 out of 19 reported sites of Neandertal pairwise nucleotide differences in HVRI are at sites known to be 'hot spots' with a high relative mutation rate. In addition, one of the Neandertals exactly matches the human reference sequence at 100% of intra-Neandertal pairwise difference sites. We examined HVRII in 143 modern humans and found an average of 8.6 differences. The 14 modern individuals with the most pairwise differences (12-14) surprisingly shared 2-7 of these differences with the Neandertal when compared to the human reference sequence. Taken together, these results suggest that Neandertals cannot be excluded from the normal range of human variability and alternatives to the "Out of Africa" model cannot be ruled out.

THE FEVER RESPONSE IN THE GARTER SNAKE (*THAMNOPHIS RADIX RADIX*): THE RESPONSE TO A WHOLE BODY INFECTION COMPARED TO A LOCALIZED INFECTION. Elana Pressman & John Temple, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. A fever is an increase in body temperature resulting from an elevation in the thermoregulatory set point. As ectotherms, snakes may behaviorally induce a fever by moving to a warmer location. This experiment compared thermoregulatory patterns in snakes given whole body infections to patterns in snakes given localized infections. For the whole-body infection, saline was injected intraperitoneally (IP), followed 48 hours later with an IP injection of alcohol-killed *Aeromonas hydrophila* bacteria. For the localized infection, saline was injected subcutaneously (SC) 2 cm anterior to the cloaca, followed 48 hours later with a SC injection of the bacteria. Following each injection, snakes were given access to a thermal gradient and the cloacal temperature and body position were recorded for 48 hours. The snakes given a whole-body infection significantly increased their body temperature by an average of 4.33% in the first 24 hours following injection of bacteria. No other significant temperature change was noted. There were no apparent differences between thermoregulatory patterns of snakes with whole body infections compared to those with SC infections.

ELECTROPORATION MEDIATED GENE TRANSFER USING INTACT PLANT TISSUE. Lou V. Garcia, NIH Bridges Program, Science Dept., J. Sargeant Reynolds Community College, Richmond, VA 23285 & Fang-Sheng Wu, Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284. The purpose of this research was to study the effectiveness of electroporation for DNA uptake into plants for studies of transient gene expression and for stable transformation. Electroporation has been found to be effective on many types of cells, and is now the method of choice for the genetic transformation of bacteria and certain animal cells. It has been shown to be a simple, fast, inexpensive, and non-toxic procedure to deliver DNA into protoplasts derived from a variety of plants. Plasmid DNA can be effectively delivered into intact plant cells and expressed at transient levels and can be used to obtain stably transformed plants by direct gene transfer into intact plant cells. The authors thank both JSRCC and VCU for their support of the NIH Bridges Program. The study was funded in part by NIH grant #1E25GM56620-01.

ACTIVATION OF p21 BY ESTRADIOL AND TAMOXIFEN AND SUBSEQUENT EFFECTS ON DNA DAMAGE REPAIR. David R. Chaves & Rosemary Barra, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. Expression of the cyclin-dependent kinase inhibitor p21 elicits a G1 phase arrest and prevents replication of damaged DNA. In addition, p21 may play a role in a cell's ability for nucleotide excision. Various hormones are known to act as transcription factors and to induce regulators of the cell cycle. This study demonstrates the effects of dexamethasone, estradiol, and tamoxifen on p21 production and DNA repair sensitivity in response to UV radiation and methyl methane sulfate induced damage. The experiments were conducted in ME-180 cells and the results indicate that estradiol and tamoxifen treatments increase p21 production. Cells treated with estradiol had an elevated capacity for nucleotide excision repair compared to control groups following exposure to UVC. Tamoxifen may have a similar effect. These results demonstrate a correlation between p21 production and nucleotide excision repair, and they also help to explain some of the known cancer preventative effects of estradiol and tamoxifen. MMS treatments did not produce the same results as UV radiation. Hormonal treatments in those experiments did not result in higher levels of DNA repair. This suggests that there may be differences in the role of p21 in MMS and UV induced DNA damage repair pathways.

CHARACTERIZATION OF A NUCLEAR LOCALIZED CaMK - II ISOZYME. ¹Nicai Q. Zollar, ²Kim Jenkins, ³Lesley Johnson, & ^{2,3}Robert Tombes, ¹NIH Bridges Program, Science Dept., J. Sargeant Reynolds Community College, Richmond, VA 23285 & ²Massey Cancer Center & ³Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284. CaM kinase II, the "multi-functional" Ca²⁺/CaM-dependent protein kinase (CaMK-II), is encoded as over two dozen splice variants through combinations of at least ten separate splice domains from 4 different genes. There is evidence that these domains target CaMK-II isozymes to intracellular locations. This work is an on going project to determine the cellular physiology of a targeting CaMK-II to the nucleus. The isozyme used in this study is a nuclear targeted variant of Beta CaMK-II linked to green fluorescent protein (GFP). When expressed in NIH/3T3 fibroblasts, this isozyme localizes within the nucleus and induces cell death over the course of three days. This study was funded in part by NIH grant #1E25GM56620-01.

AN ANALYSIS OF THE EFFECTS OF SEROTONIN DEPLETION ON COORDINATION, LOCOMOTION, AND RIGHTING TIME IN RAT SNAKES (GENUS *ELAPHE*). Russell Lederhouse & John Temple, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. Past research has indicated that depletion of central dopamine (DA) and/or serotonin (5-HT) causes movement disorders in the black ratsnake *Elaphe o. obsoleta*. In this study the biochemical and behavioral effects of *para*-chlorophenylalanine (pCPA), a drug which reduces 5-HT, was tested in cornsnakes *Elaphe g. guttata* in order to specifically address the role of 5-HT in movement control. An intraperitoneal dose of 100 mg/kg/day pCPA was administered for eight days and righting time was measured. Righting time was significantly decreased by the drug treatment. pCPA significantly decreased 5-HT in the forebrains (79.6%) while having a suggestive effect on the depletion of 5-HT in the mid (67.1%) and hindbrains (60.3%), and on DA in fore (64.6%) and midbrains (72.3%) as well. It was also observed that some of the pCPA treated snakes appeared dazed and unable to right themselves until stimulated by touch, then resumed normal righting ability. This experiment showed that pCPA significantly impairs righting times in ratsnakes. However, it remains uncertain if the observed responses are due solely to 5-HT depletion or to concomitant depletion of 5-HT and DA.

GRAY LEAF SPOT: MOLECULAR ANALYSES OF *CERCOSPORA ZEA-MAYDIS* STRAINS FROM MIDATLANTIC AND MIDWESTERN REGIONS OF THE UNITED STATES AND SOUTH AFRICA. Georgia A. Hammond¹, Verlyn K. Stromberg², Eric L. Stromberg² & George H. Lacy², ¹Dept. of Biol., Radford Univ. & ²Dept. of Plant Pathology, Physiology & Weed Science, VPI&SU. *Cercospora zea-maydis* (*Czm*) is the fungus causing Gray Leaf Spot (GLS) disease of maize (*Zea mays*). Types I and II *Czm* have been identified in the US. These types show sequence variation in the Internal Transcribed Spacer regions (ITS) of their ribosomal RNA genes. In order to design maize breeding programs aimed at developing resistance to the pathogen; it is essential to ascertain which *Czm* populations cause GLS in a given region. The goals of our research are: (1) to confirm the existence of Type I and Type II *Czm* by extending the DNA sequence analyses to the small subunit ribosomal RNA gene (ssrRNA); (2) to determine the number of differing *Czm* genotypes extant in the US and their distributions; and (3) to extend our analysis of fungal genotypes to include foreign strains. Leaves with lesions were collected, air-dried, and imported into Virginia (APHIS PPQ permit). Fungi grown on V8 agar were extracted for DNA. PCR-amplified ssrRNA genes and ITS regions were sequenced and compared with the corresponding sequences from *Cercospora beticola*, *C. sorghi*, *Pseudocercospora mali*, *P. musae*, *Mycosphaerella pomii* and *M. zea-maydis*. Our results indicate species-level differences between between Type I and II *Czm* strains. Our results demonstrate the presence of both Type I and Type II *Czm* in Virginia, and Type II *Czm* in the Republic of South Africa. Preliminary comparisons of small subunit rRNA sequences suggest the existence of a third *Czm* genotype in Virginia.

DETECTION OF THE EPINEPHRINE SYNTHESIZING ENZYME IN MOUSE SPLEEN AND THYMUS. Carolene W. Lewis¹, Michelle D. Wharthan², Jessica G. Freeman² & Jennifer K. Stewart², ¹NIH Bridges Program, Science Dept., J. Sargeant Community College, Richmond, VA 23285 & ²Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284. MRNA coding for the epinephrine synthesizing enzyme phenylethanolamine N-methyl transferase (PNMT) was localized in the mouse spleen and thymus with *in situ* hybridization. PNMT activity was measured radioenzymatically. Both PNMT activity and mRNA were barely detectable in the spleen of the mouse. However, levels of PNMT activity in the thymus were similar to those in the brainstem, and PNMT mRNA was distributed throughout the cortex and medulla of the thymus. (Supported by NSF grant 9870382 and NIH grant #1E25GM56620-01.)

INDUCTION OF NT2 CELL DIFFERENTIATION BY THE MOUSE CAUDATE PUTAMEN. B.R. Monroe & D.A. O'Dell, Dept. of Biology, Mary Washington College, Fredericksburg, VA 22401. A human embryonic carcinoma cell line (NT2 cells), can be induced *in vitro* to differentiate into neuron-like cells by the application of retinoic acid. Once differentiated, the NT2N cells lose their tumorigenicity, and have been used in studies that examine neural plasticity, cell transplantation, and the functional repair of the nervous system. NT2 cells, when injected into immunodeficient mice, rapidly form lethal tumors, except when injected into the caudate putamen. This suggests that retinoic acid is present in this region and acts by differentiating the NT2 cells into non-tumorigenic NT2N cells. It has been demonstrated that retinoic acid is present in the retina, cerebellum, and many locations throughout the fetus, but its presence in the adult caudate putamen had not been determined. Through the use of tissue culture and HPLC we attempted to determine whether retinoic acid or some other factor was responsible for the differentiation. The results indicated the presence of 4.40×10^{-5} +/- 1.19×10^{-5} M all-trans-retinoic acid in the mouse caudate putamen. This concentration is far greater than the amount needed to induce NT2 cell differentiation *in vitro* (1×10^{-5} M). Thus, retinoic acid is present in the adult mouse caudate putamen in sufficient amounts to suppress tumor formation by NT2 cells.

CHARACTERIZATION AND IDENTIFICATION OF Q-LIKE ELEMENTS IN *A. STEPHENSI*. Landon Edwards & Shirley Luckhart, Dept. of Biochemistry, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. Transposable elements (TEs) are self-propagating DNA sequences found in the genomes of both eukaryotes and prokaryotes. TEs replicate through DNA or RNA intermediates; the latter are called retroposons and are related to retroviruses. Retroposons are classified into "viral" or "nonviral" superfamilies based on structural features. One such nonviral retroposon, a Q-like element, was characterized from the African malaria mosquito *Anopheles gambiae*. The authors of this work proposed that the SE Asian malaria mosquito, *A. stephensi*, did not harbor Q-like elements based on DNA hybridization studies. We have discovered, however, that Q-like elements reside in the *A. stephensi* genome and have attempted to characterize and identify the elements through methods involving Universal PCR, Vector Anchored PCR, and Restriction Digestion and comparison of clones.

MOLECULAR PHYLOGENETICS OF *CENTELLA* (APIACEAE). Paola A. Moncada¹, Jason Noel², Gregory M. Plunkett², Ben-Erik van Wyk³, & Mahalia Schubert³, ¹NIH Bridges Program, Science Dept., J. Sargeant Reynolds Community College, Richmond, VA 23285, ²Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284, & ³Rand Afrikaans University, Johannesburg, South Africa. *Centella* is a genus of 40 species distributed throughout the world, with the greatest diversity in southern Africa. We studied 27 different species of *Centella* using DNA sequences of the internal transcribed spacers (ITS) of the nuclear ribosomal RNA genes. After phylogenetic analysis of these ITS sequences, we conclude that all 27 species sampled from *Centella* form a single evolutionary branch or "clade," so that *Centella* is said to be monophyletic. The earliest lineage to diverge in *Centella* was *C. asiatica*, a species that is distributed throughout the world. The next to diverge were *Centella glabrata* and *C. fusca*. Resolving relationship among the remaining African species will require additional molecular markers. This study was funded in part by NIH grant #1E25GM56620-01.

QUANTITATIVE DETERMINATION OF THE COMPOSITION OF SOUTHERN TOAD (*BUFO TERRESTRIS*) VENOM AND ITS METABOLISM BY SNAKE BLOOD. Kimberly Parker & John Temple, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. Toads (Genus *Bufo*) are known to emit potent compounds from their skin glands as a means of defense. The secretions include cardioactive glycosides and monoamines including serotonin and its structural analogues. One goal of this study was to determine the relative amounts of the monoamines in *Bufo terrestris* venom. Venom from the parotoid glands of the toad *Bufo terrestris* was extracted and analyzed using high performance liquid chromatography (HPLC). Serotonin (82.5 mg/g) and N-methyl serotonin (1.5 mg/g) were found in the venom, as well as one currently unidentified peak. These results demonstrate that serotonin is more abundant than N-methyl serotonin in *Bufo terrestris* venom. The second goal of this study was to develop an assay to measure monoamine metabolism in the blood of bufophagous and non-bufophagous snake species. Results indicate that blood samples must be centrifuged at 15,000 X g for 30 minutes in order to reduce the artifactual release of serotonin from platelets. These methods will be incorporated into future studies to determine the comparative metabolism of toad toxins by snake blood.

AN ASSAY OF NEURONAL GROWTH DURING LEARNING IN *DROSOPHILA*. Cathrine L. Dam & Deborah A. O'Dell, Dept. of Biology, Mary Washington College, Fredericksburg, VA 22401. Learning in three types of *Drosophila* was analyzed through classical conditioning and protein analysis. Each group of flies, wild-type, *rutabaga* and *dunce*, were trained to associate an odor with sucrose in a learning apparatus. The analysis involved calculating a learning index of the fraction of flies choosing the positive conditioned stimulus (CS+) minus the fraction of flies choosing the negative conditioned stimulus (CS-). The learning index as well as the raw data indicate that conditioned wild-type and *dunce* are able to distinguish between odors. On the other hand, *rutabaga* did not appear to learn. The biochemical analysis indicated that trained wild-type formed the highest level of GAP-43 (growth-associated protein-43), a protein associated with learning. Consequently, the cAMP-impaired mutants may be incapable of learning due to an inability to form GAP-43. This project was supported by the Undergraduate Research Fund.

CHARACTERIZATION OF AKINETE GERMINATION AND GERMLING DEVELOPMENT IN THE CYANOBACTERIUM *ANABAENA AZOLLAE*. Bridget D. Wilson, NIH Bridges Program, Science Dept., J. Sargeant Reynolds Community College, Richmond, VA 23285 & Robert W. Fisher, Dept. of Biology, Virginia Commonwealth University, Richmond, VA 23284. The objective of this research project was to monitor the changes that take place during akinete germination and filament proliferation in the nitrogen-fixing cyanobacterium *Anabaena azollae*. We induced akinete differentiation using phosphate free medium and used these akinetes for our studies. We monitored the following characteristics: cell size (with calculated surface area), granule accumulation, cells per filament, chlorophyll *a* (chl *a*) and phycobiliprotein concentrations, and nitrogen-fixation (determined by the acetylene reduction assay). The results indicate that as akinetes germinate and filaments begin to grow, the cells get smaller, the granules disappear, the cells per filament increase, chl *a* and biliproteins increase, and nitrogen-fixation is initiated. Future studies will focus on heterocyst differentiation and DNA changes that take place during akinete germination and subsequent filament growth. The authors thank both JSRCC and VCU for their support of the NIH Bridges Program. This study was funded in part by NIH grant #1E25GM56620-01.

ANALYSIS OF A NOVEL DNA-MEDIATED TRANSPOSABLE ELEMENT IN THE YELLOW FEVER MOSQUITO AND EVIDENCE FOR A DISTINCT GROUP OF TC3-LIKE TRANSPOSONS IN DIVERSE ORGANISMS. Hongguang Shao & Zhijian Tu, Dept. of Biochemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. A novel transposable element, named *Tc3-Aa*, has been discovered in the yellow fever mosquito *Aedes aegypti*. This 1592 bp transposon contains 36 bp terminal inverted repeats and a 987 bp open reading frame (ORF) separated by a 96 bp intron. The ORF codes for a transposase that is highly similar to that of the *Tc3* of *C.elegans*. There are approximately 150 copies of *Tc3-Aa* elements in the genome of *A.aegypti*. Five out of the 8 sequenced *Tc3-Aa* elements were full-length. Sequence comparisons between these elements showed 98.4-98.9% identity at the nucleotide level, suggesting that *Tc3-Aa* is either currently active or was recently active in *A.aegypti*. Therefore *Tc3-Aa* may have the potential to be used as a transformation tool. Database analysis revealed a previously unidentified *Tc3*-like element in *Drosophila melanogaster*, which we named *Tc3-Dm*. Phylogenetic analysis suggests that *Tc3-Aa*, *Tc3-Dm*, and *Tc3* of *C.elegans* formed a divergant yet distinct clade in the *Tc1* superfamily.

ACTIVE FE-CONTAINING SUPEROXIDE DISMUTASE AND ABUNDANT *SODF* MRNA IN *NOSTOC COMMUNE* (CYANOBACTERIA) AFTER YEARS OF DESICCATION. Breann L. Shirkey, Don Paul Kovarcik, Deborah J. Wright, Gabriel Wilmoth, Todd F. Prickett, Richard F. Helm, Eugene M. Gregory & Malcolm Potts, Dept. of Biochemistry & Virginia Tech Center for Genomics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061. Active Fe-superoxide dismutase (SodF) was the third most abundant soluble protein in cells of *Nostoc commune* CHEN/1986 after prolonged (13 years) storage in the desiccated state. Upon rehydration, Fe-containing superoxide dismutase (Fe-SOD) was released and the activity was distributed between rehydrating cells and the extracellular fluid. The 21-kDa Fe-SOD polypeptide was purified, the N-terminus was sequenced, and the data were used to isolate *sodF* from the clonal isolate *N. commune* DRH1. *sodF* mRNA was abundant and stable in cells after long-term desiccation. Upon rehydration of desiccated cells, there was a turnover of *sodF* mRNA within 15 min and then a rise in the mRNA pool to control levels over 24 h. The extensive extracellular polysaccharide of *N. commune* DRH1 generated superoxide radicals upon exposure to UV-A or -B irradiation, and these were scavenged by SOD.

SURVIVABILITY RATES OF THE SOCIAL SPIDER (*ANELOSIMUS EXIMIUS*) IN NORTHERN/COASTAL FRENCH GUIANA, WHEN EXTRACTED IN LIMITED QUANTITIES FROM THEIR NATIVE COLONIES. Christopher D. Fowler, New Century College of George Mason University, Fairfax, VA 22030. Research and experiments conducted in August 1999 examined the survivability rates of the social spider, *Anelosimus eximius*. With some colony sizes that reach the upper-thousands, *A. eximius*, a border-colonizing species, exhibits social tendencies in hunting and capture of their prey and the maintenance of the web colony. This study examined the ability of individual animals to survive when put into habitat in limited quantities. A total of one hundred sixty-two colonies were placed into habitat, split between the edge of the rain forest and three to five meters inside the tree line. These new colonies were populated by a uniform number of animals. Each cup contained one of the following quantities: 15, 10, 5, 2, and 1. It was discovered in our research that those colonies containing smaller amounts of animals perished at a quicker rate than that of their more numerous peer colonies.

GROUP DECISION MAKING IN THE SOCIAL SPIDER *ANELOSIMUS EXIMIUS*. Stacey J. Rathbun & Robert Furey, New Century College of George Mason University, Fairfax, VA 22030. Over a period of 17 days, collective behavior, the conduct whereby individuals will act as a group, was studied using the social spider species *Anelosimus eximius* in edge habitat in French Guiana. Spiders were gathered, counted, and released into controlled vegetation. Plants shaped in the form of a "Y" were used so that the spider's choices were limited to two similar branches. Fifteen of these Y-shaped plants were manipulated to ensure that each side of the vegetation was equivalent to the other. We used 100 spiders from separate colonies for each arrangement and they were split into groups of 70 and 30. Each Y-setup contained 2 cups, one containing 70 spiders and the other 30 spiders. This system was created to observe the collective behavior of the spiders by reducing choice in the experimental setups by giving the spiders only 2 areas for web foundation. It helps us to observe group decision-making. During the course of the field study the spiders did not group in one complete cluster, but stayed on their respective sides instead of locating on one side. The spiders grouped together on the separate sections of the plants. The collective behavior was found to exist within the smaller groups as the spiders shifted to either side of the vegetation. Once the spiders moved up into branches of the Y-setups, they formed small groups underneath the leaves.

COLLECTIVE BEHAVIOR IN THE SOCIAL SPIDER *ANELOSIMUS EXIMIUS*. Ritu Maghera & Rob Furey, New Century College of George Mason University, Fairfax, VA 22030. Collective behavior is one of the most interesting characteristics exhibited by the social organisms. As one of the 16,000 known social spider species, *Anelosimus eximius* habitually form communal web colonies. Our experiment consisted of artificial colonies set up on the edges of the French Guianes rainforest outside Cayenne. Social interaction among *A. eximius* was examined by systematically increasing the population of particular colonies and observing colony reaction. The objective of this experiment was to determine what would happen to the colony once colony population balance was disturbed. In order to observe such changes, data for population, volume, and volume per individual were collected. We augmented populations over the 10 experiment days. There was a steady increase among the experimental groups in spider population, which directly effected the volume, volume per individual, and surface areas.

Biomedical and General Engineering

COMPUTATIONAL ANALYSIS OF HUMAN THERMAL COMFORT IN A VENTILATED ROOM. A.F. Alfahaid, S.K. Chaturvedi & S.N. Tiwari, Department of Mechanical Engineering, Old Dominion University, Norfolk, VA 23529. As the majority of people nowadays spend up to 90% of their time indoors, knowledge and prediction of the indoor climate conditions are an important component influencing our overall level of health and comfort. The present study pertains to the three dimensional numerical study and characterization of thermal environment in a ventilated room. The ultimate aim of this research is to study the effect of the room ventilation on human thermal comfort, which will enable better design for ventilated rooms. Unstructured grid has been used to model the three-dimensional ventilated room. Low-Reynolds-numbers k- ϵ turbulence model is employed in computational fluid dynamic simulations. Two kinds of boundary conditions, namely, constant temperature and constant heat flux, are applied to solve the governing equations for mass, momentum and energy transport. Percentage of dissatisfaction (PD) and effective draft temperature (EDT) are used as human thermal comfort indices to show the thermal comfort in three standard levels (ankle, sitting and standing).

RAPID MEASUREMENT OF *IN VIVO* AORTIC WAVE VELOCITY USING MAGNETIC RESONANCE. V.V. Itskovich¹, K.A. Kraft² & D.Y. Fei¹, ¹Departments of Biomedical Engineering and ²Radiology, Virginia Commonwealth University, Richmond, VA, 23298. In this study, a new, rapid (120 ms acquisition time) method for obtaining the wave velocity (WV) in the human descending aorta using magnetic resonance (MR) was developed and validated in a compliant tube model. The general strategy this technique uses is to reproduce the fluid flow waveform at two separate locations along the compliant vessel. Because of the finite rate of propagation, the waveform arrives at the downstream location slightly later as compared to the upstream location. The known distance between the two measurement sites divided by this latency yields the wave velocity. Ten healthy subjects participated in the study. Age ranged from 22 to 57 years. WV ranged from 3.8 to 9.2 m/s; peak blood velocity (PBV) ranged from 56 to 113 cm/s. WV demonstrated positive correlation with age, while PBV exhibited strong negative correlation with age. Typical reproducibility values for the WV and PBV measurements for a given subject were 13% and 7%, respectively. Accurate WV assessment may be a useful predictor of potential damage in the human circulatory system.

LONG-TERM SURVIVAL OF REGENERATED CARTILAGE IN A NOVEL MODEL. J.S. Wayne, Orthopaedic Research Laboratory, Depts. of Biomedical Engineering and Orthopaedic Surgery, VCU & C.L. McDowell, Richmond VA Medical Center. Damage to articular surfaces in diarthrodial joints is a major cause of disability in our society. No technique has yet successfully regenerated a functional cartilage over a large joint surface. Our repair model regenerated a durable cartilage on a large joint surface by providing initial stress shielding from the harsh mechanical environment of the joint. In the long-term evaluation of the model, 15 canines underwent bilateral surgery in which the patellae were denuded of all articular cartilage, and small high density polyethylene joint spacers were placed on the patellar surfaces to lift them off the patellofemoral groove, thus providing stress-shielding. After cartilage regenerated on the patellae for 12 weeks, the spacers were removed to reintroduce the joint stress environment and stimulate further maturation. At one year, the regenerated cartilage continued to cover 75-100% of the entire patellar surface, the biomechanical properties (stiffness, permeability) indicated a tissue that was maturing, and the biochemical analyses (water, collagen, and proteoglycan contents) indicated the tissue was maintaining its characteristics at the one year time point. Financial support provided by RR&D of the Department of Veterans Affairs, #AR-799C.

AN INEXPENSIVE WEAR TESTING DEVICE FOR THE EVALUATION OF TOTAL JOINT REPLACEMENT MATERIALS. M. Thompson¹ & J.R. Foy², Depts. of ¹Mechanical Engineering and ²Engineering Science & Mechanics, Virginia Tech, Blacksburg, VA 24061. In attempts to predict the *in vivo* performance of orthopaedic biomaterials, numerous wear apparatus and simulators have been developed to assess *in vitro* tribological performance. The most complex and expensive machines are simulators, which test actual prostheses in scenarios with kinematics mimicking the joint of interest. This project is focused on the design of a wear apparatus that is more economical for simulating the performance of materials for total knee replacement (TKR). Specifically, our design incorporates the most significant knee kinematics: flexion/extension (F/E), anterior/posterior (AP) sliding, tibial rotation (TR), and a dynamically-applied joint reaction force synchronized to a physiologically representative F/E motion. F/E, AP sliding, and TR are controlled by programmable motors interfaced to a data acquisition system. Flexibility of the designed apparatus allows for the independent control of each degree of freedom and up to four-station, simultaneous testing. Characterization of wear rates and mechanisms are to be compared with results from the literature to determine the feasibility of using the designed apparatus as a materials screening device for TKR. Financial support provided by the OSER/Carilion Health Initiative.

THE KINEMATICS OF FIELD HOCKEY DRIVING MOTIONS. S.M. Gerke & L.A. Wojcik, Department of Engineering Science & Mechanics, Virginia Tech, Blacksburg, VA 24061. Field hockey is an ancient sport that dates back to the ancient Greek, Roman, and Aztec civilizations. Current North American versions of the sport are primarily played by women at the high school and college levels. Driving motions with a field hockey stick are used to quickly advance a ball down the field, with the left hand providing much of the force in a downward pendulum motion. In an effort to determine optimal body configurations for completion of long drives, both expert (E) and novice (N) players were tested to determine backswing and followthrough heights, swing timing, and stick velocity. Ten young women between the ages of 18 and 30 were tested, with equal distribution between the E and N groups. Each subject completed five standing drives, with infrared-emitting diodes placed over bony landmarks on the body and on the stick for kinematic data collection. Significant experience-related differences were found in the backswing height ($E > N$, $p < 0.01$) and followthrough velocity ($E > N$, $p < 0.01$). Similar trends were observed in followthrough height and downswing velocity, though without statistical significance. Further analysis will include comparisons of stick velocity at ball contact, percentage of body weight shifted to the backswing foot, and learning effects in the novice subjects.

SPARSE ASSEMBLING PROCEDURES FOR STRUCTURAL ACOUSTICS FINITE ELEMENT ANALYSIS. W.R. Watson¹, V.N. Vatsa¹, Y.Hu² & D.T. Nguyen², ¹NASA Langley Research Center, Hampton, VA 23681, ²Department of Civil and Environmental Engineering, Old Dominion University, Norfolk, VA 23529. Different sparse algorithms for assembling of global matrices in finite element procedures are developed, tested and discussed. Structural/Acoustics examples are used to evaluate the performance (using SUN workstations) of various sparse assembling strategies. Preliminary results have indicated that the "sophisticated" sparse algorithm is substantially faster than the "simple" one.

COMPLEX SPARSE LANCZOS EIGEN-SOLVERS FOR ELECTRO-MAGNETICS ENGINEERING SOLUTIONS. C. Bunting¹, T.X. Nguyen², B. Han¹, Y. Hu¹ & D.T. Nguyen¹, ¹Department of Civil and Environmental Engineering, Old Dominion University, Norfolk, VA 23529, ²NASA Langley Research Center, Hampton, VA 23681. Lanczos algorithms for solving medium to large-scale generalized eigenvalue engineering problems are developed, tested and discussed. Heavy computational tasks within Lanczos algorithms are identified. Sparse technologies are exploited to take full advantages of computer memory and computational time for solving medium to large-scale eigenvalue problems occurred in engineering applications. Both real and complex numbers appeared in the generalized eigen-equations can be treated.

HEALTH MONITORING OF A FRP BRIDGE DECK. M. Miceli¹ & J.C. Duke², Depts. of ¹Materials Science and Engineering & ²Engineering Science and Mechanics, Virginia Tech, Blacksburg, VA 24061. Statistics released in the fall 1989 show that 238,357 (41%) of the nation's 577,710 bridges are either structurally deficient or functionally obsolete. New materials, less affected by corrosive environmental conditions than conventional civil engineering materials, are being suggested for use in bridge systems to solve this problem. As engineers look to these new materials to bear the load of this problem, they must incorporate ways to construct *and* inspect the bridge more easily. Composite deck systems (e.g., glass fiber reinforced vinyl ester matrix) are favorable replacements for deteriorating conventional bridge decks due to their durability and decreased weight, which can help avoid load posting of a bridge. This paper discusses the use of Infrared Thermography as a means of detecting delaminations and voids caused by conditions encountered in fabrication and the field. As forced convection hot air is applied to the bridge deck, delaminations in the top of the deck appear cold while problems in the bottom of the deck give rise to areas of hotter concentrations. The discontinuities in thermal propagation patterns are seen by the camera and indicate possible structural deficiencies. Laboratory results revealing fabrication problems and those from *in situ* tests will be presented.

POLYMER MICRO ENGINEERING FOR CHEMICAL SENSING APPLICATION. N.V. Levit & G.C. Tepper, Department of Chemical Engineering, Virginia Commonwealth University, Richmond, VA 23284. Polymers, due to their variety of properties and amenability to chemical modification, are one of the most promising materials for sensor applications. However, the methods employed to produce polymer surfaces are crude in comparison to the microelectronics-driven technology employed to produce miniature transducers. Rapid Expansion of Supercritical Solutions (RESS) is a technique that takes advantage of the enormous solubility change that occurs in a rapidly expanding supercritical solution in order to form precipitates with narrow and tunable size distributions. Silicone polymers are attractive for chemical sensor applications because of their favorable physical and chemical properties. The main disadvantage of raw siloxanes in sensor applications is the loss of surface integrity over time due to inadequate viscosity. Micro and nano particles of siloxane-based polymers were deposited onto the sensing surface of a Surface Acoustic Wave (SAW) transducer using the RESS technique. The mechanical properties of the particles were subsequently improved by crosslinking. The resulting sensor was calibrated and exhibits fast, reversible response to organic vapor.

TEMPERATURE DEPENDENCE OF ZERO-SHEAR VISCOSITY FOR POLYPHENYLENE OXIDE BY SQUEEZE-PLATE RHEOMETRY. M.J. Miraglia & K.E. Van Ness, Department of Physics and Engineering, Washington and Lee University, Lexington, VA 24450. This work is part of an ongoing project to measure the compositional dependence of the zero-shear viscosity at a fixed temperature for miscible polyphenyleneoxide (PPO)/polystyrene (PS) blends. Previous studies of these blends have been unable to measure directly this dependence for compositions of greater than 50 wt% PPO due to the interaction of two factors: (1) the high viscosity of the PPO relative to the PS at any given temperature, and (2) the tendency of the PS component to degrade at temperatures high enough to adequately soften the PPO component. Previous methods of measurement have used the cone-and-plate-geometry. Here we use a parallel plate geometry, the method of which is known as squeeze-plate rheometry, where the polymer melt is squeezed between two parallel plates, and the viscosity is calculated from the known squeezing force and the rate at which the gap between the plates narrows. The zero-shear viscosity for PPO can be measured at temperatures low enough to avoid PS degradation, thereby allowing for the measurement of the compositional dependence of viscosity for these blends. This study was funded in large part by the Thomas F. and Kate Miller Jeffress Memorial Trust.

A TWO-DIMENSIONAL WATER QUALITY TRANSPORT MODEL FOR GRADUALLY VARIED, UNSTEADY FLOW IN OPEN CHANNELS. L.A. Gatling, A.O. Kardash & J. Yoon, Department of Civil and Environmental Engineering, Old Dominion University, Norfolk, VA 23529. A steady-state source sink SWMM/QUAL2E water quality model framework of Pea Hill Arm of Lake Gaston was used to characterize in-lake flow and pollutant transport under conditions of pipeline water intake. To further characterize pollutant transport in the study site, time-variant longitudinal kinematic wave flow was conceptualized using two-dimensional Saint Venant continuity and momentum equations between the differential gradient upper- and lower- segment boundaries that contain the pipeline water intake section. Equations are formulated using an explicit two-dimensional schema based on a two-plane Prissiman box square method to include vertical benthic uplift diffusion as well as advective and dispersive physical transport into the water column. The two-dimensional approach is intended to handle step inputs to continuously model mass flow and pollutant transport, spatiotemporally, by including vertical flow and pollutant transport originating from the channel bed during very low longitudinal flow conditions including the velocity null.

AN INVESTIGATION OF CARRIER LIFETIMES AND DEEP TRAPS IN WIDE BANDGAP COMPOUND SEMICONDUCTORS. R.F. Kessick & G.C. Tepper, Department of Chemical Engineering, Virginia Commonwealth University, Richmond, VA 23284. The electrical and optical performance of wide bandgap compound semiconductors such as mercuric iodide (HgI_2) and cadmium zinc telluride ($CdZnTe$) depends strongly on the lifetimes of the charge carriers. Carrier lifetimes are influenced by various trapping mechanisms, which can take the form of crystal defects and impurities. Trap energies have been studied in these materials using techniques such as thermally stimulated current (TSC) or thermoelectric emission spectroscopy (TEES). However, the effect of specific traps on the carrier lifetimes remains unknown. Here we report on our investigations of the effect of charge traps on carrier lifetimes using a contactless, pulsed laser microwave cavity perturbation technique. The semiconductor microwave absorption coefficient is measured during pulsed laser excitation using a critically coupled resonating cavity. Carrier lifetimes are determined as a function of temperature and transition temperatures are related to trap energies.

OBJECT-ORIENTED DATABASES, TOWARDS AN INTEGRATED ENGINEERING-COMPUTATION ENVIRONMENT. H.M. AbdelSalam & H.P. Bao, Department of Mechanical Engineering, Old Dominion University, Norfolk, VA 23529. The rapid developments in information technology and information systems are changing the methods and media by which people communicate and interact. How these emerging new technologies affect the engineering work is still a question. Usually in the development process of a new product/process, several teams of engineers with different backgrounds/responsibilities are involved. Engineers need a tool(s) to share technical and managerial information and to be able to instantly access the latest changes made by one member, or more, in the teams to determine right away the impacts of these changes in all disciplines (cost, time, resources, etc.). In other words, engineers need to participate in a truly collaborative environment for the achievement of a common objective, which is the completion of the design project in a timely, cost effective, and optimal manner. In this paper, a new framework that integrates the capabilities of two commercial software, MS Excel™ and MS Project™ with a state-of-the-art object-oriented database (knowledge-base) called InnerCircle2000™ is being presented and applied to handle the Time-Cost Trade-Off problem in project networks.

AN EMPIRICAL EVALUATION OF COMPUTER-MEDIATED COMMUNICATION TECHNOLOGIES TO SUPPORT TUTORING. P.E. Smith, B.M. Kleiner & B.A. Watford, Dept. of Industrial and Systems Engineering, Virginia Tech, Blacksburg, VA 24061. With the rapid introduction and integration of technology into everyday living, new opportunities arise to facilitate student support within higher education. Tutoring is one example of a process that may be improved. The purpose of this research was to investigate computer-mediated communication technologies used during tutoring to determine if these technologies can improve tutoring assistance and to research several different communication platforms that may be amenable to tutoring assistance. The communication conditions consisted of collocated communication, email, a chatroom, and video teleconferencing. The research design was a $2 \times 4 \times 4$ within subject's factorial design and sixty-four laboratory trials were conducted. Data related to problem solving accuracy, speed, and user satisfaction were collected to determine communication media effectiveness. In general, problem-solving accuracy was similar in all experimental conditions, while communication media affected problem-solving speed and user satisfaction. These results suggest computer-mediated tutoring was as effective as collocated tutoring based on accuracy, while collocated and chatroom tutoring were similar based on speed and user satisfaction.

INITIAL EXPERIENCE WITH PARALLEL ENGINEERING COMPUTATION UNDER MPI/FORTRAN AND LINUX PCS COMPUTER. S. Hans¹, S.Y. Bawab¹, A. Demuren¹ & D.T. Nguyen², Departments of ¹MEM and ²Civil and Environmental Engineering, Old Dominion University, Norfolk, VA 23529. Clusters of PC desktops and/or laptops are connected for general (educational & research) parallel computation, using freely available parallel MPI/FORTRAN and LINUX operating systems. Small scale, simple examples are used to explain and demonstrate the details of the step-by-step procedures.

DECOMPOSITION PROCEDURES FOR LINEAR PROGRAMMING PROBLEMS: SEQUENTIAL COMPUTER ENVIRONMENTS. Y. Hu, K. Gould, & D.T. Nguyen, Department of Civil and Environmental Engineering, Old Dominion University, Norfolk, VA 23529. Dantzig's decomposition procedures are re-examined from the viewpoint of exploiting sparse and parallel technologies. The general idea of breaking up a large-scale problem into series of small-scale problems is first briefly reviewed. Then, computational tasks which can be parallelized and enhanced by sparse algorithms are identified and discussed. Simple numerical examples are used to explain how to prepare the input data for the developed computer codes.

Botany

ICE DAMAGE TO TREES ON THE VIRGINIA TECH CAMPUS. R. W. Rhoades and R. J. Stipes, Dept. of Plant Pathology, Physiology, and Weed Science, Virginia Tech, Blacksburg, VA 24061. A survey of 200 trees representing 9 spp. was made in 1995 after 3 ice storms in 1994 each deposited 2.5 cm or more of ice on trees. Amount of ice damage was expressed as % crown damage. Overall crown damage was 8.6%, but 22.8% of individuals and 22.1% of basal areas were damaged. Most severely damaged, rated by % crown damage, were black maple (*Acer nigrum*)=16.0, American elm (*Ulmus americana*)=15.4, sycamore (*Platanus occidentalis*)=15, sugar maple (*Acer saccharum*)=12.8, Alaska white cedar (*Chamaecyparis pisifera*)=11.7, and white oak (*Quercus alba*)=10.0. Lightly damaged were flowering dogwood (*Cornus florida*)=3.8 and northern red oak (*Quercus rubra*)=1.0. Pin oak (*Quercus palustris*) was undamaged. Severe damage resulted in removal of 19 trees, including 5 American elms that had died of Dutch elm disease. A one-way analysis of variance showed that differences among species were not significant. Apparently the severe ice storm on February 13, 1994 did indiscriminate damage, thereby erasing differences among species.

POST-DISTURBANCE CHANGES IN THE UNDERSTORY OF AN OAK FOREST IN SOUTHWEST VIRGINIA. R. W. Rhoades, Department of Plant Pathology, Physiology, and Weed Science, Virginia Tech, Blacksburg, VA 24061. An Appalachian oak forest, previously dominated by scarlet and chestnut oaks, was sampled in 1994, and was re-sampled in 1999 to determine changes in composition of understory vegetation and height growth of established seedlings and saplings after disturbance by single tree gaps, primarily scarlet oak, and general canopy ice damage. Changes in overstory tree density and basal area were not significant, indicating that the stand is in a steady state phase of development. Post-disturbance increases in densities of shrubs, saplings, and red maple seedlings, plus decline in density of flowering dogwood seedlings were significant. Increase in height growth of white pine was also significant. By inference, the stand should be dominated in about 20 years by overstory trees of chestnut oak, red maple and white pine. Natural thinning of white pine saplings may negate the prediction that this species will become codominant.

EFFECTS OF SPATIAL NUTRIENT HETEROGENEITY ON COMPETITIVE OUTCOMES IN FOUR EARLY SUCCESSIONAL PLANT SPECIES. K. M. Bliss¹, R. H. Jones¹, P. P. Mou², & R. J. Mitchell³, ¹Dept of Biology, VPI & SU, Blacksburg, VA 24060, ²Dept of Forestry, VPI & SU, Blacksburg, VA 24060, Jones Ecological Research Center³, Newton, GA 31770. We hypothesize that small scale spatial heterogeneity of soil nutrients can impact competitive outcomes and succession. We established monocultures and mixtures of 2 and 4 plant species in garden plots with homogeneous or heterogeneous spatial patterns of soil nutrients. Monocultures showed that three species exhibit foraging precision: *Erechtites hieracifolia* (Eh), *Pinus taeda* (Pt), and *Liquidambar styraciflua* (Ls) ($p < .01$). After one growing season, heterogeneity enhanced aboveground biomass of Eh ($p < .01$) and reduced growth of *Solidago altissima* (Sa) ($p < .001$) in 2 species plots. Ls (grown with Pt) had larger biomass in the heterogeneous treatment (p, ns). So, heterogeneity of resources may confer an aboveground competitive advantage for precise foragers. In the four species plots, heterogeneity of nutrients enhanced performance of three species (Eh, Ls, and Pt) and hampered growth of one species (Sa), further indicating that nutrient heterogeneity may have significant effects on interspecific competitive outcomes in larger plant communities.

A COMPARISON OF NUTRIENT AVAILABILITY AND PHYTOPLANKTON GROWTH IN TWO PONDS LOCATED WITHIN COMMERCIAL DEVELOPMENTS. Stephen W. Fuller, Kelly A. Donovan, & Lori M. Walsh, Dept. of Biol., Mary Washington College, Fredericksburg, Va. 22401. Water samples were collected from two ponds located in different commercial complexes in Fredericksburg, Va. Approximately biweekly collections from early February to later April were examined for phytoplankton and tested for the nutrients silicon, nitrate and orthophosphate. The ponds were similar in nutrient content, radiation input, and temperature; however there were consistently more waterfowl present in the smaller pond. In contrast to what was expected, the smaller, younger pond had a larger phytoplankton population, and greater diversity of species. Also unexpected, and differing from the PEG model, was the paucity of diatom species and numbers in both locations. A spring outburst occurred, but was produced by an increase in the number of species in Division Chlorophyta.

RELATIONSHIPS OF CHONOCENTRUM (EUPHORBIACEAE). W. John Hayden & Sheila M. Hayden, Dept. of Biology, Univ. of Richmond, Richmond, VA, 23173. *Chonocentrum* is a poorly understood euphorbiaceous tree known only from the type collection gathered in 1854 from an island in the Rio Negro, Brazil, near its confluence with Rio Marauia. Initially, *Chonocentrum* was confused with *Discocarpus*, it was later named as a species of *Drypetes*, then named as a distinct genus, but is still assumed to be related to *Discocarpus*. The minute staminate flowers of *Chonocentrum* possess a single whorl of fused sepals, an extrastaminal disk, separate stamens, and a prominent pistillode bearing a distinctive funneliform stigmatic region; further the staminate flowers produce distinctly prolate grains, according to Punt. Features of staminate flowers, therefore, argue against classification near *Discocarpus* in tribe Wielandieae. The prolate pollen suggests placement in tribe Antidesmeae, a classification confirmed by cladistic analyses of the available morphological characters. In most analyses *Chonocentrum* occupies a sister-taxon relationship to subtribe Antidesminae, a group defined by a series of distinctive anther features not found in *Chonocentrum*.

STUDENT PROJECTS IN PLANT ANATOMY: A THEMATIC APPROACH WITH A FOCUS ON CASSAVA. W. John Hayden, Biol. Dept, Univ. of Richmond, Richmond, VA, 23173. The use of thematic projects focusing on a single plant, cassava (*Manihot esculenta*), in an undergraduate course in plant anatomy is described. Projects included: 1) library research on the biology and utility of cassava and production of stem cross sections via simple microtomy, to introduce students to the plant and to review fundamentals of plant morphology and anatomy; 2) maceration of xylem for comparison with a conifer, emphasizing differences in cell composition of water conducting tissue, differences in tracheids and vessel element lengths, and evidence for apical intrusive growth in dicot fibers; 3) leaf clearings for leaf architectural analysis; and 4) a combined LM and SEM study of foliar epidermis. Student-generated images were digitized and posted on a web page for use in lab reports. Both epidermal layers of *Manihot* are uniseriate, bear scattered druse idioblasts and unicellular hairs; intercostal regions of the abaxial surface are further characterized by brachyparacytic stomata and protruding cells that are organized into reticular patterns that surround one or two stomatal complexes. Melding of traditional content with hands-on projects and web distribution of anatomical images appears to be a successful format to teach plant anatomy emphasizing how research in plant structure is performed.

COEVOLUTIONARY IMPLICATIONS OF INTROGRESSION BETWEEN *RHODODENDRON ATLANTICUM* (ASHE) REHDER AND *R. PERICLYMENOIDES* (MICHAUX) SHINNERS. Bruce L. King, Dept. of Biol., Randolph-Macon College, Ashland, Va. 23005. Natural hybridization between *Rhododendron atlanticum* and *R. periclymenoides* was documented using a mixture of morphological and micromolecular characters. Herbivory by *Pyrrhalta rufosanguinea*, a leaf beetle monophagous for *R. periclymenoides*, was estimated by cafeteria style host-choice experiments. Statistical analyses indicated bidirectional introgression in the hybrid population. The results of feeding experiments suggested that a combination of stimulants and inhibitors affect feeding responses by the beetles. Some leaf variables may be more important for discrimination between *Rhododendron* species and discrimination among hybrids, while others may be more important for selection of the most palatable plants in populations of *R. periclymenoides*. Two hypotheses regarding the evolutionary significance of introgression are proposed: 1) introgression from *R. atlanticum* to *R. periclymenoides* may result in greater resistance of *R. periclymenoides* to the leaf beetle; 2) gene flow from *R. periclymenoides* to *R. atlanticum* may allow *P. rufosanguinea* to become adapted to *R. atlanticum*.

A DENDROECOLOGICAL STUDY OF THREE RED SPRUCE (*PICEA RUBENS*) POPULATIONS. David M. Lawrence¹, Harold S. Adams² & Steven L. Stephenson³. ¹Virginia Department of Environmental Quality, 629 E. Main Street, Richmond, VA 23219. ²Division of Arts and Science, Dabney S. Lancaster Community College, Clifton Forge, VA 24422 and ³Dept. of Biology, Fairmont State College, Fairmont, WV 26554. A dendroecological investigation was undertaken of three red spruce (*Picea rubens*) populations in the vicinity of Mountain Lake, Virginia. Tree-ring chronologies were developed from samples collected at War Spur, Mann's Bog and Little Spruce Bog. The War Spur population was the oldest, with trees dating to the 1730s, followed by Mann's Bog (1760s) and Little Spruce Bog (1860s). Response-function analyses revealed that growth in all three populations was limited by high temperatures in the previous growing season. War Spur growth was negatively correlated with temperature in the previous August and positively correlated with prior July and current March precipitation. Growth at Mann's Bog was negatively correlated with temperatures in the prior October and current August as well as with current February precipitation. Tree growth at Little Spruce Bog was negatively correlated with prior June and September temperature and positively correlated with temperature in the current April.

GEOGRAPHY OF MONTANE FORESTS IN VIRGINIA. David M. Lawrence¹, Steven L. Stephenson², Harold S. Adams³ & Stewart Ware⁴. ¹Virginia Department of Environmental Quality, 629 E. Main Street, Richmond, VA 23219, ²Department of Biology, Fairmont State College, Fairmont, WV 26554, ³Division of Arts and Sciences, Dabney S. Lancaster Community College, Clifton Forge, VA 24422 and ⁴Department of Biology, College of William and Mary, Williamsburg, VA 23187. Geographic patterns in forest community composition in the mountains of Virginia were evaluated using overstory data from more than 350 stands sampled by the authors and others during the past 30 years. Three major groups of forest communities are revealed: spruce-fir; mixed mesophytic, and oak-pine. Both indirect and direct gradient analyses supported identification of these groups by segregation of forest types within each group in more or less distinct regions of ordination space. Gradients in community composition were compared to gradients in regional factors (latitude, longitude), local factors (elevation, aspect, slope steepness, slope position, and site moisture), and temporal factors (stand basal area and density, as these two parameters reflect successional status). Both correlation and direct gradient analyses revealed that elevation, basal area, longitude, latitude and density had the strongest relationships with gradients in overstory composition.

DEFINING SPECIES, OR THE RANGE OF ECOLOGICALLY INDUCED VARIABILITY IN PHYTOPLANKTON MORPHOLOGY. Harold G. Marshall¹ and Lubomira Burchardt², ¹Dept. Biol. Sci., Old Dominion Univ., Norfolk, Va.; ²Dept. Hydrobiology, Adam Mickiewicz Univ., Poznan, Poland. Many phytoplankton species have considerable variation in morphological traits used in their identification. These differences may be initiated by environmental cues that result in an altered appearance of one or more of these taxonomic features and can result in confusion regarding species identification. Little attention is generally given to other life stages of species (e.g. dinoflagellates) that may also be used in their identification, or conditions that would modify the morphology of these stages (e.g. salinity, temperature, nutrients, pH, etc.). These environmentally induced morphological variations may also become more widely characteristic of a species, requiring a re-evaluation of that species characteristics and status. The phytoplankton analyst must be aware of the range of variations normally occurring within this community, and be familiar with seasonal morphological changes, or life cycle stages associated with members of the phytoplankton to more accurately identify many of these species. Gene sequencing will be necessary to more accurately describe the morphological variations exhibited by many phytoplankton species, and in the revision of other presently accepted taxa.

COMMERCIAL SHOPPING AREA POND WITH A RESIDENTIAL AREA POND. Heather McEachen, Lara M. Isdell, & Stephen W. Fuller, Dept. of Biol., Mary Washington College, Fredericksburg, Va. 22401. Phytoplankton succession was observed over a nine-week period in ponds from two different environs, one residential, and the other commercial. Nutrient analysis was performed on water samples for nitrate, orthophosphate, and silicon. Samples of phytoplankton were identified, preserved, and then counted on Sedgwick-Rafter cells (Woelkerling, 1976). Species from Divisions Chlorophyta and Chrysophyta were found in each pond. The commercial pond was found to have larger phytoplankton populations than the residential pond, which correlates with the presence of waterfowl there and their absence in the residential area. No difference in nutrient content in the two ponds was identified.

PHYTOPLANKTON COMMUNITY STRUCTURE IN LAKE PRINCE, SUFFOLK, VA. A PRELIMINARY REPORT. Cara M. Muscio, Old Dominion University Department of Biology. Lake Prince is a reservoir lake that provides the region with drinking water, recreational boating, and fishing. The Virginia Department of Game and Inland Fisheries has an interest in the quantity and quality of phytoplankton production in the lake, especially regarding the health of fish populations. Another concern in this reservoir is oxygen availability, and aerators have been installed in the main body of the lake. A year long examination of the phytoplankton community structure is being conducted. Duplicate surface water samples are collected monthly from three stations, along with physical and chemical baseline data. Community structure and dominance are being examined with regard to the physical and chemical parameters, as well as seasonal climate changes. Spring populations were dominated by Cryptophytes, which gave rise to high concentrations of Cyanobacteria through the summer months. Diatoms and Chlorophytes are secondary components of the phytoplankton community.

COMPARISON OF FIELD COLLECTION TECHNIQUES FOR IN VITRO CULTURES. Michael H. Renfroe & Julie F. O'Hara, Department of Biology, James Madison University, Harrisonburg, VA 22807. Germplasm conservation efforts may be augmented by plant tissue culture. Establishment of axenic cultures from field-collected materials depends upon elimination of the bacterial and fungal population on the explant surface, and maintaining the health of the explant prior to placement on a culture medium. Explants were collected from woody and herbaceous species, treated for microbial reduction and planted or stored for three days to simulate shipping prior to planting on culture medium. Best results for woody plant species (*Betula pendula*, *Corylus avellana*) were obtained by treating with ethanol, storing in an anti-microbial solution, and treating with hypochlorite prior to planting. Best results for the herbaceous species (*Portulaca oleracea*) were obtained with direct transport and sterilization in the laboratory. Direct planting in the field produced most contamination, even with anti-microbial agents in the medium. For field collection and delayed planting, a treatment in the field and laboratory with anti-microbial agents in the medium was most beneficial.

ICE DAMAGE TO TREES ON THE VIRGINIA TECH CAMPUS. R. W. Rhoades and R. J. Stipes, Dept. of Plant Pathology, Physiology, and Weed Science, Virginia Tech, Blacksburg, VA 24061. A survey of 200 trees representing 9 spp. was made in 1995 after 3 ice storms in 1994 each deposited 2.5 cm or more of ice on trees. Amount of ice damage was expressed as % crown damage. Overall crown damage was 8.6%, but 22.8% of individuals and 22.1% of basal areas were damaged. Most severely damaged, rated by % crown damage, were black maple (*Acer nigrum*)=16.0, American elm (*Ulmus americana*)=15.4, sycamore (*Platanus occidentalis*)=15, sugar maple (*Acer saccharum*)=12.8, Alaska white cedar (*Chamaecyparis pisifera*)=11.7, and white oak (*Quercus alba*)=10.0. Lightly damaged were flowering dogwood (*Cornus florida*)=3.8 and northern red oak (*Quercus rubra*)=1.0. Pin oak (*Quercus palustris*) was undamaged. Severe damage resulted in removal of 19 trees, including 5 American elms that had died of Dutch elm disease. A one-way analysis of variance showed that differences among species were not significant. Apparently the severe ice storm on February 13, 1994 did indiscriminate damage, thereby erasing differences among species.

POST-DISTURBANCE CHANGES IN THE UNDERSTORY OF AN OAK FOREST IN SOUTHWEST VIRGINIA. R. W. Rhoades, Department of Plant Pathology, Physiology, and Weed Science, Virginia Tech, Blacksburg, VA 24061. An Appalachian oak forest, previously dominated by scarlet and chestnut oaks, was sampled in 1994, and was re-sampled in 1999 to determine changes in composition of understory vegetation and height growth of established seedlings and saplings after disturbance by single tree gaps, primarily scarlet oak, and general canopy ice damage. Changes in overstory tree density and basal area were not significant, indicating that the stand is in a steady state phase of development. Post-disturbance increases in densities of shrubs, saplings, and red maple seedlings, plus decline in density of flowering dogwood seedlings were significant. Increase in height growth of white pine was also significant. By inference, the stand should be dominated in about 20 years by overstory trees of chestnut oak, red maple and white pine. Natural thinning of white pine saplings may negate the prediction that this species will become codominant.

DROUGHT TOLERANCE OF CO-OCCURRING SPECIES OF OZARK ROCK OUTCROP *SEDUM*. Heather Sahji & Stewart Ware. Dept. of Bio, Col. of William and Mary, Williamsburg, VA 23186. In rock outcrop ecosystems soil depth increases with increased distance from the exposed rock surface. On sandstone glades, two small winter annual *Sedum* species co-exist. *Sedum muttallianum* dominates closest to exposed rock, with *S. pulchellum* dominating with increased soil depth. Since soil depth directly affects moisture, we hypothesized that *S. muttallianum* is more drought tolerant than *S. pulchellum*. Plants in pots with equal amounts of soil were watered every 2 days (wet), every 10 days (intermediate), and every 3 weeks (dry). A second method was used in which pots contained soil depths of either 3, 2, or 1cm, and all pots were watered once a week. In both species there were significant differences between biomass in wet and dry, and between intermediate and dry treatments. In the second method, *S. muttallianum* was significantly larger in all treatments and had a greater percentage of maximum biomass under intermediate and dry conditions than *S. pulchellum*. In all trials, *S. muttallianum* exhibited a greater percentage of maximum flowering capability under intermediate and dry conditions than *S. pulchellum*, indicating *S. muttallianum*'s superior ability to sustain populations in drought conditions.

ROOTING LONGLEAF PINE, *PINUS PALUSTRIS* MILLER, FROM NEEDLE FASCICLES. Phil Sheridan^{1&2}, Kneeland Nesius², & Leslie Everett², ¹Meadowview Biological Research Station and ²Department of Biological Sciences, Old Dominion University. Longleaf pine is a rare plant in Virginia with only 4432 trees remaining in the wild in the state. Cone crops can be erratic and seed yields per cone are less than the average reported for southern provenance. We were interested in determining the feasibility of regenerating rare Virginia longleaf pine from needle fascicles. If we can successfully regenerate native longleaf pine trees from needle fascicles than we can compensate for erratic seed production and, more importantly, capture the entire longleaf pine genome in Virginia for conservation purposes. Our initial efforts have focused on replicating other workers results with grass stage seedlings. Up to 65% of fascicles from a seedling can produce roots when placed in a 2 cm deep solution of 100 ppm IBA for 24 hours followed by maintenance in a solution of 60 ppm H3BO3, 40 ppm NH4NO3, and 20 ppm thiamine-HCl.

PHYLOGENETIC ANALYSIS OF *ILIAMNA* (MALVACEAE) USING THE INTERNAL TRANSCRIBED SPACER REGION. T. A. Bodo Slotta, D. M. Porter & B. S. J. Winkel, Dept. of Biol., VA Tech., Blacksburg, VA 24061. The eight species of *Iliamna* have a taxonomically complex history. Since its conception in 1906, the genus was not recognized for some time, several species have been placed into other genera, and the status of a few species has been questioned. The need for systematic study became apparent since all but one species is considered rare or endangered and the differentiation between two species, *I. corei* and *I. remota*, was unclear using RAPDs. The focus of this study was to develop a phylogeny for *Iliamna* using sequences from the internal transcribed spacer in hopes of determining evolutionary history of the genus. In this molecular analysis, *Iliamna* forms a well-supported clade distinct from related genera and is monophyletic. Three well-supported groups are formed. One contains representatives from the Pacific Northwest and forms the base of the genus. Another contains all of the remaining species with the third clade nested therein. The last clade contains the two eastern species, *I. corei* and *I. remota*. However, little resolution was brought about for *I. crandallii*, *I. grandiflora*, *I. longisejala*, and *I. rivularis*. The ITS phylogeny brings new insight to the origination of and to the distribution of the genus.

PHYTOPLANKTON STATUS AND TRENDS IN THE LOWER CHESAPEAKE BAY. T. Stem, H. Marshall, M. Kokolis, C. Muscio, & B. Brown. Dept. Biological Sciences, Old Dominion University, Norfolk VA, 23529-0266. An update and review of findings from the Chesapeake Bay Phytoplankton Monitoring Program, from 1985 through 1998 is presented in addition to relative water quality. The overall status of the phytoplankton community is good for the Bay, being dominated by favorable populations (diatoms) that are active food and oxygen producers throughout the year. However, there are troublesome trends developing for increased populations of several less favorable cyanobacteria and dinoflagellates at scattered locations within the system. These trends are associated with degrading water quality conditions that include increased levels of total suspended solids and high nutrient levels. A trend of decreasing salinity in the Bay was accompanied by areas with increased concentrations of chlorophytes, cyanobacteria, and dinoflagellates. It is not certain if many of these trends represent short term responses to cyclic environmental events, or are of long term significance, that if continued, may lead to shifts in population composition. Potential toxin producing species are also being monitored with none of these associated with a toxic event in Virginia waters to date. Supported by the Virginia Dept. of Environmental Quality and EPA.

AN ECOLOGICAL STUDY OF THE SWEET BRIAR COLLEGE OLD-GROWTH WHITE OAK FOREST. Steven L. Stephenson¹, Harold S. Adams² & David M. Lawrence³. ¹Dept. of Biology, Fairmont State College, Fairmont, WV 26554, ²Division of Arts and Science, Dabney S. Lancaster Community College, Clifton Forge, VA 24422 and ³Virginia Department of Environmental Quality, 629 E. Main Street, Richmond, VA 23219. Quantitative data on the composition and structure of all strata of vegetation were collected from an old-growth white oak (*Quercus alba*) forest on the campus of Sweet Briar College in Amherst County, Virginia. In addition, increment growth cores were extracted from representative larger white oak trees for age determination. White oak, with an importance value (IV) of 32.8, was clearly the dominant species present in the tree stratum (stems >10 cm DBH), with tulip-tree (*Liriodendron tulipifera*), sourwood (*Oxydendrum arboreum*), and beech (*Fagus grandifolia*) the most important associates. White oak was conspicuously absent from the small tree (stems <10 but >2.5 cm DBH) and sapling (stems <2.5 cm DBH but >1.0 m tall) strata but had a higher importance value than any other species in the seedling stratum. The oldest cored trees dated back to the 1770s.

THE RELATIONSHIP BETWEEN ABOVE- AND BELOWGROUND STRUCTURE IN LONGLEAF PINE (*PINUS PALUSTRIS*) FORESTS. Glen N. Stevens¹, Robert H. Jones¹, & Robert J. Mitchell², ¹Department of Biology, VPI&SU, Blacksburg, VA, 24061 and ²Joseph W. Jones Ecological Research Center, Newton, GA, 31770. Understanding the relationship between above- and belowground structure is critical in longleaf pine (*Pinus palustris*) forests, where small canopy gaps play a major role in forest regeneration. We assessed fine root production across a range of overstory densities in a longleaf pine stand in Southwest Georgia. Stands were harvested to a constant basal area using three spatial arrangements: single-tree selection, small-group (~0.1ha) selection, and large-group (~0.2ha) selection. Tree basal area within a 20m radius of each sample plot was positively correlated with pine root density ($p < 0.0001$) and negatively correlated with non-pine root density ($p < 0.05$). While harvest had no significant effect on treatment-level pine root mass, there was an increase in the number of ingrowth cores with zero pine root mass as gap size increased. In addition, there was a significant change in the depth distribution of fine roots between control and large-gap harvested plots (Kolmogorov-Smirnov test, $p < 0.01$). Overall, belowground gaps in these systems occurred at much finer temporal and spatial scales than aboveground gaps.

VASCULAR FLORA OF THE WATERSHED OF WILLCOX BRANCH OF LIEUTENANT RUN, INCLUDING LEE PARK, PETERSBURG, VIRGINIA. PART I. Donna M. E. Ware, Dept. of Biol., Col. of William and Mary, Williamsburg, VA 23187-8795. A late 1930s W.P.A. project created a 10 ac. Wildflower Sanctuary in Lee Park (> 300 ac.) and the "Lee Park Herbarium". This W.P.A. program was administered by women for the purpose of aiding women heads-of-household in Petersburg during the Great Depression and addressing conservation concerns of the era. The herbarium collection consists of 325 pressed specimens (295 spp.) collected in or near this watershed by African-American women workers and identified by Donald Holden, the project supervisor, plus 238 botanical watercolors by Bessie Marshall. It includes 15 spp. now listed as rare in Virginia. My ongoing study has resulted in: 1.) annotation of Mrs. Holden's identifications of the species; 2.) updated scientific names; 3.) determination that ca. 70% of the species in the herbarium collection are present in the study area today, including 16 records for Dinwiddie Co.; 4.) determination that relatively few of the transplanted species have persisted in the Wildflower Sanctuary and that the 15 rare species are no longer present in the watershed; and 5.) collection of voucher specimens of ca. 600 spp. from the watershed. Phytogeographic analysis of the current local flora will be presented in Part II.

INTRODUCING SOUTHERN RED CEDAR (*JUNIPERUS VIRGINIANA* var. *SILICICOLA*) TO VIRGINIA BOTANISTS: ECOLOGICAL CONSIDERATIONS. Robert A. S. Wright, Parsons Transportation Group, Inc., Fairfax, Va. 22030. Recent floristic inventories in coastal fastlands have demonstrated the need to further investigate the apparently unreported occurrence of southern red cedar in seasonally-tidal forested wetlands on the outer Coastal Plain of Virginia. According to nearly all consulted literature sources, this taxon supposedly ranges only as far north along the Atlantic Coastal Plain province to Tyrell and Dare Counties, North Carolina. However, cedar trees occurring in small, nearly pure stands that better fit the ecological and morphological description of *Juniperus silicicola*, the southern coastal form of the more widespread eastern red cedar (*Juniperus virginiana*), have been documented at elevations below 10 feet MSL in numerous localities. Data will be presented to include the very localized southern red cedar as a component of the Virginia flora. Additionally, identification keys, taxonomy, life history, and ecological considerations are summarized and handout materials provided. Mounted herbarium and fresh specimens will be available for inspection.

Chemistry

THE SEARCH FOR PHYTOESTROGENS IN PEANUTS. Wendi Bousfield, Department of Chemistry, Hollins University, Roanoke, VA 24020 and Roy L. Williams, Department of Chemistry/Biochemistry, Old Dominion University, Norfolk, VA 23529. Phytoestrogens, estrogenic compounds found in plants, have become the focus of extensive research in recent years. This laboratory has been investigating the presence of such compounds in a variety of plant materials including soy, grape seeds and wine. This study has now been extended to include peanuts. Peanuts were analyzed for the presence of several isoflavonoid phytoestrogens including daidzein and genistein together with the unique stilbene phytoestrogen known as trans-resveratrol (TR). Although TR has been detected in peanuts earlier the isoflavonoid phytoestrogens have only been described in unpublished references. A method has been developed to detect both of these types of phytoestrogens using high-pressure liquid chromatography (HPLC). The results of this study have shown that raw peanuts contain a significant amount of genistein and TR. Peanut hulls showed some of the highest content of TR and genistein. Roasting the peanuts appears to destroy much of the phytoestrogens.

REDUCTION PRODUCTS OF PHYTOESTROGENS. Susan Foster Riggleman, Gabriel Rivera, Angela Rivera and Roy L. Williams. Department of Chemistry/Biochemistry, Old Dominion University, Norfolk, VA 23529. Phytoestrogens have recently attracted a great deal of attention due to their wide variety of reported biological activities and their potential as nutraceuticals. Isoflavonoid phytoestrogens such as daidzein and genistein are found in a wide variety of plant materials and undergo rapid metabolism *in vivo*. One of the major metabolic pathways is reduction of the isoflavonoid ring. This paper will describe the synthesis of 2,3- dihydrogenistein via catalytic transfer hydrogenation (CTH). The method of synthesis, a possible reaction mechanism and the spectral identification of this dihydro product will be described. This dihydrogenistein was further characterized by evaluating its potential to effect calcium influx in thrombin stimulated human platelets. While genistein has been shown to be effective and inhibits calcium entry in this model the dihydrogenistein was found to be considerably less active. The inhibition of calcium entry into human platelets has a direct impact on the development of cardiovascular disease and compounds that can be capable of calcium inhibition would be of interest pharmacologically.

REDUCTION PRODUCTS OF PHYTOESTROGENS. Susan Foster Riggleman, Gabriel Rivera, Angela Rivera, & Roy L. Williams. Department of Chemistry/Biochemistry, Old Dominion University, Norfolk, VA 23528. Phytoestrogens have recently attracted a great deal of attention due to their wide variety of reported biological activities and their potential as nutraceuticals. Isoflavonoid phytoestrogens such as daidzein and genistein are found in a host of different plant materials and undergo rapid metabolism *in vivo*. One of the major metabolic pathways is reduction of the isoflavonoid ring. This paper will describe the synthesis of 2,3-dihydrogenistein via catalytic transfer hydrogenation (CTH). The method of synthesis, a possible reaction mechanism and the spectral identification of this dihydro product will be described. This dihydrogenistein was further characterized by evaluating its potential to effect calcium influx in thrombin stimulated human platelets. While genistein has been shown to be effective and inhibits calcium entry in this model the newly synthesized dihydrogenistein was found to considerably less active. The inhibition of calcium entry into human platelets has a direct impact on the development of cardiovascular disease and compounds that are capable of calcium inhibition would be of interest pharmacologically. Structure activity studies of such compounds would help determine the mode of action of such drugs.

LUMINESCENCE OF LANTHANIDE(III) MACROCYCLIC COMPLEXES IN AQUEOUS SYSTEMS. S.A. Williams¹, R.C. Leif², J.R. Quagliano³, and L.M. Vallarino¹, ¹Department of Chemistry, Virginia Commonwealth University, Richmond, VA 23284, ²Newport Instruments, San Diego, CA, and ³Los Alamos Research Laboratory, Los Alamos, NM. Luminescent macrocyclic complexes of europium(III) and samarium(III), which are water-compatible, can be covalently attached to target substrates, and have narrow emissions with long excited-state lifetimes, are finding use as bio-markers for both cytology and immunology. The emission intensity of these complexes can be greatly enhanced by the addition of non-luminescent energy-transfer agents, such as the gadolinium(III) and yttrium(III) ions, in a buffered micellar system containing a combination of synergistic ligands. Under these conditions, the Eu(III) ${}^5D_0 \rightarrow {}^7F_2$ emission of the Eu(III)-macrocyclic complex was observed as a very sharp band with maximum at 619 nm and a characteristic fine-structure pattern. The Sm(III) emissions of the Sm(III)-macrocyclic complex appeared at 599 nm (${}^4G_{5/2} \rightarrow {}^6H_{7/2}$) and 644, 652 nm (${}^4G_{5/2} \rightarrow {}^6H_{9/2}$) as sharp bands, easily distinguished from the Eu(III) emission. This method allows simultaneous determination of the two complexes in the same solution and at the same excitation wavelength (370 nm), with detection limits of 10^{-9} M for the Eu(III)-macrocyclic complex and 10^{-7} M for the Sm(III)-macrocyclic complex.

COMPUTER SIMULATED IR SPECTRA OF GADOLINIUM COMPLEXES USING GAMESS. Kathryne Esperdy & Donald D. Shillady, Ph.D., Department of Chemistry, Virginia Commonwealth University, Richmond, Virginia 23284. The geometry optimization and vibrational analysis of some well studied gadolinium complexes were performed in order to assess whether GAMESS could accurately model the site geometry and coordination number of gadolinium(III) in polyimide hosts. Computer simulated infrared spectra of anhydrous gadolinium formate, anhydrous gadolinium acetate, and Gd(III) complexed amic-acid sites in polyimides were generated from the Hessian output of the ROHF method in GAMESS. The profile and band frequencies of these calculated spectra were compared with experimental data of the compounds from 4000 to 50 cm^{-1} . The low frequency bands for the Gd-O stretching mode and the O-C-O ring distortion show excellent agreement in all compounds proving that GAMESS can accurately predict which ligands are bound in the coordination sphere of unknown complexes. The prediction of C.N. and geometry by GAMESS remains inconclusive until more models of the hydrated complexes can be completed.

VTFT – SOFTWARE FOR OFF-LINE FTNMR DATA PROCESSING. Harold M. Bell, Department of Chemistry, Virginia Tech, Blacksburg, VA 24061. With the advent of high-field NMR and the tendency to plot spectra on letter-size paper, today's spectra have too much data squeezed into a small space. One remedy is to require the student to make expanded plots prior to departing the NMR console. However, this is time consuming and inefficient. Also, the student may not know exactly what it is that he needs to do at that point in time. A better approach is to provide the students with the FID and appropriate software and let them process the data off-line. Program VTFT was written for off-line processing of FIDs captured in various formats (JCAMP, NUTS, LYBRICS, VARIAN UNITY. Etc.). It is a freeware 32 bit application for the PC platform operating under Windows 95. Provision is made for exponential smoothing, resolution enhancement, zero filling, scale expansion, peak picking, baseline flattening, and spectrum integration. Also, the spectrum may be plotted on any Windows printer, or exported as a Windows metafile. A companion application, FIDMAKER, can be used create FIDs in JCAMP format. This is useful in cases where students do not have access to FTNMR. The simulated FIDs are indistinguishable from the real thing.

SYNTHESIS OF FUNCTIONALIZED 3-AMINOMETHYLINDOLES. James H. Wynne & Wayne M. Stalick, Dept. of Chem., George Mason Univ., Fairfax, VA 22030. A variety of 3-substituted indole alkaloids are attractive targets in the search for novel Xa inhibitor agents in the coagulation process as well as for potential antidepressants. We report a novel efficient synthetic approach, which allows for the incorporation of diverse aromatic functionalities into the 3-position of the indole ring through a unique synthetic technique employing a variety of aromatic tosylaldehydes, affording a library of 3-aminomethylindoles. The 3-aminomethylindoles can be converted into the corresponding tetrahydro- γ -carboline derivatives through a simple two-step approach involving substitution, followed by subsequent intramolecular cyclization employing a Lewis Acid. This method likewise affords a series of highly functionalized 1,4-disubstituted-tetrahydro- γ -carbolines. The current synthetic approach is designed to incorporate changes in the chelating ability by varying substitution in two positions within each molecule. The design and synthesis of these potential inhibitors will be discussed.

METHODS FOR SYNTHESIZING ALKYL PYRIDINES AND QUINOLINES FOR PYROLYSIS. Wayne M. Stalick, Chemistry Department, George Mason University, Fairfax, VA 22030. Our laboratory has been working in collaboration with NRL and as such, has been interested in fuels for Navy jets. Shale derived fuels are of interest because they have the highest alkane content, about 40%. Checking the alkane content of crude shale oil, however, shows a content of only 14%. Since the crude undergoes processing known as delayed coking, it is assumed that the extra alkanes are produced during this process. Like all crude, shale oil contains a large proportion of alkyl aromatic compounds, and it is assumed that their decomposition is responsible for the increased alkane content found. About 40% of the compounds in shale oil contain nitrogen, and of these alkyl pyridines and quinolines are the most prevalent. The idea of this project is to synthesize a number of model compounds to study under pyrolysis conditions to determine if they are the major source of the extra alkanes found in shale derived fuels. The general synthesis for these compounds has been a liquid ammonia/alkali amide system. Since the 3-substituted pyridines and quinolines are less basic than the 2- and 4- counterparts, they required other synthetic modifications and techniques. This report will cover all of the methods employed in making this series of model compounds.

DEVELOPMENT OF A LOW COST MULTI-WAVELENGTH COLORIMETER FOR THE CHEMISTRY LABORATORY. David M. Hendrickson & Harold F. Webster, Dept. of Chemistry & Physics, Radford University, Radford, VA 24141. Commercial colorimeters are marketed at costs that are sometimes prohibitive for general student use, yet colorimeters are useful for experiments involving stoichiometry, Beer's Law, chemical kinetics, and chemical equilibrium. The authors have developed a low cost colorimeter constructed of almost exclusively off-the-shelf products and a multi-colored LED. The instrument generates blue, red, or green light, and can combine these colors. The design makes protection from ambient light unnecessary, and enables software control of the instrument through an simple serial interface. Zeroing, calibration, and amplification were controlled by Labview™ software, which also enables real-time monitoring and the ability to average incoming data. The authors tested performance using Beer's law plots and kinetics experiments involving the reaction between commercial food dyes and sodium hypochlorite were performed using the device.

ANALYSIS OF THE SELECTIVE OXIDATION OF POLYPHENYLENE SULFIDE. H. Francis Webster, Dept. of Chemistry & Physics, Radford University, Radford, VA 24141. The main focus of this research was to develop methods to chemically modify the surface chemistry of polyphenylene sulfide (PPS). Methodology has been developed to create a relatively thick surface layer where most of the polymer sulfide has been converted to sulfoxide or sulfone. Potassium persulfate was effective in selectively oxidizing the sulfur group to sulfoxide, while an acetic acid / hydrogen peroxide mixture converted the sulfide first to sulfoxide and then to sulfone. The reaction kinetics at various temperatures were studied using infrared attenuated total reflectance (ATR) by monitoring the appearance of new sulfoxide or sulfone IR bands. X-ray photoelectron spectroscopy (XPS) was also used to document the conversion to sulfoxide and sulfone by following the increase in the sulfur 2p photopeak position from 164 eV to 166 (sulfoxide) or 168 eV (sulfone). ATR indicated that the modified layer was relatively thick (>10 nm).

COMPLEXES OF THE N-(4-DIMETHYLAMINOPHENYL)PHTHALAMATE LIGAND WITH Co(II), Ni(II), Cu(II), AND Zn(II): A RESEARCH-ORIENTED SENIOR-LEVEL LABORATORY COURSE. Julie Phillips, D.L. Polo & L. M. Vallarino (CHEM 406L), Department of Chemistry, Virginia Commonwealth University, Richmond, VA 23284-2006. This work is part of an ongoing class project that investigates the coordinating ability of the amic acid sites of polyimides through a study of the metal complexes of representative monomeric amic acid models. The N-(4-dimethylaminophenyl)phthalamic acid (HDiMeNPPA), synthesized from N,N-dimethyl-1,4-phenylenediamine and phthalic anhydride, was reacted with the metal acetates to yield compounds of the general formula $M(\text{DiMeNPPA})_2 \cdot \{M(\text{CH}_3\text{COO})_2\}_n \cdot (\text{H}_2\text{O})_m$, where $n = 0.5$ for Co(II) and Ni(II), 0.25 for Cu(II) and 0 for Zn(II). The complexes of Co(II), Ni(II) and Zn(II) had identical IR spectra and solubility patterns. On the basis of the d-d electronic spectra of the Co(II) and Ni(II) species, and of the ^1H NMR spectrum of the Zn(II) species, these complexes were tentatively assigned an octahedral coordination geometry with the DiMeNPPA⁻ anions acting as bidentate chelating ligands *via* the carboxylate and amide groups. The less soluble Cu(II) complex, which had a somewhat different IR spectrum, was instead assigned a dimeric or polymeric structure with bridging carboxylates.

DEVELOPMENT OF A LOW COST MULTI-WAVELENGTH COLORIMETER FOR THE CHEMISTRY LABORATORY. David M. Hendrickson & Harold F. Webster, Dept. of Chemistry & Physics, Radford University, Radford, VA 24141. Commercial colorimeters are marketed at costs that are prohibitive for many chemistry departments, yet colorimeters are useful for experiments involving stoichiometry, Beer's Law, chemical kinetics, and chemical equilibrium. The authors have developed a low cost colorimeter constructed of almost exclusively off-the-shelf products and a multi-colored LED. The instrument consists of 3 manual switches to radiate blue, red, green, or combinations of those wavelengths. The design makes protection from ambient light unnecessary, and enables software control of the instrument through an A/D interface. Zeroing, calibration, and amplification are controlled by Labview software, which also enables real-time monitoring and the ability to average incoming data. The authors performed a kinetics experiment involving the reaction between a commercial blue food dye and sodium hypochlorite, and effectively show a first order reaction with respect to the food dye with a correlation coefficient of better than 0.995.

USING WEBCT IN ORGANIC CHEMISTRY CLASS. Christine K. F. Hermann, Chemistry and Physics Department, Radford University, Radford, VA 24142. WebCt is a World Wide Web-based educational tool that facilitates getting information to students. The faculty and students connect to WebCt through a web browser, making it very accessible. The students in my Organic Chemistry class can access their class WebCt page through a login and password. No one else can log into their class page. As a designer, I am able to create a series of icons that students can click on. In the calendar, students can view the dates for quizzes and tests, the names of the upcoming labs, and other announcements for the class. Internet links can be placed in the calendar. I have placed my schedule and contact information under professor information. Students can open and print blank quizzes, blank tests, and their answer keys. Students can email one another within the class and also place their own messages on a class bulletin board. When a student logs in and checks his grade, only that student's individual grades are seen. A graph of the other grades on a particular quiz or test can be brought up. Because of the nature of the Organic Chemistry quizzes and tests, the on-line quizzes tool is not utilized. If this feature is utilized, the on-line quizzes are automatically graded. The different aspects of WebCt will be shown in this presentation.

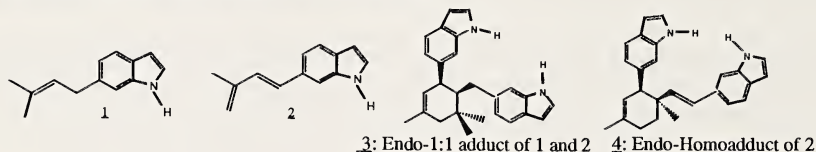
FORMATION, STRUCTURE AND PERFORMANCE OF CORROSION RESISTANT COATINGS ON AEROSPACE ALUMINUM ALLOYS. M. Todd Coolbaugh, Howard P. Groger & Sarah E. Morris, American Research Corporation of Virginia, Radford, VA 24143, arcova@swva.net. Aerospace aluminum alloys, especially Al2024-T3 and Al7075-T6, are prone to severe corrosion in marine environments. Traditionally this problem has been countered by the use of corrosion resistant coatings, i.e. conversion coatings, deposited from chromate-based formulations. Chromates have been shown to be highly toxic and mutagenic and there is intense pressure to eliminate their use. A simple, effective conversion coating based on zirconium and trivalent chromium has been developed and is undergoing field tests. The new trivalent chromium conversion coatings (tccc) have been shown to be effective in preventing both general- and pitting corrosion on Al2024-T2, and very effectively enhances adhesion of paints and adhesives to aluminum. Although the effectiveness of this new conversion coating has been demonstrated, the mechanism of its formation remains an interesting question. To probe this question, a number of surface sensitive spectroscopic tools were utilized in order to determine the composition and structure of the tccc. A possible mechanism for the formation of the tccc will also be presented.

MULTILAYER MOLECULAR SELF-ASSEMBLED THIN FILM SENSORS FOR DETECTION OF AMMONIA, K. P. Lo, E. C. Aquino, H. P. Groger, R. J. Churchill, American Research Corporation of Virginia, P.O. Box 3406, 1509 Fourth Street, Radford, VA 24143-3406. An optical sensor system based on multilayer molecular self-assembled thin films for detection of ammonia has been demonstrated. The sensing film was fabricated by immobilizing pH sensitive fluorophores in self-assembled polyelectrolyte films. Fluorescence from the thin film was excited by a laser diode and was detected using a total-internal-reflection geometry. The response of the thin film to different concentrations of ammonia vapor was characterized in the absorption and fluorescent modes. The sensor system has been demonstrated to respond reversibly to ammonia at concentrations less than 41 parts-per-billion with response and clear-down times in approximately three minutes. The estimated detection range for the sensor is between 10ppb to 20ppm.

SYNTHESIS OF LONG CHAIN FUNCTIONALIZED ALKYL QUINOLINES. Leo C. DeSesso & Wayne M. Stalick, Dept. of Chem., George Mason Univ., Fairfax, VA 22030. There are many examples of functionalized alkyl quinolines with medicinal uses that have been described in the literature and many of these have not been obtained in large quantities. Because molecules of this type are not commercially available, nor has their synthesis been reported in the literature, we sought to develop a new methodology that would afford a variety of alkyl quinolines, even in the presence of several pH sensitive functionalities. We report a novel efficient synthesis of the aforementioned compounds by a variety of methods, both with and without the implication of a protecting group. Treatment of the starting material with a strong base, followed by intermolecular substitution employing a variety of alkyl halides, affords the desired compounds. By varying the alkyl halide employed the side chain can easily be altered to the desired length. The synthetic strategy, reaction conditions, and classification of these types of compounds will be discussed in detail.

ENVIRONMENTALLY FRIENDLY CATALYTIC OXIDATION UNDER PHASE TRANSFER CONDITIONS. Christopher T. Lloyd, James H. Wynne & George W. Mushrush, Dept. of Chem., George Mason Univ., Fairfax, VA 22030. A new, efficient, environmentally friendly method for the selective oxidation of alcohols into their corresponding aldehydes is needed. Many current methodologies require unfavorable conditions and often proceed with low yields. We report the selective oxidation of primary alcohols to the respective aldehyde under ambient, neutral conditions employing an oxotriruthenium cluster complex and a phase transfer catalyst (PTC) system. At catalytic concentrations, the oxotriruthenium complex effectively promoted the transformation of primary alkyl alcohol into the corresponding aldehyde with little or no over-oxidation. The PTC is believed to play a dual role in the extraction of the metal catalyst and the oxidant from the aqueous layer. More remarkably, the tetraalkylammonium salts are believed to prevent deactivation of the ruthenium catalyst. Yields in excess of 70% with greater than 95% selectivity have been achieved on a variety of substrates. The ability of the reaction to proceed under such mild conditions represents an invaluable, environmentally friendly route to effectively oxidize primary alcohols. Reaction conditions for this oxidative process will be discussed.

DIELS-ALDER ADDUCTS OF PRENYLINDOLES FROM THE ROOT BARK OF THE TANZANIAN PLANT *MONODORA GRANDIDIERI*. Godson C. Nwokogu, Department of Chemistry, Hampton University, Hampton, VA 23668. Four compounds were isolated from the root bark of the annonaceous plant, *Monodora grandidieri*, collected from the Udzungwa National Forest Reserve in Tanzania. Mass spectra, melting points and chemical shifts are consistent with the assignment of the 6-prenylindole structures **1** and **2** to components C₁ and C₂ respectively. The mass spectra of components C₃ and C₄ suggest that these compounds are dimers and their fragmentation patterns suggest that C₃ could be a 1:1 Diels-Alder adduct of **1** and **2** while



C₄ could be a Diels-Alder homoadduct of **2**. The structurally preferred endo/ortho diastereomeric adducts from such cycloadditions are **3** and **4** for components C₃ and C₄ respectively. The stereochemistry and stereochemical composition of C₃ and C₄ have not been established yet.

CHARACTERIZATION OF MOUSE AND HUMAN GUANINE-7-METHYLTRANSFERASE. David J. Bautz, Sara Zulfiqar, Keith Newbrough & Thomas Sitz, Dept. of Biochemistry, Virginia Tech, Blacksburg, VA 24061. The methylation of the 7-position in the guanine base in the cap structure located at the 5'-end of eucaryotic mRNAs is essential for ribosome binding and translation. We have received a clone of the human guanine-7-methyltransferase expressed in *E. coli* as a fusion protein with glutathionine transferase from Dr. Shatkin. The coding sequence for this cDNA predicts an enzyme of 55K molecular weight. We used the human sequence to search the mouse genome database and found 7 ESTs that encompass the entire coding sequence for the methyltransferase in mouse. This sequence predicted a molecular weight of 53K, significantly larger than the mouse enzyme *in situ*. We determined that the molecular weight of the mouse enzyme isolated from tissue was 46K in size. When the human and mouse sequences were compared, we found that the n-terminal region of about 120 amino acids was poorly conserved while the rest of the protein was almost identical. We have produced a clone of the human methyltransferase with the n-terminal 120 amino acids deleted, generating a protein of about 42K molecular weight. We are currently characterizing this shortened enzyme for activity and stability.

PLATINUM(IV) TETRAPHENYLPORPHYRIN DIBROMIDE COMPLEXES: SYNTHESIS, CHARACTERIZATION, AND ELECTROCHEMISTRY. R. K. Boggess¹, H. Washburn¹, D. I. Grove¹, L. M. Mink², J. W. Voce², J. E. Ingersoll², & V. T. Nguyen², ¹Department of Chemistry and Physics, Radford University, Radford, VA 24142, ²Chemistry Department, California State University, San Bernardino, CA 92407-2397. Platinum(IV) porphyrins of the type $[\text{Pt}^{\text{IV}}(p\text{-X})_4\text{TPP}]\text{Br}_2$ where $(p\text{-X})_4\text{TPP}$ is a *para*-substituted tetraphenylporphyrin have been synthesized by the direct oxidation of their Pt(II) precursors with Br_2 . Both the Pt(II) and Pt(IV) complexes have been characterized by visible and ¹HNMR spectroscopy and their electrochemical properties. In both the oxidation and reduction processes, a substituent effect is evident and the reduction of $\text{Pt}^{\text{IV}} \rightarrow \text{Pt}^{\text{II}}$ is identified. The oxidation and reduction potentials of the $[\text{Pt}^{\text{IV}}(p\text{-X})_4\text{TPP}]\text{Br}_2$ complexes are compared to their $[\text{Pt}^{\text{II}}(p\text{-X})_4\text{TPP}]$ precursors and $[\text{Pt}^{\text{IV}}(p\text{-X})_4\text{TPP}]\text{Cl}_2$ analogues.

VIBRATIONAL SPECTROSCOPY IN THE STUDY OF SOLID SURFACES. James P. Wightman, Dept. of Chem., Va. Polytechnic Inst. & State Univ., Blacksburg, Va 24061. Infrared spectroscopy (IRS) is a useful technique to identify functional groups on solid surfaces. Solid powders having high specific surface areas can be run in the trans-mission mode either as a KBr pellet or as a self-supporting neat disc. However, for low surface area or infrared absorbing solids, IR spectra has to be taken in the reflectance mode. There are a number of reflectance attachments available for use on commercial IR spectrophotometers. IR spectra of both high and low surface area solids obtained by the use of transmission, attenuated total reflectance, specular reflection, diffuse reflectance and photoacoustic attachments will be shown. Thus, IRS is a powerful analytical tool to study solid surfaces by appropriate choice of an attachment. Application areas include heterogeneous catalysis, surface contamination, adhesion, thin film analysis, and composite degradation.

COMPUTERIZED MOLECULAR DESIGN OF A HEPARIN PENTASACCHARIDE MIMIC. Gunnar T. Gunnarsson & Umesh R. Desai. Dept. of Med. Chem., School of Pharmacy, VCU, Richmond, Va 23298. The anticoagulant heparin activates human plasma protein antithrombin to inhibit factor Xa and thrombin, two critical coagulation proteases. A sequence of five saccharides in heparin specifically recognizes the heparin-binding site in antithrombin and activates the inhibitor to rapidly inhibit these clotting enzymes. This pentasaccharide sequence, called DEFGH, has been the focus of recent clinical studies as a replacement for heparin and low molecular weight (LMW) heparins. Our earlier studies have shown that DEF binds and activates antithrombin equally well as DEFGH. The current study presents a design of a new organic molecule that mimics the trisaccharide DEF. Modeling programs such as *SYBYL* and *Flexidock* were used in the molecular design while the ligand-protein complex was analyzed using *HINT*. *HINT* analyzes gives a score that defines non-covalent interactions including hydrogen bond, polar and hydrophobic interactions. Comparison of the trisaccharide DEF and our designed bis-decalin derivative, v14, with antithrombin shows that both molecules give high positive *HINT* interaction scores. The modeling study suggests that v14 mimics the DEF portion of the heparin pentasaccharide and could be a potential anticoagulant.

INFLUENCE OF INTRAMOLECULAR HYDROGEN BONDING ON THE REACTIVITY OF THE ENAMINONES OF THE BARBITURIC ACID DERIVATIVES. Dmitry Pestov, Dept. of Chem. Eng., Virginia Commonwealth University, Richmond VA, 23284. The kinetics of the transamination of 1,3-dimethyl-5-anilinomethylenebarbituric acid (1) and 1,3-dimethyl-5-N-methyl-anilinomethylenebarbituric acid (2) by mono- and diamines in 2-propanol and in DMSO was studied. The first compound has intramolecular hydrogen bond (HB) and second does not. It was found that compound (2) reacts with monoethanolamine in 2-propanol medium in 10⁵ times faster than compound (1). A mechanism of the reaction with tetrahedral intermediates was suggested and confirmed by a good correlation with experimental and theoretical data. The presence of intramolecular HB in substrate (1) considerably reduces speed of the reaction by decreasing of the amount of intermediate T1 at the first step of the reaction. The presence of the intramolecular HB in intermediates T1 and T2 slows down a proton exchange in T1/T2. This step became a limiting factor for the rate of the whole reaction.

Computer Science

Education

COAST TO COAST 2000. FINDING A LAND ETHIC: INVESTIGATIONS IN NATURAL RESOURCE MANAGEMENT. Myron E. Blosser Harrisonburg High School. Education is only fully realized when it is lived. We do very well at giving our students tremendous quantities of facts. Do we provide them with enough experience living in the world and applying their knowledge? How much of our education has students meeting people with different ideas, applying concepts to current issues, solving real-life problems, and realizing that their presence will indeed change their corner of the world? In the hopes of making education experiential and our students' real scientists who indeed live their education, the vision for Coast to Coast 2000 was born. An initiative developed by Harrisonburg High School science faculty, the program seeks to connect the real world with the classroom. In fact, Coast to Coast 2000 is an educational venture where the learner is classroom is the entire nation for 22 high school students and six science faculty during their 34-day cross-country investigative trip. They will board a chartered bus equipped with computer workstations, Internet access, test kits, and probe ware. Participants will visit over 25 states, camping and study in 11 national parks. To increase dialogue they will update their web site at www.shentel.net/cst2cst.

USING CASE VIGNETTES AND SCENARIOS TO ADDRESS INSTRUCTIONAL ISSUES IN SCIENCE. Alvin M. Pettus, James Madison University, Harrisonburg, Va. Case methods provide viable options for instruction in science. Short cases and scenarios that focus on specific topics can be studied and discussed during a class session or a part of a class session to develop awareness of science issues, develop problem solving skills, assess attitudes, assess levels of understanding, and motivate students. Examples of vignettes, scenarios, and short cases were presented and different structures for discussing them were shared. Some examples included science teacher education issues. Other examples included the application of science concepts by secondary school students. Cases can be written by the teacher and/or students or they can be descriptions of real situations.

NINETEENTH CENTURY GEOGRAPHY: 21ST CENTURY'S INTERDISCIPLINARY SCIENCE? Pamela C. Turpin, Roanoke College, Salem, Va. In 1893, the Committee on Secondary Education met to discuss what subjects were to be taught in secondary schools. The sciences were broken up into separate disciplines in order to accomplish this. One of these was the section on geography. This section seemed in several ways to exceed the expectations of the overall committee. They laid a framework for instruction in geography in public schools from the elementary grades through high school. This section also provided in their report the ways and means of accomplishing the goals they set. An examination of the content and methods of instruction set forth in their section report reveal an interdisciplinary approach to teaching science. This nineteenth century report shows us involved in 21st century science instruction that even though some things have changed in instructional methods there are prevalent ideas and ideals in both centuries that remain the same in science instruction.

BIOETHICS 2000 AND LIFE SCIENCES: PROGRAMS, RESOURCES, AND EXHIBITIONS. E. G. Maurakis, Science Museum of Virginia, 2500 W. Broad St., Richmond, VA 23220. Bioethics 2000 is an educational initiative to increase understanding of bioethical issues in organ donation and genetics. Bioethics 2000 presents bioethical information via theatrical plays, lectures, panel discussions, workshops, web pages, curriculum guides, and videos. Bioscape, the Science Museum's new permanent Life Sciences Exhibition, will open during autumn 2000. Bioscape, covering 10,000 ft², is composed of 69 exhibits that contain hundreds of interactive experiences in four galleries: Molecular Biology/Genetics; Human Biology/Health Sciences; Environmental Sciences, and Biological Timing. An interactive 60-foot tall model of the DNA molecule in the Museum's East Stairwell will be the centerpiece of the galleries. Bioscape is supported by gallery demonstrations, Discovery Tours (VA S.O.L. tours of Bioscape), Mini-Med School, Mini- School of Marine Science, Funsten Lecture Series, Bioethics 2000, teacher workshops, internet resources, 10 SOL-based teacher resource curriculum guides, and more. Bioethics 2000 is funded by the Greenwall Foundation.

USING BIOLOGY CURRICULUM TO INCREASE PROFICIENCY IN MATH SOLS. J. McLaughlin, Instructional Leader for Math and Science, Lord Botetourt High School, Botetourt County Schools. In order for students to make connections between mathematical concepts and their applications in lab, as well as to prepare students for college, there is a need to incorporate more mathematical skills in introductory high school Biology labs. An effective way to implement this idea is to adopt an Algebra/Biology informal team teaching methodology, consisting of 2 teachers "teaming" individual preparations. The math concepts taught in Algebra will be immediately seen in their applications in the Biology lab. Many school systems have been slow to adopt a formal teaming approach because of its drawbacks, i.e. scheduling, organization of material. However, with a somewhat less rigid teaming approach, students can benefit from constant reinforcement of algebraic concepts. If Biology students enroll in Chemistry the next year, they will have a stronger base for algebraic concepts, and retain a better understanding of data collecting in the sciences as seen in different settings. Teachers will develop a better understanding of intra-curriculum concepts by being exposed to different teaching techniques and ideas while better recognizing remedial targets by developing a more comprehensive student portfolio.

ENVIORNMENT-PEOPLE-INTERACTIONS:SOUTHERN AFRICA AS A FOCUS STUDY FOR THE PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS. Michael Bentley, Virginia Tech, Blackburg Va. Few teachers have studied Africa and the continent is underrepresented in Virginia's K-12 curriculum. Virginia Tech's Department of Teaching and Learning has initiated the Southern African Studies Institute for Teachers, a two-year summer professional development program for teachers culminating in a multi-country field trip to Southern Africa. The program focuses upon key aspects of African society - history, economics, geography, government, education, social life, etc., and the types of habitats and wildlife found there. Social science and ecological concepts are integrated through examining social and ecological issues. Participants develop classroom portfolios as they infuse African studies into their local curriculum. Pre- and post-experience data will be collected for evaluation. The program web site is http://www.chre.vt.edu/sa_inst.

BIOSCAPE: VA S.O.L. TOURS IN SCIENCE MUSEUM'S NEW EXHIBITION GALLERIES. A. Clarke Hamm, T. D. Green, T. Kitts, E. G. Maurakis & S. Short, Science Museum of VA, 2500 W. Broad St., Richmond, VA 23220. The Standards of Learning (S.O.L.) tours, now called Discovery Tours: Science S.O.L. Connections, are newly developed materials correlating the museum's new 70 permanent life science exhibits with the Virginia S.O.L.s. Tours offer teachers and students a well-planned museum visit with hands-on learning, and provide classroom activities to reinforce the museum experience. Discovery Tours are divided into the following three formats. Materials for grades K-4 consist of chaperone-led tours with questions and answers for chaperones to ask at grade-appropriate exhibits, along with in-class activities for teacher use. Materials for grades 5-8 consist of scavenger hunts that students complete in groups while visiting the museum, as well as follow-up classroom projects. High school tours are student projects on specific life science topics. Students complete questions using museum exhibits and other resources; and then use their information to conduct an experiment or design a product that can be used to teach others about the topic. Discovery Tours: Science S.O.L. Connections will be available in fall 2000 to educators booking a group visit and on the Science Museum of Virginia website. This project was funded in part by the Robins Foundation.

TEACHING BIOLOGY THROUGH INNOVATIVE ASSIGNMENTS. J. Orion Rogers, Dept. of Biol., Radford Univ., Radford, VA 24142. Learning is a creative endeavor. Innovative assignments that emphasize application and experience enrich and motivate student learning. Both individual and group writing activities and oral presentations have been used successfully to provide personal interaction with material, foster active learning, promote cooperation among students, provide structured time on task, enhance scientific reasoning skills and integrate knowledge. Writing activities supplement and complement traditional instructional techniques by enhancing library research skills, awareness of the scientific literature, and knowledge of biology beyond what can be covered in class. Examples of writing assignments that can be used include: term papers, grant proposals, journals, letters of biological concern, brochures, critiques, reviews, posters, quantitative exercises, science fiction stories, medical mysteries and biographies and case studies. Writing assignments stimulated students and encouraged them to take more responsibility for their own learning. Students who completed these assignments commented that writing was a positive influence on their learning, and the skills they developed would be used in future courses. Students developed self-confidence as they were forced to think laterally and critically and realized implications and applications from unique perspectives.

RARE PLANTS IN THE CLASSROOM; POTOMAC ELEMENTARY SCHOOL AND THE TOYOTA TAPESTRY GRANT. P. Sheridan^{1&2}, R. Horman¹, S. Horman¹, S. Gilbert³, A. Keeton³, & M. Schmutte³, ¹Meadowview Biol. Research Station, ²Dept. of Biol. Sciences, Old Dominion Univ., and ³Potomac Elementary School. A basic challenge to educators is how to get young students involved and interested in science and biological conservation. We utilized the carnivorous yellow pitcher plant and longleaf pine to capture students imagination, answer important scientific questions, and make significant contributions to rare species recovery. We used the Toyota Tapestry Grant to fund and develop our program of scientific study and rare plant reintroduction. Students found that freezing had no effect on breaking dormancy in yellow pitcher plant seed while dilute fertilizer and soil amendments such as Miracid, Superthrive, and a solution of burned pitcher plant leaves significantly increased seedling growth over controls. Students returned over 300 pitcher plant and 95 longleaf pine seedlings to a VDOT wetland mitigation site within the historic range of the species. We think that an important reason for the success of the project was the team effort between teachers, local volunteer master gardeners, and scientific mentors. Student efforts continue with both species in a school yard "mini-nursery".

A METHOD FOR PLANTING LONGLEAF PINE, *PINUS PALUSTRIS* MILLER, ON HIGHWAY RIGHTS-OF-WAY. Phil Sheridan, Meadowview Biological Research Station and Department of Biological Sciences, Old Dominion University. Longleaf pine is a very rare plant in Virginia with only 4432 trees remaining in the wild. We were interested in utilizing highway rights-of-way to start backup populations of native Virginia longleaf pine within the historic range of the tree and to measure survivorship of longleaf pine planting. Two hundred seventeen seedlings with an average root collar diameter of 1 cm were planted in a cloverleaf in Prince George County, Virginia in mid-January 1999. Ground cover cloth was placed around each seedling, mulch was placed on top of ground cloth, and a bamboo stake with survey tape placed next to each seedling. Mowing of the site during the growing season was carefully coordinated with VDOT staff. Survivorship of longleaf pine after one season was 84% and mulching generally provided effective control of longleaf pine competitors.

COMPARISON OF INSECT CAPTURES BETWEEN WILD-TYPE AND MUTANT GREEN *SARRACENIA JONESII* WHERRY. Phil Sheridan^{1&2}, Jonathan Humphrey¹, Monique Davies¹, Chris Simon¹, & Nancy Penick¹, ¹Meadowview Biological Research Station and ²Department of Biological Sciences, Old Dominion University. Various investigators have proposed that insects are attracted to the carnivorous *Sarracenia* pitcher plants by color, nectar, and scent. Mutant pitcher plants exist which lack the ability to produce reddish-purple pigment due to a recessive allele blocking a late stage of anthocyanin biosynthesis. Normal wild-type plants of *Sarracenia jonesii* produce only cyanidin and thus the role of anthocyanin in capturing insects may be assessed through comparative studies of insect captures between wild-types and mutants. We raised both wild-type and mutant plants from seed and measured pitcher height, mouth width, and mass of insect captures in the 3 year old seedlings. We found that pitcher height and mass of insects captured by mutants was significantly greater than wild-type while there was no significant difference in mouth width.

THE YELLOW PITCHER PLANT, *SARRACENIA FLAVA* L., RECOVERY PROGRAM. Phil Sheridan, Meadowview Biological Research Station and Department of Biological Sciences, Old Dominion University. The yellow pitcher plant is a carnivorous plant restricted to fire maintained wetland ecosystems in Virginia. Due to land use changes and urban development this species has suffered significant population declines resulting in only four native populations remaining totaling less than 100 plants. Through a careful process of scientific research an effort to return the yellow pitcher plant to its historic range in Virginia is now being undertaken. This process includes: continued field research for new populations; propagation of extant and extirpated colonies; ecological and reproductive biology studies; reintroduction to the wild of both site-faithful and mixed populations; education of the general public about the importance of these plants and their environment; active programs with local schools involving them in various scientific aspects and on-site reintroductions; a registry with state agencies of all introduced sites, material planted, and origin of stock. A population has now been started in five of the eight historic counties for this species. State highway rights-of-way and wetland mitigation projects have been used for half the reintroductions with several of the sites in their third successful year of reproduction.

ROOTING LONGLEAF PINE, *PINUS PALUSTRIS* MILLER, FROM NEEDLE FASCICLES. Phil Sheridan^{1,2}, Kneeland Nesius², & Leslie Everett², ¹Meadowview Biological Research Station and ²Department of Biological Sciences, Old Dominion University. Longleaf pine is a rare plant in Virginia with only 4432 trees remaining in the wild in the state. Cone crops can be erratic and seed yields per cone are less than the average reported for southern provenance. We were interested in determining the feasibility of regenerating rare Virginia longleaf pine from needle fascicles. If we can successfully regenerate native longleaf pine trees from needle fascicles than we can compensate for erratic seed production and, more importantly, capture the entire longleaf pine genome in Virginia for conservation purposes. Our initial efforts have focused on replicating other workers results with grass stage seedlings. Up to 65% of fascicles from a seedling can produce roots when placed in a 2 cm deep solution of 100 ppm IBA for 24 hours followed by maintenance in a solution of 60 ppm H₃BO₃, 40 ppm NH₄NO₃, and 20 ppm thiamine-HCl.

Environmental Science

THE NONEQUILIBRIUM THEORY OF DISTRIBUTION AS INDICATED BY DIATOM PERIPHYTON SPECIES. Mariah Butler and Stephen Gough, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. A study of whether nonequilibrium community dynamics occurs among periphytic diatoms in a riffle zone of a small stream environment was conducted in the spring of 2000. Among other things, nonequilibrium tenants state that patchiness can exist, even in areas that are geographically close by and appear uniform in habitat. We chose to use a bar clamp collecting devise, collecting 40 random samples from rocks in a five m² area representing apparent environmental uniformity. Sampling followed heavy rains in which water and sand scoured the rocks. The samples were analyzed for the types and numbers of diatoms present. The data indicated wide variability in total numbers of the organisms, though there were only three species present. The results were attributable to the disturbance caused by the strong flows and sand, and the variety in species counts and the low diversity suggested patchiness and preliminary recolonization, thus supporting the view that nonequilibrium community dynamics were present at the site. It is possible that periphyton communities in this area rebound to near equilibrium after perturbations, but are almost always recovering from the last disturbance.

THE FATE OF INORGANIC PHOSPHORUS AND NITROGEN IN WATERS FLOWING THROUGH AN URBAN FRESHWATER MARSH. Stephen B. Gough & Tiffany L. Patrick, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. We tested a constructed wetland in an urban environment to determine whether nitrate and phosphorus were being transformed, or whether the site acted as a sink or a source for the substances. Guided by some studies in the literature, our hypothesis was that some retention of each would occur. Samples were taken from October 1999 to March 2000. On average, nitrate-nitrogen from the inflow to the outflow was reduced 15% and orthophosphate was decreased by 23%. However, there was considerable variability in reduction rates at different times of the year, with phosphorus and nitrate showing disparate seasonal trends. Nitrate was reduced significantly from October until January. In the latter month and into February release went up considerably. Conversely, phosphorus output peaked in November, at a time when inflow concentrations were the greatest. Despite some retention rates for both nutrients, hydrophyte uptake may not have played an important factor in uptake except for nitrates in the early fall and winter. Phosphorus early release rates may have been due to decomposition with concomitant outwashing.

ENVIRONMENTAL IMPACT OF COMMERCIAL AND AGRICULTURAL DEVELOPMENT ON FEEDER STREAMS OF THE RAPPAHANNOCK RIVER. J. Richardson, T. Sheffield & M. L. Bass, Environmental Science & Geology Dept., March Washington College, Fredericksburg, VA 22401-5358. Land within the Rappahannock River Basin has been in forests or in agricultural production. However, the increased population growth of the area has created more urban land uses. Nonpoint source pollution runoff from agricultural and urban sources is a major problem in the basin. This research is a continuation of efforts to quantitatively analyze the water quality of tributary streams draining the Rappahannock River Basin. The macrobenthos and water quality in the England Run drainage basin and the unnamed stream system immediately to the west of it were analyzed. Effects of land use on stream morphology, water quality and macrobenthic diversity were assessed. Water samples were tested for nitrate, orthophosphate, pH, total dissolved solids, temperature and conductivity. In undeveloped areas, beaver dams created sediment traps and wetland conditions with the potential for absorbing nutrients. Values of total dissolved solids were greater in areas receiving drainage from impervious surfaces and pH values were acidic. Values of nitrate greater than 1 ppm were found in areas where the stream ran through residential and agricultural regions. Macrobenthos scored fair to good (SOS) at most sites.

OUTLINE OF A PRELIMINARY STUDY OF THE EFFECTS OF DEVELOPMENT ON A SMALL WATERSHED. M. L. Bass & R. Strickler, Environmental Science & Geology Dept., Mary Washington College, Fredericksburg, VA 22401-5358. Previous work on two small streams feeding into the Rappahannock River has developed into an expanded study to include extensive water quality analyses, macrobenthic and periphyton community health and monitoring stream bank erosion. Planned development of a previously forested agricultural area will increase the percentage of impervious surface in the watershed. Water quality analyses will include Pb, Zn, BOD, Fecal coliform along with basic testing. Previous work showed increases in nitrate and phosphate in residential and agricultural areas. Macrobenthos was analyzed using EPA Rapid Bioassessment Protocol showing decreased health with increased sedimentation of stream bed. The macrobenthic EPT % decreased from the headwaters to the mouth of the stream. Periphyton health was decreased by sedimentation. Streambank erosion is increasing as the area is developed both residentially and commercially. Further study of the streams is continuing.

A COMPARATIVE STUDY OF SMALLMOUTH BASS AND ROCK BASS DIETS IN THE NEW RIVER, VIRGINIA. Angela C. Benson & Tammy J. Newcomb, Va. Polytechnic Institute and State University. Smallmouth bass *Micropterus dolomieu* and rock bass *Ambloplites rupestris* are important game species in the New River. Recent observations indicate a shift towards larger sizes of smallmouth bass. We compared New River (1999) diet data to historical New River (1989) and Powell River (1989) data. Diets were analyzed by use of a chi-square test to compare prey items of similar-sized smallmouth bass and rock bass. The 1999 and 1989 New River comparison of smallmouth bass showed no difference in diet composition. Compared to 1999 New River data, Powell River smallmouth bass were significantly different and ate more insects and fewer fish. Powell River rock bass also consumed more insects and fish, and 1989 New River rock bass ate more megalopterans and fewer crayfish. New River smallmouth bass (1999) ate more insects and fish than the rock bass, and New River rock bass (1999) ate more crayfish and megalopterans than the smallmouth bass. We also found that smallmouth bass and rock bass of similar sizes are not eating the same proportions of prey items. (Supported by the Biological Sciences Initiative at Virginia Tech).

GASTRO-INTESTINAL DIFFERENCES IN BIRD SPECIES. Cristina R. Faustino and P. F. Scanlon. Dept. of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, VA 24061-0321. Aspects of the gastrointestinal (GI) tracts of 10 bird species were examined and the lengths of cecal pouches (blind sacs at the junction of the small and large intestines) were compared to the overall lengths of the GI tract. (Cecal pouches were not considered in these GI tract "lengths"). Cecal pouches were absent or virtually absent in 2 species examined (Red-tailed hawk, *Buteo jamaicensis* and Mourning doves (*Zenaidura macroura*). The other 8 species, numbers examined (N), and ratio of average single cecal pouch length to GI tract length (% basis) are given as follows: Bufflehead, *Bucephala clangula*, (N=1), 4.25%; Rock dove, *Columba livia*, (N=1), <1.00%; Japanese quail, *Coturnix c. japonica*, (N=4), 10.2%; Northern bobwhite, *Colinus virginianus*, (N=6), 9.35%; ring-necked pheasant, *Phasianus colchichus*, (N=2), 15.1%; Wild turkey, *Meleagris gallopavo*, (N=2), 15.1%; Chukar, *Alectoris chukar*, (N=1), 14.2%; Ruffed grouse, *Bonasa umbellus* (N=1), 42.9%, respectively. Cecal pouch length appears to increase substantially as the proportion of fibrous food material increases in the diet.

AN EVALUATION OF BROWN TROUT SPAWNING HABITAT IN A HYDROPEAKING TAILWATER. David A. Hewitt & Tammy J. Newcomb, Dept. of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, VA 24061. Brown trout *Salmo trutta* provide an economically significant fishery in the Smith River tailwater below Philpott Dam, VA. Brown trout recruitment may be limited and could detrimentally impact the fishery. Using habitat suitability indices (HSIs), we calculated the amount of available spawning habitat in three sites below the dam. Sites were chosen based on relative abundances of age-0 brown trout because age-0 fish have been shown to be correlated with spawning areas. Microhabitat in the three sites was characterized by water depth, velocity, dominant substrate, and percent fines (substrate < 2 mm). High quality spawning habitat was limited, comprising no more than 6% of the total area of any of the sites. The most available spawning habitat was at the site closest to the dam. The least available spawning habitat was in site two, where the greatest abundance of age-0 brown trout were captured. Age-0 brown trout distribution was not correlated with high quality spawning areas. We suspect that daily releasing flows may affect their distribution by washing young fish downstream and affecting other important habitat features such as food availability and water quality.

THE EFFECTS OF HYDROLOGY ON *Chamaecyparis thyoides* (B.) B.S.P. GROWTH IN WETLAND RESTORATION EFFORTS. Kristin M. Shacochis, Jefferey W. DeBerry, Darren T. Loomis, Robert T. Belcher, and Robert B. Atkinson. Department of Biology, Chemistry, and Environmental Science, Newport News, VA 23601. During the 1900's Atlantic white cedar, *Chamaecyparis thyoides* (L.) B.S.P., an obligate wetland species, declined by over 90% in Virginia and North Carolina due to ditching, logging, and fire suppression (Laderman 1989). Red maple (*Acer rubrum*) a facultative species, and other hardwoods have replaced cedar as a dominant species in many areas. To better quantify stand composition change, importance values (IV) and weighted averages (WA) were calculated for all stratum in two intermediate (10 to 30 year old stands) sites and two mature (50 to 70 years old stands) sites located in the Great Dismal Swamp and Alligator River national Wildlife Refuges. Cedar had the highest importance in Alligator River intermediate site (196) while the lowest IV occurred in Alligator River mature site (138). Alligator River mature had the lowest WA (1.01) and the highest WA occurred in Dismal Swamp Intermediate (1.86). Since WA is a measure of plant response to hydrology, higher WA in Great Dismal Swamp National Wildlife Refuge suggests that low water tables may be contributing to cedar decline. (Supported by Environmental Protection Agency).

A SURVEY OF AQUATIC RESOURCES IN TOM'S CREEK AND AN ASSESSMENT OF THE EFFECTS OF RIPARIAN ZONE ALTERATIONS. Terry L. Smith II, Aquaculture/Fisheries Dept., Univ. of Arkansas, Pine Bluff, AR 71601 & Tammy J. Newcomb, Dept. Fisheries and Wildl. Sciences, Virginia Tech., Blacksburg, VA 24060. Tom's Creek basin, near Blacksburg, Virginia is slated for development which may result in changes in the riparian zone. We sampled physical stream habitat, water quality, and the fish community to determine baseline conditions and we used a temperature model to evaluate riparian losses. Discharge ranged from 74 to 347cm³/s, the average stream width was 6.6 m and 40% of the stream was shaded. Dissolved oxygen and water temperature was high, 8.5 ppm and 26.2° C respectively. Nitrite was constant (0.05 ppm); nitrates ranged from 0.4 ppm to 0.2 ppm. Minnow species were most abundant and other species included smallmouth bass, sunfish, darters, madtoms, suckers, and the sculpins. On a summer day, removal of shading would increase the maximum daily temperature 1.2 – 2.7° C. The addition of shading would conversely reduce the maximum daily temperature by 1.64 – 3.3° C. Removal of the riparian zone along Tom's Creek would increase water temperature, which may result in changes in water quality and fish communities.

TEMPORAL AND SPATIAL PATTERNS IN USAF BIRD-STRIKE INCIDENTS, 1988-1997: IMPLICATIONS FOR MANAGEMENT. Christine A. Tedrow, P. F. Scanlon, J. A. Parkhurst, and S. L. McMullin. Dept. Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, VA 24061-0321. Analysis of strike data is critical to determine the true economic costs of bird strikes, determine the magnitude of safety issues, and develop preventive measures. Analysis of USAF bird-strike data identified trends and indicated suggested relationships among factors contributing to damaging strikes. From FY 1988 through FY 1997, the annual mean was 2,668 bird strikes with peaks evident in fall and spring. Daylight and dusk were hazardous for bird strikes. More bird strikes occurred during airfield operations and when aircraft were operating at low altitudes (and when soaring birds are more numerous). Aircraft speed, phase of flight, bird taxonomic group, bird mass and aircraft group were the strongest predictors of damaging bird strikes. Bird strike rates were calculated for USAF aircraft. Bomber aircraft had the highest strike rate; these aircraft frequently fly long missions at low altitudes where they are likely to encounter birds. The analyses indicated that factors contributing to USAF bird strikes overlap and interact. The study allows recommendations for improving reporting of bird strikes and data management as well as make recommendations for airfield management. Results will enable USAF to better focus research on preventing bird strikes, and assess the effectiveness of bird management programs.

EROSION PATTERNS OF SHOT TYPES IN DUCK GIZZARDS. Kristina C. Walski, P. F. Scanlon, J. R. Craig, and M. H. Sherfy. Depts. of Fisheries and Wildlife Sciences and Geological Sciences, Virginia Tech, Blacksburg, VA 24061. Spent shot is frequently ingested by waterfowl and upland bird species and retained in the gizzards. Therein the shot are subjected to physical grinding and chemical erosion in the highly acidic gizzard environment. To study erosion patterns of shot in the gizzards of blue-winged teal (*Anas discors*) 3 #4 lead, copper-jacketed lead, or steel shot were force-fed to each of 3 adult teal. Shot were recovered from the gizzards after 1, 2 or 3 days, and prepared for light and electron microscopy. Copper-jacketed shot appeared to be of a darkened color after 3 days in the gizzard, presumably indicative of erosion of the copper jackets. Indentations in the surfaces of the latter shot were apparent with light microscopy. The surfaces of lead and steel shot did not indicate unusual chemical compounds or wear patterns. However, copper-jacketed shot recovered after 3 days in the gizzard had pits in the copper jackets beneath which there was substantial erosion of the underlying lead, the pits were manifest as discontinuous areas in the sections of the copper jackets.

Geography - Section Officers meeting only.

Geology

ENGINEERING GEOLOGIC EVALUATION OF ROCK SLOPE STABILITY AT NATURAL BRIDGE, VIRGINIA. Chester F. Watts¹, Gary K. Rogers², & Daniel R. Gilliam¹, ¹Department of Geology, Radford University, ²Department of Civil Engineering, Virginia Military Institute. On Saturday October 23, 1999, a rockfall from beneath the arch of Natural Bridge Virginia resulted in a tourist fatality. A multidisciplinary advisory team was assembled on behalf of the owner by Dr. Rogers to examine stability of the archway as well as of the approach areas. Dr. Watts served as team engineering geologist. Remedial action was divided into three distinct operations: 1. rock scaling along gorge sidewalls and identification of potential future rock fall areas, 2. removal and/or stabilization of ceiling slabs underneath the arch, 3. development of short-term and long-term strategies for dealing with large potentially unstable rock formations identified along upstream and downstream approach areas to the arch. Janod Ltd of Canada scaled accessible sidewalls from ropes and secured rock slabs beneath the arch under the direction of the advisory team. Additional issues arose as work progressed, including questions regarding the use of the natural arch as a highway bridge for U.S. Route 11. The tourist attraction was reopened early in the spring of 2000.

SHRINK-SWELL PROPERTIES OF SOME CHESTERFIELD COUNTY SOILS. Jeff Pluta and W. C. Sherwood, Dept. of Geology and Environmental Science, James Madison Univ., Harrisonburg, VA 22807. Expansive soils in the United States are responsible for property damages ranging into the hundreds of millions of dollars each year. The shrink-swell behavior of soils is due to the presence of smectite clays, the most common being montmorillonite. Over the past three decades, expansive soils in Chesterfield County, Virginia have caused extensive structural damage to homes and other structures. Geologists and soil scientists working in Chesterfield County commonly use Atterburg Limits tests to predict expansive soil behavior. In this study, 18 soils and their Atterburg Limits test results were obtained from a consultant working in the County. Each soil was tested for expansion using the Potential Volume change (PVC) meter. The PVC swell index ratings were as follows: Very High - one soil, High - nine soils, Moderate - six soils, and Low - two soils. Correlation coefficients were than calculated for PVC results vs. Atterburg Limits, natural moisture content, D_{200} fraction, % clay, and ratios of these. R^2 values were universally low, varying from a low of 0.003 to a high of 0.270. The 0.270 value was for PVC vs. Plasticity Index. The poor correlations appear to indicate that the use of Atterburg Limits to predict shrink-swell behavior in soils is a questionable practice and more research is needed to identify or develop a rapid and accurate test to predict soil expansion.

CREATING A CD-ROM FOR THE SCIENCE CLASSROOM ON VIRGINIA'S COASTAL PLAIN. Phyllis L. Newbill¹, Parvinder S. Sethi¹, Robert C. Whisonant¹ & Karen K. Cecil², ¹Radford Univ., Radford, VA 24142 and ²Radford High School, Radford, VA 24141 & New River Community College, Dublin, VA 24084. The Geology of Virginia CD-ROM project was initiated with the goals of providing information about the geology of Virginia to earth science teachers, students, and citizens of the state in a way that is easy to access, practical for classroom use, and inexpensive. To meet these goals, we are creating a series of four interactive, multimedia CD-ROMs: *Introduction and Geologic Background*, *Coastal Plain*, *Piedmont and Blue Ridge*, and *Valley & Ridge and Appalachian Plateaus*. Each CD-ROM is accompanied by a Teacher's Guide with worksheets for students and answers for teachers. Each CD-ROM includes text, photographs, diagrams, animations, videos, music, sound clips, and slide shows. To create the CD-ROM, information was organized, screens were created and captured, links were created, slide shows were produced, and videos, sounds, and mouseovers were linked to the screens. This presentation features *CD-ROM 2: Coastal Plain*. A demonstration of the CD-ROM is provided in the presentation.

APPLICATION OF GIS TECHNOLOGY TO CIVIL WAR GEO-ARCHEOLOGY OF SALTVILLE, VA. Brendan T. Cox¹, Ryan C. Murley¹, B. Kuennecke², R. Whisonant¹, L. LeMay², & C. Boyd³. ¹Dept. of Geology, ²Dept. of Geography, ³Department of Sociology and Anthropology, Radford Univ. Saltville, Virginia has many historical aspects. The Civil War history is just one of these aspects. Radford University is part of a multidisciplinary project that involves locating undiscovered historical features. The focus of these investigations is the salt making process. This process leaves certain signatures that can be recognized by certain types of remote sensing. NASA's involvement in this project includes the use of the AVIRIS platform, which has never been applied to geo-archeology. A GIS database was needed to correlate the AVIRIS to other digital maps of the Saltville valley. This project focuses on the process and importance of this database. Digital maps of the geology and soils were produced and overlain on topographic maps as a foundation for this GIS database.

DESIGN AND DEVELOPMENT OF AN INTERACTIVE, MULTIMEDIA CD-ROM FOR TEACHING AND LEARNING OPTICAL MINERALOGY. William Smith, Mitch Bupp, & Parvinder S. Sethi, Dept. of Geology, Radford Univ., VA 24142. This paper presents results of an ongoing instructional technology project aimed at integrating the latest CD-ROM-based multimedia techniques into the GEOL-212 (Mineralogy) course at Radford University. The goal of this project was to obtain microphotographs and micro-videographs of a total of twenty-five common rock-forming minerals via a 35-mm SLR camera and a high-resolution micro-videocamera attached to a high-quality petrologic microscope and to digitize such photographs for creation of CD-ROM screens that can be used by students both in and outside of the classroom as an electronic study aid. This presentation will demonstrate some of the multimedia screens and the ease with which students can access microphotographs, micro-video clips and mineralogical information related to a particular mineral in thin section. The authors would like to thank the Office of the Vice-President for Academic Affairs for financial support. The authors would also like to thank the Mineralogy Class of Fall, 1999 for their input via a survey that was conducted prior to the design and initiation of the first phase of this project.

GRAIN SHAPE SIGNATURE DEVELOPMENT USING FOURIER SHAPE ANALYSIS: COMPARISON OF QUARTZ GRAINS IN NEW RIVER TERRACE DEPOSITS, RADFORD VIRGINIA. Josh C. Hickman¹, Kimball Knight¹ & Jill Alcorn², ¹Dept. of Geology, Radford Univ., ²Dept. of Mathematics and Statistics, Radford Univ. Fourier Shape Analysis of sediment grain shapes provides new opportunities for river terrace deposit correlation and hydrologic studies. Replacing the tedious and often erroneous visual grain shape analysis techniques, the computer software SigmaScan Pro was modified to reproduce an exact value for each individual sample making the process numerically precise and expedient. Utilizing this method, samples were collected from sites at various terrace levels along the New River in the Radford, VA, area, and analyzed. Results of this process were then consolidated and graphed producing a terrace grain shape signature. Work is now underway to quantify these results by running the same set of twenty grains numerous times and discovering the variation due to favored orientations of grains when the Fourier Shape Analysis is run.

FORENSIC GEOLOGY: APPLICATIONS OF GEOLOGY TO CRIMINAL INVESTIGATIONS.

Daniel S. Acker, Dept. of Geology and Environmental Science, James Madison Univ., Harrisonburg, VA 22807. The earliest applications of geology to criminal investigations are found in the 1887 fictional writings of Sir Arthur Conan Doyle. These writings provided the world with scientific ideas that, until that time, had only existed in the mind of the author. However, in 1904 the first of these imaginative theories began to take form, thus establishing the field of Forensic Geology. Today, virtually every law enforcement and regulatory agency collects earth materials for investigative and forensic purposes. However, validity of this forensic evidence is determined by the amount and quality of the data collected, and by the application of probability and statistics. Therefore, Forensic Geologists are required to utilize a myriad of technical and scientific laboratory procedures associated with their fields of expertise. These procedures, including stereo and petrographic microscopy, scanning electron microscopy, x-ray diffraction, and spectrophotometry, have contributed crucial scientific evidence necessary in establishing the guilt or innocence of many individuals. This research will examine these forensic applications of geology and why they have become a valuable aid in the apprehension and adjudication of criminal offenders.

THE INFLUENCE OF AGRICULTURE ON GROUNDWATER QUALITY: A

HYDROGEOLOGICAL AND GEOCHEMICAL PERSPECTIVE. Janie B.W. Vinson, East Carolina Univ. This study was designed to examine how agriculture affects the surficial aquifer of the Pete Mitchell Swamp Drainage Basin in North Carolina. Groundwater movement in the surficial aquifer is from north to south with a seasonal water-table fluctuation of 4.5 feet (ft); the annual mean groundwater discharge is 9.01 inches for a given unit of area. Transmissivity [2452-290.2 ft²/day (ft²/d)], horizontal conductivity (181.9-20.92 ft/d), storativity (2.087×10^{-7} - 9.031×10^{-6}), and specific yield (4.446×10^{-5} - 1.781×10^{-3}) were calculated from a constant-rate aquifer test and slug tests. Water samples from the surficial aquifer in 1993 generally occurred in the calcium sulfate hydrogeochemical facies with lithology (quartz, plagioclase and potassium feldspar) having a minor impact on groundwater chemistry. However, samples along a flow path in an agricultural area of the basin had elevated sulfate, calcium, and nitrate concentrations relative to groundwater samples from nonagricultural sites. A potential source of these elevated concentrations is agricultural applications. Dissolution of solid fertilizers increases the concentration and variety of ions in groundwater. Concentrations of sulfur and nitrogen species from fertilizers may also change according to the redox state of the system.

ROCKFALL HAZARD INVENTORY ALONG THE CASCADES TRAIL, JEFFERSON NATIONAL

FOREST, GILES COUNTY, VIRGINIA. Daniel R. Gilliam¹, Chester F. Watts¹, Paul Bartholomew¹, Kelly Burton¹ & Thomas K. Collins², ¹Dept. of Geology, Radford Univ., ²U.S.D.A.-Forest Service. In joint cooperation with the U.S. D.A.-Forest Service, the Department of Geology at Radford University has undertaken a study, still in progress, examining rockfall hazards at three sites along the Cascades Trail in Giles County, Virginia. The area lies within the Valley and Ridge province, in Ordovician and Silurian-aged rocks. Site 1 concerns a rockfall topple potential, dangerous in that the rock in question is used as a shelter during severe weather by hikers along the trail. Site 2 is the location of previous rockslides, and the remaining rock is examined for potential future failures. Site 3 is a cliff surrounding the waterfall itself, from which rocks occasionally fall and roll down toward Little Stony Creek, posing a threat to visitors and man-made structures below. The three sites are analyzed using stereonet for their structural integrity. The report which constitutes the outcome of the study will present a rockfall hazard analysis which can be used in developing remedial action plans, as well as to give recommendations and guidelines for future studies, and serve as a benchmark for monitoring future changes in the areas studied with respect to rockfall potential.

GEOMORPHOLOGY AND HYDROLOGY OF A MITIGATION WETLAND SITE, OCEANA RIDGE, VIRGINIA BEACH, VIRGINIA. Richard G. Whittecar, Dept. of Ocean, Earth, and Atmospheric Sciences, Old Dominion Univ., Norfolk, VA 23529 & Melanie A. Frisch, Virginia Dept. of Transportation, Suffolk, VA 23435. Abandoned sand mine pits along a relict barrier island in eastern Virginia Beach contain 3 ponds fed only by precipitation and groundwater. Well logs and nearby exposures suggest the surficial aquifer contains at least several meters of medium-to-coarse sand. Analyses of water table wells indicate groundwater passes through the ponds as it moves away from the ridge crest to small creeks nearby. Effective Monthly Recharge (W_{em}) calculations suggest that the pond levels respond to major recharge events with a two-to-three month lag. Plans call for the creation of new wetland areas around and between two ponds that have nearly identical water level histories. According to the W_{em} analysis, from 1945 to 1995 the elevations of this new wetland surface were inundated for at least half of the growing season during more than 70% of the years of record. Thus this proposed wetland site should have sufficient hydrology from groundwater alone to maintain a viable wetland.

NOISE REDUCTION FOR IMPROVED MAGNETOTELLURIC SOUNDING. Michael Wallace & John Wallace, Hampden-Sydney College and Casting Analysis Corporation. Magnetotelluric sounding is a geophysical surveying method for finding conducting layers such as ore bodies and aquifers. To use this method, one must be able to sample and calculate small low frequency electric and magnetic field values simultaneously. In areas with power grids, filtering, data capturing and source analysis must all be taken into account. Adjusting the design of filtering electronics in a multi-channel analyzer and making the sensors portable diminished the noise sampled where measurements of electric and magnetic fields could be measured accurately. Now only a small amount of data is needed to measure the conductivity structure of the earth. With the reduction in ambient noise geomagnetic pulsations can be isolated over a spectral range. The initial phase of development for the system is complete. The next phases are creating a user interface and reducing the design to a large FPGA for a more compact instrument and implementing the different analysis models within the system for active and passive sensing.

SAND FRACTION STUDIES OF THE NORTH RIVER FLOODPLAIN, ROCKINGHAM COUNTY, VIRGINIA. Michele Butczynski and W. C. Sherwood, Dept. of Geology and Environmental Science, James Madison Univ, Harrisonburg, VA 22807. Floodplain sediments along the North and Dry Rivers in Rockingham County, Virginia are composed mainly of medium to fine sands weathered from the clastic rocks in the ridges west of the Shenandoah Valley. Sediment samples were collected from ten specified locations along the rivers starting upstream at the junction of Routes 613 and 732 and ending downstream off of Route 659. The sand fraction of each sample was analyzed in the laboratory using the phi gradation method. Based on statistical treatment of the results, several trends were noted: 1) The -230 fraction showed a general increase, and the mean sand size a general decrease from upstream to downstream; 2) standard deviation decreased downstream indicating an increase in grain sorting; 3) skewness values were positive at the first three stations but turned increasingly negative downstream; 4) compared to the relatively large positive skewness values reported for stream sands in the literature, all skewness values in this study were small, ranging from +0.27 to -0.48. Finally kurtosis, a measure of peakedness of the size distribution curve, increased downstream reflecting the increase in sorting noted above.

SLOPE STABILITY ANALYSIS RELATED TO ROAD IMPROVEMENT AND WIDENING OF ROUTE 705 IN MONTGOMERY COUNTY, VIRGINIA. Matthew L. Thornton & Chester F. Watts, Dept. of Geol., Radford University, Radford, Va 24142. Route 705 is an all weather surface road that passes through numerous road cuts that vary in lithology and orientation. The focus of this research applies to the Price Formation road cut in section 6 within the Virginia Department of Transportation (VDOT) modification designs (2000). The stereonet analysis performed on this road cut shows Markland's Tests in relation to plane, toppling and wedge failures. In site 1, part 1 plane failures are caused by steep joints and some faults, topple failures exist, and there are no current wedge failures. In site 1, part 2 plane failures are caused by steep joints and faults, topple failure exists, and there is one wedge failure that does not fall in the super critical zone. VDOT modification designs cut the current slope to forty-five degrees and sustain the current road trend at this site. Based on VDOT modification designs: site 1, part 1 will show no plane failures, no wedge failures, and no toppling failures; site 1, part 2 will show minimal plane failures, no wedge failures, and no toppling failures. It is recommended that the current slope could be remediated to forty-five degrees with minimal failures after modification.

MORPHOLOGY AND STRATIGRAPHY OF CAROLINA BAYS IN CHESTERFIELD COUNTY, VIRGINIA Sara E. Spradlin & Gerald H. Johnson, The College of William and Mary. Carolina Bays, which occur only on the Atlantic Coastal Plain, are elliptical to irregular depressions with single, multiple, or no sand rim. In Chesterfield County, Virginia over 165 Carolina Bays, most previously undescribed, are found on undissected uplands of the Middle and Upper Coastal Plain. Approximately 50 bays occur at an elevation of 115 to 100 m on the Midlothian Uplands, and the remainder on the Richmond Plain at 70 to 65 m. The Carolina Bays in Chesterfield County vary in shape from elliptical to irregular, in long axis length from 75 to 800 m, from single to compound, in orientation, and in degree of rim development. This study focused on Salisbury Bay on the Midlothian Uplands, and Baugh Bay on the Richmond Plain. Sediments in both bays were texturally and mineralogically similar to each other and to the parent material on which they formed. Salisbury Bay was slightly coarser and contained more varieties of quartz than Baugh Bay. Conditions necessary for Carolina Bay formation are: a relatively flat land surface, a denuded landscape, a prevailing wind, and a high water table. Of the many hypotheses that have been proposed to explain the origin of Carolina Bays only Thom's 1970 wind and water hypothesis meets most of these criteria.

Materials Science

INVESTIGATION OF THE ATMOSPHERIC CORROSION INSIDE THE LULING BRIDGE, NEW ORLEANS. Desmond C. Cook & Ann C. Van Orden (dec.), Old Dominion University, Norfolk, VA 23529. The corrosion products formed on the interior weathering steel box-sections of vertical support piers of the Luling Bridge in Louisiana, have been analyzed and compared with those formed on atmospherically exposed coupons for which the protective oxide layer is very adherent and stable. It was determined that very high fractions of large particle maghemite form in the hot and humid conditions inside the boxes. The high time-of-wetness also significantly reduces the fraction of nano-phase goethite which forms and this, along with the presence of maghemite, most likely prevents the formation of the adherent protective corrosion coating needed to reduce the long term corrosion of weathering steel. Spectroscopic analysis showed that the corrosion product composition varied with height of the box-sections in the pier, most likely due to the different local environmental conditions within each enclosed box. In general the corrosion products contained about 30% maghemite and 60% goethite which is very different to the composition found on well protected weathering steel and more like that found on carbon steel exposed in a mild marine environment. The large amount of sheet-like rust within the box-sections, supports the argument that insufficient wet-dry cycling conditions are available for proper protective coating formation.

THE INVESTIGATION OF CREVICE CORROSION USING COMPUTATIONAL MODELING. Jason S. Lee & Robert G. Kelly, Dept. of Mat. Sci. & Eng., Univ. of Virginia, Charlottesville, VA 22904. A two-dimensional computational model for mass transport in occluded regions has been developed at The Univ. of Virginia. The model maps the spatio-temporal chemical and potential fields within a crevice in two dimensions, taking into account diffusion, migration, and generation of species. One key characteristic of the model is its ability to handle two spatial dimensions. Crevice corrosion of nickel in 1N H₂SO₄ will be one of the systems that will be studied and presented. The results from an array of boundary conditions (e.g., gap, potential, critical current density, anodic polarization behavior) will also be presented, along with parameters predicted from the computational model (e.g., position of maximum attack).

PHOTOELECTROCHEMICAL ETCHING OF III-V COMPOUND SEMICONDUCTORS. Todd M. Harrell & Wm. Christopher Hughes, Dept. of Physics, James Madison University, Harrisonburg, VA 22801. The etching of the III-V compound semiconductor GaAs by photo-assisted electrochemical techniques has been studied. Samples of GaAs were patterned using conventional photolithography and then placed in KOH-containing solutions. While weak etching can be observed even without external biasing, the etch rate is dramatically increased by anodically biasing the sample. In addition, the etch rate was increased by the addition of hydrogen peroxide to the bath. Steep side walls were observed on mesa-like features to a depth of 2 or 3 microns under uniform illumination with ambient room light. Beyond this, the side walls tapered away due to shadowing effects. Potential mechanisms for the etching process and extension of these experiments to GaN will also be discussed.

LASER SPECTROSCOPY OF Cr²⁺ AND Co²⁺ DOPED CADMIUM CHALCOGENIDES. A. G. Bluiett, U. Hömmerich, J. T. Seo, M. Turner, S. B. Trivedi, S. W. Kutcher, R. J. Chen, C. C. Wang & H. Zong, Research Center for Optical Physics, Hampton University, Hampton, VA 23668 & Brimrose Corporation of America, 5020 Campbell Blvd., Baltimore MA 21236. Mid-infrared (MIR) lasers which are broadly tunable and operational at room temperatures are of interest for various applications. Transition metal (TM) doped solids is a favorable candidate for broadly tunable lasers, due to their vibronic operation. Further, Cr and Co doped II-VI semiconductors have shown broad absorption and emission bands in the MIR. At Hampton University, Cr and Co doped Cd_{0.55}Mn_{0.45}Te are currently being analyzed for their potential for MIR lasers. These TM shows a strong preference for the tetrahedral sites in Cd_{0.55}Mn_{0.45}Te, which is conducive to stronger transition strengths, due to the host's odd-parity crystal field. Concurrently, Cr and Co doped Cd_{0.55}Mn_{0.45}Te possess broad absorption bands at 1900nm with corresponding transition from the ⁵E to ⁵T₂ quintet spin states and ⁴A₂ and ⁴T₁ quadruplet spin states, respectively. Emission bands for Cr and Co doped Cd_{0.55}Mn_{0.45}Te are red shifted to 2500nm (FWHM:720nm) and 3700nm (FWHM:550nm).

MEASUREMENT OF THE BREAKDOWN AND REPASSIVATION POTENTIALS OF TITANIUM GRADE 5 AND TITANIUM GRADE 2 IN 3.5% NaCl SOLUTION. Mark W. Percy & Desmond C. Cook, Dept. of Physics, Old Dominion University, Norfolk, Va. 23529. The Repassivating and Breakdown potentials for grade 5 titanium (Ti-6Al-4V) and for grade 5 coupled with grade 2 titanium in 3.5% NaCl solution at varying pH were measured by Electrochemical Impedance Spectroscopy (EIS) using the cyclic polarization method. Determining these potentials established pitting corrosion behavior of the metals. The repassivation and breakdown potentials for grade 5 titanium were much lower than those of grade 2 titanium. The pH of the electrolyte had no significant effect on either the repassivation or breakdown potentials of grade 5 titanium, but did appear to have an effect on the corrosion rate of the metal. Coupling of the metals resulted in no significant change in either the repassivation or breakdown potentials for grade 5 titanium. Coupling the metals did result in an unexpected increase in the metal's corrosion rate below the repassivation potential for grade 5 titanium. It appears that the coupling of the metals has a more pronounced effect on how well the protective oxide layer protects the metal from corroding than does the pH of the electrolyte.

A COMPARISON OF THE LOCALIZED COATING FAILURE OF AA1100-H14 AND AA2024-T3. Jackie M. Williams, Oliver Schneider, & Robert G. Kelly, Center for Electrochemical Science and Engineering, Department of Materials Science and Engineering, University of Virginia, Charlottesville, VA 22904. To successfully improve coating systems used for corrosion protection on aircraft, a detailed understanding of the mechanism of coating failure leading to blister formation and subsequent localized corrosion is necessary. Coating blisters grown on AA2024-T3, a high-copper content aluminum alloy (4.5% Cu) used extensively in aircraft construction, are characterized by a red color due to replated Cu. The effects of the replated Cu on blister formation and growth and the chemistry inside these defects were studied by comparing blister behavior on AA2024 to that on AA1100-H14, a low-copper content aluminum alloy (0.12% Cu). Coated panels of AA1100 were exposed to corrosive salt solutions known to cause blister growth on AA2024. Both global electrochemical measurements and a combination of local chemical and electrochemical analyses inside individual blisters provided a means of measuring and determining the effects of replated Cu on the corrosion and chemistry inside these defects.

ELECTROCHEMICAL DEPOSITION OF METALS ON SEMICONDUCTORS. Sharon E. Koh & Wm. Christopher Hughes, Dept. of Physics, James Madison University, Harrisonburg, VA 22801. Electrochemical techniques have been examined for the metallization of III-V compound semiconductors in conjunction with soft-lithographic methods. In particular, Zn, Cu, and Ni have been electrodeposited on GaAs and ohmic contacts consisting of Cu with a Ni barrier layer have been formed. Depositions were performed using specimens patterned by conventional photolithographic techniques to optimize the electrodeposition process. As an alternative to conventional photolithography, soft-lithographic methods utilizing self-assembling monolayers (SAMs) of 1-hexadecanethiol (HDT), 16-mercaptohexadecanoic acid (MHA), and octadecylphosphonic acid (OPA) are being examined. Contact angle measurements have been taken to determine the usefulness of each of these possible SAM-forming molecules on GaAs and GaN. Dramatic changes in the wettability were observed for OPA-coated (100) GaAs. A similar, though less dramatic effect was observed for (0001) GaN. Mixed results were observed for the formation sulfur-terminated HDT and MHA monolayers on both GaAs and GaN. Possible explanations of these results and the use of these monolayers as ultra thin deposition and etch masks will be discussed.

SYNTHETIC CHROMIUM SUBSTITUTED GOETHITE. Rama Balasubramanian, D. C. Cook, Dept. of Physics, Old Dominion Univ., Norfolk, VA 23529 & M. Yamashita, Dept. of Mechanical Engineering, Himeji Institute of Technology, Japan. Chromium substituted goethite is most commonly found in the corrosion products of weathering steel. It has been observed that the formation of nano-sized goethite particles is related to the presence of chromium in the weathering steel. To understand corrosion protection properties of nano-phased goethite in a coating, synthetic chromium substituted goethite have been investigated. Chromium substituted goethite, $\alpha\text{-Fe}_{(1-x)}\text{Cr}_{(x)}\text{OOH}$ (where $x=0, 1.44, 3, 7, 10.14$ wt.%) were synthetically produced. The magnetic and crystalline properties of the samples were studied using Transmission Mössbauer spectroscopy and x-ray diffraction. As the chromium concentration increased from 0 to 10 wt.%, the particle size decreased rapidly from 200 nm to 10 nm. No appreciable lattice strain was observed. From Mössbauer measurements, the blocking temperature was determined to be 320 K for 10.14 wt. % chromium substituted goethite. The anisotropy constant for the 10.14 wt. % substituted Cr was found to be $4.23 \times 10^3 \text{ J/m}^3$. For both pure and chromium substituted goethite, the asymmetry in the doublet of Mössbauer spectrum recorded between 300 and 400 K was attributed to two contributions, one from the bulk and the other from the surface of the material.

THE INFLUENCE OF HARD SECOND PHASES ON THE FRICTION AND WEAR BEHAVIOR OF POLYMER MATRIX COMPOSITES USED IN BRAKE LINING APPLICATIONS. Jennifer A Wilcox & Dana Elzey, Dept. of Materials Science, The University of Virginia, Charlottesville, Va, 22904. Hard second phases in polymer matrix composites may play several distinct roles during sliding wear, including stiffening/strengthening of the polymer matrix, abrasive cleaning of the countersurface, and reducing the overall composite wear rate. However, debris particles generated during wear may lead to accelerated wear rates by acting as an abrasive at the sliding wear interface. Improved fundamental understanding of the multi-functional character of hard second phases is needed in order to refine, improve, or replace existing friction and wear models. Our investigation emphasizes the influence on the friction material's performance of the intrinsic properties of second phases considered hard relative to the matrix. Model composites will be made consisting of a selected (phenolic-based) polymer matrix combined with one or two second phases (SiC, Al₂O₃, SiO₂) followed by sliding wear testing. A sliding friction and wear tester was designed and built for this purpose which provides for maximum control of experimental variables such as applied load and sliding velocity. This study is funded by Carlisle Motion Control Industries, Inc.

OPTICAL AND LASER PROPERTIES OF A MID-INFRARED GAIN MEDIUM CR²⁺ DOPED Cd_{0.55}Mn_{0.45}Te. M.C. Turner¹, U. Hšmmerich¹, J.T. Seo¹, A. Bluiett¹, S.B. Trivedi², H. Zong², S.W. Kutcher², C.C. Wang² & R.J. Chen², ¹Department of Physics, Hampton University, Hampton, VA 23668 and ²Brimrose Corporation of America, 5020 Campbell Blvd., Baltimore, MD 21236. Recently there has been much interest in developing mid-infrared lasers. These lasers have many applications including laser remote sensing, medicine, and spectroscopy. Using a Cr,Tm,Ho :YAG laser, operating at 2.09μm, initial laser studies of Chromium-doped Cd_{0.55}Mn_{0.45}Te were performed. Room temperature lasing with tunable coverage from 2.17μm to 3.01μm is reported. The lasing medium has been identified to be Cr²⁺. Laser action with slope efficiencies as high as 44% were obtained. Chromium-doped Cd_{0.55}Mn_{0.45}Te was grown by a modified Bridgman technique using a three heating-zone furnace. This mid-infrared optical material can be commercially produced with high mechanical and optical quality. Details on the optical and laser properties of the material will be presented at the conference.

PHASE EQUILIBRIA OF NANOPARTICLES. C. Tom Schamp & William A. Jesser, Dept. Of Materials Science and Engineering, University of Virginia, Charlottesville, VA 22903. It has been found that as particle size gets small, the properties begin to deviate from that of bulk. To study this effect, nanoparticles with diameters of less than 50nm are used. This effect is a result of the large surface to volume ratio ($\frac{A}{V} = \frac{3}{r}$, assuming spherical particles). The particles are formed by co-vapor deposition onto heated amorphous carbon coated TEM grids in an ultra-high-vacuum system. Energy Dispersive X-ray Spectroscopy (EDXS), Nano-Beam Diffraction (NBD), and bright-field TEM imaging are used to study alloy BiSn nanoparticles. Data indicating that the two-phase size-dependent room-temperature phase boundary pinches off at about 10nm in diameter is shown. The recent data of the sub-eutectic size dependent phase diagram for the BiSn system is shown. This data is plotted with the previously published data of the pro-eutectic portion of the size dependent phase diagram.

Medical Sciences

THE EFFECTS OF IL-1 AND IL-6 ON AORTIC SMOOTH MUSCLE CELL MIGRATION AND GROWTH. Andrea Rossi & Kathryn Loesser, Dept. of Biol., Mary Washington Col., Fredericksburg, VA 22401. Atherosclerosis involves the recruitment of many cells and factors, including smooth muscle cells. Previous research has suggested that interleukins play a role in the migration and proliferation of smooth muscle cells during plaque formation. The hypothesis tested in this experiment was that IL-1 and IL-6, introduced separately, would increase smooth muscle cell migration. A Boyden migration chamber was used to determine that in all cases, the interleukins increased cell migration, as compared with the control. IL-6, at a concentration of 0.4 ng/ml, had the greatest impact on migration with a 200% increase in migration from controls in each trial. Migration of cells in presence of IL-6 at 0.4ng/ml and IL-1 at 100ng/ml both showed statistically significant differences from the control, and IL-6 was statistically different from IL-1 at 100ng/ml and IL-6 at 0.2ng/ml. When compared with the control, IL-6 0.4ng/ml increased migration by an average of 270 +/- 33.3 % and IL-1 100ng/ml had a mean increase in migrated cells, as compared with the control, of 49.3 +/- 21.2 %. Further studies investigating the role of interleukins on smooth muscle cell actions during atherosclerotic lesion formation would be helpful in determining the specific role of IL-1 and IL-6 in the atherosclerotic process.

OPIOID RECEPTOR LEVELS IN Δ^9 -THC- AND MORPHINE-TOLERANT MICE. Diana L. Cichewicz and Sandra P. Welch, Dept. of Pharmacology, Virginia Commonwealth Univ., Richmond, Va. 23298. We have shown that after short-term administration of a combination of low doses of THC and morphine p.o. to mice, there is no behavioral tolerance to the opioid. If we have been able to prevent tolerance to morphine by co-administering THC, then we should not see the manifestation of that tolerance at the receptor level. We evaluated the levels of opioid (μ , κ , δ) and cannabinoid (CB1) receptors in mouse models of short-term exposure to THC, morphine, or both drugs in combination. Tissue samples (midbrains and spinal cords) were collected from mice treated for 5-7 days. Western blot analysis revealed that μ receptor levels are significantly decreased in morphine-tolerant mouse midbrains, confirming previous laboratory results. We also saw that in animals treated with a combination of low doses of THC and morphine for several days, there was no change in opioid receptor levels in the midbrain. This indicates that our prevention of behavioral tolerance to morphine is substantiated by a lack of opioid receptor down-regulation. Further studies with spinal cord tissue are in progress to elucidate receptor levels in tolerant and non-tolerant mice.

PROPERTIES OF Fe-SUPEROXIDE DISMUTASE FROM PORPHYROMONAS ASACCHAROLYTICA. E. A. Clark & E. M. Gregory, Dept. of Biochemistry, Virginia Tech, Blacksburg, VA. *Porphyromonas assacharolytica* is a gram-negative anaerobe frequently isolated from infected bite wounds. The anaerobe synthesized the antioxidant enzyme superoxide dismutase (SOD) which catalyzes the disproportion of superoxide radical. *Porphyromonas assacharolytica* SOD was isolated to electrophoretic homogeneity. The isolated protein had a specific activity of 2100 Units/mg. The SOD eluted from calibrated Sephadex G-100 as a 40kD protein and as a single 20kD protein in SDS-PAGE. The *Porphyromonas assacharolytica* SOD is therefore a dimer of equally sized subunits. The SOD was instantaneously inhibited by low concentrations of sodium azide and was 50% inactivated after 10 minutes incubation H_2O_2 , characteristic of iron-containing SOD. This indirect evidence is consistent with synthesis of an iron-containing SOD in *Porphyromonas assacharolytica*. (Supported in part by Va. Tech Biological Sciences Initiative. A portion of this work was completed by EAC as a Fralin Biotechnology Summer Fellow)

PHYTOESTROGENS AS CALCIUM CHANNEL MODULATORS IN THROMBIN-ACTIVATED HUMAN PLATELETS. Y. Dobrydneva¹, R.L. Williams¹ & P.F. Blackmore². ¹Department of Chemistry and Biochemistry, Old Dominion University, Norfolk, VA 23529 and ²Eastern Virginia Medical School, Norfolk, VA 23501. Previously we have shown that phytoestrogenic compound *trans*-resveratrol inhibits platelet function by inhibiting calcium influx into activated platelets. In the present study, using the method of radiometric dyes for monitoring free intracellular calcium concentration it has been shown that most abundant dietary phytoestrogens, namely genistein and daidzein, inhibit calcium influx into thrombin-stimulated human platelets, thus preventing aggregation. These phytoestrogens are also inhibiting thapsigargin-induced calcium influx and basal activity of calcium channels, and genistein glucoside is also active suggesting that phytoestrogens are directly modifying the activity of SOCC (store-operated calcium channels). IC_{50} for genistein and daidzein to inhibit platelet function is in low micromolar range, which can be physiologically achieved in plasma by moderate consumption of phytoestrogen-rich foods. Therefore these compounds may serve as natural blood thinners. (This work was supported by grant from Jeffress Memorial Trust).

CHARACTERIZATION OF *SPHINGOMONAS CAPSULATA* SUPEROXIDE DISMUTASE. S. J. Free and E. M. Gregory, Dept. of Biochemistry, Virginia Tech, Blacksburg, VA. Superoxide dismutase (SOD), a metalloenzyme, was isolated 176 fold from *Sphingomonas capsulata* to a specific activity of about 2,500 units/mg. Native polyacrylamide gels stained for superoxide dismutase activity revealed a single band of activity in cell extracts (14.4 units/ mg) or as isolated. Under the growth conditions imposed, *Sphingomonas capsulata* synthesizes only one type of SOD. The molecular weight of the SOD was 40,000 based on chromatography through calibrated Sephadex G-100. Sodium azide (0.5 mM) inhibited SOD activity by 50%. SOD was also rapidly inactivated upon incubation with H_2O_2 . One hour incubation of the enzyme with hydrogen peroxide (2mM) resulted in 90% inactivation. SOD rapidly lost activity at pH <4 but remained stable up to pH 9. Modest inactivation was observed at pH > 9. These data are consistent with synthesis of a single Fe-containing SOD in *Sphingomonas capsulata*. (Supported in part by Va. Tech. Biological Sciences Initiative. A portion of this work was completed by SJF as a Fralin Biotechnology Summer Fellow)

MATHEMATICAL MODEL OF THE GROWTH AND TREATMENT OF *IN VITRO* CARCINOMA CELL CULTURES - EFFECTS OF THE NOVEL MICROTUBULE PERTURBING AGENT CURACIN A. Frank P. Kozusko¹, Billy W. Day² & John C. Panetta³, ¹Department of Mathematics, Hampton University, Hampton, Virginia 23668, ²University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania 15238 and ³St. Jude Children's Research Hospital, Memphis, Tennessee 38105. A mathematical model of cancer cell growth and response to treatment with the antimetabolic drug curacin A is presented. Rate parameters for the untreated growth of A2780 ovarian and MCF-7/LY2 breast cancer cell lines are determined from *in vitro* growth studies. Subsequent growth studies with 2.5nM, 25nM and 50nM doses of curacin A are used to determine the effects of the drug on the cell cycle. The model's system of ordinary differential equations yields an approximate analytical solution which predicts the minimum drug dose necessary to prevent growth. The model shows that cell growth is arrested when the apoptotic rate is greater than the mitosis rate and that the S-phase transition rate acts to amplify the effect. The drug is rapidly absorbed into the cells of both cell lines causing an increase in the S-phase transition and a decrease in the M-phase transition. The rate of apoptosis remains virtually constant for MCF-7/LY2 while that of A2780 increases.

AGE-RELATED PRODUCTION OF α β -CRYSTALLIN AND UBIQUITIN IN RAT MYOCARDIUM. Merissa J. Lantz & Kathryn E. Loesser, Mary Washington College. Young animals can tolerate high fevers, a form of major stress, for long periods of time, where as adult animals cannot. Research shows that a class of proteins, heat shock proteins (hsp) are expressed in animals after periods of stress. They have been implicated in protein chaperoning, protein protection and protein folding. This research focused on two hsp. Ubiquitin has a small molecular weight and is associated with the break down of proteins. Alpha B-crystallin, another small molecular weight hsp, has been shown to have a chaperoning function to prevent aggregation and help with protein folding. The goal of this research was to determine whether juvenile animals constitutively express heat shock proteins. Juvenile and adult rats were heat shocked, allowed to recover, and their hearts were analyzed for the presence of hsp. The heart samples were homogenized; the protein concentrations determined, polyacrylamide gel electrophoresis (PAGE) was performed. Using Western Blot trials and monoclonal anti-ubiquitin and anti- α B-crystallin protein presence was detected. The results showed that juvenile rats did have constitutive expression of the proteins. The adult rats only had expression of the proteins after being heat shocked. More studies need to be done to further prove these findings.

TUMOR-INDUCED MACROPHAGE DYSFUNCTION IS MEDIATED VIA DYSREGULATION OF CD40L EXPRESSION. Ryan S. Martins¹, David W. Mullins², & Klaus D. Elgert¹, ¹Dept. of Biol., Virginia Tech, Blacksburg, VA 24061 and ²Carter Immunology Center, Univ. of Virginia, Charlottesville, VA 22901. Tumors evade immune responses, in part, through the release of suppressor signals that dysregulate host effector cell function. We demonstrate that tumor growth suppresses immune activation by inhibiting T cell CD40L expression, disrupting macrophage (M ϕ) activation pathways, which impairs production of immunostimulatory mediators, interleukin (IL)-12 and IL-18 by tumor-bearing host (TBH) M ϕ s. IL-12 and IL-18 production by normal M ϕ s is lowered upon incubation with tumor-derived supernatants, demonstrating the role of tumor-derived factors. Disruption of CD40L expression, via dysregulation of IL-12 and IL-18 production, impedes T cell interferon (IFN)- γ , which in turn exacerbates M ϕ dysfunction. IFN- γ is essential for expression of IFN consensus sequence binding protein (ICSBP); TBH M ϕ s demonstrated lowered expression of ICSBP, which regulates CD40L, IL-12 and IL-18 expression through the IFN-stimulated response element (ISRE). Thus, dysregulated CD40L expression significantly contributes to tumor-induced immune dysfunction. (This study was supported, in part, by The Virginia Academy of Science.)

ADOPTIVE TRANSFER OF LYMPHOCYTES FROM TYROSINASE-DEFICIENT ANIMALS MEDIATES AUTOIMMUNE VITILIGO IN HLA-A*0201-TRANSGENIC MICE. D.W. Mullins, T.A. Colella, T.N.J. Bullock, C.J. Luckey & V.H. Engelhard, Carter Immunology Center, University of Virginia, Charlottesville, VA 22908. Antigens recognized by melanoma-reactive CTL may originate from melanocyte differentiation proteins (MDPs), including the pigmentation enzyme tyrosinase. We used a murine model to test the impact of tyrosinase expression on immune effector populations. Following adoptive transfer of CTL specific for the HLA-A*0201-restricted tyrosinase epitope (FMDGTMSQV), transgenic mice expressing the HLA-A*0201 molecule developed vitiligo, consistent with CTL-mediated destruction of melanocytes. Naïve splenocytes from HLA-A*0201+ mice with a radiation-induced deletion of the tyrosinase gene also induced vitiligo on adoptive transfer, demonstrating that tyrosinase-derived antigens are expressed in an immunogenic context. These results suggest that an active self-tolerance mechanism may limit the development of vitiligo under normal circumstances. Collectively, these data demonstrate that CTL-based adoptive transfer therapies directed against tyrosinase can overcome peripheral tolerance and induce melanocyte destruction. As vitiligo has been associated with spontaneous melanoma regression, these data suggest that MDPs are useful targets for immunologic intervention in melanoma patients.

REVERSAL OF MORPHINE TOLERANCE WITH THE PKA INHIBITOR, KT5720. Alicia A. Robinson & Sandra P. Welch, Dept. of Pharmacology & Toxicology, Virginia Commonwealth University, Richmond, VA 23298. Previous work in our laboratory demonstrates that the PKA inhibitor, KT5720, can reverse tolerance to morphine. We now report the time-course administration of KT5720 reversal of morphine tolerance. Male ICR mice were implanted with either a placebo pellet or 75mg morphine pellet. The mice were subsequently injected twice per day with morphine (20 mg/kg, s.c.). Tolerance was induced in the mice as determined by a shift in the ED50 for morphine from 2.1 mg/kg (1.3-3.6) to 18.3 mg/kg (13.5-24.7) as determined using the tail-flick test. The acute administration of DMSO vehicle or KT5720 (1.3 microgram/mouse, i.c.v.) did not alter the ED50 for morphine in placebo-pelleted mice. However, the administration of KT5720 (i.c.v.) simultaneous with a morphine challenge dose s.c., in morphine-tolerant mice, reversed tolerance observed in such mice. The ED50 for morphine-tolerant mice was shifted significantly to the left (ED50 = 5.8 mg/kg [4.5-7.4]) and did not differ for mice that were placebo-pelleted and not morphine-tolerant (ED50 = 3.5 mg/kg [1.8-6.7]). These data confirm that KT5720 reverses tolerance, however, additional data suggest the reversal is only transient. Work supported by NIDA grants KO2DA00186 & DA05274 .

Natural History and Biodiversity

SAMPLING TECHNIQUES FOR TERRESTRIAL SALAMANDERS. Carola A. Haas¹, Douglas N. Harpole², Shannon M. Knapp³ & Donald G. Mackler¹. ¹Department of Fisheries and Wildlife Sciences, Virginia Tech., Blacksburg, VA 24061 ²(current affiliation) Virginia Cooperative Extension Service, ³(current affiliation) US Fish and Wildlife Service. Salamanders are difficult to observe and much information can be obtained only by capturing and marking animals. We discuss 3 capture methods (night-time area constrained searches, day-time time constrained searches, and coverboards). Night searches appear to give the least biased estimates of species, age, and sex classes present in the population. There are few reports on successful marking techniques for salamanders. As others have found, we had good success with toe-clipping for a study of short duration, but this technique is difficult on salamanders with very small toes. The most promising techniques appear to be injected fluorescent pigments (challenge is placing pigments where they can be seen on dark-bodied salamanders) which work well on small fish and pit tags (challenge is placement in a small salamander) which are retained by salamanders when incisions are closed with surgical glue. Work developing and comparing capture and marking techniques is essential to our ability to answer questions about behavior, ecology, and conservation of this important but little studied group.

ANT DEFENSIVE BEHAVIORS IN RESPONSE TO ANTING BY SONGBIRDS. Hannah C. Revis, Old Dominion University, Norfolk, VA, 23529. Anting behavior is defined as the application of ants, held in the bill of a songbird, to it's own plumage. The defensive reaction, relative to songbird anting behavior, of five genera in subfamilies Myrmicinae and Formicinae was examined. Study hypothesizes were: 1.) ant pair trials would produce similar ant responses, 2.) a significant effect would exist between temperature/humidity upon ant responses. Ant genera were chosen based upon their average size and general defensive mechanism (mechanical vs. chemical). Ant paired trials consisting of two trays, each holding 20 ants, were conducted at the Virginia Living Museum Songbird Aviary, Newport News, VA. Ant defensive reactions were identified as active running or a group clumping response. Alarm pheromones emitted by ants under duress have low molecular weights and low specificity. This allows different ant species to respond to a perceived danger. Commonly perceived alarm pheromones suggest a similar response between ant pair trials would exist. While a significant difference did exist between the total response of the five genera, no significant difference existed between paired trials (Kruskal-Wallis test, $p=0.032$, & $p=0.684$ respectively). A two-factor ANOVA of temperature & humidity on ant response found no significant difference ($p=0.1654$).

ANTENNAE OF DIFFERENT TERMITE CASTES COMPARED USING LIGHT AND SCANNING ELECTRON MICROSCOPY. John Di Cicco, Keith Carson & Deborah Waller, Old Dominion University, Norfolk, VA, 23529. Termites perceive the environment through the sensillae on their antennae via chemo- and mechanoreception. Food, nestmates and enemies are all sensed through the antennae. Termite workers and soldiers have different functions in the colony and we hypothesized that the morphology of their antennae would reflect these differences. We compared the antennae of the Eastern Subterranean Termite, *Reticulitermes flavipes* (Rhinotermitidae, workers and soldiers using light and scanning electron microscopy. Termites from two colonies (five workers and five soldiers per colony) were collected from southeastern Virginia and examined for number of antennal articles, terminal article length, total length of the antenna and scape length. Worker and soldier antennae differed significantly in number of antennal articles and terminal article length, but they did not differ in total length of the antenna or scape length. Article shape differed between workers and soldiers; articles on soldier antennae appeared to have a neck while those of workers did not. Antennae of both workers and soldiers had circular patterns of setae on both the scape and the pedicel.

COMPARISON OF SPAWNING AND NON-SPAWNING SUBSTRATES IN NESTS OF SPECIES OF *EXOGLOSSUM* AND *NOCOMIS*. E. G. Maurakis^{1&2} & T. D. Green¹, ¹Science Museum of VA, Richmond, VA 23220 and ²Univ. of Richmond, VA 23173. Percent composition of pebble size classes from spawning and non-spawning substrates of nests were used to test the hypothesis that distribution of pebble sizes is random in nests of *Exoglossum laurae*, *Exoglossum maxillingua*, *Nocomis leptocephalus*, *Nocomis micropogon*, *Nocomis platyrhynchus* and *Nocomis raneyi* in Virginia. In all species, males selected 6.0 mm pebbles for spawning areas. Males of *N. micropogon*, *N. platyrhynchus*, and *N. raneyi* also selected 11.3 mm pebbles for spawning areas. Male *Exoglossum* and *Nocomis* expend significant amounts of time reorganizing substrate material of nests before and during spawning, resulting in relatively uniform sizes of substrate material in spawning areas. We propose that selection of 6.0 and 11.3 mm size classes for spawning areas is related to spawning behaviors and enhancement of egg and larval survival. Sizes larger than 11.3 mm interfere with spawning behaviors, and sizes smaller than 6.0 mm form a compacted substrate, which can crush eggs and larvae, or impede water flow and aeration of eggs and larvae. This study was funded in part by the Science Museum of VA, the Univ. of Richmond and the VA Academy of Science.

A KARST RESOURCE INVENTORY OF THE GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS. Terri Brown¹ & Dawn Kirk², ¹VA Natural Heritage Program and ²George Washington & Jefferson National Forests. The George Washington and Jefferson National Forests (GW&JNF) stretch across nearly 1.8 million acres of the central and southern Appalachians in western Virginia and eastern West Virginia. Approximately 90 caves are documented on the Forest, although the exact locations, dimensions, and natural heritage value of many of these caves is not currently known. Important karst resources occur along the perimeter of the GW&JNF on private land, and could be potentially affected by forest management activities. The Forest Ecology Group determined that a detailed inventory of the natural heritage value of the caves is essential to the proper management and protection of karst resources both within and beyond the Forest boundary. The first phase of the inventory focuses on stygobitic fauna in the cave environments. A volunteer group of cavers formed the Karst Resource Inventory Team, and were trained to document their observations and correctly collect voucher specimens of stygobitic fauna from cave stream, epikarst, and phreatic habitats. The data will be used to enhance the management and protection of karst resources, and will serve as the basis for prioritizing the caves for "significant" status under the Federal Cave Protection Act (FCPA).

BIODIVERSITY OF GROUND BEETLES (CARABIDAE) IN NATURAL AND CREATED WETLANDS. Allyson R. Beckman & Deborah Waller, Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529. A created wetland is often constructed as part of mitigation packages that attempt to compensate for wetland losses caused by increasing development and farming activities. Few studies have examined whether created wetlands have similar invertebrate fauna as natural wetlands. During the spring of 2000, ground beetles were collected from both natural and created wetlands in Chesapeake, Virginia. Three natural and three created wetlands were sampled. A total of nine different beetle genera were collected from the sites, totaling 152 individuals. More individuals were collected from the created sites than from the natural (86 and 66, respectively). Seven of the genera were found in both the natural and created wetlands; however, these genera were represented unevenly among the sites. A t-test of the Shannon-Weiner Diversity Indices calculated for the sites showed that the diversity of ground beetles was significantly higher in the natural wetlands.

ANT SPECIES DIVERSITY COMPARED IN COASTAL VERSUS BARRIER ISLAND HABITATS ALONG THE EASTERN SHORE OF VIRGINIA. Deborah A. Waller, Old Dominion University, Norfolk, VA, 23529. Ants play important roles in habitats as predators, scavengers, seed dispersers and soil translocators. Some ant species are very specialized and are restricted to specific microhabitats while others are more opportunistic. The objective of this study was to compare the ant fauna of coastal habitats with ants on a nearby barrier island. Barrier islands experience more extreme environmental conditions than the mainland and therefore might be expected to have fewer ant species. Ants were collected from coastal forests and adjacent marshes in Brownsville on the Eastern Shore of Virginia and from the forest and beach on nearby Parramore Island. In each habitat, ants were sampled using baits and pitfall traps every 10m along five 100m transects. Litter was collected at 0m and 100m from each transect and returned to the laboratory for extraction using a Berlese funnel. In addition, foliage sweeps and searches of litter and logs were conducted. A preliminary count revealed 19 ant species from the mainland forest, 10 species from the mainland marsh, and six species each from the island forest and the island beach. Ants characteristic of open, disturbed were common on Parramore Island, and subterranean and litter species were more abundant in the mainland forest.

GEOGRAPHIC VARIATION IN THE BROWN BULLHEAD, *AMEIURUS NEBULOSUS*. Erin D. Casey & Werner Wieland, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, VA 22401. The brown bullhead, *Ameiurus nebulosus*, has long been speculated to exist as a northern and southern subspecies, *Ameiurus nebulosus nebulosus* and *Ameiurus nebulosus marmoratus*, respectively. This specific problem remains elusive and has not been addressed. A study was conducted using traditional morphometric methods to resolve this problem. Anal ray, pelvic ray, vertebrae, and gill raker counts, along with color, were used to determine patterns of geographic variation. This study was limited to older preserved specimens from the U.S. National Museum of Natural History. Pelvic ray counts, vertebral counts, and coloration showed geographic variation. However, coloration proved to be the only character supporting subspecific designation. Populations north of the James River, Virginia have a solid dark coloration whereas populations south of the Santee River, South Carolina have a mottled color pattern. Populations from the James River south to the Santee River were found to vary becoming progressively more mottled from north to south. The results are therefore inconclusive with regard to subspecific status.

A METHOD FOR PLANTING LONGLEAF PINE, *PINUS PALUSTRIS* MILLER, ON HIGHWAY RIGHTS-OF-WAY. Phil Sheridan, Meadowview Biological Research Station and Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529. Longleaf pine is a very rare plant in Virginia with only 4432 trees remaining in the wild. We were interested in utilizing highway rights-of-way to start backup populations of native Virginia longleaf pine within the historic range of the tree and to measure survivorship of longleaf pine planting. Two hundred seventeen seedlings with an average root collar diameter of 1 cm were planted in a cloverleaf in Prince George County, Virginia in mid-January 1999. Ground cover cloth was placed around each seedling, mulch was placed on top of ground cloth, and a bamboo stake with survey tape placed next to each seedling. Mowing of the site during the growing season was carefully coordinated with VDOT staff. Survivorship of longleaf pine after one season was 84% and mulching generally provided effective control of longleaf pine competitors.

WITHIN SITE SELECTION OF ARTIFICIAL CAVITY TREES BY RED-COCKADED WOODPECKERS. A. Nicole Chadwick, Jeffrey R. Walters, & Carola A. Haas, Virginia Tech. Red-cockaded woodpeckers (*Picoides borealis*) are unique in that they excavate cavities in mature living pine trees. This unique feature, however, is thought to limit populations because of the difficulty of cavity excavation and the shortage of trees suitable for excavation. In order to compensate for these limits, artificial cavities often are constructed to increase the number of cavities available to red-cockaded woodpeckers. We examined several artificial cavity tree characteristics to determine how they relate to red-cockaded woodpecker use of artificial cavities within active clusters on Eglin Air Force Base, FL. Additionally, these variables were examined to determine if differences exist between nest trees and other trees within the cluster. Cavity tree characteristics measured were diameter at breast height (DBH), diameter at cavity height (DCH), cavity entrance height (CHT), cavity entrance orientation (OR), tree age (AGE), and relative sap flow (SAP). Active trees had significantly higher DBH ($n=122$, $p=0.0165$), DCH ($n=122$, $p=0.0171$), and CHT ($n=125$, $p=0.0171$). Nest trees had significantly higher CHT than other trees within the cluster ($n=89$, $p=0.0232$). Our results indicate that cavities placed in the largest trees available with high cavity entrances are more likely to be used than other artificial cavities.

COMPARISON OF INSECT CAPTURES BETWEEN WILD-TYPE AND MUTANT GREEN *SARRACENIA JONESII* WHERRY. Phil Sheridan^{1&2}, Jonathan Humphrey¹, Monique Davies¹, Chris Simon¹, & Nancy Penick¹, ¹Meadowview Biological Research Station and ²Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529. Various investigators have proposed that insects are attracted to the carnivorous *Sarracenia* pitcher plants by color, nectar, and scent. Mutant pitcher plants exist which lack the ability to produce reddish-purple pigment due to a recessive allele blocking a late stage of anthocyanin biosynthesis. Normal wild-type plants of *Sarracenia jonesii* produce only cyanidin and thus the role of anthocyanin in capturing insects may be assessed through comparative studies of insect captures between wild-types and mutants. We raised both wild-type and mutant plants from seed and measured pitcher height, mouth width, and mass of insect captures in the 3 year old seedlings. We found that pitcher height and mass of insects captured by mutants was significantly greater than wild-type while there was no significant difference in mouth width.

FISHFAUNA OF THE GREAT DISMAL SWAMP: 1949-1971. Katherine Merten & Werner Wieland, Dept. of Biological Sciences, Mary Washington College, Fredericksburg, Va 22401. The Great Dismal Swamp is located on the Atlantic Coastal Plain in southeastern Virginia and northeastern North Carolina. Just north of the swamp's center is Lake Drummond. The lake is geologically young and its dark, acidic waters are host to numerous species of fish. Field collection notes from the swamp were obtained and entered into database format for analysis. The collections were conducted over a 22 years by Dr. Robert D. Ross and others between March 5, 1949 and May 9, 1971. A total of 41 species were discovered to inhabit the swamp, with *Centrarchus macropterus* being the most frequent species and *Notemigonus crysoleucas* being the most abundant. Several specimens were listed by genus only (*Lepisosteus* sp., *Enneacanthus* sp., *Etheostoma* sp. and *Holelepis* sp.) and their specific identity is yet to be determined. Five species (*Alosa aestivalis*, *Anchoa mitchilli*, *Noturus gyrinus*, *Strongylura marina* and *Menidia beryllina*) were documented in the collection notes which were formerly unknown to the swamp.

THE YELLOW PITCHER PLANT, *SARRACENIA FLAVA* L., RECOVERY PROGRAM. Phil Sheridan, Meadowview Biological Research Station and Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529. The yellow pitcher plant is a carnivorous plant restricted to fire maintained wetland ecosystems in Virginia. Due to land use changes and urban development this species has suffered significant population declines resulting in only four native populations remaining totaling less than 100 plants. Through a careful process of scientific research an effort to return the yellow pitcher plant to its historic range in Virginia is now being undertaken. This process includes: continued field research for new populations; propagation of extant and extirpated colonies; ecological and reproductive biology studies; reintroduction to the wild of both site-faithful and mixed populations; education of the general public about the importance of these plants and their environment; active programs with local schools involving them in various scientific aspects and on-site reintroductions; a registry with state agencies of all introduced sites, material planted, and origin of stock. A population has now been started in five of the eight historic counties for this species. State highway rights-of-way and wetland mitigation projects have been used for half the reintroductions with several of the sites in their third successful year of reproduction.

RARE PLANTS IN THE CLASSROOM; POTOMAC ELEMENTARY SCHOOL AND THE TOYOTA TAPESTRY GRANT. P. Sheridan^{1&2}, R. Horman¹, S. Horman¹, S. Gilbert³, A. Keeton³, & M. Schmutte³, ¹Meadowview Biol. Research Station, ²Dept. of Biol. Sciences, Old Dominion Univ., Norfolk, VA, 23529 and ³Potomac Elementary School. A basic challenge to educators is how to get young students involved and interested in science and biological conservation. We utilized the carnivorous yellow pitcher plant and longleaf pine to capture students' imagination, answer important scientific questions, and make significant contributions to rare species recovery. We used the Toyota Tapestry Grant to fund and develop our program of scientific study and rare plant reintroduction. Students found that freezing had no effect on breaking dormancy in yellow pitcher plant seed while dilute fertilizer and soil amendments such as Miracid, Superthrive, and a solution of burned pitcher plant leaves significantly increased seedling growth over controls. Students returned over 300 pitcher plant and 95 longleaf pine seedlings to a VDOT wetland mitigation site within the historic range of the species. We think that an important reason for the success of the project was the team effort between teachers, local volunteer master gardeners, and scientific mentors. Student efforts continue with both species in a school yard "mini-nursery".

HISTORICAL RELATIONSHIPS OF MAINLAND RIVER DRAINAGES IN GREECE. E. G. Maurakis^{1,2}, M. K. Pritchard¹ & P. S. Economidis³, ¹Science Museum of VA, Richmond, VA 23220, ²Biology Dept., Univ. of Richmond, Richmond, VA 23173, and ³Zoology Dept., Aristotle Univ., Thessaloniki 54006 Greece. Historical relationships of 23 river drainages in Greece were determined with distributions of 53 primary freshwater native cyprinids using cladistic methodologies. Analyses resulted in an area cladogram suggesting vicariant events (marine transgression and regression, orogeny, and karst stream autopyracy) as major factors shaping relationships among river drainages and current distributions of the freshwater cyprinid ichthyofauna in Greece. Two biogeographical divisions of river drainages are recognized in Greece: *Ponto-Aegean* and *Neo-Hellas*. The *Ponto-Aegean* in Greece is composed of two subdivisions: *Thracian-East Macedonia*, which is further separated into *Paleo-Aegean* (Evros and Strymon rivers) and *Neo-Aegean* (Filiouris, Nestos, and Gallikos rivers) subdivisions; and the *Macedonia-Thessaly* division (Axios, Loudias, Aliakmon, and Pinios in Thessaly). The *Neo-Hellas* is represented by three subdivisions: *Attiki-Boetia* (Holorema, Sperchios, Atiki, and Kifissos), *Ionian* (Kalamas, Aheron, Louros, Arachthos, Acheloos, Evinos, and Mornos rivers) and *Adriatic* (Aoos River). Methods for testing these hypotheses are presented.

ENVIRONMENTAL IMPACT STATEMENTS IN KARST: THE NEED FOR DETAILED FIELD WORK; CASE STUDY FROM PROPOSED POWER LINE CORRIDOR, SKYDUSKY HOLLOW AREA, BLAND COUNTY, VIRGINIA. Wil Orndorff², Joe Thompson¹, and Terri Brown², ¹VPI Cave Club, & ²Virginia Division of Natural Heritage. The preferred and alternate corridors of American Electric Power's proposed 765kV transmission line cross five major belts of karst, which is sensitive to contamination due to rapid conduit flow of groundwater through subterranean channels formed by the dissolution of soluble bedrock. The watershed of one of Virginia's significant karst areas, Skydusky Hollow (SH), is crossed by both proposed corridors. SH includes hibernacula for *Myotis sodalis* and *Corynorhinus Townsendii Virginianus*, federally endangered bat species, as well as a host of rare &/or threatened invertebrate fauna. Data available to AEP was inadequate to document karst in the proposed corridors. Detailed field work performed resulted in 1) extension of the documented watershed via dye trace studies, 2) a near doubling in the documented number of endangered hibernating bats, 3) discovery of a possible new species of amphipod, and 4) location and survey of 14 new or poorly known caves. Had this field work been completed during the scoping phase of the power line routing process, it is doubtful that the proposed route would have been chosen.

Psychology

AGGRESSIVE DRIVING: CONGESTION PER TRAFFIC LIGHT CYCLE AND PREDICTING RED LIGHT RUNNING. Solomon Luckett Jr. & Bryan E. Porter, Psychology Department, Old Dominion University, Norfolk Va. 23529. In this study crowding was explored as a predictor of red light running behavior. Specifically, high traffic volume (high congestion) was expected to predict higher rates of red light running. Two large urban intersections were observed twice weekly for four weeks. Observations occurred during low and high volume hours (9-11 a.m., 4-6 p.m.). For each of 1,972 light cycles, the light status of the last vehicle (color of the light when the last vehicle entered the intersection), the total number of red light runners, and the number of vehicles crossing the intersection (volume) were recorded. Findings indicated that the number of cars entering intersections during each cycle predicted the occurrence of red light running even after controlling for time of day and intersection. The role of frustration with crowded roads as a reason for red light running behavior is discussed.

AN INVESTIGATION OF CONTROL CONDITIONS IN ASCH-TYPE EXPERIMENTS: I. Karen E. Herrera, Thomas E. Mattingly, P. Trey Hannah & James P. O'Brien, Tidewater Community College, Virginia Beach Campus. In his classic studies on conformity and independence 50 years ago, Asch found that almost 95% of his control subjects were error free (% error = 0.08). While dozens of studies have found women to be more conforming than men, people from collectivists cultures to be more conforming than those from individualistic cultures, etc.; few have replicated Asch's control conditions with their subjects. In fact, a recent study (O'Brien, et al., 1999) found no significant differences among male and female experimental and control subjects. In the present systematic replications of Asch's control conditions, only white male college students were as error free (% error = 0.00 & 0.00) as Asch's controls. More variable error performance (% errors 3 to 14.6 times larger than Asch's 0.08) was found for female college undergraduates, male and female community college students, whether the stimulus presenter was an authority figure (as in Asch's case) or a peer (as in O'Brien, et al.). Since studies are premised on the proposition that Asch's stimuli are unambiguous, and since this may not be true for all subjects, caution must be exercised in generalizing Asch's results to groups other than white male college students.

EFFECTS OF TEXT COHERENCE ON CHILDREN'S READING COMPREHENSION. Otey Anne Arnold & Danielle S. McNamara, Psychology Department, Old Dominion University, Norfolk VA. Adults better understand highly coherent text, particularly when they possess less knowledge about the topic. Contrary to this, texts that are created for children are based on Readability formulas, and therefore often contain language that is overly simple and difficult to understand. The focus of previous research has been on adults and not on children who are just beginning to read. This study examines how children are affected by increasing coherence of two typical children's books. 46 second-grade students read two texts, both of which were either high or low coherence versions an expository or fiction text. The results indicated that for less skilled readers, high coherence facilitated comprehension for the more familiar fiction text, but hindered comprehension for the skilled readers. This study has provided evidence that increasing text coherence is important for texts with less familiar concepts.

DETECTION OF VISUAL TARGETS GIVEN VARIOUS FORMS OF DISTRACTER MOTION. Nathan R. Bailey & Mark W. Scerbo, Dept. of Psychology, Old Dominion Univ., Norfolk, VA 23529. When human subjects were presented with a variety of different moving stimuli, differences were found based upon the presence or absence of motion, the type of motion and the density of the targets. The presence of motion is detected much quicker than the absence of motion. Moreover, for motion present searches the appearance of increasing numbers of targets or type of motion have little effect on search times. By contrast, searching for the absence of motion appears to be affected by target density, although at present this effect seems to be limited to the random motion condition. From a broader perspective, these findings suggest that situation awareness is likely to be hampered by the need to look for stationary targets in a field of moving elements.

CHILDREN OF DRUG ABUSING PARENTS: AN EXAMINATION OF FUNCTIONING. Cathy G. Cooke, William Fals-Stewart & Michelle L. Kelley, Department of Psychology, Old Dominion University, Norfolk, VA 23529. Parental substance abuse is linked to many of the problems facing American children. Research suggests that children of substance abusing parents may exhibit high levels of psychopathology. These children may exhibit behavioral problems at home and with their peers and may be involved in delinquent activities. Most studies have focused on parents who abuse alcohol. In this project, we examine parents who primarily abuse substances other than alcohol. The purpose of this project was 1) to examine the psychosocial functioning of school-age children whose fathers were entering treatment primarily for substance abuse other than alcohol; and 2) to determine the degree to which indices of the severity of paternal drug use were correlated with children's psychosocial functioning. Findings indicate that these children exhibit higher levels of psychosocial dysfunction than a normative group of children. These children were also more likely to have scores indicative of psychosocial impairment than were children in the normative sample. Additionally, children's psychosocial functioning was positively correlated to their fathers' Addiction Severity Index. That is, higher addiction severity was related to greater psychosocial impairment in children.

MOTHER'S WORK HISTORY AND PSYCHOLOGICAL ADJUSTMENT: THE EFFECTS ON CHILDREN'S CLASSROOM BEHAVIOR AND PRE-ACADEMIC SKILLS. Margaret S. Hart & Michelle L. Kelley, Department of Psychology, Old Dominion University, Norfolk, VA 23529. Current changes in welfare policy have placed a lifetime limit on benefits. Little information is available on how forcing mothers, who formerly received welfare, into the workforce may impact the development of their preschool age children. The purpose of the present study was to examine the relationships between maternal work history and psychological factors and how these maternal variables influence children's development. In home visits were conducted with 42 Head Start mothers and their children. It was hypothesized that maternal variables would be related to and would subsequently predict child outcomes. Results indicate a moderate negative relationship between maternal stress and pre-academic skills. A negative correlation was also found between the number of months the mother was employed and teacher reported asocial behavior in the classroom.

RETROACTIVE REPORTS OF PARENTING, ADULT ATTACHMENT STYLE, AND DEPRESSIVE SYMPTOMOLOGY IN YOUNG ADULTS. Suzanne M. Mischell & Michelle L. Kelley, Old Dominion University. Research has demonstrated that parent-child attachment is important for adjustment in childhood and adulthood. Attachment style is believed to be stable throughout the individual's life and may impact peer and romantic relationships, interactions between work colleagues, psychosocial functioning, and the individual's ability to adjust to new situations. The focus of the present study was to examine the degree to which retrospective reports of parenting and adult attachment styles were related to young adults' psychosocial functioning. Undergraduate students completed questionnaires assessing retrospective reports of parenting behavior, attachment style, and psychosocial functioning. Individuals who reported harsh parenting (i.e., childhood rejection and psychological control) and insecure attachment styles reported significantly greater depressive symptomology than those who reported a secure attachment style and positive parenting.

RESULTS OF ADDICTION TREATMENT RECOMMENDATIONS FROM A MILITARY PSYCHIATRIC HOSPITALIZATION. Robert M. Storer, Department of Psychiatry, Naval Medical Center Portsmouth, Portsmouth VA & William Fals-Stewart, Psychology Department, Old Dominion University, Norfolk VA. Untreated Substance Use Disorders represent significant costs to society. For the military there is additional concern due to the threat to military readiness. Procedures in place for Psychiatry service at Naval Medical Center Portsmouth result in reliable identification and recommendations for treatment, but it was not known what proportion of those recommended were actually enrolled, nor what variables are reliable predictors of a "successful" referral. A review of records for patients recommended for treatment of substance dependence between January 1, 1998 & July 1, 1999 revealed that only 16% had been enrolled in the recommended treatment. Additionally, none of the variables chosen for study were found to be reliable predictors of success. Comparison of demographic data found that substance dependent patients were younger than those normally enrolled in treatment, and more likely to be recommended for separation from the military although their past psychiatric history and level of dangerousness was found to be no worse than other US Navy subjects. The possible meanings of these findings are discussed as well as suggestions for future studies.

GENDER ATTITUDES AND COERCIVE SEXUAL BEHAVIOR. J. J. Winters, Department of Psychology, Old Dominion University, Norfolk, VA 23529 & S. L. Ellyson, Department of Psychology, Youngstown State University, OH 44555. Male college students (N=62) completed questionnaires containing measures of gender related attitudes, rape myth acceptance, coercive sexuality, and likelihood of raping. Gender related measures included own sex role satisfaction, sex role stereotyping, adversarial sexual beliefs, sexual conservatism, and acceptance of interpersonal violence. The coercive sexuality scale measured history of a wide range of coercive sexual behavior and methods of coercion. Results supported previous findings of a wide spectrum of coercive sexual behavior. Rape myth acceptance and sex role stereotyping were associated with a history of sexual coercion. About one third of the participants indicated a likelihood of raping. However, likelihood of raping was not related to actual history of sexual coercion. Types of sexual coercion were not related to any of the other measures. Own sex role satisfaction, adversarial sexual beliefs, sexual conservatism, and acceptance of interpersonal violence were not associated with coercive sexuality or likelihood of raping. Results indicate traditional correlates of rape may not be related to less severe levels of sexual coercion.

AWARENESS OF HYPERTENSION AMONG AFRICAN AMERICAN COLLEGE STUDENTS. Michelle Pigott, Toya Joyner, Dr. Bertha Davis, & Stase Michaels, Health Studies, Behavior Science Research Center, Hampton University, Hampton, VA 23668. This study examined knowledge of hypertension in 199 African American college students with a mean age of 18.5. It was hypothesized that seniors would be more knowledgeable and would report more risk factor behaviors related to hypertension. A 34-item questionnaire with three subscales related to general knowledge, experiences related to hypertension, and risk behaviors was administered at the end of a college semester at an African American university. Crosstabs by classification and a Pearson Chi Square test were run as statistical analyses. Results supported the hypotheses showing that freshman were the least knowledgeable when it came to overall general knowledge while seniors reported the most risk behaviors. This suggests that as African American college students get older their levels of awareness regarding hypertension increases and yet by behaviors, they may become more at risk for hypertension. More studies are suggested that would examine how knowledge and behavior / risk factor variables interact on a health issue such as hypertension.

HOW THE ACADEMIC AND SOCIAL LIVES OF AFRICAN AMERICAN COLLEGE STUDENTS AFFECT THEIR EATING PATTERNS. Cecelia Bonner Dr. Bertha Davis, & Stase Michaels, Health Studies, Behavior Sciences Research Center, Hampton University, Hampton, VA 23668. This study examined how the academic and extracurricular activities of college students influence their eating patterns and their use of the student cafeterias. Participants were 67 males and 157 females at a historically black university. Each filled out a 23-item questionnaire related to activities, times, locations, and frequencies of eating patterns as well as nutritional content of meals. Statistical analyses were done using Crosstabs by gender to analyze the data. Results showed that females tend to be more active in extracurricular activities and consequently, report feeling busier than males. Many students miss three to six major meals per week (dinner). Although students compensate for missed meals by snacking, results show that overall nutritional content is markedly low and weighted too heavily by ingestion of starches. A follow up study is suggested to examine how academic success and minor health issues such as colds, fatigue, and stress relate to students' eating patterns.

EFFECTS OF STRESS UNDER HIGH OR LOW PRESSURE CONDITIONS IN AFRICAN AMERICAN COLLEGE STUDENTS. Maro L. Mitchell, Dr. Bertha Davis, & Ms. Stase Michaels, Health Studies, Behavior Sciences Research Center, Hampton University, Hampton, VA 23668. This study examined the effects of stress on 141 African American college students at a historically black university as they took a bogus test. As the experimental design, some were placed in a "high" pressure condition, others in a "low" pressure condition. The test they took was created specifically for this study and consisted of 10 questions, of which six were extremely difficult while four were extremely easy. To create stress artificially, those in the high pressure group were told (a) that others had answered all questions correctly and (b) that these were entrance exam questions at a predominantly white college. A t-test was run as statistical analysis between groups as well as Crosstabs for descriptive analyses. Results showed no significant differences between high and low pressure groups; however, individual questions revealed interesting trends related to how they may handle stress.

THE INFLUENCE OF MEDIA VIOLENCE ON ADOLESCENTS' DELINQUENT BEHAVIOR. Carol D. Roldan & Bryan E. Porter, Psychology Department, Old Dominion University, Norfolk VA 23508. For the past five decades, researchers have studied the effects of media violence on children's behavior and adolescents' imitation. Most studies have found positive correlations between media violence, specifically television violence, and aggression. In recent years, studies have also found positive correlations between parental rejection and delinquency. The current study examined the relationships between media violence, parental rejection, and juvenile delinquency for a sample of 97 freshman students from Old Dominion University between 18 and 20-years-old. Findings revealed that (a) parental rejection was a good predictor of delinquency, (b) media violence by itself did not predict delinquency, (c) but frequency of media violence viewing and exposure to "real" violence experienced during adolescence tended to be better predictors of delinquent behavior.

EFFECTS OF VERBAL AND PICTORIAL IMAGERY ON MEMORY. Daniel M. Birdwhistell & David G. Elmes, Dept. of Psychol., Washington and Lee Univ., Lexington, VA 24450-0303. The present study examined the coding redundancy theory of Paivio by having people recall both the objects and the modality of presentation for items presented as pictures, words, or both pictures and words. Although presenting an item as both a picture and a word enhanced memory, compared to a word alone, memory was no better than for items presented as pictures. Memory for presentation modality was poorest for items presented as both a picture and a word. The results are analogous to those reported by Tracy and associates that showed little advantage to having both auditory and visual images for to-be-remembered items. Thus, the coding redundancy theory does not receive complete support. It is likely that the complex referential connections engendered by two forms of presentation overload working memory and inhibit memory for modality.

THE EFFECT OF ETHANOL ON ELEVATED PLUS MAZE PERFORMANCE OF HYPOGLYCEMIC RATS. Michael G. Grasso, Perry M. Duncan & Juan Constantine, Department of Psychology, Old Dominion University, Norfolk, VA 23529-0267. This ongoing research investigated the effect of ethanol intoxication on hypoglycemic rats. Previous studies have shown that anxiety is experienced during the early stages of the hypoglycemic condition. The focus of this study was to investigate ethanol's ability to attenuate this anxiety. To date, the subjects have consisted of 24 male (Long-Evan) rats in 4 treatment groups of 6 each. In the experimental condition insulin was administered to produce hypoglycemia and ethanol to study its effect. Control conditions were produced using saline injections. Anxiety and activity levels of the subjects were both measured and timed during 5 minute runs in an Elevated Plus Maze (EPM). A significant insulin/ethanol interaction was demonstrated by total time spent in the open arms of the EPM. This clearly indicates reduced anxiety for hypoglycemic rats under the influence of ethanol ($F 6.69, p < .018, df 1,20$). Other significant findings include decreased activity in the hypoglycemic subjects and increased activity while under the influence of ethanol. These findings are important to the diabetic community. Early results suggest that insulin dependent diabetics should be warned of ethanol's ability to mask hypoglycemic symptoms.

ERRORS IN MULTI-CHANNEL AUDITORY SEARCH: LOCALIZATION VERSUS DETECTION. Joseph T. Coyne & Mark D. Lee, Psychology Department, Old Dominion University, Norfolk VA 23529-0267. There has been little research addressing the issue of auditory information processing. However with advances in auditory technology, it becomes increasingly important that we understand human capacity for processing auditory information. The purpose of this study was to gain an understanding of the prevalence of the different sources of errors made in auditory search. Subjects were randomly assigned to either a detection or localization group. Subjects in the detection identified whether the target was presented, and subjects in the localization group identified which speaker emitted the target. The groups were compared on several dimensions including accuracy, reaction time, sensitivity, and the effects of load and speaker position.

BODY IMAGES OF MEN AND WOMEN COLLEGE STUDENTS OVER THE 1980S AND 1990S. April A. Perry & Thomas F. Cash, Old Dominion University. Men and women's body images differ in several respects. Women evaluate their appearance more negatively and are more invested in their looks, as compared to men. Studies have suggested a growing gender gap in body images. In the present study, the authors examined body image changes among college students over the 1980s and 1990s. It was hypothesized that for men and women appearance evaluations have become worse and investments in appearance or appearance orientations have become more important. The authors expected to find that men and women view their bodies more negatively now than in past years, with the negative change even more pronounced for women. Also expected was an increase in investment of appearance for men and women, with the change again being more important for women. Some, but not all of these expected findings were reported.

INFLUENCE OF SPEAKER GENDER ON TARGET DETECTION IN AUDITORY SEARCH. Amy N. Cunningham & Mark D. Lee, Dept. of Psychology, Old Dominion University, Norfolk, VA 23529. The present study investigated the influence of speaker gender on the performance of locating a target in an auditory search task. Controlled combinations of male and female voices and frequency manipulations of male voices were utilized to create several conditions that examined distinctiveness, distractor homogeneity, and artificially altered sound frequency. Participants ($N=15$) were required to complete a computer-interactive experiment, exposed to four simultaneous streams of auditory data consisting of digits and letters. Results indicated that there was a significant influence of speaker gender on detection. Possible causal factors are discussed.

THE EFFECTS OF TRAINING ON TEAM COHESION. Kari R. Strobel, Robert M. McIntyre & Lara B. Tedrow, Department of Psychology, Old Dominion University, Norfolk, VA 23529. Team cohesion generally refers to a measure of individual attraction to a group in pursuit of either social affiliation or task-related goals. Recognition of the practical importance and theoretical significance of cohesion has led to considerable research into its presumed antecedents and beneficial outcomes. Unfortunately, these investigations have almost exclusively relied on cross-sectional designs, which do not allow for more definitive statements as to whether these correlates lead to, or stem from, cohesion. The primary objective of this study was an attempt to train 25 university student teams made up of 2-6 persons on fundamental teamwork concepts so as to develop measurable improvements in team cohesion. A multiple analysis of variance procedure was used to test for significance between groups over the course of a semester. Results indicated that there was not a significant difference between trainees and controls at baseline; however, compared to the control group, trainees were more cohesive immediately following the training and at one-month follow-up. This research provides insight as to the development and maintenance of cohesive teams, given that most organizations are interested in the creation of team cohesion, rather than simply its cross-sectional correlates.

Statistics Section (VAS Chapter, A.S.A.)

USING JAVA TO TEACH STATISTICS. Sundar S. Dorai-Raj, Christine M. Anderson-Cook & Timothy J. Robinson, Department of Statistics, Virginia Polytechnic Institute and State University, Blacksburg VA 24061. Traditional lectures often do not convey the concepts of statistics in a way that is easily understood or remembered by students in a first course. A series of eight groups of applets have been developed and stored on a universally accessible webpage for students to experience these concepts. Ideas such as extracting probabilities from a distribution, the central limit theorem, confidence intervals, test of hypothesis, control charts, and experimental design are demonstrated. Initial student feedback to the applets has been very positive and students seem better able to retain the concepts. The applets can be found on the author's webpage at <http://www.stat.vt.edu/~sundar/java/applets/>. Funding for this project was provided by a grant from the Virginia Tech Center for Innovation in Learning and the Center for Excellence in Undergraduate Teaching.

ON THE IMPROVED ESTIMATION OF LOCATION PARAMETERS SUBJECT TO ORDER RESTRICTIONS IN LOCATION-SCALE FAMILIES. Steven T. Garren, Department of Statistics, University of Virginia, Charlottesville, Va. 22904--4135. For some models the isotonic regression estimator is known to universally dominate reasonable unrestricted estimators of the smallest location parameter, μ_1 , under a simple order restriction, $\mu_1 \leq \dots \leq \mu_k$. We show that the former estimator of μ_1 fails to dominate the unrestricted maximum likelihood estimator in terms of mean squared error, when the variances are unknown and unequal in a normal model. The former also fails to universally dominate the unrestricted best equivariant estimator, when the scale parameters are known in an exponential model. A different estimator of μ_1 is shown to universally dominate the unrestricted best equivariant estimator, when the scale parameters are known in an exponential model under more general linear order restrictions. Universal domination results involving the other location parameters and other estimators having bounded support also are discussed.

Shelton Horsley Research Award

The Horsley Award was not given in 1999-2000 because no papers were submitted for consideration.

Horsley Cancer Research Fund Grants

A total of \$33,592.00 in funding was recommended. In December, 1999, the Research Committee of the Virginia Academy of Science recommended the funding of the following new proposal by the Horsley Cancer Research Fund provided by the trust of Mary Louise Old Andrews.

David M. Gardner, Roanoke College, \$6592.00, "Quantitative studies of N-cadherin-mediated cell adhesion and invasiveness in Src-transformed chondrocytes"

In December, 1999, the Research Committee of the Virginia Academy of Science also recommended the funding of the following old unfunded or partially funded proposals by the Horsley Cancer Research Fund provided by the trust of Mary Louise Old Andrews. This was an extraordinary disbursement to remove excess funds created by the rise in the stock market.

Proposals submitted in 1998:

John J. Ryan, Virginia Commonwealth University, \$6000.00, "Determining the mechanism of Kit inhibition and apoptosis avoidance by mastocytomas" VCU Proposal Number 99-0437-00

Roy L. Williams, Old Dominion University, \$3000.00, "Naturally occurring phytoestrogens as tools to study apoptosis in human cancer cells" Proposal Number 99141

Proposals submitted in 1997:

Dr. Todd A Houston, Virginia Commonwealth University, \$6000.00, "Design of novel glycoside inhibitors to disrupt angiogenesis"

Charles L. Rutherford and Yun Qui, \$4000.00, "Mechanisms of activation of erbB2/neu by IL6 in prostate cancer cells, LNCaP", Grant Number 435745

Barbara A. Davis, Virginia Polytechnic Institute and State University, \$3000.00, "Role of glucocorticoids in vitamin B6 deficiency: Preliminary study of the relationship between nutrition, immune function, and cancer"

Proposal submitted in 1996:

Julie A. Kerry, Eastern Virginia Medical School, \$5000.00, "Regulation of cellular genes by Human cytomegalovirus" Grant Number 103-231-564010

Small Project Research Funds

A total of ten proposals were funded out of a total of 15 proposals submitted, for a total of \$12,000.00. In May, 2000, the Research Committee of the Virginia Academy of Science recommended the funding of the following proposals by the Virginia Academy of Science.

D. J. Bautz and T. O. Sitz, Virginia Polytechnic Institute and State University, were awarded \$1250.00 for their proposal titled "Processing of an enzyme targeted to the nucleus?".

Daniel Cristol, College of William and Mary, was awarded \$1100.00 for his proposal titled "The role of diet and molt in the departure of the white-throated sparrow, *Zonotrichia albicollis*".

Daniel Druckenbrod and Herman H. Shugart, Jr., University of Virginia, were awarded \$1233.00 for their proposal titled "Forest dynamics in the Virginia piedmont".

Rhonda Edwards and Duncan M. Porter, Virginia Polytechnic Institute and State University, were awarded \$1077.00 for their proposal titled "Phylogeny and biogeography of *Clematis* subgenus *Viorna*".

Joseph O. Falkinham III, Virginia Polytechnic Institute and State University, was awarded \$1174.00 for his proposal titled "Genetic expression of virulence or stress-induced genes by intracellular *M. avium*".

Jeremy L. Goodin and Charles Rutherford, Virginia Polytechnic Institute and State University, were awarded \$1250.00 for their proposal titled "Analysis of cAMP induced terminal neuroendocrine differentiation in human prostatic adenocarcinoma cell line LNCaP".

Mundy Hackett and John F. Pagels, Virginia Commonwealth University, were awarded \$1250.00 for their proposal titled "A study of the northern flying squirrel in southwestern Virginia using radio telemetry for habitat analysis".

Michael T. Mengak, Ferrum College, was awarded \$1236.00 for his proposal titled "Demographic characteristics and habitat selection criteria of the golden-winged warbler (*Vermivora chrysoptera*)".

Michael H. Renfro, James Madison University, was awarded \$1250.00 for his proposal titled "Propagation of African violet by synthetic seeds".

Timothy W. Stewart, Longwood College, was awarded \$1180.00 for his proposal titled "Combining high taxonomic resolution and regression analysis to quantify relationships between physically complex habitat and benthic invertebrate community attributes in the James River".

**Virginia Junior Academy of Science
awards Presented at Radford University
May 2000**

AGRICULTURAL AND ANIMAL SCIENCE

- Honorable Mention: ANNA K.M. BEST
Patrick Henry High School
- Honorable Mention: ZACHARY J. CAPPELLO
Stonewall Jackson Middle School
- Honorable Mention: MELISSA E. FORERO-HORDUSKY
Marshall Middle School
- Third Place: EDWARD J. WILSON
Blacksburg High School
- Second Place: SARAH J. GRUBB, AMY S. HODGES
Cave Spring High School
- First Place: ANNIE E. WY SOCK
Chesterfield County Math & Sci. H. S.

ANIMAL BEHAVIOR (ETHOLOGY)

- Honorable Mention: KARA L. CAPELLI
Chickahominy Middle School
- Honorable Mention: JAMIE R. KILGORE
Patrick Henry High School
- Honorable Mention: MEAGHAN E. O'BRIEN
Chesterfield County Math & Sci. H. S.
- Third Place: GABRIEL L. AURIOLES
Chesterfield County Math & Sci. H. S.
- Second Place: BRETT M. WILSON
Atlee High School
- First Place: EMILY C. MCCONNELLY
Williamsburg Middle School

BOTANY 'A'

- Honorable Mention: ERIN K. AUKWARD, LAUREN D. RUSSO
Roanoke Valley Governor's School
- Honorable Mention: M. TRUE BECK
Tuckahoe Middle School
- Honorable Mention: JENNIFER F. GOODLATTE
Roanoke Valley Governor's School
- Third Place: KATHERINE M. FOSTER
Yorktown High School
- Second Place: VICTORIA L. CHIOU
Governor's School for Gov. & Intn. Studies
- First Place: ERIN B. FRACKLETON
Central Virginia Governor's School

BOTANY 'B'

- Honorable Mention: COLLEN JAMES
Cave Spring High School
- Honorable Mention: BRYAN T. JARRETT
Mills E. Godwin Specialty Center
- Honorable Mention: ANNA N. JURKEVICS
Yorktown High School
- Third Place: EMILY A. MOLLICK
Warwick High School
- Second Place: ELIZABETH D. MADDEN
Central Virginia Governor's School
- First Place: JOANN E. KELLY
Gloucester High School

BOTANY 'C'

- Honorable Mention: BRYAN K. PELFREY
Gloucester High School
- Honorable Mention: CHRISTINA SADLER
Patrick Henry High School
- Honorable Mention: ALLAN M. SCHMIDT
Bishop Denis J. O'Connell High School
- Third Place: KAYLA E. SCHEINER
Yorktown High School
- Second Place: DAVID C. SCHAFFER
Tuckahoe Middle School
- First Place: ELLEN A. YOUNG
Manchester Middle School

CHEMISTRY 'A'

- Honorable Mention: ALEXANDER P. ARKIN
Tuckahoe Middle School
- Honorable Mention: GRAHAM GILMER
Central Virginia Governor's School
- Third Place: MAURICE S. FISHER
Atlee High School
- Second Place: JEREMY S. GRABOYES
Harry F. Byrd Middle School
- First Place: JOANNE M. CUNNINGHAM
Atlee High School

CHEMISTRY 'B'

- Honorable Mention: DAVID MINASKANIAN
Mills E. Godwin Specialty Center
- Honorable Mention: SREEJIT A. NAIR
Thomas Jefferson H. S. for Sci. & Tech.
- Honorable Mention: JUSTIN P. NANCE
Central Virginia Governor's School

- Third Place: MICHELLE MINASKANIAN
Mills E. Godwin Specialty Center
- Second Place: ALISA KHAN
Thomas Jefferson H. S. for Sci. & Tech.
- First Place: JASON A. NG
Yorktown High School

CHEMISTRY 'C'

- Honorable Mention: LAURA S. SHANKMAN
Yorktown High School
- Honorable Mention: CLAIRE W. THOMAS
George H. Moody Middle School
- Honorable Mention: DAVID G. WEISZ
Chesterfield County Math & Sci. H. S.
- Third Place: MARY E. PECK
Harry F. Byrd Middle School
- Second Place: DANIEL R. WITSIL
Robinson High School
- First Place: ASHLEY A. WHITE
Warwick High School

COMPUTER SCIENCE

- Honorable Mention: KARLA L. CHILDRESS
Central Shenandoah Valley Governor's School
- Honorable Mention: CORT C. HANLON, JOSH MCLAUGHLIN, JON SHORT
Central Shenandoah Valley Governor's School
- Third Place: BENJAMIN A. MICKLE
Meadowbrook High School
- Second Place: REED J. HUMPHREY
J.R. Tucker High School
- First Place: ALEX C. GOOLSBY
Manchester Middle School

CONSUMER SCIENCE 'A'

- Honorable Mention: BRANDON M. ANDERSON
J.R. Tucker High School
- Honorable Mention: MARK J. BENNETT
James River High School
- Honorable Mention: SIOBHAN L. CLEARY
James River High School
- Third Place: DANIEL P. CLAYTOR
James River High School
- Second Place: CHIKA I. ANYADIKE
Gloucester High School
- First Place: J. AUTUMN BARKER
Gloucester High School

CONSUMER SCIENCE 'B'

- Honorable Mention: LINDSAY C. DOYLE
Blacksburg High School
- Honorable Mention: JESSIE E. DI GREGORY
Bishop Denis J. O'Connell High School
- Honorable Mention: SHEENA JAIN
Cave Spring High School
- Third Place: BRIAN J. HEBERLEIN
J.R. Tucker High School
- Second Place: NIKOLAI A. EROSHENKO
Tuckahoe Middle School
- First Place: PETER D. HOGGE
Gloucester High School

CONSUMER SCIENCE 'C'

- Honorable Mention: LAUREE V. MORGAN
Varina High School
- Honorable Mention: PHILIP H. O'BRIEN
Governor's School for Gov. & Intn. Studies
- Honorable Mention: RITA N. PATEL
James River High School
- Third Place: ERIN K. MCGRAW
Chickahominy Middle School
- Second Place: KATHERINE J. MIDLAND
Ocean Lakes High School
- First Place: DONIKA K. PATEL
Southwest Virginia Governor's School

CONSUMER SCIENCE 'D'

- Honorable Mention: SUSAN E. SCHALLER, AMANDA E.F. GRAY
Williamsburg Middle School
- Honorable Mention: KIRSTEN E. STUDER
Patrick Henry High School
- Honorable Mention: ANH N. TRAN
William Fleming High School
- Third Place: MARY K. SPRINKEL
Atlee High School
- Second Place: DANIEL W. STEENECK
Gloucester High School
- First Place: CALLIE C. SPENCER
Central Shenandoah Valley Governor's School

EARTH AND SPACE SCIENCE

- Honorable Mention: BRITTANY HERTZOG
Hayfield High School
- Third Place: RAVI A. DEEPAK
Poquoson Middle School

Second Place: TOM J. HAGAN
Cave Spring High School

First Place: LAURA G. GAMSE
Yorktown High School

ENGINEERING 'A'

Honorable Mention: WILLIAM B. HOGGE
Gloucester High School

Honorable Mention: MICHAEL C. HSU
James River High School

Honorable Mention: EVAN P. LANE
Gloucester High School

Third Place: CHRISTOPHER S. KOVES
Hayfield High School

Second Place: JAKOB B. HARMON
Atlee High School

First Place: LAUREN M. EDGAR
Yorktown High School

ENGINEERING 'B'

Honorable Mention TOMMY REEDER, THOMAS DICARLO
Cave Spring High School

Honorable Mention: VERONICA A. ROHRMOSER
Manchester Middle School

Honorable Mention: THEODORE J. TZAVARAS
Ocean Lakes High School

Third Place: WILLIAM J. PRENTISS
Woodside High School

Second Place: BRIAN SEAVEY
Ocean Lakes High School

First Place HANS K. SHMIDHEISER
Central Shenandoah Valley Governor's School

ENVIRONMENTAL SCIENCE 'A'

Honorable Mention: KATHERINE K. FU
Yorktown High School

Honorable Mention: MAEVE E.M. GOULD
Tuckahoe Middle School

Honorable Mention: envAHM-3
envAHM-3 sch

Third Place: DARBY J. DUNNAGAN
Southwest Virginia Governor's School

Second Place: CURTIS C. COPELAND
Gloucester High School

First Place: RACHEL P. BANKS
Chesapeake Bay Governor's School

ENVIRONMENTAL SCIENCE 'B'

- Honorable Mention: MARGARET S. KROME-LUKENS
Gloucester High School
- Honorable Mention: BRIANNA A. KURTZ
Roanoke Valley Governor's School
- Honorable Mention: BEN S. LACKER
George H. Moody Middle School
- Third Place: RUTH A. HALL
Mills E. Godwin Specialty Center
- Second Place: SARA B. JONES, ELIZABETH R. BLAIR
Thomas Jefferson High School for Science and Technology
- First Place: THOMAS B. LENTZ
Blacksburg High School

ENVIRONMENTAL SCIENCE 'C'

- Honorable Mention: MEGHAN E. REYNOLDS
Gloucester High School
- Honorable Mention: NISHA M. THURUTHY
Central Virginia Governor's School
- Honorable Mention: SUSAN T. WALLACE
Tuckahoe Middle School
- Third Place: AMY L. SLIVA
Central Virginia Governor's School
- Second Place: NAOMI E. ROSS
Yorktown High School
- First Place: MELISSA L. POLLOCK
Gloucester High School

GENETICS AND CELLULAR BIOLOGY

- Honorable Mention: CORRINE L. BELT, VIVEK TANEJA
Hayfield High School
- Honorable Mention: ESTHER H. CHA
Bishop Denis J. O'Connell High School
- Honorable Mention: WESLEY E. DERRYBERRY
Cave Spring High School
- Third Place: ANDREA E. NICULESCU
Chesterfield County Mathematics and Science High School
- Second Place: BRANCH W. TRENT
Mills E. Godwin Specialty Center
- First Place: MARISSA R. KESSLER
Mills E. Godwin Specialty Center

MATHEMATICS AND STATISTICS

- Honorable Mention: FINALE P. DOSHI
Governor's School for Government and International Studies
- Honorable Mention: JONATHAN C. HENDRIX
Woodberry Forest School

- Honorable Mention: ALEX S. JONES
Bishop Denis J. O'Connell High School
- Third Place: BERNARD E. FARLEY
Mills E. Godwin Specialty Center
- Second Place: MATTHEW E. LYNCH
Chesterfield County Mathematics and Science High School
- First Place: LYRIC P. DOSHI
Short Pump Middle School

MEDICINE AND HEALTH 'A'

- Honorable Mention: MEGHAN R. EWELL
James River High School
- Honorable Mention: KATHERINE J. FENSTERMACHER
Gloucester High School
- Honorable Mention: PHEBE V. GREENWOOD
Tuckahoe Middle School Tuckahoe Middle School
- Third Place: SARAH A. HEIL, MICHELLE L. DAVIS
Cave Spring High School
- Second Place: MELISSA A. BINKLEY
Yorktown High School
- First Place: SHAUNAK K. DEEPAK
New Horizons Governor's School

MEDICINE AND HEALTH 'B'

- Honorable Mention: ELIZABETH K. JETTON
Cave Spring High School
- Honorable Mention: LAUREN T. LASTINGER
Southwest Virginia Governor's School
- Honorable Mention: ANDREW P. LAWHORNE
Central Virginia Governor's School
- Third Place: ANNA M. PALUMBO
New Horizons Governor's School
- Second Place: JOHN P. MCCLURE
Williamsburg Middle School
- First Place: DARIN M. HINMAN
J.R. Tucker High School

MEDICINE AND HEALTH 'C'

- Honorable Mention: SUSAN C. SU
New Horizons Governor's School
- Honorable Mention: RAPHAELLA D. TESCHNER
Gloucester High School
- Honorable Mention: JULIA A. WILLIAMS
Henrico High School
- Third Place: SARAH E. SHANKMAN
Yorktown High School
- Second Place: CARRIE R. SHREVE
James River High School

First Place: NATALIE R. SIMMONS
Ocean Lakes High School

MICROBIOLOGY 'A'

Honorable Mention: STEVE A. BRADY
Yorktown High School

Honorable Mention: NOAH A. DEICH
Williamsburg Middle School

Honorable Mention: MACKENZIE E. FAMA, MEAGAN S.Y. HUBBARD
Warwick High School

Third Place: AMBER E. BLANCHETTE
Menchville High School

Second Place: DAVID A. EMERY
Chesterfield County Mathematics and Science High School

First Place: CHARLES L.P. HAWKINS
Wakefield High School

MICROBIOLOGY 'B'

Honorable Mention: STEPHANIE B. LEWIS
Yorktown High School

Honorable Mention: MICHAEL A. MORA, III
Ocean Lakes High School

Honorable Mention: GAURI R. RAVAL
Mills E. Godwin Specialty Center

Third Place: WILLIAM B. MCCONNELL
Roanoke Valley Governor's School

Second Place: BRANDON E. MORGAN
Roanoke Valley Governor's School

First Place: BRANT M. PRIEST
Gloucester High School

PHYSICS 'A'

Honorable Mention: ALEXANDER I. ARSENOVIC
Gloucester High School

Honorable Mention: CHIP BARRINGER
Chickahominy Middle School

Honorable Mention: MATTHEW A. DEVENNY
Central Shenandoah Valley Governor's School

Third Place: CAROLINE GIBSON
Hayfield High School

Second Place: LUKE M. DAVIS
Patrick Henry High School

First Place: ESTER P. ERB
Tuckahoe Middle School

PHYSICS 'B'

Honorable Mention: VINCENT M. MANISCALCO
Atlee High School

- Honorable Mention: FAITH M. MEYERS
Yorktown High School
- Honorable Mention: KATRINA M. RAMSDELL
Chesterfield County Mathematics and Science High School
- Third Place: BRITTANY A. PETERSON
Yorktown High School
- Second Place: MICHELLE L. JONES
Homer L. Hines Middle School
- First Place: SARAH E. MARLAY
Swanson Middle School

PHYSICS 'C'

- Honorable Mention: HILLARY B. SHAYNE
Tuckahoe Middle School
- Honorable Mention: SURAVI SIRCAR
Harry F. Byrd Middle School
- Honorable Mention: MATTHEW E. WALKER
Harry F. Byrd Middle School
- Third Place: JOHN M. WHITTET
Tuckahoe Middle School
- Second Place: EREN H. TURGAY
Chesterfield County Mathematics and Science High School
- First Place: MICHELLE E. ROLLISON
Hayfield High School

PSYCHOLOGY - GENERAL

- Honorable Mention: GINGER E. HAWBERT, BIRGIT E. WAIDMANN
Yorktown High School
- Honorable Mention: ERIN KUYKENDALL
Hermitage High School
- Honorable Mention: EMILY C. OSWALD
James River High School
- Third Place: DEBORAH R. SWARD
J.R. Tucker High School
- Second Place: SAMANTHA V. DEBICKI
Yorktown High School
- First Place: EMILY K. ANTHES
Yorktown High School

PSYCHOLOGY - LEARNING & PERCEPTION 'A'

- Honorable Mention: VERONICA B. BARLAS
Yorktown High School
- Honorable Mention: JOSHUA P. COLVER
George H. Moody Middle School
- Honorable Mention: JUSTIN J. GREEN
Yorktown High School
- Third Place: LUKE M. GOODWIN
George H. Moody Middle School

- Second Place: PAUL N. BUI, JAMES A. MEDITZ
Yorktown High School
- First Place: ZANE J. JOHNSON
Central Virginia Governor's School

PSYCHOLOGY - LEARNING & PERCEPTION 'B'

- Honorable Mention: COLLIN D. RILEY
Gloucester High School
- Honorable Mention: MARLIANA E. SPENCE
J.R. Tucker High School
- Honorable Mention: JOEL H. WEST
Central Shenandoah Valley Governor's School
- Third Place: TIMOTHY D. NANCARROW
Central Virginia Governor's School
- Second Place: KIMBERLY N. WITT
Central Virginia Governor's School
- First Place: KATHLEEN T. PARKERSON
J.R. Tucker High School

PSYCHOLOGY - SOCIAL

- Honorable Mention: NORA E. GRAY
Yorktown High School
- Honorable Mention: LAURA M. ROSS, JULIA E. SEYMOUR
Yorktown High School
- Honorable Mention: ASHLEY L. SNOWDON
Yorktown High School
- Third Place: MOLLY O. BRANNON
Chesterfield County Mathematics and Science High School
- Second Place: NICHOLAS SUMMERS
Yorktown High School
- First Place: ANN E. GARDNER
Blacksburg High School

ZOOLOGY 'A'

- Honorable Mention: LINDSEY A. CONKLIN
Yorktown High School
- Honorable Mention: DYLAN L. FISHER
Gloucester High School
- Third Place: ANDREW S. ANDERSON
Gloucester High School
- Second Place: REBEKAH L. ARMSTRONG
Central Virginia Governor's School
- First Place: LAUREN C. BAKER
New Horizons Governor's School

ZOOLOGY 'B'

- Honorable Mention: HEATHER D. MUNDY
Roanoke Valley Governor's School

Honorable Mention:	AMY L. VAN DEUSEN Southwest Virginia Governor's School
Third Place:	CARMEN E. MYERS Central Virginia Governor's School
Second Place:	BETHANY B. SKELTON Washington-Lee High School
First Place:	CANDICE J. MILLER Gloucester High School

SPECIAL AWARDS

Botany Section Award, given by the Botany Section of the VAS, to the best paper on a botanical subject. (\$150.00)

ERIN B. FRACKLETON
Central Virginia Governor's School

VJAS Neuroscience Awards supported by the Virginia Neurological Society and the Auxilliary of the Virginia Neurological Society are given to four outstanding papers in the field of neuroscience (\$100.00 each).

DARIN HINMAN
J.R. Tucker High School

SHAUNAK K. DEEPAK
New Horizons Governor's School

NATALIE R. SIMMONS
Ocean Lakes High School

Mathematics, Computer, and Statistics Award for the paper that evidences the most significant contribution in the field of Mathematics. (\$200.00)

LYRIC P. DOSHI
Short Pump Middle School

Smith Shadomy Infectious Disease Award in honor and memory of Dr. Smith Shadomy given by the Virginia Chapter of the National Foundation of Infectious Diseases. (\$50.00)

CHIKA ANYADIKE
Gloucester High School

Roscoe Hughes Award for the best paper in the field of Genetics.....(\$150.00)

MARISSA KESSLER
Mills E. Godwin Speciality School

Rodney C. Berry Chemistry Award for the paper that evidences the most significant contribution in the field of chemistry.(\$200.00)

JASON NG
Yorktown High School

The Dr. and Mrs. Preston H. Leake Award in Applied Chemistry (\$200.00) will be given to the author of a research paper which best exemplifies how chemicals, chemical principles, or chemistry have been used, are used, or might be used to enhance or even to save life. Dr. Preston H. Leake will present this award.

MARISSA R. KESSLER
Mills E. Godwin Specialty Center

Russell J. Rowlett Award for the Best Research Paper of the Year.(\$300.00)

NATALIE R. SIMMONS
Ocean Lakes High School

The Virginia Psychological Foundation Meritorious Research Awards recognize outstanding presentations of research in the various fields of psychology. Each award includes a prize of \$100.00.

EMILY K. ANTHES
Yorktown High School

ZANE J. JOHNSON
Central Virginia Governor's School

KATHLEEN T. PARKERSON
J.R. Tucker High School

ANN E. GARDNER
Blacksburg High School

Virginia Sea Grant College Program Award is given by the Virginia Sea Grant College Program for outstanding marine or coastal research. (\$100.00)

CURTIS C. COPELAND
Gloucester High School

American Cancer Society Award - This award is to recognize outstanding science papers related to cancer research. A certificate to each and to 1st place - \$500, 2nd place \$300, 3rd place \$125, and honorable mention \$75. There will be a ribbon with a pin for each winner. These awards are provided by the American Cancer Society (Virginia Council). These awards are being presented by Jennifer Greiner, American Cancer Society, Roanoke, VA.

Honorable Mention - (\$75)
RAPHAELLA D. TESCHNER
Gloucester High School

First Place - (\$500)
DARIN HINMAN
J.R. Tucker High School

The Gamma Sigma Delta Award (Agriculture). Presented by the VPI & SU Chapter of the Honor Society of Agriculture. This award of \$100 is presented in recognition of excellence in research dealing with application of new technologies and/or concepts in agriculture forestry, or veterinary medicine.

ANNIE E. WY SOCK
Chesterfield County Mathematics and Science High School

W. W. Berry Award. This award is given by VA Power in honor of Mr. W. W. Berry who was a past Chairman of the Board of VA Power. This award of a \$500.00 Savings Bond will be presented to the best engineering paper.

HANS K. SHMIDHEISER
Central Shenandoah Valley Governor's School

The Joyce K. Peterson Award is presented for the outstanding paper by a middle school student. It is presented in honor of Mrs. Joyce K. Peterson who has been an outstanding teacher in the Arlington County Schools. (50.00)

CONRAD ZEUTENHORST
Swanson Middle School

The Ann M. Hancock Memorial Award - (\$500 - 1999, 2000, 2001) This award is given to the best paper in genetics and is given in memory of Anne Hancock who retired from Patrick Henry High School in Hanover County and who gave many years of service to the Jr. Academy not only by teaching but also serving on the Jr. Academy Committee.

MARISSA KESSLER
Mills E. Godwin Specialty Center

Sarah Forst of Casio, Inc. has donated 5 color power graphic scientific calculators to deserving science students Attending this year's VJAS conference. Casio would like to support continued growth in science learning and discovery. These are presented to students who have demonstrated technical use of the scientific method in their research.

Jaquan L. Thompson
Hunting Middle School

Michael Fraser
Swanson Middle School

Laura Zimmerman
Atlee High School

Amy Waddill
Mills E. Godwin High School

Justin Gayle
Atlee High School

VABE Award - For the first time, the Virginia Association of Biological Education is proud to present this cash award for the best paper in the area of Zoology. This group is dedicated to encouraging the quality of biology education in the Commonwealth of Virginia and is pleased to make this award to encourage interest in biological research carried out by Virginia's future scientists. (50.00)

LAUREN BAKER
New Horizons Governor's School

Naval Science Awards - We are pleased to represent Rear Admiral Paul G. Gaffney, II, the chief of Naval Research and Assistant Deputy Commandant of the Marine Corps for Science and Technology, to present the Naval Science Awards to the following outstanding young scientists. The Navy has a long history of funding science that changes the world, from old discoveries like the magnetic core memory that is the basis of every computer, to recent discoveries like blood substitutes and techniques for preventing hearing loss. The Navy stays at the cutting edge of science and technology by nurturing and funding world class scientists and engineers throughout their careers, from high school to active research in universities, industry and our own naval laboratories. The ideas protect the freedom of our nation and our allies, and also provide technologies that touch the lives of all our citizens. Each year, the Navy and Marines participate in over 450 fairs to encourage students to pursue careers in the sciences and engineering. The winners selected demonstrated special excellence in a field of science or engineering. The award consists of a scientific calculator, and an invitation to participate in another fair which is partnered

by the Army, Navy, Marines and Air Force. We are pleased and proud to present the Naval Science Awards to:

Justin Abshire
Gloucester High School

Alan Schmidt
Bishop Denis O'Connell High School

Jake Harmon
Atlee High School

Brittany Peterson
Yorktown High School

Dorothy S. Knowlton Award - This award is given in honor of Dorothy S. Knowlton for the best Consumer Science Paper

DONIKA K. PATEL
Southwest Virginia Governor's School

Trip to AJAS - AAAS Meeting for two students and two alternates for presenting outstanding papers. The 2000 meeting will be held in Feb. in San Francisco

Winner: MARISSA KESSLER
Mills E. Godwin Specialty Center

Winner: RACHEL P. BANKS
Chesapeake Bay Governor's School

Alternate: ERIN B. FRACKLETON
Central Virginia Governor's School

Alternate: EMILY K. ANTHES
Yorktown High School

Honorary Membership - AAAS given to two students.

JAKE HARMON
Atlee High School

BRITTANY PETERSON
Yorktown High School

Honorary Membership - VAS given to a student.

JESSICA HAWTHORNE
Hermitage High School

Bethel High School Scholarship - This \$1,000 Scholarship Award comes from the interest earned from a \$10,000 endowment contributed by the students of Bethel High School, Hampton, Va., over a two year period. Accompanying this scholarship is a rotating plaque to be displayed in the student's school for the next year. This award is based on both the students presentation and paper.

GAURI R. RAVAL
Mills E. Godwin Specialty Center

Frances and Sydney Lewis Environmental Scholarship: A \$14,000 scholarship (\$3,500 per year for four years) for the best effort by a student in grades 9 to 12 in the field of environmental science. This scholarship is in the name of Frances and Sydney Lewis and is given by the Virginia Environmental Endowment.

MELISSA L. POLLOCK
Gloucester High School

E.C.L. Miller Science Teacher of the Year Award is given to an outstanding science teacher. An all-expense-paid trip to next year's AAAS which will be in Anaheim, CA

SUSAN STEWARD
Williamsburg Middle School

VJAS Distinguished Service Award, most prestigious award given by the VJAS, is presented to a person for exceptionally outstanding service to the VJAS. This award will be presented by R. Dean Decker and Susan Booth.

ERTLE THOMPSON
University of Virginia

Election results:

Secretary - Jessica Hawthorne, Hermitage High School
Vice President - Kashauna Gill, Atlee High school
President -Alexander Griffith, Godwin High School

BEST STUDENT PAPER AWARDS
Virginia Academy of Science
Awards for Papers Presented at Radford University
May 2000

Biology

First Place

Kelly M. Passek, Virginia Tech

Honorable Mention

Daniel A. Warner, Virginia Tech

Anna Leung, Virginia Tech

Biomedical and General Engineering

First Place

Vitalii V. Itskovich, Virginia Commonwealth University

Honorable Mention

Matthew Thompson, Virginia Tech

Michael J. Miraglia, Washington-Lee University

Botany

First Place

T.A.B. Slotta, Virginia Tech

Natural History and Biodiversity

First Place

A.N. Chadwick, Virginia Tech

Honorable Mention

Erin D. Casey, Mary Washington College

Phil Sheridan, Meadowview Biological Station

Chemistry

First Place

David J. Bautz, Virginia Tech

David M. Hendrickson, Radford University

Christopher T. Lloyd, George Mason University

Honorable Mention

Kathy Esperdy, Virginia Commonwealth University

James H. Wynne, George Mason University

Statistics

First Place

Paula C. Johnson

Sundar Dorai-Raj

Materials Science

First Place

Sharon E. Koh, James Madison University

Honorable Mention

Jackie M. Williams, University of Virginia

Mark Percy, Old Dominion University

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EDITOR/BUSINESS MANAGER:

James H. Martin

Dept. of Biology - PRC

J. Sargeant Reynolds Community College

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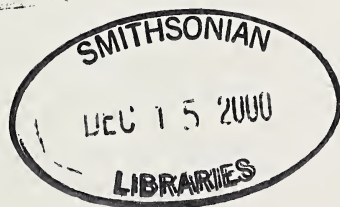
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Small Mammal Communities In Riparian And Upland Habitats on The Upper Coastal Plain Of Virginia

A. Scott Bellows¹ and Joseph C. Mitchell²

Conservation Management Institute, Virginia Tech,
Blacksburg, Virginia 24061

ABSTRACT

We compared small mammal communities between riparian (stream corridor) and nearby upland habitats in a hardwood forest ecosystem on Fort A.P. Hill, Caroline County, Virginia. We used a combination of small-scale drift fence/pitfall trap arrays and snap traps to capture small mammals during April – October 1998, with an additional winter sample in January 1999. We captured seven small mammal species at 14 sites (7 pairs). Numbers of species were not significantly different between habitat types. Bray-Curtis polar ordinations showed that plant and small mammal community compositions were similar in upland sites and that these communities were most varied in riparian sites. Riparian sites supported wetland and moist soil obligate plants that made this habitat type distinct from upland sites. Small mammal communities were dominated by *Peromyscus leucopus* and *Blarina brevicauda*. Numbers of individual small mammals captured were higher in riparian sites than in upland sites. Mean number of captures per trap night averaged 2.6 in riparian sites and 1.4 in upland sites but the difference was not statistically significant. Numbers of rodent captures were significantly higher in both habitat types than captures for insectivores. Hardwood habitats in riparian and upland systems support diverse small mammal communities in the upper Coastal Plain of Virginia. Because small mammals use both habitat types extensively, composition of contiguous upland habitats should be considered in studies of these animals in riparian ecosystems.

INTRODUCTION

Focus on riparian ecology and management has intensified recently because of local, state, and federal mandates to protect water quality and biodiversity (see reviews in Verry et al., 2000). For example, species and their habitats are required to be protected (or at least managed for their protection) under such federal mandates as the National Forest Management Act and Section 404 of the Clean Water Act. Most of the research that has been conducted on the ecology of small mammals in riparian ecosystems has occurred in the Midwest (Geier and Best, 1980) and the Pacific Northwest (e.g., Doyle, 1990; McComb et al., 1993). Comparatively little research has been conducted in eastern North America. Two studies in southeastern North America

1 Correspondence address of ASB: Department of Biology, Old Dominion University, Norfolk, Virginia 23529.
2 Correspondence address of JCM: Department of Biology, University of Richmond, Richmond, Virginia 23173.

compared small mammal communities in varying widths of riparian habitats (Dickson and Williamson, 1988; Thurmond and Miller 1994). DeGraaf and Yamasaki (2000) listed no studies based in deciduous forests of northeastern North America that compared small mammal communities in these habitat types.

The purpose of our study was to compare small mammal communities between stream corridor (riparian) and adjacent upland habitats in a forested ecosystem in the Upper Coastal Plain of Virginia. Because riparian habitats are used extensively by terrestrial vertebrates in North America (Thomas et al., 1979; Brinson et al., 1981) and because riparian systems act as dispersal corridors for some species (Harris, 1984), we hypothesized that small mammal species richness and species relative abundance this habitat type would be higher than in upland habitats. Fort A.P. Hill offers a diverse array of forested habitats, a network of streams, and sufficient topographic relief to make this kind of study feasible in the Coastal Plain Physiographic Province.

MATERIALS AND METHODS

Study Location and Site Descriptions

This study was conducted at Fort A.P. Hill, Caroline County, Virginia. Fort A. P. Hill is a 30,329 ha military training installation that is located within the Coastal Plain Physiographic Province. Descriptions of the environment and habitats of the base are in Mitchell and Roble (1998), Bellows (1999), and Bellows et al. (1999).

We selected fourteen sites for study—seven in riparian forests and seven in upland forests. All study sites were located in non-impact areas of the base. Riparian sites were located on floodplains of seven different creeks. The seven upland sites were 150-250 m from the adjacent riparian site. Average elevation for riparian sites was 37 m (20-60 \pm 17 m) and average elevation for upland sites was 56 m (40-70 \pm 10 m). Two of the pairs of sites were located in the Mattaponi River watershed (RF-UF, RG-UG) and the remainder occurred in the Rappahannock River watershed. The latter drainage offered greater topographic relief than the former.

Sampling and Collection Methods

A sampling area approximately 30 m in diameter was established within each study site. Pitfall traps with drift fences and snap traps were used to collect animals. These two trapping techniques have been shown to be complementary when assessing small mammal assemblages (Kalko and Handley, 1993, Bury and Corn, 1987). Pitfall traps are effective for capturing long-tailed shrews (genus *Sorex*) and jumping mice. Snap traps are effective for capturing mice and voles and are generally as effective as pitfall traps for capturing short-tailed shrews (genus *Blarina*) (Kalko & Handley, 1993; Mitchell et al., 1993). We constructed three pitfall arrays approximately 120° apart and 15 m (\pm 2 m) from the center of each study site. Pitfall arrays followed the design in Handley & Varn (1994). We made drift fences with plastic silt fencing 61 cm high and one m in length. We used plastic 3.8-L buckets (18 cm in diameter x 19 cm in height) for the center pitfalls. We used plastic 2-L soda bottles with the tops cut off (11 cm in diameter x 20 cm in height) for the peripheral pitfalls; one 2-L bottle was placed on each side of the distal end of all three drift fences. There were a total of seven pitfalls per array. We set nine Museum Special snap traps, three per 120° sector, in each site at the beginning of each trapping session. Each was baited daily during each trapping

session with a mixture of peanut butter and oatmeal. A schematic of the combined trapping system is provided in Bellows et al. (1999).

We conducted trapping sessions every 12-16 days during 9 April through 12 October 1998. Exceptions included one trapping session scheduled for late June 1998 that was cancelled and one session in mid-July postponed one week; both alterations were due to intense training activity and limited access. We also conducted a mid-winter trapping session 21-24 January 1999. There were a total of 12 four-day (three-night) trapping sessions that amassed a total of 8,468 trap nights—5,854 associated with pitfalls and 2,614 associated with snap traps. One trap night equals one functional trap open for one 24-hour period. At the beginning of each trapping session, we uncovered the pitfall traps and filled them with water to a depth of 6 to 9 cm. Pitfall traps, when uncovered and not flooded, were considered functional. Flooded pitfall traps were subtracted from the total effort. Snap traps found sprung and empty were also considered nonfunctional, and one trap night was subtracted from the total effort for each sprung trap (after Nelson & Clark, 1973).

We collected specimens on days 2-4 of each trapping session. On the final day of each trapping session, pitfall traps were covered and snap traps were removed from the site. All mammals collected will be deposited in the Virginia Commonwealth University Mammal Collection.

Habitat Analysis

We identified to species all trees ≥ 4.5 m in height within each study site. Trees were placed into three size classes based on diameter at breast height (dbh): saplings (<2.5 cm), understory trees (2.5-9.9 cm), and overstory trees (≥ 10 cm).

We assessed habitat variables for each study site by a line intercept method (after Canfield, 1941) using eight equally-spaced 25-m transects that radiated from the center of each study site. Variables were recorded at one-meter intervals (total = 200) and included presence or absence of downed woody debris (DWD), stumps, snags, herbs, shrubs, and a subcanopy. We also recorded litter type (i.e., evergreen, deciduous, both) and the species of all forbs and shrubs. These data and the aforementioned tree data allowed us to calculate frequencies for individual plant species. Percent canopy closure was estimated visually over each point by viewing the canopy through a cardboard tube (4.5 cm diameter x 11.5 cm in length). Habitat Descriptions

Riparian sites - The overstory tree community of all riparian study sites consisted primarily of hardwood species. Loblolly pine (*Pinus taeda*) was the only pine species observed and only in low numbers. Several commonly observed hardwood species, including river birch (*Betula nigra*), red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), and black gum (*Nyssa sylvatica*) are considered facultative wetland species in this region (Reed, 1988). Others, including white oak (*Quercus alba*), chestnut oak (*Q. prinus*), and American beech (*Fagus grandifolia*), are considered facultative upland species within this region. One frequently observed species, sweetgum (*Liquidambar styraciflua*), is common to both riparian and upland habitats. Understory tree communities were represented by sapling overstory species and understory species such as American holly (*Ilex opaca*), flowering dogwood (*Cornus florida*), ironwood (*Carpinus caroliniana*), and sweetbay (*Magnolia virginiana*). Shrub species were dominated by blueberries (*Vaccinium* spp.), coast pepperbush (*Clethra alnifolia*), and spicebush (*Lindera benzoin*), all of which are common in

wetland habitats. Ground level forbs were represented by obligatory wetland species, including royal fern (*Osmunda regalis*), lizard's tail (*Saururus cernuus*), skunk cabbage (*Symplocarpus foetidus*), golden club (*Orontium aquaticum*), and broad-leaved arrowhead (*Sagittaria latifolia*), as well as facultative wetland species, including cinnamon fern (*Osmunda cinnamomea*), netted chain fern (*Woodwardia areolata*), sensitive fern (*Onoclea sensibilis*), and false nettle (*Boehmeria cylindrica*). Partridgeberry (*Mitchella repens*) was the only facultative upland forb observed in our riparian study sites.

Upland sites - The overstory tree community of all upland study sites consisted primarily of hardwood species. Both *P. taeda* and Virginia pine (*P. virginiana*) were observed, and in one study site (UF) these were the dominant species. Most hardwood species, including *Q. alba*, southern red oak (*Q. falcata*), pignut hickory (*Carya glabra*), tuliptree (*Liriodendron tulipifera*), and *F. grandifolia*, are facultative upland species in this region (Reed, 1988). Other common tree species were either facultatively upland, such as *A. rubrum* and *N. sylvatica*, or common in riparian and upland habitats, such as *L. styraciflua*. Understory tree communities were represented by sapling overstory species and understory species and similar in composition to riparian sites. Commonly observed shrub species were blueberries (*Vaccinium* spp.) and mountain laurel (*Kalmia latifolia*). Ground level forbs were relatively sparse and represented primarily by facultative upland species, including Christmas fern (*Polystichum acrostichoides*), *M. repens*, spotted wintergreen (*Chimophila maculata*), and hog-peanut (*Amphicarpa bracteata*).

Statistical Analyses

Most analyses of small mammal data were based on captures per unit effort because effort varied among study sites and because some traps were found nonfunctional. We assumed that riparian sites and their adjacent upland sites were not ecologically independent. For this reason we used paired t-tests to compare mean total captures/100 trap nights (TN) and captures per 100TN for individual species between riparian and upland habitats (Zar, 1996). We also used paired t-tests to compare insectivore and rodent captures per 100TN for all sites, among riparian and upland sites, and between riparian and upland sites for both insectivores and rodents. Wilcoxon rank sum test was used to compare species richness between riparian and upland habitats because of non-normal distribution of small mammal species richness values within these data sets (Zar, 1996). We used Kruskal-Wallis one-way ANOVA on ranks followed by Kruskal-Wallis multiple comparison Z-value test compare captures per 100TN among small mammal species (Hintze, 1998).

We used Bray-Curtis polar ordinations (Euclidean distance measure) to examine similarities of the 14 study sites based on (1) the frequencies of forb, vine, shrub and overstory tree species and (2) small mammal community compositions. Bray-Curtis was selected because it is relatively insensitive to nonlinear relationships present in most ecological data sets (Gauch and Whitaker 1972). Polar ordination positions sites within a coordinate system (along axes), such that a site position in relation to each axis and other sites indicates general similarity among sites (Ludwig and Reynolds 1988). These positions should reflect site relations with environmental gradients, in this case (1) plant community and (2) small mammal community composition. In addition, we used Kendall's rank correlation to determine if there were relationships

between each small mammal species and the position of study sites along the three polar ordination axes (Zar, 1996).

RESULTS

Habitat Analysis

The first three Bray-Curtis polar ordination axes explained 60% of the variation in plant communities among the 14 study sites (Figure 1a and 1b). All but one of the upland sites (UF) were grouped together along axis I (32% of explained variance) reflecting the general similarity among their plant communities. Site UF was isolated from the other upland sites primarily because of the relatively high frequencies of *Pinus taeda* and *P. virginiana*. Riparian sites were arranged into three general groups (RA; RB, RD, and RE; RC, RF, and RG) along axis I. Site RA was isolated due to high frequency of grasses, high diversity of vine species relative to all other sites, and low diversity of overstory tree species. Sites RB, RD, and RE were grouped together based primarily on the mutual absence or low abundance of several plant species. Sites RC, RF, and RG were grouped together due to similar shrub communities. All upland sites were grouped together along axis II (16%) and III (12%) based primarily on similar plant communities. Sites RF and RB were isolated from the other five riparian sites along axis II. Site RF was the only riparian site with a substantial number of overstory pines. Shrub frequency of site RB was represented by only one species, spicebush (*Lindera benzoin*). Sites RE and RG were isolated from the other five riparian sites along axis III. Site RE had high fern frequency relative to all other sites and low forb diversity relative to the other riparian sites. Site RG was the only riparian site with substantial numbers of the normally upland white oak (*Quercus alba*).

Small Mammals

A total of 162 small mammals representing four insectivore and three rodent species were collected (Table 1). Two species, star-nosed mole (*Condylura cristata*) and eastern chipmunk (*Tamias striatus*), were represented by single individuals. Our protocol was not designed to accurately assess the abundance of either of these species and data for these two species were excluded from most analyses.

Median number of small mammal species recorded for riparian sites was 4 (25% quartile=3, 75% quartile=4) and for upland sites averaged 2 (25%=2, 75%=3) (see Table 2). Three species of insectivores were caught in the riparian sites and four were caught in upland sites (Table 1). Two species of rodents were caught in riparian sites and two in upland sites. Total number of species was similar between habitat types (5 riparian, 6 upland). There was no significant difference ($P=0.16$, $T=-18.0$) in small mammal species richness between riparian and upland sites.

Mean small mammal captures per 100TN in riparian study sites (2.6 ± 1.5) ranged from 1.0 (site RF) to 5.3 (RA) (Table 2). Mean small mammal captures per 100TN in upland study sites (1.4 ± 0.5) ranged from 0.9 (UE) to 2.1 (UF) (Table 2). There was no significant difference between mean numbers of small mammals captured in riparian and upland habitats ($P=0.12$, $t=1.82$). Median captures per 100TN for *Peromyscus leucopus* (1.1, 25% quartile=0.8, 75% quartile=1.5) were significantly higher ($P<0.05$) than *Sorex longirostris* (0.2, 0.0, 0.3) ($Z=3.83$, critical value = 1.96), *S. hoyi* (0.0, 0.0, 0.2) ($Z=5.62$), *Blarina brevicauda* (0.2, 0.2, 0.4) ($Z=3.03$), and *Zapus*

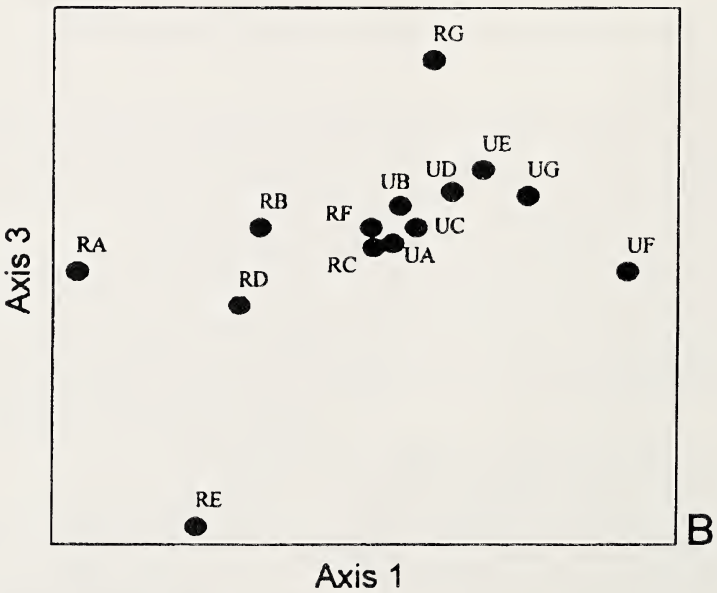
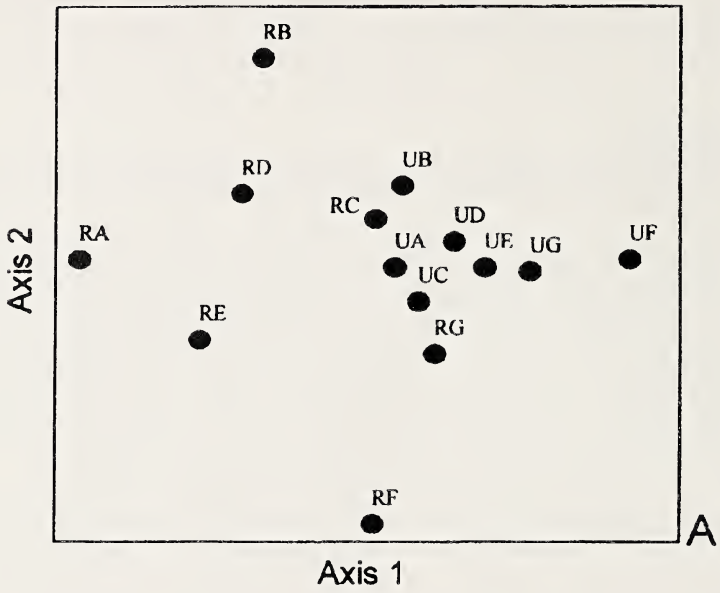


FIGURE 1. Bray-Curtis polar ordination diagram based on similarities in plant communities among the 14 trapping sites. Distance between points relative to each axis reflects similarity of plant communities for that axis. (A) Axes I and II, (B) Axes I and III.

TABLE 1. Summary of insectivore and rodent captures in riparian and upland habitats from April 1998 to January 1999 on Fort A.P. Hill, Caroline County, Virginia.

Species	Riparian	Upland	Total
Insectivora			
<i>Blarina brevicauda</i> (northern short-tailed shrew)	11	12	23
<i>Condylura cristata</i> (star-nosed mole)	0	1	1
<i>Sorex hoyi</i> (pygmy shrew)	4	1	5
<i>Sorex longirostris</i> (southeastern shrew)	9	6	15
Subtotal	24	20	44
Rodentia			
<i>Peromyscus leucopus</i> (white-footed mouse)	74	41	115
<i>Tamias striatus</i> (eastern chipmunk)	0	1	1
<i>Zapus hudsonius</i> (meadow jumping mouse)	2	0	2
Subtotal	76	43	118
Total number of captures	100	62	162
Total number of species	5	6	

hudsonius (0.0, 0.0, 0.0) ($Z=6.03$) (Table 2). Median captures for *B. brevicauda* were significantly higher ($P<0.05$) than *S. hoyi* ($Z=2.59$) and *Z. hudsonius* ($Z=3.01$). Median captures for *S. longirostris* were significantly higher ($P<0.05$) than *Z. hudsonius* ($Z=2.19$). No small mammal species was captured with significantly higher success ($P<0.05$) in either riparian or upland habitats: *S. longirostris* ($P=0.43$, $t=0.85$), *S. hoyi* ($P=0.26$, $t=1.24$), *B. brevicauda* ($P=0.97$, $t=0.04$), *P. leucopus* ($P=0.08$, $t=2.08$), and *Z. hudsonius* ($P=0.17$, $t=1.55$).

Mean captures per 100TN for insectivores for the 14 study sites (0.5 ± 0.4) ranged from 0.0 (UG) to 1.1 (RA and UC). Mean captures for rodents for the 14 sites (1.4 ± 1.0) ranged from 0.5 (UD) to 4.2 (RA) (Table 2). For all sites, mean captures for rodents was significantly higher ($P<0.01$, $t=-4.07$) than mean captures for insectivores. Mean captures for rodents was significantly higher in riparian sites ($P=0.01$, $t=-3.55$) and upland sites ($P=0.04$, $t=-2.61$) than mean captures for insectivores. There was no significant difference in mean captures of insectivores ($P=0.32$, $t=1.07$) between riparian and upland study sites. There was no significant difference in mean captures of rodents ($P=0.07$, $t=2.19$) between riparian and upland study sites.

The first three Bray-Curtis polar ordination axes explained 99% of the variation in small mammal communities among the 14 study sites. In general, upland habitats were grouped together along axis I (91% of explained variation) and riparian sites were grouped together along axis II (6% of explained variation) (Figure 2). Study site positions in relation to axis I were strongly influenced by the distribution of *P. leucopus* as shown by the positive correlation between the positions of study sites along axis I and the abundance of *P. leucopus* among study sites ($\tau = 0.966$) (Figure 3a). Site positions in relation to axis II were influenced primarily by the distribution of *B. brevicauda* as shown by the positive correlation between the positions of study sites along axis II and the abundance of *B. brevicauda* among study sites ($\tau = 0.788$).

TABLE 2. Summary of effort, captures per 100TN, and species richness for all trapping sites, and captures per 100TN for three insectivore and two rodent species collected from 10 April 1998 through 24 January 1999 on Fort A. P. Hill, Caroline County, Virginia. Mean (± 1 sd) captures per 100TN for all sites, mean (± 1 sd) captures per 100TN for insectivores and rodents, median (25% quartile and 75% quartile) small mammal species richness, and median (25%, 75%) captures per 100TN for each mammal species are provided. (-) denotes no captures

Site	TNs	<i>S. long</i>	<i>S. hoyi</i>	<i>B. brev</i>	<i>P. leuc</i>	<i>Z. huds</i>	Insectivore	Rodent	Total	Richness
RA	553	0.4	0.2	0.5	4.2	-	1.1	4.2	5.3	4
RB	512	0.6	-	0.4	2.7	-	1.0	2.7	3.7	3
RC	630	0.2	0.2	0.2	2.1	-	0.6	2.1	2.7	4
RD	552	0.2	-	0.2	0.9	0.2	0.4	1.1	1.5	4
RE	631	0.2	0.3	0.3	1.1	-	0.8	1.1	1.9	4
RF	593	-	-	0.2	0.8	-	0.2	0.8	1.0	2
RG	601	0.2	-	0.2	1.2	0.2	0.4	1.4	1.8	4
Total (riparian)	4072									
Mean (riparian)	582 \pm 44									
Median (riparian)		0.2 (0.2, 0.3)	0.0 (0.0, 0.2)	0.2 (0.2, 0.4)	1.2 (1.0, 2.6)	0.0 (0.0, 0.1)	0.6 \pm 0.3	1.9 \pm 1.2	2.6 \pm 1.5	4 (3, 4)
UA	566	0.2	-	-	1.1	-	0.2	1.1	1.3	2
UB	592	-	-	0.2	1.4	-	0.2	1.4	1.6	2
UC	613	0.3	-	0.8	0.8	-	1.1	0.8	1.9	3
UD	593	0.3	-	0.2	0.5	-	0.5	0.5	1.0	3
UE	699	-	-	0.3	0.6	-	0.3	0.6	0.9	2
UF	675	0.1	0.1	0.4	1.5	-	0.6	1.5	2.1	4
UG	658	-	-	-	0.8	-	-	0.8	0.8	1
Total (upland)	4396									
Mean (upland)	628 \pm 50									
Median (riparian)		0.2 (0.0, 0.3)	0.0 (0.0, 0.0)	0.2 (0.0, 0.4)	0.8 (0.6, 1.3)	0.0 (0.0, 0.0)	0.4 \pm 0.4	1.0 \pm 0.4	1.4 \pm 0.5	2 (2, 3)
Total Trapsights	8468									
Mean (all sites)	605 \pm 51									
Median (all sites)	605 + 51	0.2 (0.0, 0.3)	0.0 (0.0, 0.2)	0.2 (0.2, 0.4)	1.1 (0.8, 1.5)	0.0 (0.0, 0.0)	0.5 \pm 0.4	1.4 \pm 1.0	2.0 \pm 1.2	3 (2, 4)

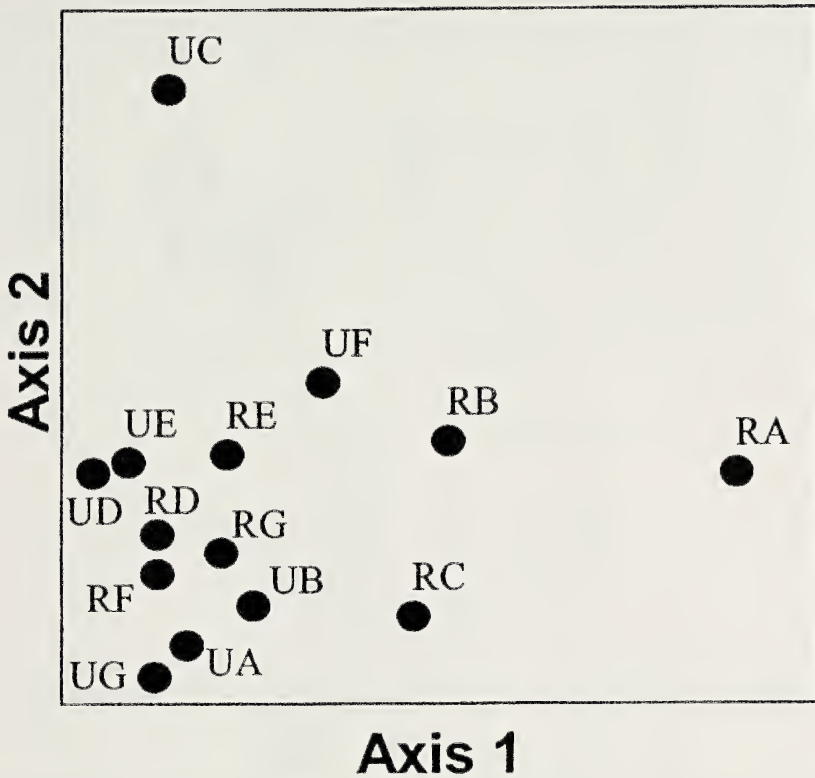


FIGURE 2. Bray-Curtis polar ordination diagram based on similarities in small mammal communities among the 14 trapping sites. Distance between points relative to each axis reflects similarity of small mammal communities for that axis.

(Figure 3b). The position of study sites along axis III (2% of explained variance) is due to the distributions of the remaining three species, *S. longirostris*, *S. hoyi*, and *Z. hudsonius*. No strong correlations, positive or negative, were shown between any of these remaining three species and the position of sites in relation to any of the three polar ordination axes.

DISCUSSION

Habitats

Results of the Bray-Curtis polar ordination indicated that the seven upland sites had similar plant communities. We attribute this similarity to two factors, (1) the contiguous nature of upland habitats across the landscape on Fort A. P. Hill, and (2) the fact that upland forests on Fort A. P. Hill are subject to perturbations as a result of forest management practices (e. g., timber harvest) more frequently than riparian forests. Overstory tree species heterogeneity was higher in upland sites and forb and shrub species heterogeneity was lower than in riparian sites. In general, plant communities among the seven riparian sites varied more than in upland sites. We attribute this

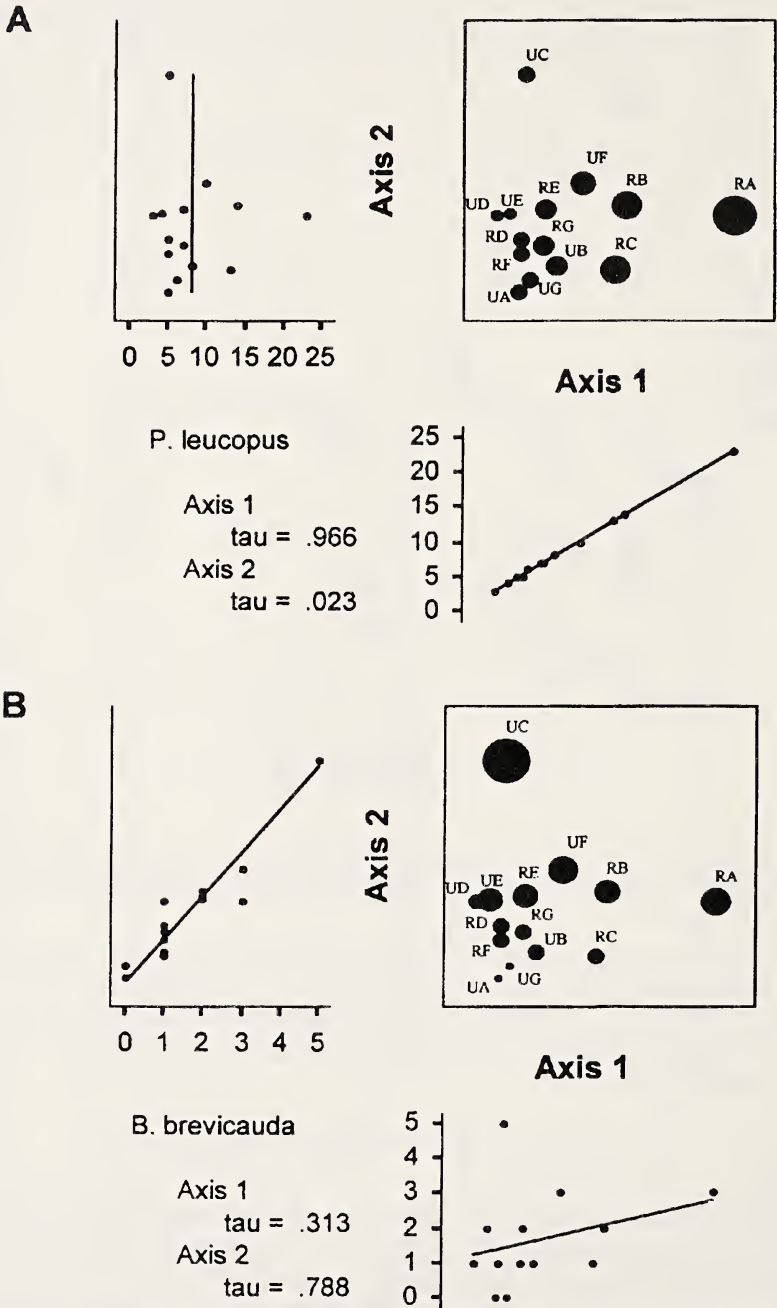


FIGURE 3. Graphic overlays of the abundances of the most frequently encountered rodent (*Peromyscus leucopus*, 3a) and insectivore (*Blarina brevicauda*, 3b) to Bray-Curtis polar ordination diagram points (see Figure 2). The sizes of study site points indicate relative abundance of that species for that site. Scatterplots depict the relationship between the small mammal species and explained variance for each axis. Kendall's rank correlation coefficients (tau) for these relationships are provided.

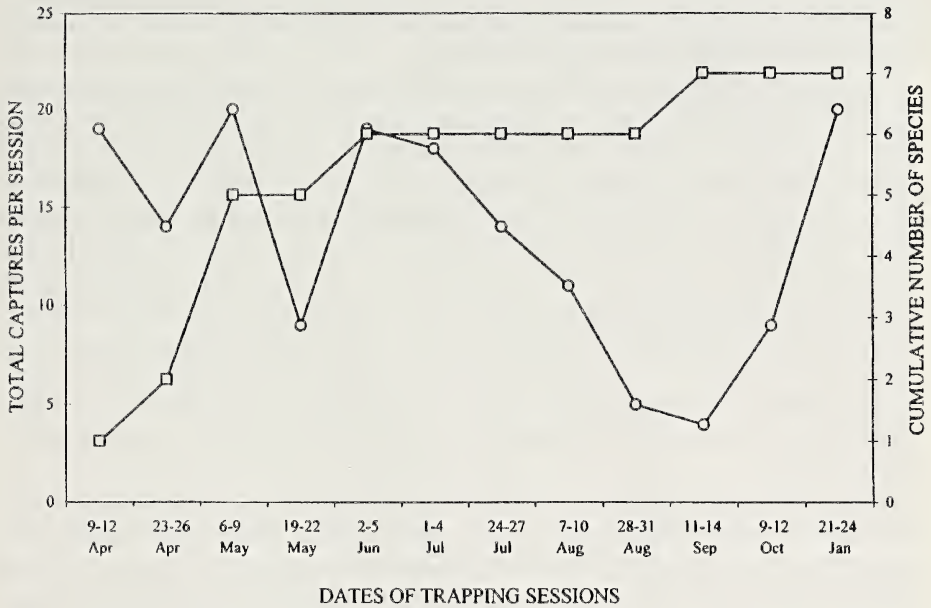


FIGURE 4. Comparison of total captures per session (circles) and cumulative number of small mammal species encountered (squares) for both riparian and upland habitats on Fort A. P. Hill from April 1998 through January 1999.

to the fact that riparian habitats on Fort A. P. Hill, while numerous and relatively isolated, occur in two different drainage systems and include different soil types and a wider variety of plant species. Williams and Moriarity (1998) found plant species composition in four streamside riparian habitats in Pennsylvania to be comprised of a mix of upland and riparian species, thus, supporting a wider variety of plant species than nearby upland habitats.

Small Mammals

Our use of small-scale pitfall/drift fence arrays and Museum Special snap traps in a combined trapping protocol ensured that the widest variety non-volant small mammal species living within our study sites would be represented. Even so, the disproportionate numbers of captures between rodents and insectivores in this study is consistent with other studies that have used snap trap and pitfalls (e.g., Snyder & Best, 1988; Kalko & Handley, 1993). All of the small mammal species captured in this study are known to occur in the mid-Atlantic region (Hall, 1981; Linzey 1998). No introduced species, such as the black rat (*Rattus rattus*), Norway rat (*R. norvegicus*), and house mouse (*Mus musculus*), were encountered.

Species accumulation curves and trapping success for this survey (Figure 4) support our conclusion from our 1997 study (Bellows et al., 1999) that assessment of small mammal species richness and the composition of small mammal assemblages within the region can be accomplished in about five months using our protocol. However, because rodent capture success was high in our mid-winter trapping session (January

1999), we maintain our original recommendation that small mammal surveys conducted within this region should include mid-winter sampling in order to provide an accurate representation of all species present.

Because rainfall patterns are known to affect small mammal activity and capture success (Gentry & Odum, 1957; Sidorowicz, 1960; Mystkowska & Sidorowicz, 1961; Vickory & Bider, 1978; Kalko & Handley, 1993), low captures per unit effort for both rodents and insectivorous small mammals in late summer and early fall 1998 are presumably a function of below normal rainfall experienced in the region during our study. Rainfall averaged 17% below normal for the months we trapped in 1998 (National Oceanic and Atmospheric Administration, Climatological Data for Virginia, 1998). We attribute fluctuations in capture success throughout the survey to episodic rainfall events. Our capture success was greater in months with higher than normal rainfall. Lower than normal rainfall during this survey may be responsible for higher overall captures of rodents than insectivores for all sites. Insectivores have higher metabolic requirements than rodents and they are intolerant of low moisture situations (Getz, 1961).

Bray-Curtis polar ordination indicated that small mammal community composition varied more among riparian habitats than upland sites. We make this conclusion based on relatively large distances between riparian sites compared to upland sites with respect to axis I—the axis with the highest amount of explained variance (91%) (Figure 2). These results are similar to those we found for plant communities and were likely influenced by (1) the variation in plant communities among riparian sites, (2) a suite of physical factors responsible for the variation in plant communities among riparian habitats, and (3) the distribution of our riparian study sites in two drainages.

Captures were dominated by one rodent species, *Peromyscus leucopus* (n=115; 71% of all captures). Populations of *P. leucopus* in riparian and upland habitats in Illinois were similar in density and demographic structure but the floodplain population served as a source of recruitment for the upland population (Batzli, 1977). *Blarina brevicauda* (n=23) was the most commonly encountered insectivore, representing 14% of all individuals captured. Clearly, small mammal community composition for riparian and upland habitats was directed by the distributions of *P. leucopus* and *B. brevicauda*. Both of these species are extremely common on Fort A. P. Hill and were the predominate small mammal species in this survey and our initial survey involving a much wider range of upland habitats (n=11) (Bellows et al., 1999). These two species are well known as habitat generalists (Jameson, 1949; Wrigley et al, 1979; Kirkland, 1981; Adler and Wilson, 1987; Pagels et al., 1992) that can occupy wide variations in habitat and environmental conditions. Thus, the importance of these habitat generalists as integral components of regional ecological communities can not be understated. As modern land-use practices continue to fragment natural habitats, the preservation of those species considered common and/or habitat generalists will be essential to maintain natural levels of biodiversity.

Olson and Knopf (1988) determined that small mammal communities in riparian and upland sites in Colorado were similar at low elevations but dissimilar at high elevations. Plant community composition, and attributes that increase habitat structure correlated positively with small mammal species richness in riparian systems in Iowa (Geier and Best, 1980). We could not discriminate between two possible explanations for the differences in captures between riparian and upland habitats because of below

normal rainfall during the study. Higher captures in riparian habitats may have been due to (1) reduced moisture levels in upland sites and the subsequent movement of individuals to nearby riparian zones or (2) due to riparian zones being used as normal resident areas and dispersal corridors that year. In addition, low mean elevation of our study sites may have influenced the lack of significant differences in small mammal species richness and relative abundance. Whereas, variation in plant community composition was greater among riparian sites than upland sites, commonalities in plant species composition between the two habitat types likely influenced small mammal species distributions and may have contributed to the lack of significance for many of our analyses.

Riparian habitats are used extensively by small mammals for permanent residence and dispersal corridors (Brinson et al, 1981). Species composition of small mammal communities in Georgia was effected by width of the riparian zone (Thurmond and Miller, 1994). Wide streamside riparian zones maintained populations characteristic of mature riparian habitats whereas narrow zones did not. These results contrasted with those of Dickson and Williamson (1988) who found more small mammals, predominately the fulvous harvest mouse (*Reithrodontomys fulvescens*), in narrow riparian zones (< 25 m) compared to wider zones (>30 m) in Texas. *Peromyscus* spp. were abundant in all widths studied. Riparian zone width in the upper Coastal Plain of Virginia may determine whether small mammals reside in this habitat type or use it temporarily for residence or dispersal, but this aspect of their ecologies has not been studied in this area. Although we did not measure them, riparian habitat zones in our study were highly variable in width. How width of habitat zones correlates with small mammal home ranges and movement patterns is unknown.

Hardwood habitats in riparian and upland systems support diverse small mammal communities in the upper Coastal Plain of Virginia. Because small mammals use both habitat types extensively, composition of contiguous upland habitats should be considered in studies of these animals in riparian ecosystems. We conclude that both hardwood habitat types are essential to the long-term survival of the small mammal fauna in the upper Coastal Plain of Virginia.

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LITERATURE CITED

- Adler, G. H., and M. L. Wilson. 1987. Demography of a habitat generalist, the white-footed mouse, in a heterogeneous environment. *Ecology* 68:1785-1796.

- Batzli, G. O. 1977. Population dynamics of the white-footed mouse in floodplain and upland forests. *American Midland Naturalist* 97:18-32.
- Bellows, A. S. 1999. Landscape and microhabitat affinities of small mammals in a continuum of habitat types on Virginia's Coastal Plain. Master's Thesis. Virginia Commonwealth University, Richmond, VA. 37 pp.
- Bellows, A. S., J. C. Mitchell, and J. F. Pagels. 1999. Small mammal assemblages on Fort A. P. Hill, Virginia: habitat associations and patterns of capture success. *Banisteria* 14:3-15.
- Brinson, M. M., B. L. Swift, R. C. Plantico, and J.S. Barclay. 1981. Riparian ecosystems: their ecology and status. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-81/17. Kearneysville, WV. 154 pp.
- Bury, R. B., and P. S. Corn. 1987. Evaluation of pitfall trapping in northwestern forests: trap arrays with drift fences. *Journal of Wildlife Management* 51:122-119.
- Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. *Journal of Wildlife Management* 39:388-394.
- DeGraaf, R. M., and M. Yamasaki. 2000. Bird and mammal habitat in riparian areas. Pp. 169-192 In E.S. Verry, J. W. Hornbeck, and C. A. Dolloff (eds.), *Riparian Management in Forests of the Continental Eastern United States*. Lewis Publishers, Boca Raton, FL.
- Dickson, J. G., and J. H. Williamson. 1988. Small mammals in streamside management zones in pine plantations. Pp. 375-378 In R. C. Szaro, K. E. Severson, and D. R. Patton (eds.), *Management of Amphibians, Reptiles, and Small Mammals in North America*. USDA Forest Service, General Technical Report RM-166. Fort Collins, CO.
- Doyle, A. T. 1990. Use of riparian and upland habitats by small mammals. *Journal of Mammalogy* 71:14-23.
- Gauch, H. G., and R. H. Whitaker. 1972. Comparison of ordination techniques. *Ecology* 53:868-875.
- Geier, J.E., and L.B. Best. 1980. Habitat selection by small mammals of riparian communities: evaluating effects of habitat alteration. *Journal of Wildlife Management* 44:16-24.
- Gentry, J. B., and E. P. Odum. 1957. The effect of weather on the winter activity of old-field rodents. *Journal of Mammalogy* 38:72-77.
- Getz, L. L. 1961. Factors influencing the local distribution of shrews. *American Naturalist* 65:67-88.
- Hall, E. R. 1981. *The Mammals of North America*. John Wiley and Sons, New York. 1181 pp.
- Hamilton, W. J., Jr., and J. O. Whitaker, Jr. 1998. *Mammals of the Eastern United States*. Cornell University Press, Ithaca. 583 pp.
- Handley, C. O., Jr., and M. Varn. 1994. The trapline concept applied to pitfall arrays. Pp. 285-287 In J. F. Merritt, G. L. Kirkland, and R. K. Rose (Eds). *Advances in the Biology of Shrews*. Special Publication No. 18, Carnegie Museum of Natural History, Pittsburgh, PA.
- Harris, L. D. 1984. *The Fragmented Forest: Island Biogeography theory and the preservation of biotic diversity*. University of Chicago Press, Chicago, IL. 211 pp.
- Hintze, J. L. 1998. *Number Cruncher Statistical Systems (NCSS 2000)*. Kaysville, Utah.

- Jameson, E. W., Jr. 1949. Some factors influencing the local distribution and abundance of woodland small mammals in central New York. *Journal of Mammalogy* 30:221-235.
- Kalko, E. K. V., and C. O. Handley, Jr. 1993. Comparative studies of small mammal populations with transects of snap traps and pitfall arrays in southwest Virginia. *Virginia Journal of Science* 44:3-18.
- Kirkland, G. L., Jr. 1981. The microdistribution of small mammals at the coniferous-deciduous forest interface. *National Geographic Society Research Reports* 13:329-336.
- Linzey, D. W. 1998. *The Mammals of Virginia*. McDonald Publishing Co., Blacksburg, VA. 459 pp.
- Ludwig, J. A., and J. F. Reynolds. 1988. *Statistical Ecology—A Primer on Methods and Computing*. John Wiley and Sons, New York. 337 pp.
- McComb, W. C., K. McGarigal, and R. G. Anthony. 1993. Small mammal and amphibian abundance in streamside and upslope habitats of mature Douglas-fir stands, western Oregon. *Northwest Science* 67:7-15.
- Mitchell, J. C., and S. M. Roble. 1998. Annotated checklist of the amphibians and reptiles of Fort A. P. Hill, Virginia, and vicinity. *Banisteria* 11:19-31.
- Mitchell, J. C., S. Y. Erdle, and J. F. Pagels. 1993. Evaluation of capture techniques for amphibian, reptile, and small mammal communities in saturated forested wetlands. *Wetlands* 13:130-136.
- Mystkowska, E. T., and J. Sidorowicz. 1961. Influences of the weather on captures of micromammalia: II. Insectivora. *Acta Theriologica* 5:263-273.
- Nelson, L., Jr., and F. W. Clark. 1973. Correction for sprung traps in catch/effort calculations of trapping results. *Journal of Mammalogy* 54:295-298.
- Pagels, J. F., S. A. Erdle, K. L. Uthus, and J. C. Mitchell. 1992. Small mammal diversity in forested and clearcut habitats in the Virginia Piedmont. *Virginia Journal of Science* 43:171-176.
- Olson, T. E., and F. L. Knopf. 1988. Patterns of relative diversity within riparian small mammal communities, Platte River Watershed, Colorado. Pp. 379-386 R. C. Szaro, K. E. Severson, and D. R. Patton (eds.), *Management of Amphibians, Reptiles, and Small Mammals in North America*. USDA Forest Service, General Technical Report RM-166. Fort Collins, CO.
- Reed, P. B., Jr. 1988. National list of plant species that occur in wetlands: 1988 national summary. U. S. Department of the Interior, Fish and Wildlife Service. *Biological Report* 88(24). 246 pp.
- Sidorowicz, J. 1960. Influence of the weather on capture of micromammalia: I. Rodents (Rodentia). *Acta Theriologica* 4:137-158.
- Snyder, E. J., and L. B. Best. 1988. Dynamics of habitat use by small mammals in prairie communities. *American Midland Naturalist* 119:128-136.
- Thomas, J. W., C. Maser, and J. E. Rodick. 1979. Riparian zones. Pp. 40-47 *In* J. W. Thomas (ed.), *Wildlife Habitats in Managed Forests: The Blue Mountains of Oregon and Washington*. Agricultural Handbook 553. Washington, DC.
- Thurmond, D. P., and K. V. Miller. 1994. Small mammal communities in streamside management zones. *Brimleyana* 21:125-130.

- Verry, E. S., J. W. Hornbeck, and C. A. Dolloff. 2000. Riparian Management in Forests of the Continental Eastern United States. Lewis Publishers, Boca Raton, FL. 402 pp.
- Vickory, W. L., and J. R. Bider. 1978. The effect of weather on *Sorex cinereus* activity. Canadian Journal of Zoology 56:291-297.
- Williams, C. E., and W. J. Moriarity. 1998. Riparian vegetation survey of four small streams in northwestern Pennsylvania. Northeastern Naturalist, 331-342.
- Wrigley, R. E., J. E. Dubois, and H. W. R. Copland. 1979. Habitat, abundance, and distribution of six species of shrews in Manitoba. Journal of Mammalogy 60:505-520.
- Zar, J. H. 1996. Biostatistical Analysis. Prentice Hall, Upper Saddle River, NJ. 662 pp. + appendices.

Oviposition Sites and Emergence Habitats of 13-year Periodical Cicadas (Brood XIX) in Eastern Virginia

Heather F. Sahli and Stewart Ware, Department of Biology
The College of William and Mary, Williamsburg, VA 23187-8795

ABSTRACT

While much research has been done on periodical cicadas, apparently no quantitative studies have been carried out to determine the vegetational structure of periodical cicada brood emergence sites or oviposition sites. We determined large tree and small tree densities and dominance in five forest stands which experienced high densities of Brood XIX cicada emergence in 1998. Paired observations were made at one of these sites to determine whether there was a preference for egg deposition in woodland edges versus the forest interior. A list was compiled of all the tree species which exhibited evidence of egg deposition. We found that the canopies of emergence sites can be dominated by loblolly pine (*Pinus taeda*), oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), and beech (*Fagus grandifolia*), with red maple (*Acer rubrum*) or holly (*Ilex opaca*) important in the understory. The abundance of loblolly pine, the only common species in which no egg deposition was found, suggests that 13 years earlier, periodical cicadas found a sufficient number of other tree species in which to deposit their eggs. This also suggests that the roots of pine trees might be capable of sustaining the cicada nymphs. Brood XIX cicadas showed a significant preference for depositing their eggs on twigs on forest edges rather than depositing on shaded twigs in the forest interior.

INTRODUCTION

The periodical cicada, *Magicicada* spp., has been the source of intrigue for many researchers since the first mention of them in scientific literature in 1666 (Williams and Simon, 1995). This great interest is due to the remarkable synchronized emergence of *Magicicada* after spending either 13 or 17 years underground. For over 300 years research has taken place to understand the behavior of these periodical cicadas and their evolutionary history. Three morphologically distinct species of 17-year *Magicicada* have been identified (*M. septendecim*, *M. cassini*, and *M. septendecula*), and their 13-year morphological counterparts have also often been treated as three species (*M. tredecim*, *M. tredecassini*, and *M. tredecula*) (Williams and Simon, 1995). In any given area, emergence time of all three species is synchronized.

After hatching from eggs deposited in small twigs, the nymphs of *Magicicada* drop to the ground into which they tunnel until they reach a plant root. The nymphs will then begin to feed on the xylem fluid of this root, and will feed on it and those nearby for 13 or 17 years (depending on the brood), going through five instars. Older instars feed on deeper roots (down to at least one meter). When nymphs are ready to eclose into adults, they make their way to the surface, where most will emerge within 7-10 days of one another (Williams and Simon, 1995). This synchronous emergence can

produce millions of cicadas which, in turn, satiate their predators. This allows for the survival of *Magicicada* populations.

In 1998, D. M. E. Ware, S. Ware, and N.J. Fashing observed the emergence of 13-year periodical cicadas (Brood XIX) in the Coastal Plain of Virginia, in western James City County and adjacent eastern Charles City County (unpublished data). The vast majority of the cicadas were *Magicicada tredecim*, though some individuals of the other two 13-year species were present as well. The recording of this emergence represented a considerable northward and eastward expansion of the known geographical range of 13-year cicadas. The previous northernmost confirmed location for Brood XIX was in the southern Piedmont of Virginia (Williams and Simon, 1995; Cooley and Marshall, 1999).

We chose to examine three generalizations that have been made about the oviposition behavior of 17-year periodical cicadas to see if they also applied to the 13-year cicada Brood XIX in eastern Virginia:

(1) *Periodical cicadas have very broad oviposition preferences in woody species.*

A number of papers exist which report on the broad species range of trees and shrubs used for egg deposition (Karban, 1983; White, 1981). We provide here a list of woody species that we observed to be used for egg deposition in our study area.

(2) *Females are more likely to deposit their eggs in twigs along the edges of forests and woodlots than in the interior of the forest.* Many researchers have noted that periodical cicadas choose woodland edges or exposed places for oviposition sites (Lloyd and White, 1976; Williams and Simon, 1995). However, this generalization apparently is based on casual observation only, with no quantitative data to confirm this preference. Therefore, we gathered quantitative data on oviposition sites of Brood XIX at woodland edges versus the forest interior.

(3) *Oviposition and emergence are related to forest community types.* Over 99% of cicadas captured during the Spring 1998 emergence at the five study sites were *Magicicada tredecim* (S. Ware, D.M.E. Ware, & N. Fashing, unpubl. data). The 17-year equivalent of that species, *M. septendecim*, is reported by Dybas and Lloyd (1974) and Lloyd and White (1976) to inhabit "mature upland forests," in contrast to the floodplain sites (rich in ash and elm) preferred by *M. cassini*. It has also been generally agreed that periodical cicadas do not normally live in coniferous forests (White, et al. 1982). While these broad descriptions of habitat exist, apparently no quantitative studies have been carried out investigating the vegetational structure of sites of brood emergence or the sites of egg deposition. We have done quantitative sampling of five forests inhabited by the 13-year periodical cicadas of Brood XIX.

METHODS

Choice of Oviposition Species: Throughout all of our field studies we recorded each new species on which we found oviposition slits on the twigs. We then compared our species lists with published vegetation studies in the Coastal Plain to see whether any abundant species were absent from our list.

Vegetation of Cicada Habitats: Five study sites were chosen based on high densities of emergence. This was evidenced by high concentrations of chorusing during the emergence of the cicadas, by large densities of emergence holes in the ground, by many oviposition sites in twigs, or all three of these. While high limbs on canopy trees could not be reached for visual investigation, evidence of deposition of

eggs often appeared in the form of "flagging." This occurs when large amounts of egg deposition in one twig cause it to become susceptible to breakage in the wind. Such flagging could be seen both as twigs with dead leaves hanging in the trees and as similar dead twigs on the ground. Fallen dead twigs found on the floor of the forest often showed evidence of much egg deposition.

The five stands chosen were sampled with the combined Bitterlich/circular plot method (Levy and Walker, 1971). At each sample point the dominance of each species was determined by measuring cross-sectional area at breast height (m^2/ha) by the Bitterlich variable radius method using the Spiegäl Relaskop (sighting prism). Density for overstory species (in trees/ha) was calculated by counting all stems ≥ 10 cm in diameter at breast height (dbh) within a circular plot of 10 m radius at each sample point. All plots in a stand were combined, and relative dominance and relative density for each species were separately calculated as a percent of total dominance (m^2/ha) or percent of total density (stems/ha) respectively. These two relative (%) values were averaged to yield an importance percent (I.V.) for that species in the stand. These methods are the same as those used by others to sample forest vegetation in Virginia (Clark and Ware, 1980; Diggs and Hall, 1981; Farrell and Ware, 1991).

We also sampled the density of understory trees by counting all stems ≥ 2 cm and <10 cm dbh in a 10 m radius circle. Only relative density was calculated for the understory layer, since no separate basal area measurements were taken in that stratum.

Oviposition Site Preferences: To determine whether these periodical cicadas preferred to deposit their eggs on woodland edges versus twigs in the interior of the woods, paired observations were made of twigs at the forest margin and of twigs in the interior of the forest. At a site where a road paralleled the edge of the forest, an observer walked along the edge of the forest. At five meter intervals, the observer faced into the forest and chose the nearest branch with appropriately sized twigs at about eye level, provided it was not *Pinus taeda*, loblolly pine. [Previous observations indicated cicadas did not use this common species for oviposition in our area]. The observer then examined twigs on the chosen branch, the branch immediately above it, the branches to the right and left of it, and the branch below it (if any) for oviposition slits. The species of the tree or shrub and the presence or absence of oviposition slits in examined twigs was recorded. For each observation point, a second observation was made at least 15 meters into the forest. Because twigs of appropriate size are much more abundant at the edge of the forest, we chose twigs from a wider band within the forest as compared with the forest edge. The first suitable eye-level branch encountered beyond 15 meters into the forest was chosen, and the tree or shrub was examined and scored, as were those at the forest edge. In all cases, twigs of the appropriate size were found before 20 meters into the forest had been reached. The four occurrence categories were (1) present on edge, present in interior; (2) present on edge, absent in interior; (3) absent on edge, present in interior, and (4) absent on edge, absent in interior. We were able to make 40 paired observations before reaching the end of the stand.

RESULTS

A list of all tree species in which egg deposition slits were found is provided in Table 1. Of all the species examined, only loblolly pine (*Pinus taeda*), a very abundant species, was devoid of all egg deposition. The second most abundant pine, *Pinus virginiana*, did have egg deposition slits at several sites. In our study sites we did not

TABLE 1: Woody species on which we noticed egg deposition.

Cupressaceae	Fagaceae
<i>Juniperus virginiana</i>	<i>Castanea pumila</i>
<i>Taxodium distichum</i>	<i>Fagus grandifolia</i>
Pinaceae	<i>Quercus alba</i>
<i>Pinus virginiana</i>	<i>Quercus falcata</i>
Aceraceae	<i>Quercus muehlenbergii</i>
<i>Acer rubrum</i>	<i>Quercus phellos</i>
Anacardiaceae	<i>Quercus prinus</i>
<i>Rhus copallina</i>	<i>Quercus velutina</i>
Aquifoliaceae	Hamamelidaceae
<i>Ilex opaca</i>	<i>Liquidambar styraciflua</i>
Betulaceae	Juglandaceae
<i>Carpinus caroliniana</i>	<i>Carya ovalis</i>
Caprifoliaceae	<i>Carya tomentosa</i>
<i>Viburnum prunifolium</i>	Lauraceae
Cornaceae	<i>Sassafras albidum</i>
<i>Cornus florida</i>	Magnoliaceae
Ebenaceae	<i>Liriodendron tulipifera</i>
<i>Diospyros virginiana</i>	Myricaceae
Ericaceae	<i>Myrica cerifera</i>
<i>Kalmia latifolia</i>	Nyssaceae
<i>Oxydendrum arboreum</i>	<i>Nyssa sylvatica</i>
<i>Vaccinium corymbosum</i>	Platanaceae
	<i>Platanus occidentalis</i>
	Rosaceae
	<i>Amelanchier arborea</i>
	<i>Prunus serotina</i>

encounter *Pinus echinata*, the third most abundant native pine (Rice and Ware, 1983), so we do not know whether it is used for oviposition.

The results of paired observations and oviposition preference are presented in Fig. 1. We tested the hypothesis that, had egg deposition site been random, the expected frequency for each category would be 10 observations. Observed frequencies of egg deposition site differed significantly from expected frequencies ($\chi^2=9.4$, $df=3$, $0.05>P>0.025$). Therefore, egg deposition in twigs at woodland edges was significantly greater than egg deposition in twigs in the forest interior.

Of the five stands sampled, four were very level, but stand #1 had more internal topographic relief. Stand #2 was quite low, not more than a foot above the James River. The vegetational composition studies showed that stands #1 and #2 were dominated by *Pinus taeda* (loblolly pine) in the canopy (Table 2). Loblolly pine is characteristic of successional rather than mature forests. Stand #1 had *Liquidambar styraciflua*

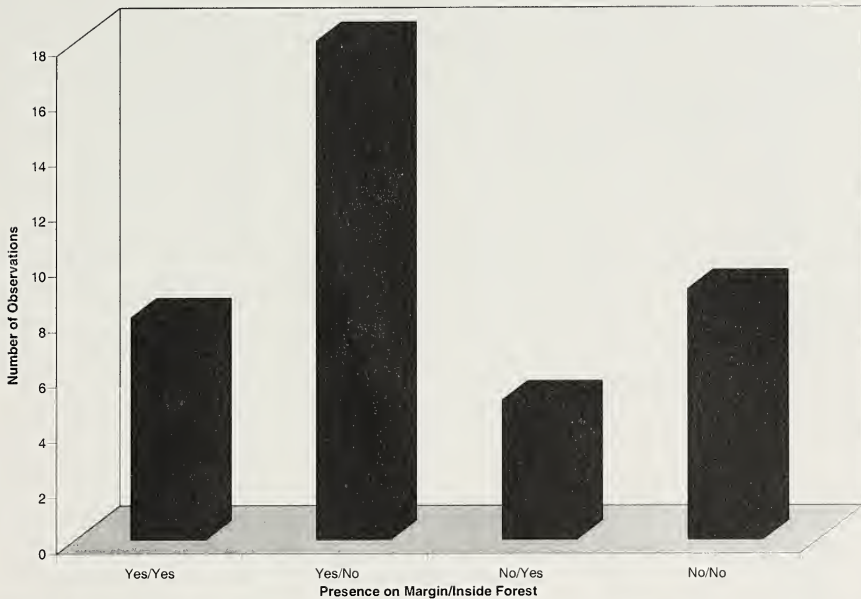


FIGURE 1. Presence of Egg Slits in Wood Margins vs. Forest Interior. Observed frequencies of egg deposition site differed significantly from expected frequencies ($\chi^2=9.4$, $df=3$, $0.05>P>0.025$).

(sweetgum) as a co-dominant. Sweetgum had a large I.V. in stands #4 and #5 as well. Stands #3 and #4 were white oak dominated forests, with *Quercus alba* (white oak) having an I.V. of 30.6% in both stands. Sweetgum and *Carya tomentosa* (mockernut hickory) also comprised a large part of the overstory in these stands, with I.V. of 17.5% and 14.6% respectively. Stand #5 was an oak-sweetgum forest, with the total oak I.V. of 32.4% and an I.V. of 16.7% for sweetgum. *Ilex opaca* (American holly) comprised much of the understory density in all five stands, and dominated the large tree class in stand #5 with an I.V. of 44%. *Acer rubrum* (red maple) had a high I.V. in stand #3 and also had a high relative density in the understory of stands #1 and #3 (Table 2).

DISCUSSION

The five stands sampled were dominated by several different tree species, including a conifer. Therefore, species composition of the canopy must not be the primary basis used by the insects in choosing their habitat. Overall, the stands showed less *Liriodendron tulipifera* (tulip tree) and *Cornus florida* (dogwood) than the forests of this area generally contain (DeWitt and Ware, 1979; Monette and Ware, 1983). Stands #3 and #4 were both white oak forests, and these hardwood dominated stands are typical of the usual habitat of the periodical cicadas. The large I.V. of *Pinus taeda* in stands #1 and #2 was unexpected, given the lack of evidence of egg deposition in loblolly pine in our area, and the known low hatching success of eggs deposited in extremely resinous pines. White, Lloyd, and Karban (1982) showed that resin secretion of pines imprisons the egg within the twig, thereby preventing the egg from hatching; or, if

hatching does occur, encasing the nymph in the resin. However, the pines were accompanied by large numbers of *Liquidambar styraciflua* and *Acer rubrum* in stand #1, and *Ilex opaca* and *Quercus falcata* in stand #2. Therefore, the cicadas of 13 years before had other species for oviposition. That the cicadas were so successful in emergence in a stand with high densities of large *Pinus taeda* trees suggests that perhaps the roots of this species are a primary source for nymphal feeding. The ability of *Magicicada* spp. to feed on the roots of resin-producing trees was suggested by White, Lloyd and Karban (1982) who studied a white pine and hemlock forest with an extremely large emergence. On the William and Mary campus, shed skins of the dogday cicada (*Tibicen canicularis*) are reliably found each year on the trunks of a stand of scattered old loblolly pines with no hardwoods among them (S. Ware, pers. observ.). Thus, it might be supposed that at least this species of cicada can feed successfully on the roots of loblolly pines, and may mean that the periodical cicada can as well.

While no studies have directly proven the ability of *Magicicada* spp. to feed on the roots of these resin-producing trees (R. Karban, pers. comm., October 1999), there is much circumstantial evidence to support this. Although the understories of stands #1 and #2 contain high densities of *Ilex opaca*, hardly any of these understory trees showed evidence of oviposition. Except for several very large hollies in stand #5, these trees do not make up the canopy and are in the interior of the woods, so they apparently do not contribute to the oviposition sites of the cicadas. Further, these understory trees live in the shade of the canopy, so they might not be very productive of photosynthate. Therefore, there is a smaller probability that understory holly roots can support the large numbers of cicada nymphs. Yet, emergence was very high in both of the pine-dominated stands, and, as noted above, this suggests that the dominant pine may have served as a food host.

The large I.V. of *Ilex opaca* in stand #5 results from the large size of many of the hollies in this stand. This suggests that the forest was selectively cut at some point, allowing the hollies to increase in size to > 4" dbh in response to the open canopy (Glascock and Ware, 1978). While shorter than the remnant pines in the canopy, these hollies were tall enough to receive much direct sunlight on their crowns. Whether these larger, faster growing hollies would be better food sources for feeding nymphs than would understory hollies is unknown, although it seems reasonable.

As we collected data on vegetation and on egg deposition sites, we frequently found fallen dead twigs on the ground in the interior of the forest that exhibited evidence of oviposition. Our data on oviposition preference showed that the cicadas made few egg depositions on twigs in the interior of the forest, at least in the understory. However, the presence of fallen twigs with many oviposition slits in the interior of the forest suggests that the cicadas deposited eggs in twigs in the canopy, even in the interior of the forest. Perhaps the cicadas did not choose a twig based on whether it was on the woodland edge or in the interior, but rather based on whether or not it was in the sun. Both woodland edge and high canopy twigs would be in the sun, but understory twigs in the interior of the forest would not be. A preference for twigs in sunlight might be advantageous because twigs in the sun have greater photosynthetic productivity, and thus the trees that bear them would provide a richer underground source of food in the roots on which the nymphs can feed.

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LITERATURE CITED

- Clark, D., & S. Ware. 1980. Upland hardwood forests of Pittsylvania Co., Virginia. *Virginia Journal of Science* 31: 28-32.
- Cooley, J., & D. Marshall. "Cicada Pages." Ummz Insect Division (April 27, 1999). Available on WWW (<http://insects.umz.lsa.umich.edu>).
- DeWitt, R., & S. Ware. 1979. Upland hardwood forests of the central Coastal Plain of Virginia. *Castanea* 44: 163-174.
- Diggs, G.M., & G.W. Hall. 1981. Vascular flora and vegetation of the Kent Branch watershed, Fluvanna Co., Virginia. *Virginia Journal of Science* 32: 23-33.
- Dybas, H.S., & M. Lloyd. 1974. The habitats of 17-year periodical cicadas (Homoptera: Cicadidae: *Magicicada* spp.). *Ecological Monographs*. 44: 279-324.
- Farrell, J., & S. Ware. 1991. Edaphic factors and forest vegetation in the Piedmont of Virginia. *Bulletin of Torrey Botanical Club* 118: 161-169.
- Glascocock, S., & S. Ware. 1979. Forests of small stream bottoms in the Peninsula of Virginia. *Virginia Journal of Science* 30: 17-21.
- Karban, R. 1983. Induced responses of cherry trees to periodical cicada oviposition. *Oecologia* 59: 226-231.
- Levy, G. F., & S. W. Walker. 1971. The combined Bitterlich-range-finder-circular quadrat method in phytosociological studies. *Jeffersonia* 5: 37-39.
- Lloyd, M. & J. White. 1976. On the oviposition habits of 13-year versus 17-year periodical cicadas of the same species. *Journal of New York Entomological Society* 84: 148-155.
- Monette, R., & S. Ware. 1983. Early forest succession in the Virginia Coastal Plain. *Bulletin of Torrey Botanical Club* 110: 80-86.
- White, J. 1981. Flagging: host defenses versus oviposition strategies in periodical cicadas (*Magicicada* spp., Cicadidae, Homoptera). *The Canadian Entomologist* 113: 727-738.
- White, J., Lloyd, M., & R. Karban. 1982. Why don't periodical cicadas normally live in coniferous forests? *Environmental Entomology* 11: 475-482.
- Williams, K., & C. Simon. 1995. The ecology, behavior, and evolution of periodical cicadas. *Annual Review of Entomology* 40: 269-295.

Effects of Blood Extraction on the Mortality of the Horseshoe Crab, *Limulus polyphemus*.

Elizabeth A. Walls and Jim Berkson, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

ABSTRACT

Horseshoe crabs (*Limulus polyphemus*) are bled by biomedical companies for the extraction of Limulus Amoebocyte Lysate (LAL), a clotting agent used in the detection of endotoxins. In 1998, the Atlantic States Marine Fisheries Commission mandated that all biomedical companies collecting horseshoe crabs for the production of LAL study the horseshoe crab mortality rates resulting from the company's blood extraction process. BioWhittaker, a Cambrex Company is one of the largest producers of LAL in the world. During the summer of 1999, bled and unbled horseshoe crabs were transported from BioWhittaker's bleeding facility in Chincoteague, Virginia to the Virginia Seafood Agricultural Research and Extension Center's aquaculture facility in Hampton, Virginia. At the aquaculture facility, they were kept in a tank and their survival was monitored for a period of two weeks. Mortality for bled crabs was 15%, while mortality for unbled crabs was 0%. Because of the importance of horseshoe crabs to a wide variety of interests, proper management requires monitoring and consideration of mortality effects on the population.

INTRODUCTION

Horseshoe crabs (*Limulus polyphemus*) are the target of a large commercial fishery that provides bait for the American eel (*Anguilla rostrata*), whelk (commonly referred to as conch *Busyon* spp.), and, to a lesser extent, catfish fisheries (HCTC, 1998). The horseshoe crab fishery has been increasing rapidly (Loveland et al., 1996; Berkson and Shuster, 1999) and is the subject of much controversy (Berkson and Shuster, 1999).

Biomedical companies also catch horseshoe crabs to produce Limulus Amoebocyte Lysate (LAL), a clotting agent used to detect the presence of endotoxins pathogenic to humans in injectable drugs and all implantable devices (Novitsky, 1984; Mikkelsen, 1988). The LAL test is now a standard used to protect human health around the world, and horseshoe crabs are the only source of LAL.

The Food and Drug Administration (FDA) mandates that biomedical companies release their horseshoe crabs alive after they have been caught and bled. Because mortality rates in the capture and bleeding processes are poorly understood, the Atlantic States Marine Fisheries Commission mandated in 1998 that all biomedical companies actively bleeding horseshoe crabs estimate mortality rates resulting from their bleeding process. Proper management of the resource requires information on all human induced sources of mortality.

BioWhittaker, a Cambrex company, is the largest producer of LAL in the world. In response to the ASMFC mandate, BioWhittaker requested Virginia Tech to conduct

the mortality study. The objective of the study was to evaluate the mortality rates between bled and unbled crabs in a controlled holding facility.

METHODS

To examine the impact of blood extraction on the horseshoe crabs used by BioWhittaker, mortality rates were compared between crabs that underwent the bleeding process ("bled") and crabs that were suitable to undergo the bleeding process but did not ("unbled"). On 8 July 1999 and 22 July 1999, horseshoe crabs were captured using BioWhittaker's standard operating procedure of trawling in the Atlantic Ocean off the coasts of Chincoteague, Virginia and Ocean City, Maryland. After capture, horseshoe crabs were brought to BioWhittaker's bleeding facility in Chincoteague. The procedure was the same for each of the two sample and monitoring periods. Ten newly-matured, male crabs (identified by pristine shell condition and boxing-glove lower claws) were randomly selected from all of the crabs obtained in that day's trawls. These ten were not put through the bleeding process and served as a control in the experiment. They were packed in coolers labeled "unbled," and set aside. Ten additional newly-matured, male crabs were then randomly selected from the remaining crabs and underwent BioWhittaker's normal bleeding process. Upon completion of the bleeding process, the crabs were packed in coolers labeled "bled."

All coolers containing horseshoe crabs, both "bled" and "unbled," were immediately packed in an air-conditioned vehicle, and transported to the Virginia Seafood Agricultural Research and Extension Center's aquaculture facility in Hampton, Virginia. Here, the "unbled" crabs were marked so as to distinguish them from the "bled" crabs, and all crabs were placed into a re-circulating marine aquaculture system. The horseshoe crabs remained under observation in Hampton for a period of two weeks. They were maintained in appropriate conditions (Brown and Clapper, 1981), fed a diet of squid, and monitored daily.

At the conclusion of each two-week period, the status of each crab (dead or alive) was recorded. The results from the two samples were combined and the overall percentage mortality was calculated for the bled and the unbled groups. All surviving horseshoe crabs were removed from the tank, placed in the coolers, packed in an air-conditioned vehicle, and returned to BioWhittaker's bleeding facility in Chincoteague, Virginia. They were then returned to the Atlantic Ocean in accordance with BioWhittaker's standard operating procedures.

RESULTS

The results for each of the two-week periods on mortality differences between crabs bled by BioWhittaker and crabs suitable for bleeding, but not undergoing the bleeding process, are summarized in Table 1. Bled crabs had an overall mortality rate of 15% compared to the 0% mortality rate of the unbled crabs.

DISCUSSION:

The results obtained in this study show that there is a level of mortality resulting from the blood extraction process. This is consistent with results obtained in previous studies (Rudloe, 1983; Thompson, 1998). Based on a tagging study in Florida, Rudloe (1983) found that bleeding increased mortality by 10% during the first year after bleeding, and 11% during the second year. Thompson's (1998) study on horseshoe

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TABLE 1. Comparison of mortality rates between bled and unbled groups of horseshoe crabs.

Dates	Unbled Horseshoe Crabs			Bled Horseshoe Crabs		
	# of crabs monitored	# of crabs that died	% dead at study end	# of crabs monitored	# of crabs that died	% dead at study end
07/08/99 – 07/22/99	10	0	0%	10	0	0%
07/22/99 – 08/05/99	10	0	0%	10	3	30%
Totals:	20	0	0%	20	3	15%

crabs in South Carolina estimated mortality rates associated with LAL processing to be 15%.

Each LAL producer has a unique operation in processing horseshoe crabs. They each have unique bleeding methods, method of capture, distance and method of travel to bleeding lab, holding time and conditions, and methods of return most appropriate to their own setting and situation. The results found in this study reflect those of BioWhittaker and may not be reflective of other companies' procedures.

Additional examination of the effect of blood extraction on mortality of horseshoe crabs would provide more detailed information. Further studies examining this effect are planned and will involve larger sample sizes. The sample sizes used in this study were limited by the size of the holding tank at the aquaculture facility.

This study examined the survival of the crabs in a controlled environment (a re-circulating marine system), as opposed to their natural environment. While this may not be reflective of the mortality rate of crabs returned to the wild, it may be thought of as a maximum mortality that these crabs could experience. Transfer and holding may induce stress on the crabs. Thus, the survival of the bled crabs could be compromised in translocation and confinement in the tank.

Further, this study looked only at newly matured, male crabs in an attempt to minimize variation of external influences. In each set of monitored crabs, the only difference between the two groups was whether or not they underwent the blood extraction process. Capture, transport, sample size and holding period were consistent in all groups of crabs. Additional research should also look at differences in mortality in other age and gender classes.

The Food and Drug Administration estimates that 260,000 horseshoe crabs were caught, bled, and returned to the ocean by biomedical companies in 1997 (HCTC, 1998). The commercial fishery reported landings of 1,885,883 pounds in 1997 with a 100% mortality rate, down from the 5,153,630 reported in 1996 (HCTC, 1998). These numbers are known to be incomplete, with actual landings likely to be substantially higher (HCTC, 1998). When comparing the commercial fishery to BioWhittaker's bleeding process, in terms of the numbers of crabs caught and their associated mortality rates, it is evident that the bleeding process has a substantially smaller impact than the commercial fishery on the horseshoe crab population.

CONCLUSIONS

In conclusion, it is evident that the blood extraction process performed by biomedical companies results in some mortality of horseshoe crabs. This study reports the impact of BioWhittaker's bleeding process to be 15%. Because horseshoe crabs are a valuable resource to numerous interests, any impact on their mortality rates should be carefully monitored. With this information, managers can regulate the resource ensuring the needs for horseshoe crabs can be met on an ongoing basis.

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LITERATURE CITED

- Berkson, J. M., and C. N. Shuster, Jr. 1999. The horseshoe crab: The battle over a true multiple-use resource. *Fisheries* 24(11):6-10.
- Brown, G. G., and D. L. Clapper. 1981. Procedures for maintaining adults, collecting gametes, and culturing embryos and juveniles of the horseshoe crab, *Limulus polyphemus* L. in *Laboratory animal management: Marine invertebrates*. National Academy Press, Washington, D.C.
- HCTC. 1998. Status of the Horseshoe crab (*Limulus polyphemus*) population of the Atlantic coast. Horseshoe Crab Technical Committee. Atlantic States Marine Fisheries Commission, Washington, D.C.
- Loveland, R. E., M. L. Botton, and C. N. Shuster, Jr. 1996. Life history of the American horseshoe crab (*Limulus polyphemus* L.) in Delaware Bay and its importance as a commercial resource. Pages 15-22 in J. Farrell and C. Martin, eds. *Proceedings of the horseshoe crab forum: status of the resource*, University of Delaware Sea Grant College Program, Lewes, Delaware.
- Mikkelsen, T. 1988. *The secret in the blue blood*. Science Press. Beijing, China. 125 pgs.
- Novitsky, T. J. 1984. Discovery to commercialization: the blood of the horseshoe crab. *Oceanus* 27(1):13-18.
- Rudloe, A. 1983. The effect of heavy bleeding on mortality of the horseshoe crab, *Limulus polyphemus*, in the natural environment. *J. Invertebr. Pathol.* 42:167-176.
- Thompson, M. (1998). "Assessments of the population biology and critical habitat for the horseshoe crab, *Limulus polyphemus*, in the South Atlantic Bight," M.S. thesis, University of Charleston, Charleston, South Carolina.

Observations on Amphibians and Reptiles in Burned and Unburned Forests on the Upper Coastal Plain of Virginia

Joseph C. Mitchell¹, Conservation Management Institute, Virginia Polytechnic Institute State University, Blacksburg, VA and Department of Biology, University of Richmond, Richmond, VA

ABSTRACT

I evaluate the results of a short-term study on the effects of prescribed burning on terrestrial amphibians and reptiles on Fort A.P. Hill, Caroline County, Virginia. Six species of amphibians and reptiles were observed in unburned sites and eight species were observed in burned sites. More individual amphibians (46) were observed in unburned stands than in burned stands (15). Adults of two species (*Bufo americanus*, *Plethodon cinereus*) were found dead under logs in the still smoldering prescribed burn. The results of this study suggest that prescribed burning may have some negative effects on amphibians and reptiles. Because the literature on this subject from eastern North America is contradictory, it is premature to make broad scale geographic generalizations. More studies with replications are needed to provide evidence that prescribed burning is harmful to terrestrial amphibians and reptiles in the mid-Atlantic region.

INTRODUCTION

Prescribed burning of temperate zone forests for timber and wildlife management has been used for decades (Pyne, 1982; Williams, 1989). The use of fire to achieve ecosystem management goals has been increasing substantially, especially in areas where the dominant plant communities evolved with fire (e.g., Stoddard, 1962; Robbins and Myers, 1992; Russell et al., 1999). Most of the research conducted on the effects of prescribed fire on amphibians and reptiles has been conducted in southeastern North America (e.g., Means and Campbell, 1981; Mushinsky, 1985, 1986), in prairie ecosystems (Biggam et al., 1964; Ervin and Stasiak, 1979), and in chaparral habitats in the far West (Lillywhite, 1977). These studies compare compositions of herpetofaunal assemblages in forest tracts maintained by fire management to assemblages in unburned forest tracts or report observations on mortality of individuals following fires. The literature review by Russell et al. (1999) included papers in fire-maintained ecosystems and only three papers from non-xeric habitats (Kirkland et al., 1996; McLeod and Gates, 1998; Ford et al., 1999). These studies examined the effects of prescribed fire on temperate zone hardwood forest herpetofaunas and small mammals. Fire is used as a forest management tool on Fort A.P. Hill (JCM, personal observations). However, the effects of prescribed burning in this area on amphibians and reptiles have not been evaluated.

1 Correspondence adress, Department of Biology, University of Richmond, Richmond, VA 23173

In 1997 I had the opportunity to obtain information on the terrestrial herpetofauna in an area on Fort A.P. Hill that was being burned for forest management. My hypothesis was that the numbers of species and individuals observed in burned forests would not be significantly different from numbers in adjacent unburned forests. Here I evaluate comparative information from these two areas and review the literature on this subject to gain insights into the effects of prescribed burning on terrestrial amphibians and reptiles in the upper Coastal Plain of Virginia.

MATERIALS AND METHODS

My field crews and I conducted time-constrained, haphazard transect surveys in mixed hardwood forests in Fort A.P. Hill Training areas 5C, 6B, 6C, and 7A during 2-7 April 1997 (see Mitchell and Roble, 1998 for locations of training areas). Fort A.P. Hill (US Army), Caroline County, Virginia, is a training facility for infantry and support operations, and is comprised of 30,329 ha of reclaimed farmland that is now in various stages of ecological succession. Descriptions of the base are in Mitchell and Roble (1998) and Bellows et al. (1999). Training area 5C, an area covered largely by mixed hardwood and pine forest, was burned with a low-intensity fire on 2 April 1997. I surveyed four different areas separated from each other by several hundred meters. The fire was still burning inside logs and along the forest floor during the afternoon of these surveys. I selected four nearby sites in the other training areas noted for comparative sampling. The other training areas supported stands of mixed oak (*Quercus* spp.) and Virginia pine (*Pinus virginiana*). These were surveyed on the same day, as well on three subsequent days. I assumed that recent rainfall history and pre-burn soil conditions were similar between burned and unburned sites and that these micrographic variations would have no measurable effects on the activity of amphibians and reptiles. All observations were recorded by 2-3 people during one-hour daytime surveys. All individuals were recorded and observations were made on dead and dying animals, as well as pertinent microhabitat features.

RESULTS

Six species of amphibians and reptiles (4 salamanders, 1 frog, 1 lizard) were observed in unburned sites and 8 species (3 salamanders, 1 frog, 2 lizards, 2 snakes) were observed in burned sites (Table 1). Forty-five individual amphibians were observed in unburned sites, most of which (43) were *Plethodon cinereus*. Comparatively, 14 amphibians (8 *P. cinereus*) were found in the burned sites. One lizard was observed in one unburned site and two lizards and two snakes were observed in the burned sites. No amphibians or reptiles were found in Training Area 6B despite the fact that 340 logs of various sizes were overturned. *Ambystoma maculatum* egg masses and strings *Bufo americanus* eggs were found in a vernal pool in 6B.

In Training Area 5C, one *Notophthalmus viridescens* eft was found alive and healthy under a 7.6 cm diameter log that had burned all the way around except directly underneath. One adult gravid female *P. cinereus* (43 mm SVL, 55 mm total length, 1.4 g) was found limp and apparently dead under a 25 cm diameter log. The adult *Bufo americanus* was found dead and partially concealed under a small log. The *Ambystoma maculatum* was a 48 mm SVL, 3.2 g juvenile that was found under a 7.6 cm diameter log at the top of its burrow entrance. In addition to these observations, one 35 mm adult

TABLE 1. Number of amphibians and reptiles observed in four unburned hardwood forest tracts and in four sampling sites in one large burned hardwood forest on Fort A.P. Hill, Virginia. Number and letter designations represent Training Areas. All the burned sites were located in Training Area 5C.

Species	Unburned				Burned			
	6C	6B	7A	5C	1	2	3	4
Amphibians								
<i>Ambystoma maculatum</i>	0	0	0	0	0	0	1	0
<i>Plethodon cinereus</i>	29	0	11	3	3	5	0	0
<i>Plethodon cylindraceus</i>	0	0	0	0	0	2	0	0
<i>Pseudotriton ruber</i>	1	0	0	0	0	0	0	0
<i>Notophthalmus viridescens</i>	0	0	1	0	1	1	1	0
<i>Bufo americanus</i>	0	0	0	0	0	0	0	1
<i>Rana clamitans</i>	0	0	1	0	0	0	0	0
Total Amphibians	30	0	13	3	4	8	2	1
Reptiles								
<i>Eumeces fasciatus</i>	0	0	1	0	0	0	1	0
<i>Sceloporus undulatus</i>	0	0	0	0	0	0	0	1
<i>Diadophis punctatus</i>	0	0	0	0	0	0	1	0
<i>Elaphe obsoleta</i>	0	0	0	0	0	0	0	1
Total Reptiles	0	0	1	0	0	0	2	2
No. Person Hours	2	2	2	2	3	2	2	2

four-toed salamander (*Hemidactylum scutatum*) was found in a small seepage area that was 2 m from burned substrate.

DISCUSSION AND CONCLUSIONS

Equal numbers of species of amphibians and four times the number of reptiles were found in burned forest sites than in unburned forest sites. In contrast, larger numbers of individual amphibians (mostly salamanders in the genus *Plethodon*) were found in unburned forests than in the burned forest. The few reptiles observed in these sites preclude any realistic conclusions. These observations suggest that there was no difference in species richness between burned and unburned forests. The larger number of salamanders in unburned sites may be due to the higher moisture content of unburned litter and cooler soil compared to the burned area that affected their occurrence on the surface.

Kirkland et al. (1996) used drift fences and pitfall traps to study small mammals and amphibians in burned and unburned oak-dominated forest plots following a prescribed fire in Pennsylvania. They captured a total of 6 species and 35 individual amphibians in the burned plot and 5 species and 15 individuals in the unburned plot. Most species were represented by 1-5 individuals. The American toad (*Bufo americanus*) was significantly more abundant in the burned plot than the unburned plot.

However, it is difficult to evaluate this result because the populations were not studied before the prescribed burn occurred, 4.5 months earlier. Ford et al. (1999) evaluated the effects of a high intensity burn on amphibians and small mammals in pitch pine habitats in a mountainous area in southwestern North Carolina. They sampled burned and unburned areas before and after the fire using time-constrained searches and drift fences with small pitfall traps. Four species of plethodontid salamanders were found but there were no significant differences between burned and unburned plots. Only one study has been conducted on herpetofaunal communities in burned forest habitats and other forest types in the mid-Atlantic region. McLeod and Gates (1998) conducted a two-year study using drift fences and pitfall traps in forest stands on the Eastern Shore of Maryland. The sites were comprised of hardwoods, cutover hardwoods, mixed pine-hardwoods, and prescribed burned pines. They found significantly fewer individual amphibians and reptiles in the burn site than in other sites. Nine species of amphibians and 8 species of reptiles were recorded for the burn site compared to hardwood stands (14 amphibians, 11 reptiles), cutover hardwoods (12/13), and pine (11/12) sites. Species richness between pine and burned stands was not significantly different. They concluded that the deeper leaf litter and more dense overstory in the pine stand kept the forest cooler and more moist than in the burned stand. These factors may have made the pine stand more hospitable to these ectotherms than the drier burned site. The conflicting results of these three studies suggests that there may be regional, habitat, and sampling design differences that affect inferences about prescribed burns on amphibians and reptiles.

The results of my short-term study on Fort A.P. Hill, combined with those in McLeod and Gates (1998), suggest that prescribed burning may have negative effects on amphibians and reptiles at lower elevations in the mid-Atlantic region. Although numbers of species may be similar between treatments, the number of individuals that burned stands can support may be less than numbers in unburned stands. Limited observations on Fort A.P. Hill on mortality in burned areas also indicate that some individuals may be at risk of death from heat in some circumstances. These observations are too few, however, to produce broad scale geographic generalizations. This is because a number of factors directly influence the effects of fire, including fire intensity, seasonal activity of amphibians and reptiles, seasonal timing of prescribed fires, microgeographic variation in moist areas, effects from recent rains, slope angle, aspect, and forest type. I agree with deMaynadier and Hunter (1995) and Russell et al. (1999) that more precise experimentally designed studies with replications are needed to evaluate the extent to which prescribed burning may be harmful to terrestrial amphibians and reptiles in the mid-Atlantic region.

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LITERATURE CITED

- Bellows, S.A., J.F. Pagels, and J.C. Mitchell. 1999. Small Mammal Assemblages on Fort A.P. Hill, Virginia: Habitat Associations and Patterns of Capture Success. *Banisteria* 14:3-15.
- Bigham, S.R., J.L. Hepworth, and R.P. Martin. 1964. A Casualty Count of Wildlife Following Fire. *Proc. Oklahoma Acad. Sci.* 44:47-50.
- deMaynadier, P.G., and M.L. Hunter, Jr. 1995. The Relationship between Forest Management and Amphibian Ecology: a Review of the North American Literature. *Environ. Rev.* 3:230-261.
- Erwin, W.J., and R.H. Stasiak. 1979. Vertebrate Mortality during the Burning of a Reestablished Prairie in Nebraska. *Am. Midl. Nat.* 101:247-249.
- Ford, W.M., M.A. Menzel, D.E. McGill, J. Learn, and T.S. McCay. 1999. Effects of Community Restoration Fire on Small Mammals and Herpetofauna in the Southern Appalachians. *Forest Ecol. Manage.* 114:233-243.
- Kirkland, G.L., Jr., H.W. Snoddy, and T.L. Amsler. 1996. Impact of Fire on Small Mammals and Amphibians in a Central Appalachian Deciduous Forest. *Am. Midl. Nat.* 135:253-260.
- Lillywhite, H.B. 1977. Effects of Chaparral Conversion on small Vertebrates in Southern California. *Biol. Conser.* 11:171-184.
- McLeod, R.F., and J.E. Gates. 1998. Response of Herpetofaunal Communities to Forest Cutting and Burning at Chesapeake Farms, Maryland. *Am. Midl. Nat.* 139:164-177.
- Means, D.B., and H.W. Campbell. 1981. Effects of Prescribed Burning on Amphibians and Reptiles. Pp. 89-96 *In* G.W. Wood (ed.), *Proceedings of a Symposium: Prescribed fire and Wildlife in Southern Forests*. Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC.
- Mitchell, J. C., and S. M. Roble. 1998. Annotated Checklist of the Amphibians and Reptiles of Fort A. P. Hill, Virginia, and Vicinity. *Banisteria* 11:19-31.
- Mushinsky, H.R. 1985. Fire and the Florida Sandhill Herpetofaunal Community: with Special Attention to Responses to *Cnemidophorus sexlineatus*. *Herpetologica* 41:333-342.
- Mushinsky, H.R. 1986. Fire, Vegetation Structure and Herpetofaunal Communities. Pp. 383-388 *In* A. Rocek (ed.), *Studies in Herpetology, Proceedings of the 3rd European Herpetological Meeting*. Prague, Czechoslovakia.
- Pyne, S.J. 1982. *Fire in America: a Cultural History of Wildland and Rural Fire*. Princeton University Press, Princeton, NJ. 653 pp.
- Robbins, L.E., and R.L. Myers. 1992. Seasonal Effects of Prescribed Burning in Florida: a Review. *Tall Timber Research Inc., Misc. Publ.* 8:1-96.
- Russell, K.R., D.H. Van Lear, and D.C. Guynn, Jr. 1999. Prescribed Fire Effects on Herpetofauna: Review and Management Implications. *Wildl. Soc. Bull.* 27:374-384.
- Stoddard, H.L. 1962. Use of Fire in Pine Forests and Game Lands of the Deep Southeast. *Proceedings of the Tall Timbers Fire Ecology Conference*. Tall Timbers Research Station, Tallahassee, FL, 1:31-42.
- Williams, M. 1989. *Americans & Their Forests, A Historical Geography*. Cambridge University Press, New York, NY. 599 pp.

Botanizing with Darwin¹

Duncan M. Porter, Department of Biology,
Virginia Polytechnic Institute & State University,
Blacksburg, VA 24061, and Darwin Correspondence Project,
University Library, West Road, Cambridge CB3 9DR UK

INTRODUCTION

Today, we tend to think of Charles Darwin (1809-1881) primarily as a zoologist, who used evidence from the relationships of the Galapagos finches to work out his theory of evolution by natural selection. Neither of these assumptions is correct.

After his return from the *Beagle* voyage in 1836, the British Museum ornithologist John Gould pointed out to Darwin that his collection of darkish birds from the archipelago, which he thought represented several different families, actually were quite closely related and represented a single family new to science. Darwin was never able to work out their relationships, because he had neglected to label the specimens as to which islands they had been collected upon. But he recognized that they had evolved from a common ancestor.

The only time that Darwin ever called himself anything but a naturalist in print, it was to refer to himself as a geologist. And this was in a botanical journal (Darwin 1855). Indeed, Darwin's career can be divided into three phases: first as a geologist, secondly as a zoologist, and thirdly as a botanist. However, these phases overlap, and an interest in botany can be traced to his childhood. In his *Autobiography*, first published in 1887 (F. Darwin 1887), Darwin stated that by the time he went to school at age eight, "my taste for natural history, and more especially for collecting, was well developed. I tried to make out the names of plants, and collected all sorts of things, shells, seals, franks, coins,, and minerals. The passion for collecting which leads a man to be a systematic naturalist, a virtuoso or a miser was very strong in me, and was clearly innate, as none of my sisters or brother ever had this taste." (Barlow 1958, pp. 22-23).

One of Darwin's boyhood friends, William Allport Leighton, who became a botanist himself, remembered Darwin's "bringing a flower to school and saying his mother had taught him how by looking at the inside of the blossom the name of the plant could be discovered. ...""This greatly roused my attention and curiosity, and I inquired of him repeatedly how this could be done?""----but his lesson was naturally enough not transmissible." (Barlow 1958, p. 23n). I think that Darwin's mother must have been trying to teach him Linnaeus' sexual system, by counting the numbers and forms of stamens and pistils in a flower in order to name the plant.

In this paper, I will take a look at Darwin's life and some of his botanical and other interests. I will also indicate where his and my paths have crossed during my own career as a botanist.

1 Sidney S. Negus Memorial Lecture, Radford University, May 25, 2000

BOYHOOD TO MANHOOD

Charles Robert Darwin was born in Shrewsbury, England on 12 February 1809, the same day as Abraham Lincoln. However, Darwin was born under somewhat better circumstances than Lincoln. His father, Robert Waring Darwin (1766-1848), a successful physician, was the son of the famous physician, philosopher, poet, and evolutionist Erasmus Darwin (1731-1802). His mother, Susannah Darwin (1765-1817), was the eldest child of Josiah Wedgwood (1730-1795), the founder of the Wedgwood pottery firm. As the second son and fifth of six children, Charles was not his father's primary heir. However, his marrying in 1839 his first cousin Emma Wedgwood (1808-1896) helped to make him financially independent and not beholden to a job.

Following schooling at home and at Rev. Case's day school, where Darwin tried to tell Leighton the mystery of flower identification, in 1818 he entered Shrewsbury School. In his *Autobiography*, Darwin relates stories about this time of his life and of the wretchedly classical curriculum of Shrewsbury School, but he has nothing to say about plants.

In October 1825, when he was 16, Darwin entered Edinburgh University to join his brother Erasmus Alvey Darwin (1804-1881) in the study of medicine. Although Erasmus eventually qualified as a physician, the experience proved a failure for Charles, who could not stand to watch the carnage of an operating theater before the days of chloroform. During his time at Edinburgh, Darwin should have taken the Materia Medica class at the Royal Botanic Garden. I searched in vain in its library for the professor's book for 1826-1827 that students had to sign in order to attend lectures. The one for 1825-1826 is there, but Darwin's name is not in it. However, in his *Autobiography*, Darwin wrote cryptically, "Lectures ... were intolerably dull ... Dr. Duncan's lectures on Materia Medica at 8 o'clock on a winter's morning are something fearful to remember." (Barlow 1958, p. 47).

Realizing that his son would never become a physician, Robert Darwin sent him to Cambridge University at Christmas 1827 to enroll for the Lent Term 1828. Now Charles was set for a career as a clergyman. He accepted this without argument, as the English clergy had a long history of interest in natural history. When a schoolboy, Darwin had read Rev. Gilbert White's *Natural history of Selborne* (White 1789) and commented, "From reading White's *Selborne* I took much pleasure in watching the habits of birds ... In my simplicity I remember wondering why every gentleman did not become an ornithologist." (Barlow 1958, p. 45). He was to pay great attention to birds while on the *Beagle* voyage.

At Cambridge, Darwin soon became acquainted with Rev. John Stevens Henslow (1796-1861), Professor of Botany. Henslow kept a weekly open house for students and faculty. Darwin attended regularly, and Henslow soon became his mentor. Darwin must have shown some potential as a scientist. Not only did he attract the eye of Henslow, but also those of Rev. Adam Sedgwick (1785-1873), Woodwardian Professor of Geology, and the great historian and philosopher of science Rev. William Whewell (1794-1866), Master of Trinity College. Darwin later geologized with Sedgwick, as we shall see below, and wrote that, "Dr. Whewell was one of the older and distinguished men who sometimes visited Henslow, and on several occasions I walked home with him at night." (Barlow 1958, p. 66). One would like to know what they discussed.

Darwin attended Henslow's botanical lectures while at Cambridge, "and liked them much for their extreme clearness, and the admirable illustrations; but I did not study botany." He also participated in Henslow's class field trips to view plants and animals in the Cambridge area: "these excursions were delightful." (Barlow 1958, p. 60). Darwin and Henslow became close friends, and Henslow "influenced my whole career more than any other." (Barlow 1958, p. 64). This influence and friendship are discussed more fully in Darwin's "Recollections of Professor Henslow" (Darwin 1862a). One botanical anecdote bears repeating (Barlow 1958, p. 66):

"I cannot resist mentioning a trifling incident, which showed his kind consideration. Whilst examining some pollen-grains on a damp surface I saw the tubes exerted, and instantly rushed off to communicate my surprising discovery to him. Now I do not suppose any other Professor of Botany could have helped laughing at my coming in such a hurry to make such a communication. But he agreed how interesting the phenomenon was, and explained its meaning, but made me clearly understand how well it was known; so I left him not in the least mortified, but well pleased at having discovered for myself so remarkable a fact, but determined not to be in such a hurry again to communicate my discoveries."

He would show such reticence later in first publishing his evolutionary ideas.

The Rev. Jerry Falwell once spoke of Darwin as "a theological school dropout." Falwell was wrong on both counts. Cambridge was not a theological school, although a man had to have a degree from Cambridge or Oxford in order to become a priest in the Church of England. Darwin graduated from Christ's College, Cambridge at the end of Easter Term in 1831. Although he later wrote that, "During the three years which I spent at Cambridge my time was wasted, as far as the academical studies were concerned, as completely as at Edinburgh and at school." (Barlow 1958, p. 58), Darwin graduated tenth out of 178 students who did not take an honors degree that year (Shipley 1924).

Following graduation, "Henslow then persuaded me to begin the study of geology." (Barlow 1958, p. 68). Darwin soon found himself in the field with Sedgwick, mapping the surface geology of North Wales. On his return from this short trip in August 1831, the fateful letter from Henslow announcing that Captain Robert Fitzroy (1805-1865) was seeking a gentleman naturalist to accompany him on a two-year surveying voyage to South America awaited him. Henslow had recommended Darwin. After overcoming his father's objections and several delays, Darwin set sail from Devonport on HMS *Beagle* on 27 December 1831.

THE BEAGLE VOYAGE

"The voyage of the *Beagle* has been by far the most important event in my life and has determined my whole career" (Barlow 1958, p. 76). While on this almost five-year voyage, Darwin paid close attention to geology and zoology. But he did not neglect botany, beginning his plant collecting in the Cape Verde Islands, the first landfall (Porter 1983). His *Beagle* "Geological Diary" and "Geological Notes" cover 1383 pages and the "Zoological Diary" 368 pages. There is no "Botanical Diary", but about 20% of the pages of the "Zoological Diary" are devoted to plants, including fungi and lichens (Porter 1987). Darwin's geology notebooks were the source materials for the

three books subtitled *the geology of the voyage of the Beagle* (Darwin 1842, 1844, 1846) and 12 papers in journals. (Barrett 1977). Likewise, the zoology notebooks produced the five-part *Zoology of the Beagle* (Darwin 1839-1843) and a further 4 papers (Barrett 1977). The book now known as *The voyage of the Beagle* (Darwin 1839, 1845) was drawn from his personal journal, parts of which were sent home to his family from time to time. It has been continuously in print since 1839.

Before Darwin left England, Henslow apparently had agreed to identify the plants that he collected. However, because of the press of other duties, Henslow never seemed to have much time to do so and called on his friend William Jackson Hooker (1785-1865), Regius Professor of Botany at Glasgow University for help (Porter 1980a, 1984a). Hooker identified some collections, mainly Asteraceae, and helped Henslow write two papers on some of Darwin's specimens (Henslow 1837, 1838). Later, some of the collections were identified by Hooker's son, the botanist Joseph Dalton Hooker (1817-1911), in his *Flora Antarctica* (Hooker 1844-1847). Darwin was particularly keen to have his Galapagos Islands plants identified, and J. D. Hooker, who soon became Darwin's best friend and confidant and Henslow's son-in-law, did so (Hooker 1847a). He also used them to write the first phytogeographic study of the archipelago (Hooker 1847b).

This is where our paths begin to cross. After I received my Ph.D. in 1967, the late Ira L. Wiggins, Professor of Botany at Stanford University, under whose guidance I had received my M.A., invited me to become a postdoctoral assistant on a study of Galapagos plants. Our collaboration resulted in *Flora of the Galapagos Islands* (Wiggins & Porter 1971). Curious about how our flora compared with that of Hooker (Wiggins and I authored different families and had 19 collaborators; I had not seen any but my own contributions before the book was published), I compared the two. I was horrified to find that 47 of the names used by Hooker were not in our flora. I later established that all but one or two of the differences were due to Hooker's misidentifications or use of names that are now considered synonyms. This led to a desire to see Darwin's Galapagos specimens.

In 1973, my wife and I had a vacation in Britain. During this time, we visited the Cambridge University Herbarium, where the first set of Darwin's *Beagle* vascular plant collections reside. Peter Sell, then Assistant Curator, brought out what looked like some old over-sized shoe boxes and revealed the specimens. I looked at a dozen and said, "Most of these havn't been identified." Peter answered, "No one here at Cambridge has ever been much interested in the flora of South America. Why don't you identify them?" I pondered a bit, took Peter's advice, and got a grant from the American Philosophical Society. The summer of 1976 was spent at Cambridge and the Royal Botanic Gardens, Kew, where the second set resides, and the Hookers worked, studying Darwin's Galapagos plants. This resulted in an historical and taxonomic study (Porter 1980b). At the same time, I had followed Hooker's lead and studied the phytogeography of the islands (Porter 1976). This latter interest led to a series of papers, culminating in one presented at a meeting of the Linnean Society in 1983 (Porter 1984b).

Being a taxonomist, I was also interested in the history of Darwin's plant collections. This led to a paper presented at the Natural History Museum in London in 1979 (Porter 1980a). After my presentation, I went to lunch with three Darwin experts (David Kohn, the late Sydney Smith, and the late David Stanbury), who told me that I should now identify the rest of his *Beagle* plants. The next year, with a grant from the National

Geographic Society, my family and I spent ten months at Cambridge while I did so. This resulted in a paper that filled a single issue of the *Botanical Journal of the Linnean Society* (Porter 1986). While we were in Cambridge, Darwin's notes on his *Beagle* plants, which I had hypothesized might turn up some day (Porter 1980a), along with those of Henslow, were discovered by herbarium assistant Rita I'Ons (Porter 1981). Rita's discovery led me to search out all Darwin's manuscript materials on his *Beagle* plants and publish them (Porter 1987). Along the way, the histories of all his collections, botanical (including algae and fungi), geological, and zoological were ferreted out (Porter 1985).

While he was on his voyage, Darwin collected 1445 specimens of vascular plants. Although he was in the Galapagos for only six weeks, he made 224 collections there. In contrast, in Chile, where he spent a total of 22 months, he made only 248 collections (Porter 1999). Not only the geology and the zoology of the Galapagos appear to have caught his interest there. Indeed, evidence from all three fields helped lead Darwin to become an evolutionist.

BOTANY AFTER THE VOYAGE

Following his return to England in October 1836, Darwin's time initially was spent in putting his collections in order and trying to find experts to identify them. The plants he left to Henslow and later Hooker, as we have seen above. Much of his time was devoted to working up the geology and zoology. There were a few letters of inquiry to the *Gardeners' Chronicle* in the 1840s regarding flowers, seeds, and leaves but nothing of great import. However, following discussions with J. D. Hooker in 1855 on dispersal mechanisms in plants, Darwin began a series of experiments in which he immersed seeds in salt water for various lengths of time. These experiments resulted in several notes in the *Gardeners' Chronicle* (Barrett 1977) and a longer paper (Darwin 1857). Earlier, in 1846, Hooker had told Darwin that one could not truly understand how species arose until he had done a taxonomic study of a large group of organisms. This resulted in Darwin's eight year, four volume study of barnacles (Darwin 1851a, 1851b, 1854a, 1854b), a classic monograph.

After the barnacle research was completed, Darwin returned to gathering information on how species were formed, research begun in 1836. He wrote to a number of naturalists around the world and continued combing the literature for useful data. One of his correspondents in the Dutch East Indies, the naturalist and collector Alfred Russel Wallace (1823-1913), had recently published a paper (Wallace 1855) that the geologist Sir Charles Lyell (1797-1875) had brought to Darwin's attention. Lyell, an old friend, was one of the few privy to Darwin's evolutionary ideas (Porter 1993). Realizing that Wallace was thinking along the same lines as Darwin, Lyell was afraid that Wallace might scoop him and urged Darwin to get his ideas down on paper. This led Darwin to begin work on what he called his "Big Book," titled *Natural selection*, most of which was not published until 1975 (Stauffer 1975).

It was while writing *Natural selection* in June 1858 that Darwin received the fateful letter announcing Wallace's ideas about species change that resulted in the publication of their so-called "joint paper" (Darwin & Wallace 1858). Darwin began immediately to write an abstract of *Natural selection*, which he first envisioned as a 30 page paper, but which grew into the 511 page *On the origin of species* (Darwin 1859). Following its publication, Darwin was criticized by many for not citing the sources of his many

data. Readers were unaware that the citations were in the bibliography of *Natural selection*. In 1860, Darwin began to mine this work for the first of three projected books intended to supplement *The origin*. Because of illness off and on during the 1860s, *Variation under domestication* was not published until 1868 (Darwin 1868), while the other two were never written. *Variation*, based on the first three chapters of *Natural selection*, had plenty of information on plants in it, both from the literature and from personal observation. What it lacked, like *The origin*, was any discussion of human evolution. This lack was later rectified by the publication of *The descent of man* (Darwin 1871), his second most controversial book after *The origin*. *The expression of the emotions* (Darwin 1872) resulted from data that were too voluminous to be included in *Descent*. Darwin wrote on the evolution of his own family in a preliminary essay to a translation of a scientific biography of his grandfather Erasmus by the German botanist Ernst Krause (1839-1903). Darwin's essay (Darwin 1879) was longer than Krause's original contribution.

It was after the publication of *The origin* that Darwin's botanical research came to the fore. Searching for adaptations arising through natural selection, Darwin discovered the pollination mechanisms of orchids. Several years of data gathering and experimentation yielded another book, *Fertilisation of orchids* (Darwin 1862b). Interest in pollination led to more experiments and the publication of papers on primroses (Darwin 1862c), flaxes (Darwin 1863), and loosestrifes (Darwin 1864). The first two explained the phenomenon of distyly in flowers, the third announced the discovery of tristily. These papers, plus data from further experiments in the 1860s and '70s, eventually resulted in another book, *Forms of flowers* (Darwin 1877). The year before, Darwin had published the results of a long series of crossing experiments with other plants, begun in the 1860s, as *Cross and selffertilisation* (Darwin 1876). "This survey of the nature of the mechanisms favouring cross fertilisation and the advantages to be gained by it was considered by Darwin to form a complement to that on the "Fertilisation of Orchids." (Freeman 1977, p. 152).

With all these plant experiments being undertaken, Darwin decided that he needed a hothouse, which was built early in 1863. The hothouse was first used to house tender plants borrowed from the Royal Botanic Gardens, Kew, where J. D. Hooker was now Assistant Director to his father. Growth phenomena were studied in these plants, particularly their adaptations for climbing. This study originated when Darwin read a short paper by his friend Asa Gray (1810-1888), Fisher Professor of Natural History at Harvard University, on the movement of tendrils in the wild cucumber (Gray 1858). Darwin obtained seeds from Gray and began observations on climbers, which culminated in another book, *Climbing plants* (Darwin 1865). Further experiments on stem and leaf movements led to yet another, *Power of movement in plants* (Darwin 1880).

As if this wasn't enough, while on holiday in 1860, Darwin had noticed a sundew on the edge of a path that had trapped some insects on the sticky trichomes (he called them "tentacles") of its leaves. Hence was born another long-term study, worked on over a series of years, to investigate how small amounts of substances could make these trichomes move. *Insectivorous plants* (Darwin 1875), then, was not a study in natural history, as one might assume, but a study in plant physiology.

Darwin's final book, on earthworms (Darwin 1881), was also based on research begun long ago, this time in the late 1830s and '40s. In this eminently readable book, Darwin relates a number of personal observations on earthworms, both in the field and

lab. Noting that earthworms in his garden frequently dragged leaves into their holes in order to eat them, Darwin experimented with pieces of paper in order to work out the shapes of leaves that they preferred. They also showed a preference for the leaves of *Rhododendron*. Darwin had his son Francis (1848-1925), who served as his research assistant, play his bassoon to them to check the acuity of their hearing. Today, the parlor of Down House, Darwin's home in Kent, is set up to illustrate his earthworm experiments, including Francis' bassoon on display.

After Darwin's death, Francis Darwin edited six volumes on his father's letters (F. Darwin 1887, 1892; F. Darwin & Seward 1903). These included about 20% of Darwin's presently-known correspondence. Unfortunately, the letters were edited and censored by Francis Darwin, without indication of where omissions had been made. In 1974, Frederick Burkhardt and Sydney Smith began a new, unexpurgated edition of Darwin's correspondence, which has now published 11 volumes (Burkhardt, et al. 1985-1999). Volume 11 covers the year 1863, when crossing experiments and climbing plants kept Darwin's attention. The volumes to come will contain much botany.

EPILOGUE

Charles Darwin died on 19 April 1882, aged 73. During his lifetime, he had published 20 books, two of two volumes each. Nine of these were devoted to botany, wholly or in part. He produced second editions for eleven of his books; *The origin* went through six editions. After Darwin's death, second editions of two books and third editions of three other books were published, augmented with additional material that he had amassed. In addition, he published about 170 papers (Porter & Graham 1993). I figure that from 1837 to 1881 Darwin published an average of over 300 pages a year.

There are a number of persistent myths about Darwin. One is that he never would have gotten tenure in an academic position because he did not publish much after the *Beagle* voyage. Another is that he retired to Down House after the *Beagle* voyage, was sick a lot, and didn't do much. I hope that this presentation convinces you that these assertions are both false.

ACKNOWLEDGMENTS

A shorter version of this paper was given as the Sidney S. Negus Memorial Lecture at the annual meeting of the Virginia Academy of Science at Radford University on 25 May 2000. I thank President John Hess and the Academy for inviting me to do so, and Sarah Porter and Peter Graham for useful comments on the manuscript.

LITERATURE CITED

- Barlow, N. (ed.). 1958. *The autobiography of Charles Darwin. 1809-1882*. New York: W. W. Norton & Company.
- Barrett, P. H. (ed.). 1977. *The collected papers of Charles Darwin*. 2 vols. Chicago: University of Chicago Press.
- Burkhardt, F., et al. (eds.). 1985-1999. *The correspondence of Charles Darwin. Vols. 1- 11*. Cambridge: Cambridge University Press.
- Darwin, C. (ed.) 1838-1843. *The zoology of the voyage of H.M.S. Beagle*. 5 parts. London: Smith Elder and Co.
- Darwin, C. 1839. *Narrative of the surveying voyages of His Majesty's Ships Adventure and Beagle...* Vol. III. *Journal and remarks. 1832-1836*. London: Henry Colburn.

- Darwin, C. 1842. *The structure and distribution of coral reefs*. London: Smith Elder and Co.
- Darwin, C. 1844. *Geological observations on the volcanic islands*. London: Smith Elder and Co.
- Darwin, C. 1845. *Journal of researches into the natural history and geology of the countries visited during the voyage of H.M.S. Beagle round the world, under the Command of Capt. FitzRoy, R.N.* ed. 2. London: John Murray.
- Darwin, C. 1846. *Geological observations on South America*. London: Smith Elder and Co.
- Darwin, C. 1851a. *A monograph of the sub-class Cirripedia, with figures of all the species. The Lepadidae; or, pedunculated cirripedes*. London: The Ray Society.
- Darwin, C. 1851b. *A monograph of the fossil Lepadidae, or pedunculated cirripedes of Great Britain*. London: Palaeontographical Society.
- Darwin, C. 1854a. *A monograph of the sub-class Cirripedia, with figures of all the species. The Balanidae, (or sessile cirripedes); the Verrucidae, etc., etc., etc.* London: The Ray Society.
- Darwin, C. 1854b. *A monograph of the fossil Balanidae and Verrucidae of Great Britain*. London: Palaeontographical Society.
- Darwin, C. 1855. Does sea-water kill seeds? *Gardeners' Chronicle* no. 21, 16 May, p. 356.
- Darwin, C. 1857. On the action of sea-water on the germination of seeds. *Journal of the Proceedings of the Linnean Society (Botany)* 1: 130-140.
- Darwin, C. 1859. *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. London: John Murray.
- Darwin, C. 1862a. Recollections of Professor Henslow. Pp. 51-55 in L. Jenyns, *Memoir of the Rev. John Stevens Henslow*. London: Van Voorst.
- Darwin, 1862b. *On the various contrivances by which British and foreign orchids are fertilised by insects, and on the good effects of intercrossing*. London: John Murray.
- Darwin, C. 1862c. On the two forms, or dimorphic condition, in the species of *Primula*, and on their remarkable sexual relations. *Journal of the Proceedings of the Linnean Society (Botany)* 6: 77-96.
- Darwin, C. 1863. On the existence of two forms, and on their reciprocal sexual relation, in several species of the genus *Linum*. *Journal of the Proceedings of the Linnean Society (Botany)* 7: 69-83.
- Darwin, C. 1864. On the sexual relations of the three forms of *Lythrum salicaria*. *Journal of the Linnean Society (Botany)* 8: 169-196.
- Darwin, C. 1865. *On the movements and habits of climbing plants*. London: Longman, Green, Longman, Roberts & Green and Williams & Norgate.
- Darwin, C. 1868. *The variation of animals and plants under domestication*. 2 vols. London: John Murray.
- Darwin, C. 1871. *The descent of man, and selection in relation to sex*. 2 vols. London: John Murray.
- Darwin, C. 1872. *The expression of the emotions in man and animals*. London: John Murray.
- Darwin, C. 1875. *Insectivorous plants*. London: John Murray.
- Darwin, C. 1876. *The effects of cross and self fertilisation in the vegetable kingdom*. London: John Murray.

- Darwin, C. 1877. *The different forms of flowers on plants of the same species*. London: John Murray.
- Darwin, C. 1879. A preliminary notice. Pp. 1-127 in E. Krause, *Erasmus Darwin*. London: John Murray.
- Darwin, C. 1880. *The power of movement in plants*. London: John Murray.
- Darwin, C. 1881. *The formation of vegetable mould, through the action of worms, with observations on their habits*. London: John Murray.
- Darwin, C. & A. R. Wallace. 1858. On the tendency of species to form varieties, and on the perpetuation of varieties and species by natural means of selection. *Journal of the Proceedings of the Linnean Society* 3: 2-62.
- Darwin, F. (ed.). 1887. *The life and letters of Charles Darwin, including an autobiographical chapter*. 3 vols. London: John Murray.
- Darwin, F. (ed.). 1892. *Charles Darwin: his life told in an autobiographical chapter, and in a selected series of his published letters*. London: John Murray.
- Darwin, F. & A. C. Seward (eds.). 1903. *More letters of Charles Darwin. A record of his work in a series of hitherto unpublished letters*. 2 vols. London: John Murray.
- Freeman, R. B. 1977. *The works of Charles Darwin. An annotated bibliographical handlist*. Folkestone: Wm. Dawson & Sons; Hamden, CT: Archon Books.
- Gray, A. 1858. Note on the coiling of tendrils in plants. *Proceedings of the American Academy of Arts and Sciences* 4: 98-99.
- Henslow, J. S. 1837. Descriptions of two new species of *Opuntia*; with remarks on the structure of the fruit of *Rhipsalis*. *Magazine of Zoology and Botany* 1: 466-469.
- Henslow, J. S. 1838. Flora Keelingensis. An account of the native plants of the Keeling Islands. *Annals and Magazine of Natural History* 1: 337-347.
- Hooker, J. D. 1844-1847. *The botany of the Antarctic voyage of H.M. discovery ships Erebus and Terror in the years 1839-1843 ... Part 1. Flora Antarctica*. 2 vols. London: Reeve Brothers.
- Hooker, J. D. 1847a. An enumeration of the plants of the Galapagos Archipelago; with descriptions of those which are new. *Transactions of the Linnean Society of London* 20: 163-233.
- Hooker, 1847b. On the vegetation of the Galapagos Archipelago as compared with that of some other tropical islands and of the continent of America. *Transactions of the Linnean Society of London* 20: 235-262.
- Porter, D. M. 1976. Geography and dispersal of Galapagos Islands vascular plants. *Nature* 264: 745-746.
- Porter, D. M. 1980a. Charles Darwin's plant collections from the voyage of the *Beagle*. *Journal of the Society for the Bibliography of Natural History* 9: 515-525.
- Porter, D. M. 1980b. The vascular plants of Joseph Dalton Hooker's *An enumeration of the plants of the Galapagos Archipelago; with descriptions of those which are new*. *Botanical Journal of the Linnean Society* 81: 79-134.
- Porter, D. M. 1981. Darwin's missing notebooks come to light. *Nature* 291: 13.
- Porter, D. M. 1983. Charles Darwin, the Cape Verde Islands, and the Herbarium Webb. *Webbia* 26: 225-228.
- Porter, D. M. 1984a. William Jackson Hooker and Charles Darwin's *Beagle* plants. *Huntia* 5: 107-116.
- Porter, D. M. 1984b. Relationships of the Galapagos flora. *Biological Journal of the Linnean Society* 21: 243-251.

- Porter, D. M. 1985. The *Beagle* collector and his collections. Pp. 973-1019 in D. Kohn (ed.). *The Darwinian heritage*. Princeton: Princeton University Press.
- Porter, D. M. 1986. Charles Darwin's vascular plant collections from the voyage of HMS *Beagle*. *Botanical Journal of the Linnean Society* 93: 1-172.
- Porter, D. M. 1987. Darwin's notes on *Beagle* plants. *Bulletin of the British Museum (Natural History)*, *Historical Series* 14: 145-233.
- Porter, D. M. 1993. On the road to *The Origin* with Darwin, Hooker, and Gray. *Journal of the History of Biology* 26: 1-38.
- Porter, D. M. 1999. Charles Darwin's Chilean plant collections. *Revista Chilena de Historia Natural* 72: 181-200.
- Porter, D. M. & P. W. Graham. 1993. *The portable Darwin*. New York: Penguin Books.
- Shiple, A. E. 1924. *Cambridge cameos*. London: Jonathan Cape.
- Stauffer, R. C. (ed.). 1975. *Charles Darwin's Natural Selection; being the second part of his big species book written from 1856 to 1858*. Cambridge: Cambridge University Press.
- Wallace, A. R. 1855. On the law which has regulated the introduction of new species. *Annals and Magazine of Natural History* ser. 2, 16: 184-196.
- White, G. 1789. *The natural history of Selborne*. London: B. White and Son.
- Wiggins, I. L. & D. M. Porter. 1971. *Flora of the Galapagos Islands*. Stanford: Stanford University Press.



Samuel S. Obenshain

Forme Academy president, Samuel Shockley Obenshain died peacefully Wednesday, July 26, 2000, at this home. At age 96, he was still running the family farm. In his bright red sweater, he was a familiar figure to many in Blacksburg as he took his daily walks along his farm on Prices Fork Road, determined to keep active each day of his life. He had a long and distinguished career at Virginia Tech, from his graduation as No. 2 in the Class of 1927 to his 36 years as a professor of agronomy. He was a pioneer in soil research in the state. During his tenure, Tech's soils mapping and classification program was generally recognized as one of the strongest programs in the United States - and therefore the world. As a classroom professor, he taught and mentored a generation of farmers, scientists and extension agents. As the first chairman of the graduate committee for Tech's College of Agriculture, he encouraged many students to pursue advanced degrees and scientific careers. In the 1950's, he became the first faculty member at Virginia Tech qualified to use radioisotopes in his research after studying at Oak Ridge, Tenn. He was also the first Tech faculty member to serve as a consultant for a U.S. international aid team from the U.S. State Department. He headed a three-man team of U.S. experts to Korea to analyze the nation's fertilizer needs after the separation of North and South Korea. He later led a three-man team to Bangladesh to evaluate whether an irrigation system could be built along the Ganges. In 1965, he served as president of the Virginia Academy of Science. Among other honors, he was named Virginia Tech's Outstanding Graduate of the College of Agriculture and Life Sciences for the Class of 1927, and in 1997, received Virginia Tech's Ag Alumni Citation Award for years of service to Virginia's agriculture industry and to the university. He also founded Soils Consultants, a successful soils engineering firm in Northern Virginia.

Surviving are two sons and daughters-in-law, a daughter-in-law, one daughter, 10 grandchildren, and nine great-grandchildren.

These abstracts were received on time for publication in the proceedings issue of the *Journal* but were omitted for various technical reasons. We are sorry for the delay in their publication.

PHYTOESTROGENS AND APOPTOSIS IN HUMAN CANCER CELLS. G. Morris¹, R. L. Williams¹, M. Elliott¹ & S. J. Beebe², ¹Department of Chemistry and Biochemistry, Old Dominion University, Norfolk, VA 23529 and ²Center for Pediatric Research, Children's Hospital of the King's Daughters and Eastern Virginia Medical School, Norfolk, VA 23510. Resveratrol (3', 4, 5'- *trans*-trihydroxy stilbene) (TR) is a naturally occurring antifungal agent produced by plants in the spermatophyte family, shown to be an agonist to the human estrogen receptor. Previously we demonstrated that TR induced apoptosis in the hormonally sensitive prostate cancer cell line LNCaP by 24 hours. The present study demonstrates that TR activates caspase(s) by six hours in LNCaP cells and is also toxic to the hormonally insensitive prostate cancer cell line DU 145. This suggests that TR's mechanism of action is not exclusively through hormone receptors. It was also found that TR's hydroxyl groups were important to its mechanism of action through use of TR's methyl analog trimethoxy-TR (TmTR). TmTR was compared to TR in cell viability assays and found to induce DU 145 cells to grow in contrast to TR's toxic effect. This study was funded in part by the Virginia Academy of Science through a Horsley Grant and an internal grant from Eastern Virginia Medical School.

TOCOPHEROL (VITAMIN E) CONTENT IN BROWSE SPECIES TYPICAL OF A SHRUB-DOMINATED COMMUNITY IN SOUTHERN WEST VIRGINIA. John L. Hess¹, Gabriel C. Wilmoth¹, and Joyce G. Foster², ¹Department of Biochemistry, Virginia Polytechnic Institute and State University, and ²USDA ARS Appalachian Farming Systems Research Center, Beaver, WV. The tocopherol (vitamin E) content of forage from several weedy shrub species was measured to assess the value of the shrubs as a source of vitamin E for goats browsing on overgrown Appalachian pastures. Plant tissue was collected at a site in southern West Virginia in June 1999. Alpha-, beta-, gamma-, and delta-tocopherol were extracted from the leaf tissue with hexane, separated by high performance liquid chromatography on a normal phase diol column, and quantified. Significant differences ($P < 0.001$) in concentrations were found among species for alpha-tocopherol but not for beta-, gamma, or delta-tocopherol. Alpha-tocopherol predominated, accounting for at least 80% and up to 99% of the total tocopherols. Alpha-tocopherol concentrations (mean ppm on a dry matter basis; SE±67 unless noted otherwise were): 500 ppm in multiflora rose (*Rosa multiflora* Thunb.), 800 ppm in autumn olive (*Elaeagnus umbellata* Thunb.), 570 ppm in bush honeysuckle (*Lonicera morowii* Gray), 480±82 ppm in blackberry (*Rubus* spp.), 610 ppm in greenbrier (*Smilax* spp.), 320 ppm in hawthorne (*Crataegus* spp.), 610 ppm in poison ivy (*Rhus toxicodendron*, 260 ppm in black locust (*Robinia pseudoacacia* L.), 350 ppm in wild crab (*Pyrus cronaria* L.) and 380 ppm in redosier dogwood (*Cornus stolonifer* Michx.). Goats browsing on weedy shrubs may obtain adequate intake of vitamin E from certain species such as autumn olive, greenbrier and poison ivy. Nutritive value and concentrations of antiquality factors are not known for all of these species and may affect animal performance. The actual vitamin E intake will depend on the feeding behavior of the goat.

METHODOLOGY DEVELOPMENT FOR USE OF WEDGE CLAM (*Rangia cuneata*) IN BIOMONITORING STUDIES. E. G. Maurakis^{1,2} and D. V. Grimes³,
¹Science Museum of VA, Richmond, VA 23220, ²Biology Dept., Univ. of Richmond, Richmond, VA 23173, and ³Virginia Dept. of Environmental Quality, Richmond, VA 23219. Sporadic, high mortality rates in test populations of *R. cuneata* limit their use in biomonitoring studies. To determine if high mortality was due to ontogeny or study design, mortality of control *R. cuneata*, and groups subjected to varying transport conditions was determined at 7, 14, 21 and 60 days redeployment. The use of three transport times (1, 2, 3 hrs.), two vehicle conditions (open, closed) and three transport treatments (open, closed, iced containers) yielded 18 test groups. Individual test group mortalities were below 10% through the 21 day redeployment period and peaked at 13% at the 60 day redeployment point. Mortality was significantly ($p \leq 0.05$) higher in the 1 hour transport time and closed transport treatment test groups. Although significant differences in mean clam size were present between some test groups, clam size was not significantly ($p \leq 0.05$) correlated with mortality. The low rates of mortality observed by this study indicate reasonable collection and transport of *R. cuneata* does not significantly increase native mortality, suggesting other experimental design parameters associated with test sites may be significantly correlated to the sporadic high mortality of test populations. Funded in part by a University of Richmond Faculty Research Grant.

Notes

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EDITOR/BUSINESS MANAGER:

James H. Martin

Dept. of Biology - PRC

J. Sargeant Reynolds Community College

P.O. Box 85622

Richmond, VA 23285-5622

Phone: (804)371-3064

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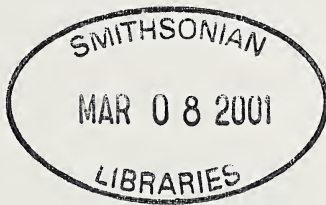
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The Dyke Marsh Preserve Ecosystem

David W. Johnston, The Friends of Dyke Marsh,
5219 Concordia Street, Fairfax, VA 22032

ABSTRACT

For over a century, Dyke marsh along the Potomac River just south of Alexandria, VA, has been a favorite site for natural history studies. Despite earlier attempts at diking to create agricultural land and dredging for sand and gravel, the remaining marsh represents the last major tidal freshwater wetland on the upper Potomac River, and is now owned and maintained by the National Park Service as the Dyke Marsh Preserve. In the present paper historical data on physical properties and biota are compared and contrasted with more recent biological investigations to show functioning ecosystem components, interrelationships among the flora and fauna, and documented changes in biotic communities over the years. As a haven for migratory waterfowl and shorebirds, unique plant communities, and large, dynamic insect and vertebrate populations, the Preserve is constantly threatened by river pollution, nearby large-scale development projects, and bridge construction. The long-term stability of this unique Preserve depends largely on the vigilance of the Park Service, concerned citizens, and environmental groups to ensure the preservation of this valuable functioning ecosystem.

Key Words: Ecosystem; Freshwater Wetland; Biotic Communities; Floodplain.

INTRODUCTION

Wetlands, whether they be marshes, swamps, or floodplain forests, are habitats that support a diverse group of aquatic or semi-aquatic plants and animals. Wetlands play an integral role in maintaining the quality of life through material contributions to a region's economy, food supply, water supply and quality, flood control, wildlife habitats, and as "carbon sinks." They buffer shorelines from erosion, filter sediments and contaminants from the water column, and serve as a basic nutrient source, chiefly in the form of decaying organic material, for microorganisms and animals in the food chain. Wetlands are also crucial feeding, breeding, and nursery sites for hosts of fish and waterfowl. Bird-watching, boating, and fishing are popular contemporary recreational uses of wetlands. Additional values of wetlands are discussed in Odum (1983).

National interest in wetlands was set forth in the findings of the Emergency Wetlands Resources Act of 1986 in which the Congress found that wetlands are known to play a vital role in maintaining environmental quality. Thus, they contribute to the overall health, safety, recreation, and economic well-being of all citizens of the Nation.

From the 1780s through the 1980s, Virginia's wetlands were reduced from an estimated 1.85 million acres to 1.07, a 42 percent loss, most of these converted to agricultural land. Although the rate of conversion has slowed in recent years, wetland losses continue to outdistance gains. According to the Council on Environmental Quality report (1996), over the past 25 years "the key factor driving the dramatic change

in wetlands losses, has been the enactment of laws and implementation of federal, state, and local programs that protect and restore wetlands." An example is enactment of the Clean Water Act of 1972. Even so, many of the remaining wetlands have declined in quality because of nutrient loading, altered hydrology, and urban encroachment.

Wetlands along the Potomac River are commonly found within or associated with its tributaries. For example, the largest remaining freshwater tidal wetland in the Washington area, Dyke Marsh Preserve (DMP), is representative of the Potomac watershed wetlands of 200 years ago. It lies in the littoral zone of the Potomac estuary with cattails forming the dominant vegetation cover over most of the marsh. Because of its proximity to metropolitan Washington, DC, the marsh has been a favorite spot for naturalists and fishermen for at least 100 years. Although heavily impacted by typical urban pressures, such as air and water pollution, invasion of exotic plants, and population spread, the preserve remains as one of the largest wetlands adjacent to the Nation's Capitol.

Although salt marshes have been intensely researched for decades, tidal freshwater wetlands have, for the most part, been ignored by limnologists. In a review of the two ecosystems, Odum (1988) pointed out (p. 170) "...while the basic structure and processes are the same in the two environments, significant differences do exist in species numbers and composition and in the pattern, rates, and end products of many of the processes." Specifically, numbers of intertidal vascular plants, reptiles, and amphibians decline dramatically between tidal freshwater and salt marshes. Other groups, such as macro algae, invertebrates, and fishes increase. Although salinity plays an important role in most of the differences between the two environments, other factors (sulfide, species/area relationships) operate in a synergistic fashion and should be included in a thorough analysis.

Furthermore, mud flats of the tidal freshwater marshes are mostly covered with water during high tides and seasonal river flooding, and many may be covered with fleshy macrophytes in summer. Recent changes in submersed aquatic vegetation can be associated with nutrient enrichment or "eutrophication" of the river by fertilizers, sewage, and pollution coming from upstream.

To understand the intricate biological and physical interactions in the tidal freshwater DMP, it is treated here as an example of a wetland ecosystem, a basic functional unit in ecology. The ecosystem conceptually includes both the living and nonliving environment, each influencing the properties of the other and both necessary for maintenance of the system. In this report, attention will be given to the fundamental living and nonliving components and their interrelationships in DMP. A caveat--for some components of DMP, data are sparse, so additional studies are needed.

THE ECOSYSTEM CONCEPT

Living organisms and their nonliving environments are inseparably interrelated and interact with each other. The ecological system (or ecosystem) includes all of the communities of organisms in a given area interacting with their physical environment so that energy flow leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and nonliving parts). From the trophic standpoint, an ecosystem has two components: (1) an autotrophic component, in which fixation of light energy, use of simple inorganic substances, and buildup of complex substances predominate; and (2) a heterotrophic component, in which

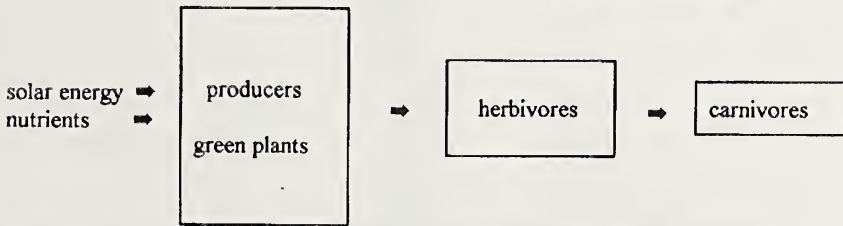
utilization, rearrangement, and decomposition of complex materials predominate. For descriptive purposes, it is convenient to recognize the following components as comprising the ecosystem: (1) inorganic substances involved in material cycles, (2) organic compounds that link the biotic and abiotic, (3) climatology, (4) producers, chiefly green plants which manufacture food from simple inorganic substances, (5) macroconsumers (heterotrophic organisms, chiefly animals that ingest other organisms or particulate organic matter), and (6) microconsumers (heterotrophic organisms chiefly bacteria and fungi which break down the complex compounds of dead protoplasm, absorb some of the decomposition products, and release inorganic nutrients that are usable by the producers together with organic substances).

One of the universal features of all ecosystems, whether terrestrial, freshwater, or marine, is the interactions of the autotrophic and heterotrophic components. To understand these interactions, it is necessary to identify the following: (1) energy pathways, (2) food chains and webs, (3) diversity patterns in time and space, and (4) nutrient cycles,

A generalized energy flow through an ecosystem follows (much energy is lost from the system at each transfer) (adapted from Odum 1997).

(AUTOTROPHS)

(HETEROTROPHS)



Food chains are of two basic types: grazing food chain which, starting from a green plant base, goes to grazing herbivores and on to carnivores; the detritus food chain which goes from dead organic matter into microorganisms and then to detritus-feeding macroorganisms and their predators. Food webs integrate several food chains to reveal alternate pathways (Odum 1997).

DESCRIPTION OF THE DYKE MARSH AREA

Just below the City of Alexandria, the DMP/Belle Haven area consists of approximately 550 acres of developed parkland, river shoreline, and marsh. This area, east of the George Washington Memorial Parkway, is managed by the U.S. National Park Service (Fig. 1). In addition to a large and significant remnant wetland habitat (DMP), a developed area known as Belle Haven includes a marina and picnic area. Situated in Fairfax County, Virginia, the park area extends from the Alexandria City line south along the Potomac River for 2 ½ miles (Fig. 2). The mouth of Hunting Creek is on the northern boundary; Belle Haven Country Club is adjacent to the northwest boundary; Morningside Lane and Wellington Heights are located along the southern boundary; and Belle Haven Community, Westgrove, Marlen Forest and Villamay communities are on the western boundary.

Aquatic habitats associated with the tidal reaches of the Potomac River include unvegetated subtidal bottoms, intertidal flats, submerged aquatic vegetation, emergent

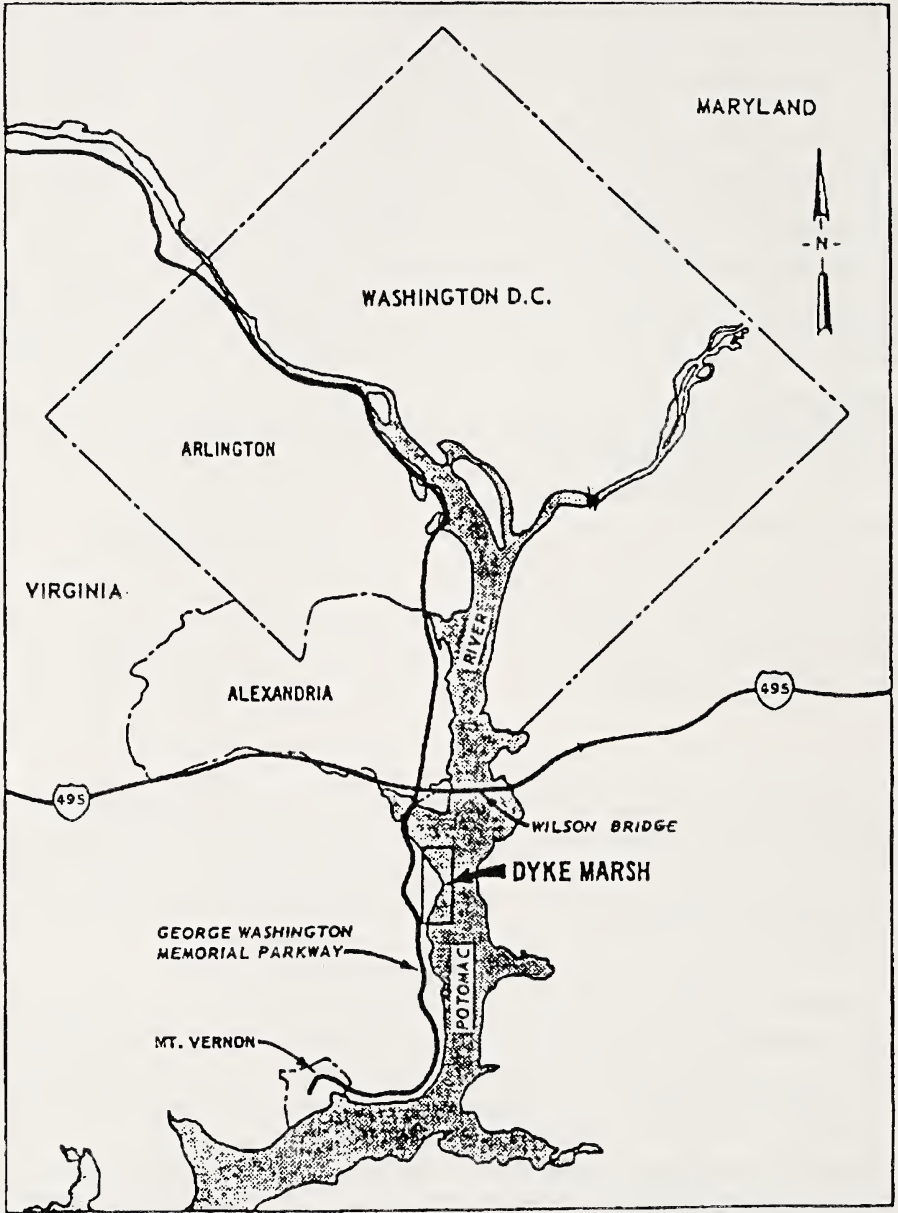


FIGURE 1. Location Map of Dyke Marsh.

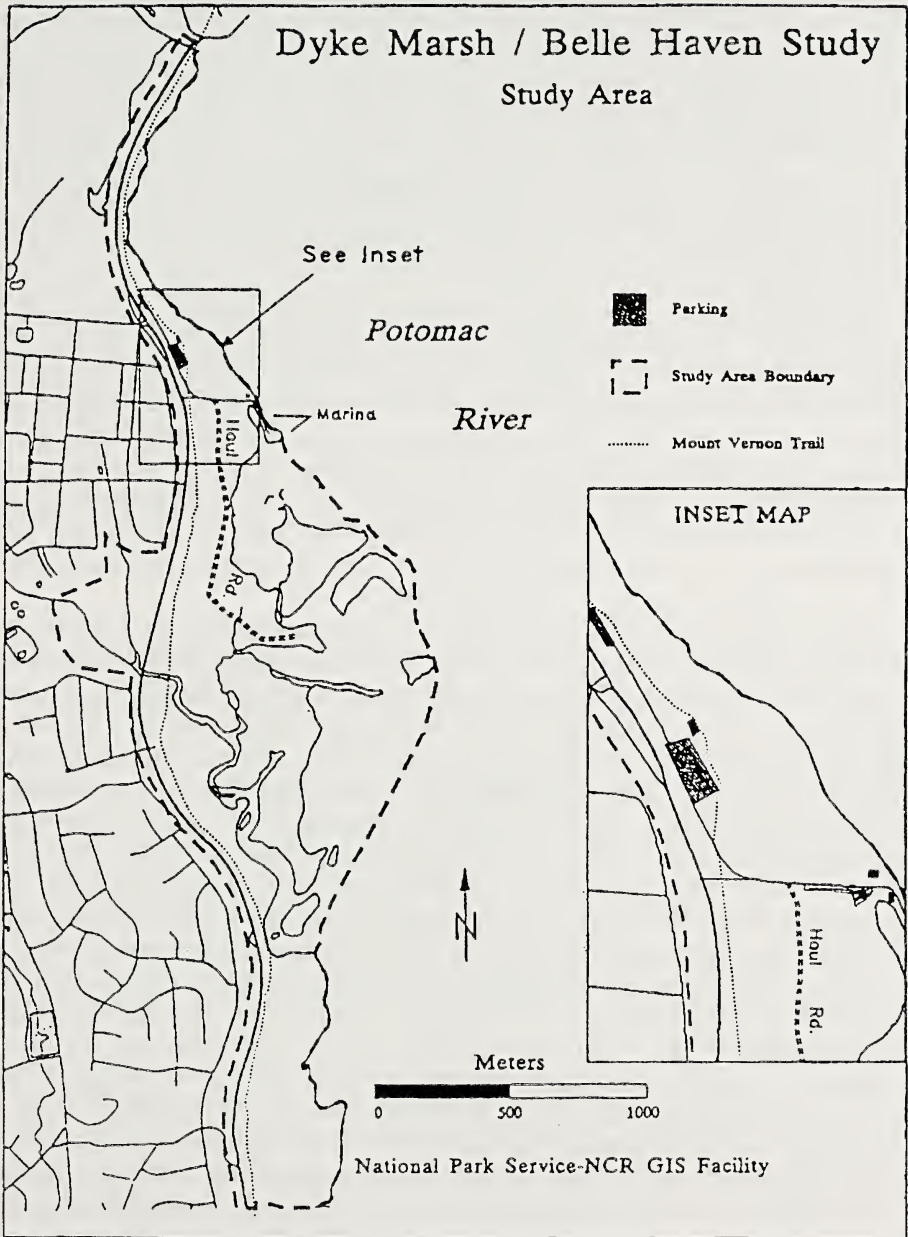


FIGURE 2. The Dyke Marsh-Belle Haven area.

marshes, and forested wetlands. Non-tidal waters are restricted to both modified/natural stream channels and woodland ponds.

Hunting Creek was undoubtedly a dominant factor in the formation of DMP through its deposition of sediment and diversion of stronger river currents away from the Preserve. The force of the creek has been muted as its confluence with the Potomac River has been boxed in with the construction of the George Washington Memorial Parkway, the Capital Beltway, Belle Haven Country Club, and Hunting Towers apartment complex. The creek was described in 1918 by W. L. McAtee as filled with aquatic vegetation and having an interesting flora with peculiar marsh and mud plants. But much of this has changed. Buildings and roads now sit on former wetlands and sewage effluent from the City of Alexandria and Fairfax County is discharged into its waters (Thomas 1976).

Nonetheless, one of the largest mudflat areas along the Potomac River is found in the Hunting Creek embayment which generally extends from the area south of the Route 1 interchange east to Jones Point Park and south to the Belle Haven marina. These mudflats perform important ecological functions by providing foraging sites for migratory and resident birds, fisheries habitats and nurseries, nutrient assimilation, maintenance of water quality, and floodflow attenuation. Mud flats contain nutrient rich sediments which support bacterial, phytoplankton, and zooplankton communities. The presence of these communities is particularly important to the production of benthic invertebrates and subsequent richness of fisheries and migrating birds occurring in the region.

Since at least 1878, the area from Hunting Creek to Mount Vernon, a distance of about eight miles, has been a favorite resort for bird-watchers and other naturalists. However, in the 1950s extensive dredging of the soils underlying the marsh threatened its existence. Vigorous lobbying efforts by members of the Audubon Naturalist Society led to the Congressional action which set aside DMP as an "irreplaceable wetland" on June 11, 1959 for the protection and preservation of wildlife. At that time DMP was one of the last freshwater tidal marshes remaining within the Washington Metropolitan area. It included upland forest, wetland (forested and marsh), and open water, and comprised an area of about 400 acres, about one-half its original size.

Less than 100 miles from the confluence of the Potomac River and Chesapeake Bay, DMP is strongly influenced by the Bay's tides. At the Preserve the daily average three-foot tide cycles are more important than the river's current. In fact, the outer reaches of the Preserve are separated from the 25-40'-deep ship channel by over 2,000 feet of a shallow plateau.

In their view of DMP in 1963 Myrick and Leopold reported it as: "The marsh area appears uniformly flat to the eye. In early spring the dried vegetation has been bent over by snow [winter weather], so that at low tide one can walk with ease over nearly the full unchanneled area. There are some small areas within the marsh on which timber is the primary cover. Though some of these timbered areas appear to have a slightly higher elevation than average for the marsh, other timber patches appear to be flooded regularly. By midsummer, the marsh vegetation is thick and green, standing at least knee high."

Much of the emergent marsh lies on a plateau at about 4 feet above mean low tide and thus is not inundated by the usual three-foot tidal cycles. Despite this relative lack

of major topographical relief, even these minor differences in elevation have a marked effect on the vegetational zones of the wetlands. Earlier dredging activity extended deep enough into the extant marsh to create a direct connection of the two major guts. The result has been the creation of two islands out of what was originally portions of the intact marsh. Several deep holes up to 30 feet below mean low tide exist. These holes are gradually filling by deposition, but it can be conservatively estimated to take hundreds of years of deposition before ongoing sedimentation could bring the entire bottom back up to the previously undisturbed levels. Dredging also eliminated at least two tidal guts with their associated ecosystem dynamics.

DMP can be divided into three major zones or communities: the marsh proper, the floodplain forest, and the swamp forest. The marsh proper, which comprises about 35 percent of the area, is partially underwater except at low tide. The floodplain and swamp forest are about 4 feet above mean high tide and are not inundated during the normal tidal cycles. However, the tide does carve deep fingers, called "tidal guts," into the land. Occasionally, strong easterly winds coupled with an incoming tide can flood the marsh for several hours. The swamp forest is a depressed area possibly formed by an old river bed.

Estuarine systems, such as those found in the tidal freshwater DMP, characteristically possess higher concentrations of nutrients than the Chesapeake Bay or contributing freshwater systems. These features will be discussed in detail later in this report.

CLIMATOLOGY

The climate of DMP-Belle Haven area is typical of the Washington, DC region: temperate with strong seasonal patterns and fairly evenly distributed precipitation (National Park Service 1976). Average annual precipitation is 40 inches, of which as much as 12 inches might be in snowfall. Heavy rainfall may occur during summer thunderstorm events, particularly when tropically derived. Summers are warm and humid (July mean daily maximum is 88° F) and winters are mild (January mean daily minimum is 28° F). These temperatures are tempered because of the moderating effect of the Potomac River. Easterly to southerly winds create surface waves which can break on an exposed shore, thus contributing to shoreline erosion. Infrequent major coastal storms and boat waves can create periods of stronger wave action. The wooded islands at the northern end protect the marsh against the winter's northwesterly winds.

These climatic conditions combine to give the DMP area a relatively long growing season of approximately 208 days. Generally, the favorable weather conditions and fertile soils not only encouraged farming during the agricultural era, but also contributed to the regrowth of forests after farming faded as a livelihood. Vegetational response to seasons because of slower water temperature change is evident as the marsh vegetation is generally slower to initiate growth above the soil surface than dry land types in the spring but remains longer in the fall. Much of the woody vegetation on islands in the marsh is probably the result of earlier diking and agricultural uses.

Air quality in the DMP area is similar to that along the Potomac River from Washington, DC southward (Wester and Sullivan 1970). The principal pollutants are oxidants (ozone) derived from sunlight interaction with carbon combustion compounds from vehicles (photochemical oxidants). No information exists relating air pollution

episodes (which occur during periods of low wind and upper atmospheric inversion) to vegetation stress at DMP, although such correlations may exist.

HISTORY

Before Europeans came, this part of northern Virginia supported a variety of plant communities such as oak-pine and other forests which formed the habitat for abundant wildlife, ranging from black bears and mountain lions to chipmunks and mice, and from eagles and wild turkey to passenger pigeons. Marshlands began evolving in the shallows of Pleistocene deposits at DMP at least 5,000 to 7,000 years ago (National Park Service 1976). A succession of cultural groups occupied and abandoned the area. By the early 1700s, explorers recorded numerous Indian villages along the banks of the Potomac River in the area south of what is now Alexandria. Hunting Creek appears first on a map drawn in 1731. Some of the tribal names reported from this area were Nameroughquera, Assomeek, Namasingaheut, Tauxenent (near Mount Vernon) and Doeg or Dogue. These Indians cultivated the bottom lands along the Potomac River, growing mostly corn but also peas, pumpkins, gourds, potatoes, mayapples, squash and tobacco. They also hunted game in the forests, trapped fish with fish weirs along the river and collected mussels from the creeks (Parsons et al. 1976).

As European colonization increased, the colonists cleared the original forests for lumber and farmland, and many dirt roads were made. All this activity undoubtedly led to siltation of the streams. The earliest settlers also must have chased out or killed bears, elk, and mountain lions in the area. Wolves were still present as late as 1782. It is also likely that trapping affected beaver and muskrat populations.

Originally the Dyke Marsh area was part of a vast land grant known as the "Northern Neck" made in 1688 by Charles II of England to Thomas, Lord Culpeper and six other noblemen. Over 5 million acres of this property came into the ownership of Thomas, Sixth Lord of Fairfax in 1735 and, after selling part, he placed his cousin Colonel William Fairfax in charge of managing his estate. Some of the earliest land grants in Fairfax County were made in these watersheds in 1657 and other large grants were made here in 1674 and 1678. Large-scale land changes did not take place until about 1690-1710.

By the 1790s, the Potomac River at the latitude of the present White House was nearly a mile across, over twice its present width. Tiber Creek emptied into the river near the present Lincoln Memorial, and the main channel of the river cut through on the west side of Anlostan (Roosevelt) Island. By the mid-1880s, large marshes and shallows had developed on both sides of the river, at least in part from silt washed down the river from upland farms and cut-over woodlands upstream. Wild rice, wild millet, and smartweeds covered these marshes, thus making them ideal waterfowl habitats. By 1950, chiefly because of dredging and filling, few of the marshes remained (Slavik and Uhler, 1951).

In the 1930s, the area to the south of Alexandria was also experiencing a surge in growth and development. "Belhaven," which was the earliest permanent English settlement in what was to become Fairfax County, has an interesting recent-day history. A single immigrant family was responsible for much of the early 20th century development in the Belle Haven watershed. Augusta Olmi, a stone mason from Italy, arrived in the United States just after 1900. His family settled in Pennsylvania, and his son Eugene, who became an entrepreneur in real estate development, made his first

million by the age of 25. Depression losses in the 1930s spurred the family to move to Virginia where Olmi began building once again. Of the 380 homes in the Belle Haven community today, over 300 were built by the Olmi father-and-son team.

Development in the watershed began in earnest in the late 1940s as housing construction accelerated dramatically after World War II. Today most of the watershed is developed into private homes, apartments or commercial areas with the exception of the area east of the George Washington Memorial Parkway.

It is believed that DMP originated from the sediment dropped as the current from Great Hunting Creek lost velocity upon reaching the mainstream of the Potomac River. Hunting Creek and especially its mouth play an important role in the existence of DMP. In addition to deposition, the marsh depends upon periodic flushing and scouring from the Potomac River floods which maintain this dynamic freshwater tidal system and retard succession to a wetland forest.

In the early 1800s one of the first colonial land owners of the marsh, Col. Augustine J. Smith of Westgrove Plantation, sought to increase his land holdings for grazing and perhaps real estate purposes through the establishment of a perimeter of earthen dikes in the shallow waters around Dyke Marsh (Edith Sprouse, pers. comm.). Two series of dikes had been placed in the marsh. One dike project was for reclaiming land for agricultural purposes from bottom land and pocosins; it apparently consisted of a large ditch dug shortly after the Revolutionary War that runs southeast from near Belle Haven across the emergent marsh to the river with strategically located embankments made from gravel obtained from the nearby hill. Vandals disrupted this system, but the remnants of one of the embankments which crossed Hog Island gut can be seen in the vicinity of that stream and the George Washington Memorial Parkway. The other dike project was a shad fishery with the embankments of gravel and brick placed in the submerged marsh. The placement of these dikes are well shown on a 1917 U.S.G.S. map and remnants can still be seen around the edge of the open marsh. Eventually trees began growing on the dikes. Parts of these outer embankments are still in evidence today. The quality of the wet meadow established did not justify the efforts necessary to maintain the dikes because breaches (beneficial to fishermen) were left unrepaired in sections of the dike; these led to more tidal guts into the wetlands. The tidal guts, along with the thickly growing wetland vegetation formed an almost impenetrable area to such an extent that it became popularly known as "Hell Hole" (National Park Service, 1976).

A dramatic description of "Hell Hole" appeared in the Alexandria Gazette of 10 August 1858. The article ("A Sporting Ground") read in part: "It is a vast expanse of mud, stumps, water-plants, and water, with here and there a narrow strip of dry land, just sufficient to afford a dwelling place for its terreous inhabitants, girted by a worn-out embankment--for an attempt was made many years ago to reclaim it--the outer margin of which is washed by the waters of the Potomac river, Hunting and Muddy Creeks, while along the entire length of its inner border grow in rank luxuriance, and close set, large and tall water-oaks and sycamores, among the exposed and twisting roots of which can be seen at this season many beautiful varieties of the marsh snake....Hell Hole is a grand, wild place, and, save for the miasm and mosquitoes which reign there pre-eminent, would be a magnificent abode for those fond of following the pursuits of Nimrod and Walton."

By the first quarter of the 20th century Smoot Sand and Gravel Corporation (SSGC) gained ownership of the southern portions of the marsh from Bucknell University. The northern end was transferred to the Department of Interior from the Department of Agriculture along with responsibility for the George Washington Memorial Parkway. By 1940, SSGC commenced dredging in open water areas for the valuable Pleistocene sand and gravel beds which lay in a thick layer from 16 to 40 feet deep. The dredging encroached onto emergent wetland sections and by the early 1950s wildlife enthusiasts became concerned. It was not until 1959, however, that largely through the efforts of Congressmen Reuss and Dingell was it possible to reach an agreement with SSGC which would ultimately lead to cessation of dredging and protection of significant portions of the marsh.

The arrangements were formalized in PL-86-41 (June 1959). This law conceded rights for continued dredging in specified areas of the marsh, including those under the jurisdiction of the Department of Interior for 20 and 30 year periods, in return for ownership by the United States of the major Smoot properties.

Exchange of properties, however, dragged on for several years. According to Briggs (1954): "For a decade, at the request of natural history societies, the Smoot Company has refrained from substantial operations in the Dyke area; it has offered at financial sacrifice to exchange its Dyke acreage for other government lands with equivalent deposits. But lack of agreement among government departments has blocked a solution. Unless effective action is soon forthcoming, no one will criticize the Smoot Company if it is compelled to continue its dredging."

In a review of the situation, *The Sunday Star*, Washington, DC., July 19, 1970, noted: "At issue is a million-dollar land swap between the Interior Department and the Richmond, Fredericksburg, and Potomac Railroad. After 35 years of haggling, the railroad has obtained access to the George Washington Memorial Parkway from an oddly shaped 42-acre chunk of land locked between the Potomac Yard and the Parkway near National Airport. Without access, the land has not been usable. In return, the Park Service has received 28 acres of swamp and underbrush at the southern end of the marsh, farther down the Parkway near Mount Vernon. The marsh is considered a priceless haven for waterfowl.

The 28-acre property is owned by Charles Fairchild, an Alexandria developer who will lease the railroad land from RF&P in order to build another Crystal City--a vast office-building development to be called Potomac Center. According to the agreement..., Fairchild will be allowed to build a highway bridge and cloverleaf from the railroad's property onto the Parkway at the current entrance to the Daignerfield Island sailing marina. In exchange for this privilege, the remaining piece of the marsh will be absorbed by the Park Service, the wetlands will be protected from further desecration."

In 1998, RF&P gave up access rights in exchange for release of covenants on their land in Arlington County.

No monies were available to buy out Smoot's interests. It was the expressed purpose and spirit behind the law that the Dyke Marsh area should be administered as wetland habitat for wildlife preservation. Congressman Dingell stated, "We expect that the Secretary will provide for the deposition of silt and waste from the dredging operations in such a way as to encourage the restoration of the marsh at the earliest possible moment." Between 1959 and 1973, SSGC dredged further into the marsh until

the current configuration was reached (Fig. 2). In the meantime permits had been issued for dumping of "clean" materials into dredged areas. Hopper barges carried materials into open water areas while construction of a haul road with fill material accommodated truck dumping. Nearly one-half of the original wetland at DMP had been destroyed by dredging and filling. These activities ceased in 1972 when it was recognized that there was no effective management plan for the site. An additional 28 acres of contiguous marsh on the southern end (the Fairchild Tract) were acquired by the National Park Service in 1962. By January 1976 Potomac Sand and Gravel, the successor to SSGC, relinquished claims to dredging rights in the marsh, leaving unimpeded the management options open to the National Park Service.

Today the Haul Road is a soft surfaced trail, which provides access to the marsh. It is 3,600 feet long, impacts drainage patterns, and sustains occasional wash-overs during storm events. The trail is scenic and is used for hiking, access for fishing, bird-watching, and other forms of recreation.

LEGISLATION PERTAINING TO DYKE MARSH PRESERVE

Federal legislation dealing with the purchase and governance of DMP is included in Appendix A.

THE ABIOTIC OR NONLIVING ENVIRONMENT

Geological and Historical Perspectives

The Belle Haven-DMP area and surrounding lands are located in the physiographic province known as the Atlantic Coastal Plain. The Coastal Plain of Virginia is underlain by stratified deposits of mud, sand, clay, gravel, and shells laid down by the ocean when it encroached onto the eastern edge of the continent over the past 100 million years. DMP lies on the Pleistocene Columbia Terrace; bedrocks in the vicinity are nearly 600 feet deep (Danton 1950).

Hunting Creek was once a major drainage stream, now markedly reduced, of the crystalline Piedmont through the unconsolidated sediments of the undifferentiated Cretaceous Potomac group and the stratified Pleistocene terraces of gravel, sand and clay. The creek was, therefore, a major source of the mineral deposits found beneath DMP.

In the past, velocity of this sediment-carrying creek slowed as it entered the quiet water of the estuary allowing deposition of the coarser sediment. This created a local rise in the gradient of the Potomac River, thus effectively reducing the major current to the point where the finer sediment dropped. This sequence provides a likely explanation for the evolution of DMP. Hunting Creek today plays a reduced role on DMP chiefly because its outflow has been severely altered by construction of the George Washington Memorial Parkway, ramps to and from the Capital Beltway, and channelization of its course. The sediment loads from increased urbanization have left a delta in the Hunting Creek embayment. This self-imposed barrier slows the discharge rate, allowing more deposition and reducing the discharge velocity into the main stream Potomac River. Recent boring probes in Hunting Creek Bay revealed areas of sand deposition on top of soft muds. Confining the creek's confluence with the Potomac is allowing deposition and preventing flushing.

Soils

From the geological evidence presented above, soils of the Coastal Plain came from mixed crystalline rocks and sediments. The soils derived from the unconsolidated sediments of the Coastal Plain adjacent to the Potomac estuary have sandy and clayey textures. The major soil group found in the Hunting Bay-Belle Haven-DMP watershed is the Mattapeake-Mattapex-Woodstown soil association. For DMP, the geological formations are probably of the Potomac group (Johnston 1964). On the area's eastern edge along the Potomac is the moderately well drained Metapeake type (Parsons et al. 1976).

Extensive boring in the marsh by the Smoot, Sand and Gravel Company in 1932-1934 and the U.S. Army Corps of Engineers in 1976 revealed the predominance of sand and gravel deposits with lenticular interlayered units of silt and clay. The sand and gravel deposits are found between -16 and -50 feet overlain by soft depositional muds. The sedimentary sequence found here reflects the changing conditions in depositional environment from one of swift moving waters, where only heavy sands and gravel would fall out, to one of slack water allowing finer silts and clays to settle.

The surface soils at DMP reflect to a major extent the source materials in the uplands to the west of the marsh, although some of the smaller materials could be derived from materials almost anywhere in the Potomac drainage. As the result of the Fairfax County Soil survey conducted in 1955, it can be stated with reasonable confidence that these soils are Coastal Plain loamy and gravelly sediments belonging primarily to the Beltsville and Matapeak soil associations.

Preliminary tests of the outer dike structures, which have existed since the early 1800s, indicate that internally they contain no rock or other material foreign to the marsh area. It appears that the dikes were constructed from immediately available materials. Cobblestones on the surface of one dike are typical and similar to rock found in the nearby Potomac basin.

As part of the DMP Restoration Project, soil samples were collected at two sites in the summer of 1976 (National Park Service, 1976; Table 1). For the most part, effects of any or all of these elements and compounds DMP are presently poorly known.

Hydrology

According to Carter et al. (1994) the tidal Potomac River near DMP "... is fresh (salinity $< 0.5 \text{ mgL}^{-1}$) except during periods of low discharge. The average annual flow is $323 \text{ m}^3 \text{ s}^{-1}$. The mean tidal range in the upper tidal river is 0.6 m to 0.9 m and in the lower tidal river 0.5 to 0.6 m.... The waters of Dyke Marsh are dominated by the Potomac River with some, mostly historical, input from Hunting Creek. Also the marsh is bathed by daily Potomac tidal cycles which have a normal 3-foot flux. Flow rates of fresh water contributed by upstream areas of the Potomac go past the marsh at an average volume of 11,000 cubic feet per second. With few exceptions from major summer storm events, the highest flows can be expected in March and April following snow melts on upstream portions of the Potomac River. Even during high flow periods the water level is seldom raised one to two feet higher than normal. These flows generally occur before marsh vegetation becomes established in the spring.

Two islands with the remaining remnant dikes protect the main marsh from any downriver flows which might be directed towards the marsh. However the combined effects of southerly to easterly winds, incoming tides, or both can cause temporary

TABLE 1. Analysis of soil samples in Dyke Marsh Preserve (National Park Service, 1976). Given are mean values in ppm.

	In Marsh	In Demonstration Site
Nutrients:		
organic carbon	4.48	3.12
ammonium	51	54
total phosphorus	35	517
Metals:		
arsenic	0.34	0.44
lead	3.69	4.28
manganese	53.25	186
mercury	0.014	0.006
molybdenum	0.03	0.05
cadmium	0.23	0.35
chromium	0.30	0.86
copper	6.58	7.15
iron	119.50	243.50
nickel	1.67	2.19
zinc	24.50	34.75
No PCBs		
Chlorinated hydrocarbons (DDE)	0.04	0.068

periods of high water which may completely inundate the marsh. It should be noted that damage is most severe as waters begin to flow over the marsh, not when the marsh is covered. Thus, DMP is entirely within the annual flood plain of the Potomac estuary. To date the significant effect of water action, may be the result of wind and boat-created waves, and scour from major flood events, which lap at the steep-sided shorelines left from previous dredging. These shorelines are gradually being eroded back in several areas, and vegetation is impacted due to loss of soil cover.

The erosive potential of the tidal cycle toward the creation of a tidal marsh drainage pattern can actually be gleaned from recorded history in this area. After the digging and filling behind the dikes in the early 1800s, no drainage guts occurred through the embankments aside from the two natural channels at the inner marsh. The point of significance here is that tidal action naturally tends toward the evolution of tidal guts and typically a natural dynamic equilibrium exists between depositional land forming activity and the erosive action of tidal movements. The erosive action at DMP would persist until the energy differential caused by shoreline heights and river bottom depths is dissipated. There are no persistent freshwater streams flowing through the marsh, other than the Potomac River. Dyke Marsh Creek and Hog Island Gut do serve to conduct drainage from the high lands west of the marsh.”

In an unpublished report Harper and Heliotis (1992) developed a hydrological model for DMP. Among their findings was the fact that dye tests taken in various parts

of the marsh confirmed the high flushing rate in each tidal cycle. The main marsh was primarily watered by the Hog Island Gut from the south and secondarily from the north by the inlet south of the Haul Road. This demonstrable flushing action is significant to nutrient flow and export from DMP.

Water Quality

Water quality at DMP is dominated by the man-related effluent from upstream which includes high levels of persistent turbidity, excessive nutrients, and some loads of heavy metals or other toxic chemicals. Turbidity has undoubtedly been the critical factor in the loss of submerged vegetation in the upper Potomac estuary. In terms of the food chain, the loss of this vegetation has led to the depletion of dependent biota which is the food base for wildlife such as diving ducks and fish. In the past nutrient loads have become heavy enough for the surficial blue green algae populations to explode and then decline. This dying biomass supports increased bacterial populations which utilize the dissolved oxygen supply for their respiration and deprive the fish and other biota of the same life-sustaining element. It is critical to the future of DMP, as well as to the entire Potomac Estuary, that both turbidity and nutrient loading be decreased.

A decrease in one of these is not enough and might even be more harmful. For example, a decrease in turbidity along with continued high nutrient content eventually would lead only to the aforementioned condition of low dissolved oxygen or eutrophication. Preliminary studies by Horace V. Wester (pers. comm.) suggested free chlorine as one of the primary pollutants specifically affecting aquatic vegetation. More efforts are needed to define the effects of this and other pollutants as a way of predicting their impact on wetland vegetation. The decrease of some vegetation such as *Zizania aquatica* (wild rice) and even the pest water chestnut can be attributed to water pollution conditions preventing vigorous growth. In the meantime, qualitative and quantitative data serve as a frame of reference as to the status of pollutants in the environment.

Data collected from the Blue Plains Sewage Station were indicative of generally poor water quality. During the period 1962-1971, the surface mean chloride content near Blue Plains averaged 0.02 ppt, water temperatures ranged from 1° to -30.5°C, alkalinity as expressed by CaCO₃, between 23-142 mg/L and pH between 6.8-8.3. However, DO (dissolved oxygen) was low (12%), BOD reached a maximum of 0.5 or 14.1 mg/L, and fecal coliform density ranged near 1 million MPN/100 mL. Typical levels of key ingredients indicate periodic high levels, suggesting that when high nutrient loads coincide with warm water temperature and ample sunlight algal populations will increase to bloom proportions, thus leading to eutrophication (National Park Service, 1976).

In 1979, water quality in the river including the DMP region was considered to be in the good range--pH 8.1-8.4; dissolved oxygen 6.0-7.9 mg/L; suspended solids 25-80 mg/L; total organic carbon 5-20 mg/L; nitrate nitrogen 0.21-0.60 mg/L; total phosphorus 0.05-0.25 mg/L; chlorophyll a 25-49 µg/L; fecal coliform bacteria =201-500 (U.S. Army Corps of Engineers, 1988).

More specifically, average summer conditions in Hunting Creek embayment for 1985 were--pH=6.1 (range for region=7.0-8.1); dissolved oxygen=7.1 (7.4-8.6) mg/L; total suspended solids=39 (9-14) mg/L; total organic carbon=8.0 (2.4-3.3) mg/L; nitrate nitrogen=0.19 (0.73-1.94) mg/L; total phosphorus=0.13 (0.09-0.10) mg/L;

chlorophyll *a*=10 (7-13) $\mu\text{g/L}$; fecal coliform bacteria =2,306 (20-8,590). These averages resulted in an index score of 4.25 which put the embayment in the "GOOD" range of water quality classification. However, both the pH and bacteria counts were considered to be standard violations.

In a report, "1984 Dyke Marsh Water Quality Data," from the Metropolitan Washington Council of Governments, results of sample analyses indicated that (1) throughout the summer months dissolved oxygen remained close to saturation, (2) total suspended solids were generally less in DMP than in the main Potomac River channel, (3) total phosphorus loads decreased, (4) nitrogen decreased, and that (5) chlorophyll *a* reached a peak in July and decreased thereafter. As far as the suspended solids are concerned, the data support the idea that the presence of submersed aquatic vegetation (SAV) promotes settling of sediments and improved water quality.

Clarity is another important water quality consideration which has a direct impact on aquatic ecosystems. High turbidity, measured by total suspended solids, results in reduced light penetration into the water column and therefore, reduced light availability for aquatic life. Water quality in the embayments of the Potomac River tends to be better than in the mainstream. Several factors contribute to this phenomenon, one of which is the quick settling rate of sediments to the bottom because of the slower, reduced flow conditions typical of embayments. Another factor is the assimilation of particles by aquatic vegetation as a nutrient source. In addition, trapping the particles from the water column prevents them from being carried away by the current to other areas.

These data on water quality need to be updated to assess possible future effects on the DMP area.

Drainage Patterns

Drainage patterns within DMP are controlled by the overall influence of the Potomac and the tidal flow. However, as part of the peculiarity of the dredged and formerly diked marsh, minor drainage flows generally away from the outer edges of the emergent marsh toward the two major tidal creeks. This is due to human removal of large portions of the marsh, leaving the earlier highest portions of the marsh at its extremity.

The Hunting Creek Estuary has a drainage basin of 0.79 mi^2 , the channel length is 1.48 mi ., and severe sedimentation has occurred, leaving a bed of silt, clay and rich organic material (Parsons et al., 1976).

Conducting field work in the late spring and summer of 1963 on the Wrecked Recorder Creek (now largely destroyed), Myrick and Leopold reported that "...the southern of the three estuarine channels carries away nearly all the surface runoff originating in the high ground adjacent to the marsh. The water exchanged with the Potomac estuary is here quite fresh (not salty).... Shortly thereafter, dredging operations for commercial gravel production destroyed the channel system.... For Wrecked Recorder Creek, water depths generally increased as a function of distance from the channel origin, from about 3 feet below level of the marsh to about 5 feet. Width of the channel increased from 18 to 134 feet.... Velocity, and thus discharge, at a given stage was dependent both on the maximum stage attained by the particular tidal cycle and the range of stage in the tidal cycle.... The estuarine channel differs from a terrestrial one in that discharge at any section in an estuary varies depending on how

the flow shaped the entire length of the channel between the point in question and the main body of tidal water. The result is that a tidal channel changes more rapidly in width and less rapidly in depth as discharge changes downstream than does a terrestrial channel.... In tidal channels, zero discharge occurs twice in every tidal cycle, and thus there are also two occurrences of high discharge in each cycle."

THE BIOLOGICAL ENVIRONMENT

Some Historical Reports

The oldest known plant identifications were those of Waldo McAtee (1918, p. 96) who described the flora of Hunting Creek: "Hunting Creek, just below Alexandria, has a very interesting flora. It is filled with aquatic vegetation, among which *Potamogeton robbinsi* and *Utricularia macrorhiza* are its exclusive possessions in this vicinity. The peculiar marsh plants are *Eleocharis flaccida*, *Carex gracillima*, *Plantago cordata* (also found opposite Alexandria) and *Eupatorium cannabinum*; and mud flats, *Isoetes riparia* and *Micranthemum micranthemoides*. Other interesting species occurring here are *Alopecurus geniculatus*, *Pedicularis lanceolata* and *Galium asprellum*." For DMP, he continues "The marsh is a beautiful sight during the flowering season of the abundant introduced *Iris pseudoacorus*. In this marsh only has been collected the fragrant ladies tresses (*Ibidium odoratum*)."

Submersed Aquatic Vegetation

SAV has long been a subject of controversy in the Potomac River near Washington. The debate has largely centered around the benefits and negative effects of the SAV. SAV is rooted in the bottom and typically grows in water six feet or less. Generally, SAV, on the one hand, provides shelter and food for a variety of wildlife, reoxygenates the water column, absorbs nutrients, and reduces erosion. It has been estimated that SAV supplies nearly one-half of the summer diet of most waterfowl species (Anonymous, Army Corps of Engineers 1988). On the other hand, the presence of some SAV tends to shade out other aquatic plants, reduce the diversity of aquatic flora and fauna, and clog waterways making them less accessible to swimmers and boaters (Steward et al. 1984).

Virginia Carter, Nancy Rybicki, and their colleagues at the U.S. Geological Survey have published several pertinent papers on the biology and distribution of SAV along the Potomac River in recent years. Prior to the 1930s, species reported from the tidal Potomac River included *Vallisneria americana* Michx., *Ceratophyllum demersum* L., *Najas flexilis* (Wild.) Rostk. and Schmidt, *Elodea canadensis* (Michx.) Planch., and *Potamogeton crispus* L. (Carter et al. 1994). In the late 1930s, these plants largely or entirely disappeared. In 1983 SAV began returning to the freshwater portion of the Potomac River. In 1986 the percent cover of SAV in DMP was 70-100.

A 1978-81 survey of submersed aquatic macrophytes in the tidal Potomac River showed that there were virtually no plants in the freshwater tidal river between Chain Bridge and Quantico, Virginia (Carter and Rybicki, 1986). Carter and Haramis (1980) related the loss of SAV to the decline of waterfowl in the Potomac River. From a systematic survey conducted in 1978 and 1979, they concluded: "The limited distribution of submersed aquatic vegetation is associated with a decline in use of the tidal Potomac by wintering diving ducks, particularly pochards [diving ducks]. These waterfowl have either shifted their food consumption to a higher percentage of animal

foods or moved to other areas. Very few diving ducks are found in the tidal river, larger concentrations are found in the transition zone and lower estuary where small mollusks and submersed aquatic vegetation are more abundant. It is possible that degraded wintering habitats have indirectly reduced winter survival of waterfowl and may have been one factor causing continental waterfowl declines in this century."

Richard Hammerschlag (1984, 1985) reported on studies relating to the physiology of *Hydrilla* at DMP with special reference to water quality. These studies followed an invasion of *Hydrilla* in the Potomac estuary since 1981. He found that (a) a principal contribution to the intensive growth of *Hydrilla* was unusually warm April water temperatures, (b) the effects of *Hydrilla* on dissolved oxygen levels were important to the biological stability of the estuary, (c) *Hydrilla* reduced suspended particles in the water column, (d) *Hydrilla* mass increased visibility in the water column, (e) growth of *Hydrilla* reduced turbidity through reduction of particles in the water column, (f) *Hydrilla* did not appreciably affect the overall level of solutes, and (g) higher nutrient levels were recorded in the spring and fall with depressed levels occurring during the summer season. Thus, a positive effect of SAV would be to utilize and thus remove nutrients from the water column and hydrosol during the growing season. One result of this action is that SAV could be an effective nutrient buffer in the estuary by serving as a nutrient sink during the summer growing season and serve as a releasing mechanism for nutrients into the water column in the fall.

Carter and Rybicki (1986) also reported that "In 1983, 12 species of submersed aquatic macrophytes were found in the tidal river. Population increases were dramatic: by fall 1985, plants had colonized all shallow areas between Alexandria and Gunston Cove, Virginia. *Hydrilla verticillata* dominated in Dyke Marsh-Hunting Creek and Swan Creek. Most other areas contained a variable mixture of *Heteranthera dubia*, *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Vallisneria americana*, *Najas guadalupensis*, and *Hydrilla verticillata*. No plants were found along the main river or in tidal embayments in the reach between Gunston Cove and Quantico, Virginia. Total dry weight collected in the upper tidal river in fall 1985 was 14.5 times that of spring 1985, and four times that of fall 1984.

"Thirteen species were reported from the tidal river during 1983-1989. The most widespread species from 1983 to 1989 were *Hydrilla verticillata*, *V. americana*, *Myriophyllum spicatum*, *C. demersum*, and *Heteranthera dubia*. The dominant species currently in terms of biomass and cover are *H. verticillata*, *M. spicatum*, and *V. americana*. *H. verticillata* and *M. spicatum* are exotic species and are often considered nuisance plants because they outcompete native species."

In another report, Carter et al. (1985) provided additional information on the distribution and abundance of SAV in the tidal Potomac River and Transition Zone of the Potomac estuary, Maryland, Virginia, and the District of Columbia. They noted the species distribution at several DMP sampling transects in 1984--Spring, *Hydrilla verticillata* (*Hydrilla*); fall, *Ceratophyllum demersum* (coontail), *Hydrilla*, *Nitella flexilis* (muskgrass), *Myriophyllum spicatum* (Eurasian watermilfoil). In biomass (g/m²)--Spring, trace-27; fall, 691. Overall species diversity was low, 1-2, especially when compared with transects downriver from Dyke (>4). The substrates were clay and silt.

To understand the effects of weather (especially wind) and water quality on SAV, Carter et al. (1994) analyzed the results of a number of tests. In the Potomac River at DMP, growing-season Secchi depths were <0.60 m. before resurgence of macrophytes. Following the resurgence of macrophytes in 1983, they found "... a growing-season Secchi depth of 0.86 m, total suspended solids of 17.7 mg/L, chlorophyll a concentrations of 15.2 µg/L, significantly higher than average percent available sunshine, and significantly lower than average wind speed. From 1983 to 1989, mean seasonal Secchi depths <0.65 m were associated with decrease in plant coverage and mean seasonal Secchi depths >0.65 were associated with increases in plant coverage." They concluded that Secchi depth is highly correlated with plant growth in the upper tidal river, and that wind speed is an important influence on plant growth.

By 1996, various reports indicated increased coverage by SAV. According to the Council on Environmental Quality (1996), "between the Woodrow Wilson Bridge and Indian Head, vegetation is beginning to return to sites along the George Washington Parkway (such as DMP) for the first time since 1989." The Environmental Quality Advisory Council for Fairfax County (EQAC) annual report on the environment in 1996 noted that "Vegetation is increasing between Roosevelt Island and the Woodrow Wilson Bridge. In this reach most beds are dominated by Hydrilla but several large beds, such as one along Reagan National Airport, are dominated by wild celery (*Vallisneria americana*). Water stargrass (*Heteranthera dubia*) dominates a bed on the shoal just south of National Airport.

Between the Woodrow Wilson Bridge and Indian Head, vegetation is beginning to return to sites along the George Washington Parkway (such as DMP) for the first time since 1989. Vegetation continues to grow in embayments on the Maryland side, but not nearly to the extent it did in the past. Wild celery or hydrilla are the dominant species here."

Emergent Vegetation

In an early preliminary observation of marsh plants and moist-soil herbs, Francis M. Uhler (1963) listed 49 plant species. He continued, "A study made during the growing season will undoubtedly add many other marsh and swamp plants as frosts had caused the vegetation to disintegrate before these observations were made. A few drifting plants of sago pondweed (*Potamogeton pectinatus*) and wild celery (*Vallisneria spiralis*) in the open water at the north end of the DMP indicated that some of these important, submerged, seed plants still exist in sections where the water is clear enough to permit the necessary penetration of sunlight." Of the 49 species, Uhler considered 14 to be good to excellent waterfowl foods.

Similarly in 1963, Myrick and Leopold reported general observations of the vegetation: "The dominant vegetation [of the marsh] consists of cattails, *Typha latifolia*, and probably also *T. angustifolia*. [a note appended to the paper indicates that the latter species is the dominant, as determined by Uhler.] Both species are to be expected in localities such as this, but *T. angustifolia* is in general dominant in areas of salty water. The basal part of some stands of *Typha* is whitened in spring, probably showing the limit of tide. Another plant common to the area is the arrow arum, *Peltandra virginica*. Some of the plants are unusually luxuriant and might be taken for the yellow water lily, *Nuphar advena*, especially where partly submerged. The trees growing in some areas slightly higher in elevation than average marsh surface

include green ash, *Fraxinus lanceolata* [= *pennsylvanica*], which is a common tree in such places in the tidewater region. The willows are probably *Salix nigra*, common along the Potomac in the Washington area."

As a result of an intensive and extensive survey of the DMP flora, Xu (1991) provided a list of 373 species (see Xu 1991, for a complete list of species found). Most of the species are common species of the local flora. Of these, 60 species (16%) were listed as obligate wetland species.

Xu also initiated eight east-to-west permanent transects across the Preserve with sampling points on marshland at (normally) 20-m intervals. During the fall of 1991 both wooded and herbaceous (open marsh) sites were sampled, determining the species present, individual species counts, coverage, height, and circumference, as well as noting surrounding flora. His findings indicated, among other things, that the natural wave action of water in the river is dredging the marsh away. The establishment of the permanent transects would assist in monitoring such effects in the future.

The results of a continued transect survey at Hog Island gut, although probably not reflecting vegetation of the entire marsh, by Lindholm (1992) indicated that:

(1) greater than 98% of the open marsh consisted of the eight species (from highest to lowest frequency of percent of quadrats with at least one specimen): *Peltandra*, *Typha*, *Impatiens*, *Nuphar*, *Cuscuta*, *Acorus*, *Leersia*, and *Scirpus*. Thus, species richness is generally low in the open marsh. The open marsh points (n=53) sampled result in a Shannon-Wiener diversity index of 1.668. Density in the open marsh was: *Impatiens capensis*, 41.2%; *Peltandra virginica*, 20.8%; *Acorus calamus*, 12.8%; *Typha* spp., 13.0%; *Nuphar luteum*, 5.5%; *Leersia* sp., 3.5%; *Scirpus fluviatilis*, 1.2%.

(2) average cover per species: *Peltandra*, 29.9%; *Impatiens*, 20.8%; *Nuphar*, 20.3%; *Typha* spp., 17.6%; *Acorus*, 4.9%; *Cuscuta gronvii*, 2.4%; *Leersia*, 0.9%.

(3) species density (average number / m²) in decreasing order: *Impatiens*, *Acorus*, *Peltandra*, *Typha*, *Nuphar*, *Leersia*, *Scirpus*.

(4) average species heights in meters, in decreasing order: *Typha*, *Scirpus*, *Acorus*, *Impatiens*, *Leersia*, *Nuphar*, *Peltandra*.

(5) it appears that *I. capensis* and *P. virginica* are among the dominant species at this time of year [summer] throughout the open marsh, with *A. calamus*, *Typha* spp., and *N. luteum* sharing cover (and hence dominance as one moves from north to south in the open marsh).

Little is presently known about the composition of the botanical community within the Belle Haven recreation site. Additional inventory is needed to establish a baseline database for this area.

Changes in Vegetation

Historical data indicate that significant changes have occurred in the vegetation of DMP in recent decades. Some plant species, such as the heart-leaf plantain (*Plantago cordata*), have become extinct (Kelso et al., 1993). The species was recorded as common in Alexandria and DMP area since the 1870s according to available collections of this species in the Smithsonian Institution (US Herbarium). Existence of this species in DMP until 1918 is revealed in those collections. But since 1918, no records of this species have been found in DMP and the adjacent area. Curators of the Smithsonian and other institutions have explored the DMP several times in recent

decades, but no one was able to re-collect this species. Perhaps other species have also disappeared.

Among the changes in vegetative patterns are those reported by Kelso et al. (1993). Many clumps of Spatter Dock (*Nuphar luteum*) do not appear in the 1970s aerial photos, but are now obvious, in Hunting Bay near the outlet of Hunting Creek. In the marsh, the same species has filled a lot more waterways, and occupies larger area than in 1970s. Exotic species continue to be controversial, some apparently invading natural communities. The Common Reed (*Phragmites australis*) was observed without a clear stand in 1970s, but now forms two large stands in the marsh. One of these is on artificial substrate at the Haul Road, and the other in an area considered to be early successional. Sweetflag (*Acorus calamus*) has taken over some areas that were occupied by Arrow Arum (*Peltandra virginica*) in recent decades according to their community size. Some of these changes are not so much "invasions" by other species as changes in hydrology and sedimentation. Even so, some vines are invading the swamp forest.

Studies show that since the 1970s changes in vegetation in DMP demonstrate the dynamics found in an active marsh ecosystem. The variance of information found in studies conducted by Thomas (1976) and Xu (1991) indicates the strong need for an active monitoring and research program to monitor changes taking place within the marsh.

Plant Communities

DMP can be divided into three major zones or plant communities: the marsh proper (tidal freshwater marsh), the floodplain forest, and the swamp forest. Parts of the marsh proper, which comprises about 35 percent of the area, are partly underwater except at low tide. The floodplain and swamp forest are about 4 feet above mean high tide and are not inundated during normal tidal cycles. The tide, however, does carve deep tidal guts into the marsh. Occasionally, strong easterly winds coupled with an incoming tide can flood the marsh for several hours.

The marsh proper is about one-half covered with cattails, with other common marsh plants such as arrow arum, sweetflag, and spatterdock also prevalent.

Parsons et al.(1976) reported that the tidal freshwater marsh contained common wild rice, cattail, yellow pond lily, pickerel weed, many sedges. "The plant community can be divided into two zones. Very tall herbs, such as cattails, wild rice and polygonums, are found on the shore. In comparison, much shorter vegetation including pickerel weed, yellow pond lily and tuckahoe grow right along the river. The marshland of this environment, known as Dyke Marsh, is not dominated by any one plant, although the most abundant species are the cattails, with pickerel weed-arrow arum second in abundance and yellow pond lily third."

The floodplain forest is separated from the marsh proper by a border of shrubs including swamp rose, buttonbush, and alder. Elm, sweetgum, red and silver maple, and box elder are among the dominant trees. The swamp forest is a depressed area possibly formed by an old river bed. In this forest are found green and pumpkin ash, black willow, spicebush, arrow wood, and many other trees.

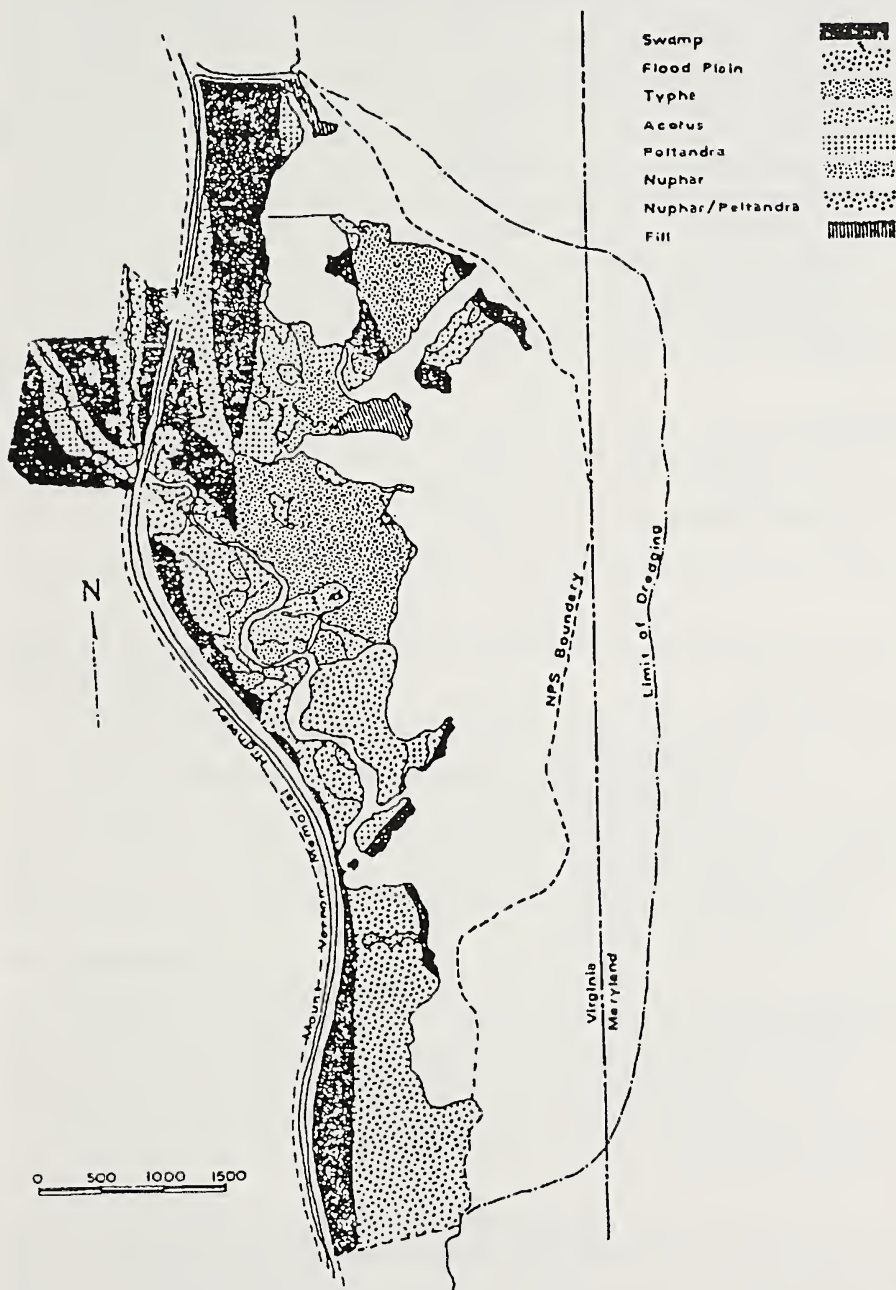


FIGURE 3. Vegetation map of Dyke Marsh Preserve.

TABLE 2. Vegetation types from transects in Dyke Marsh (Xu, 1991)

Vegetation Types	Acres	Percent
Dyke Marsh Proper		
Floodplain forest	89	36
Secondary vegetation	13	5
Swamp forest	47	19
<i>Nuphar-Peltandra</i>	22	9
<i>Typha</i> (mixed)	49	19.5
Mixed non- <i>Typha</i>	28	11
Wild rice (mixed)	0.8	0.3
<i>Phragmites</i> (pure)	0.5	0.2
Total	249.3	100
Hunting Bay area		
Secondary vegetation	51	82
<i>Typha</i> (mixed)	5	8
Floodplain forest	6	10
Total	62	100

The general vegetation composition of DMP (Fig. 3) was delineated by Thomas (1976) as follows:

DMP as a whole--

1. *Nuphar* (spatterdock) zone 1%
2. *Nuphar-Peltandra* (spatterdock and arrow-arum) mixture 5%
3. *Peltandra* (arrow-arum) zone 8%
4. *Acorus* (sweetflag) zone 4%
5. *Typha* (cattail) zone 20%
6. Swamp forest zone 30%
7. Floodplain forest zone 32%

The marsh proper--

1. *Nuphar* zone 2%
2. *Nuphar-Peltandra* 12%
3. *Peltandra* zone 21 %
4. *Acorus* zone 12%
5. *Typha* zone 52%

The Swamp forest zone contained Pumpkin ash (*Fraxinus tomentosa*), Green ash (*F. pennsylvanica*), Black willow (*Salix nigra*), American elder, swamp haw, black gum, and others.

The Floodplain forest contained American elm, White mulberry, cottonwood, sweetgum, black cherry, red and silver maple, willow oak, American Beech.

Xu's transect studies (1991) provided a classification of plant communities and the estimated acreage of each (Table 2).

In 1976, L. K. Thomas, Jr., as part of a team for an environmental assessment of DMP, reported a preliminary delineation of the DMP vegetation. In that report, 289 acres of the marsh vegetation and 87 acres of the swamp forest were mapped. Comparing numbers in 1976 with the ones in Xu's 1991 report, it appears that some 40 acres of marsh and swamp forest each were lost in the 15-yr. period area, while the floodplain forest remained virtually unchanged.

Within the marsh, *Nuphar* (spatter dock) has filled more waterways and increased in acreage since 1976. This may mean that the sediment deposit has increased in the marsh in the last two decades. The *Acorus-Bidens* mixture may have taken over some of the areas previously identified as the *Peltandra* territory. It is evident that in the marsh at the southernmost of the parkland *Acorus* grows with *Peltandra* but the former species shades the latter one. The two species occur in similar water levels and grow in the same season. The *Typha* community remains the climax vegetation, relatively stable in its community size.

From an unpublished report of a morning hike on 20 May 1991 along the Haul Road. "The area had a high diversity of exotic plant species including: *Lonicera japonica*, *Celastrus orbiculatus*, *Alliaria petiolata*, *Ampelopsis brevipedunculata*, and *Rosa multiflora*. Marshes that could be observed from the trail appeared to be free of *Phragmites* indicating potential high quality. A boardwalk and trail crosses a stretch of nutrient-rich marsh containing *Numphar luteum*, *Peltandra virginica*, *Acorus calamus* and other species, and a *Liquidambar styraciflua-Fraxinus pennsylvanica* swamp. Habitat for the rare plant *Carex decomposita* was noted in areas both north and south of the parking lot."

It must be emphasized that vegetation "changes" in general are not always real but may be artifacts of different sampling methods, different definitions of some zones, and differences in location of the outer bounds of the area studied.

These studies *en toto* demonstrate the dynamics of the marsh ecosystem and possible environmental impacts on the ecosystem, all of which suggest the need of setting up a long-term monitoring program so that biodiversity changes of this ecosystem in the future can be identified based on adequate quantification.

Rare Plant Species

From searches of herbarium and museum specimens and literature sources, a Natural Heritage Inventory in June 1991 identified rare plant species in the DMP area: rough avena (*Geum laciniatum*), river bulrush (*Scirpus fluviatilis*), the Virginia mallow (*Sida hermaphrodita*), and epiphytic sedge (*Carex decomposita*).

Xu (1991) reported the presence of American plum (*Prunus americana*) in the marsh, great burrweed (*Sparganium eurycarpum*), and small leaf elm (*Ulmus carpinifolia*).

INVERTEBRATES

To date, complete sampling of any invertebrate taxa in DMP has not been carried out. The following discussion presents what is currently known from scattered reports, chiefly those of Parsons et al. (1976) and the U.S. Army Corps of Engineers (1988).

Aquatic Communities

The benthic community in the Potomac River plays an important role in the aquatic food web. Some species are important because of their commercial and recreational

value. Although the precise composition of the benthic community of the River and DMP waters is not known, reports from the Potomac River and the Belle Haven area suggest the presence of a variety of Annelida (segmented worms), Mollusca (bivalves), aquatic insects, Crustacea isopods, amphipods, and others) (Parsons et al. 1976; U. S. Army Corps of Engineers 1988).

Ectoprocta (moss animals)

Belle Haven estuary at DMP

Ectoprocta--*Fredericella sultana*

Annelida

Bottom samples collected at DMP reveal a benthic fauna characteristic of polluted waters, with tubifex worms and chironomid flies predominating.

Belle Haven Estuary at DMP

Oligochaeta

Hirudinea (leeches)

Mollusca

According to observations of Dr. Francis M. Uhler in 1963, "In addition to the abundant, viviparous Japanese snail (*Viviparous japonicus*), several native snails and clams, including *Goniobasis virginica*, *Helisoma* sp., *Musculium* sp., and larger thin-shelled clams, were common in the shallow waters. These compose useful resources of invertebrate foods for aquatic wildlife." Gerberich (1984) reported that the endangered *Lasmigona subviridis* (Green floater) and the threatened *Elimia virginica* (Piedmont elimia) have been taken along the Potomac River near DMP. Beetle (1973) provided a checklist of 35 species of the land and freshwater mollusks of Virginia known from Fairfax County (Appendix B). Some of these species have been found in DMP and the surrounding areas.

Arthropoda

As mentioned above, chironomids are characteristic in the benthic fauna.

Odonata--one record for the rare clubtail dragonfly (*Gomphus fraternus*) (Natural Heritage Inventory). From the Belle Haven estuary, *Perithemis* sp. (Parsons et al. 1976).

Crustaceans--Historic records gleaned from museum specimens and the literature show that rare amphipods (*Stygobromus*) were once collected nearby: Alexandria, *S. phreaticus*; Belle Haven Golf Course, *S. tenuis* (Natural Heritage Inventory). Dr. Uhler (1963) also reported "a good supply of crayfish."

Hexapoda (insects)

In the past the DMP area has produced several additions to the crane flies of the region, and has yielded the only specimen so far obtained of the remarkable horsefly, *Merycomyia*. The large hymenopteran, *Pepsis elegans*, related to the western tarantula hawk, was seen only at DMP and Mount Vernon in a broad-scale survey of the region by McAtee (1918). From the Belle Haven estuary, Hemiptera (Gelastocoridae, toad bugs) and Diptera (Chironomidae, midges) have been reported.

In 1997 Edward M. Barrows of Georgetown University began a survey of hexapod habitats, richness, and relationships on the DMP. That continuing long-term survey

will provide lists of species and will provide a large baseline data set which can be used in forthcoming years to assess the effects of environmental changes and other factors on this Preserve. Using floating Malaise traps that move up and down with the tide in an open marsh, Dr. Barrows and his students will continue to collect specimens throughout the year. Traps will be set in the low forest, open marsh, and forest-marsh ecotone.

At least 6,000 hexapod species may be found in this Preserve. Appendix C provides preliminary lists of the orders (32) and number of species (292) by taxonomic order that have been found by the end of 1998.

Foods of these hexapod orders are also found in Appendix C. As expected, insect foods vary from detritus, bacteria and fungi, plant parts to carnivores on other insects and vertebrates. This information can be used in developing specific food chains and food webs of DMP.

VERTEBRATES

Fish

A recent report from the U.S. Army Corps of Engineers (1988) noted that "The study area supports a moderate amount of sport fishing. Sport fishing occurs most frequently in the tributaries where the catch includes yellow perch, white perch, catfish, largemouth bass, sunfish, crappie and chain pickerel. As a result of improved water quality conditions and the resurgence of SAV, the upper tidal river has been attracting more recreational fishing with largemouth bass, striped bass, yellow perch, and catfish being the most frequently sought after species."

Several anadromous fish utilize the Potomac River for spawning and care must be exercised that activities in DMP and the River should be scheduled as to minimize impact on these fish. Examples of such fish are Alewife, Blueback Herring, White Perch, American Shad, Striped Bass, and potentially the Atlantic Sturgeon.

Although no complete survey of fishes has been carried out in DMP or specifically in the contiguous Potomac River, occasional observations and reports as well as distribution maps from the published literature strongly indicate the presence of 62 species (see Appendix D). A preliminary analysis of the residency habits of these species shows the following categories: 7 anadromous, 1 catadromous, 7 rare or probably extirpated, and at least 20 permanent residents. From what is known about their feeding habits, 5 are filter-feeders, 4 are omnivores, and 45 are predators (on arthropods, small invertebrates, fish).

Future studies should elucidate in greater detail the roles of specific fish species on the DMP ecosystem.

Amphibians and Reptiles

Although making no specific mention to the DMP area, in an early "List of batrachians and reptiles of the District of Columbia and vicinity" Hay (1902) included several species found at Mount Vernon just south of DMP. Species included were Marbled salamander, Scaly salamander, Slimy salamander, Newt, Swamp treefrog, Brown-back lizard, Ground snake, Ring-necked snake, Red-bellied snake, and DeKay's snake. Most of these have not been found in recent years.

Observations by Walter Bulmer (1996-99) and his students in DMP have revealed the presence of the species listed in Appendix E. Only 9 species of amphibians, 7

TABLE 3 - The numbers of amphibian and reptile species found in principal habitats of Dyke Marsh Preserve

	Forest Ponds	Marsh	Woodland ¹
Salamanders	1		1
Frogs and Toads		5	2
Turtles		6	1
Lizards			2
Snakes		1	2

¹ a combination of swamp and floodplain forests

turtles, 2 lizards, and 3 snakes were found during this time period. Habitats utilized by these species are given in Table 3.

Amphibians and reptiles listed in previous reports (Abbott 1976, Parsons et al. 1976) but not found currently are also given in Appendix E. The Parsons report included areas outside of DMP, such as Dogue Creek.

Birds

Birds comprise an obvious faunal element of DMP, represented by many resident and migratory species. Because of birds' conspicuous attribute and the increasing numbers of bird-watchers at the marsh and contiguous areas, more data are available for birds than any other animal group.

A summary of historical records indicates a long-time interest in the bird life of DMP and surrounding areas. Famous ornithologists and naturalists observed birds in the region between 1895 and 1925: Harry C. Oberholser, Alexander Wetmore, W. L. McAtee, Ludlow Griscom, E. A. Preble, May Thacher Cooke, R. W. Shufeldt, Francis Harper, Albert K. Fisher, and Frederick C. Lincoln. Their reports are found chiefly in *Bird-Lore*, *Wilson Bulletin*, and *Auk*. The earliest bird record for the DMP area is mention of "...king fishers which now build their nests in its rugged sides..." and "...I bagged six brace of as fine woodcock as you would wish to see..." (Alexandria Gazette, 10 August 1858).

Marsh Wrens were formerly abundant in the marshes bordering the Potomac River where "Hundreds of the large globular nests, affixed to the swaying reeds, used to be found in the bit of marsh bordering the Lee estate, and thence toward the Virginia end of long Bridge" (Coues and Prentiss 1883:44). With the destruction of those marshes, DMP is now the sole upriver tidal freshwater marsh where these wrens breed. In 1950 Irston Barnes counted 87 singing males at DMP (Davis, 1950), but by 1994 only 31 territories were found (S. Spencer, pers. obs.).

Early Christmas bird counts and other reports included some rare birds: Yellow-throated Warbler (1915), Red and White-winged crossbills (1916, 1917), Ruffed Grouse (adult and young, 1894), nesting Red-shouldered Hawks (1920), and breeding Prothonotary Warbler (1922). Halle (1947) provided fascinating descriptions of DMP and its wildlife--flocks of ducks, Bald Eagles, nesting Ospreys, and Marsh Wrens in profusion. His book was illustrated by the famous artist, Francis Lee Jaques, whose drawings of wildlife of the region and elsewhere are legendary. Uhler, in his present-

TABLE 4. Bird species found on breeding bird surveys (1992-2000) in and near Dyke Marsh Preserve

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Number of species found	57	72	75	80	85	81	81	75	76
Number of confirmed breeders	26	31	34	37	37	42	32	34	36

TABLE 5. Numbers of species found in general groups at Dyke Marsh Preserve.

waterfowl and divers	30
waders	13
hawks and owls	13
quail and doves	3
marsh birds	5
shorebirds	29
gulls and terns	15
woodpeckers	7
cuckoos, goatsuckers, swift, hummingbird, kingfisher	7
flycatchers and lark	8
swallows	6
crows and jay	3
wrens, thrushes, mimics	15
chickadees, titmouse, nuthatches	5
starling, kinglets	5
vireos	6
wood warblers	34
tanagers and sparrows	17
blackbirds, orioles	7
finches	6

tations to the U. S. Congress (1963, 1968), noted the abundance of waterfowl and their favorite foods supplied by the marsh.

Breeding bird surveys of the picnic area, marina, haul road, and DMP were taken from 1992 to 2000 (L. Cartwright, pers. comm.; Table 4). Confirmed breeders over these years included waterfowl (Canada Goose, Mallard, Wood Duck), Osprey, and 10 neotropical migrants (flycatchers, warblers, vireos, orioles). Population trends cannot be derived from these data because of annual variations in observer-hours.

In 1992, Erika Wilson created a DMP database that consisted of 6,272 records of 202 species recorded from 1954-1991, with the bulk of the records occurring from 1985-1991. A check-list ("Birds of Dyke Marsh") issued by the National Park Service included Wilson's records and consisted of 208 species, but through 2000 the total is approximately 246 (Kurt Gaskill, pers. comm.) (Appendix F). Those species fall into general groups (Table 5). Clearly, DMP provides an important series of habitats for

TABLE 6. Generalized feeding categories of bird species at Dyke Marsh Preserve.

Piscivorous (fish-eating)	13%
Carnivorous (eating other vertebrates)	5%
Insectivorous (insects and other arthropods)	63%
Granivorous (seeds, fruits)	13%
Other (omnivores, scavengers, pollen)	6%

TABLE 7 -Generalized feeding categories of mammal species at Dyke Marsh Preserve

Insectivores	10
Insect and seed-eating	8
Herbivores	3
Carnivores	5
Omnivores	4

feeding, resting, and breeding to groups such as waterfowl and neotropical migrants, such as wood warblers.

The same species can be placed into generalized feeding categories (Table 6). Insectivores are the most commonly found species.

The bird records *en toto* from DMP show that some species have been lost as breeding birds over the years (Wilson, 1991), many shorebirds, waterfowl and neotropical migrants use the site for refueling in migration, both waterfowl and neotropical migrants breed there, and that birds play important roles in the DMP ecosystem.

Mammals

Historical records of mammals in and near DMP are few. Oberholser (1895) found four common mammal species at Belle Haven in June 1895. Bailey's (1896) "List of mammals of the District of Columbia," included some observations from Alexandria and Mount Vernon but none specifically from the DMP area. Kelso et al. (1993) believed that large-scale dredging in DMP caused the apparent decline of muskrats. Both Abbott (1976) and Parsons et al. (1976) provided lists of mammals seen at DMP and some nearby areas (Appendix G). Walter Bulmer has begun to survey current mammalian life at DMP. Using live traps and observations from 1996 through 1999, he has found mammal species similar to those reported in the two earlier studies (Appendix G).

Indicating roles played in the marsh ecosystem, the mammal species reported in these three surveys fall into categories (Table 7). As with birds, most mammals found in DMP are insectivores.

ECOSYSTEM CHARACTERISTICS

As indicated above, the mudflats associated with DMP perform important general ecological functions including foraging and nursery areas for avian species, fisheries habitat, nutrient assimilation, water quality maintenance, and floodflow attenuation.

Mud flats contain nutrient rich sediments which support phytoplankton and zooplankton communities. The presence of these communities is particularly important to the production of benthic invertebrates and subsequent richness of fisheries and avian resources occurring in the region.

Aquatic species distribution and abundance are controlled by physical, chemical, and biological water parameters such as salinity, dissolved oxygen, temperature, pH, depth, nutrient levels, and substrate composition. Estuarine systems as represented by DMP characteristically possess higher concentrations of nutrients than the Chesapeake Bay or contributing freshwater systems. The underlying source for relatively higher nutrient concentrations arises from a biodepositional process initiated by the large "sediment bank" which these systems maintain. Sediments act to retain and release nitrates and phosphates which are essential to the production of microflora and suspension-feeding fauna. The interrelationship between the presence of zooplankton/phytoplankton and other "higher" life forms such as benthic invertebrates, fish, birds and mammals is generally recognized as an association of interdependency.

Such interdependencies at DMP can be represented by food chains which are of two basic types: grazing food chain and the detritus food chain. Food webs integrate several food chains to demonstrate alternate pathways.

Some concise food chains at DMP:

Grazing food chain (semi-aquatic)
green plants → seeds → waterfowl, mice

Grazing food chain (terrestrial)
green plants → shoots, leaves, underground parts → insects, mice → shrews, birds

Detritus food chain (particulate and dissolved)
detritus on mudflats → zooplankton, crustaceans, microbes → fish, shorebirds

Aquatic food chain
dead plants and animal parts → fungi and bacteria, detritus →
detritus consumers (invertebrates, minnows) →
simple organic/inorganic compounds → small carnivores (small game fish, predacious
arthropods) → large (top) carnivores (large game fish, fish-eating birds)

Interrelationships or interdependencies are the keys to functioning and sustained ecosystems. When any of the links in food chains are disrupted or destroyed, some particular faunal or floral element will be disturbed and perhaps eliminated from the ecosystem. This is especially true of the top carnivores, because previous ecological studies have unequivocally demonstrated that elimination of large carnivores such as mountain lions or bears often precipitates the loss or drastic transformation of the ecosystem. Thus, for DMP it can be concluded that persistence of the marsh depends on maintenance of its manifold interrelationships among its many biological elements and the essential non-living components of the environment.

MANAGEMENT RECOMMENDATIONS

Any management plan for the DMP area should consider the separate parts of the area, especially because some parts, as identified below, can play an integral role on

the stability and even existence of the marsh itself. The area is here divided into (1) the mouth of Hunting Creek and Hunting Creek Bay, (2) Belle Haven picnic area, (3) Belle Haven marina, (4) the George Washington Trail, (5) DMP proper, and (6) the adjacent Potomac River. Recreational uses of all these areas are high at certain times of the year.

(1) The mouth of Hunting Creek contains run-off waters of the creek itself which in turn drains upland areas and those of some marshlands abutting I-95. Partly because of tidal fluctuations, the mouth of the creek and the Bay periodically expose extensive mudflats. As pointed out above, these mudflats contain nutrient rich sediments which support bacteria, fungi, phytoplankton and zooplankton communities, thus providing foraging sites for migrating shorebirds and wading birds, as well as fisheries habitat and nurseries. It is also extremely important for a wintering population of Bald Eagles. Construction of a new Wilson Bridge will undoubtedly severely impact this habitat.

(2) The picnic area is a partially wooded area which fronts the Potomac River and contains picnic tables, parking lots, and restroom facilities.

(3) The marina, comprised chiefly of fill material, was established in the 1950s and is managed by a private concessioner under contract to the National Park Service. It contains rental slips and moorings for approximately 140 boats many of which are sail boats.

(4) The Mount Vernon Trail is an extensive multi-purpose trail stretching some 18 miles from the Mount Vernon Estate to Roosevelt Island. Its principal uses at all seasons, but especially in the warmer months, include visits by walkers, joggers, cyclists, and roller-bladers. The trail is principally along the eastern edge of DMP's forested zones but also includes a boardwalk through the open marsh. (5) DMP proper, the principal object of this detailed report, consists of three zones--the open marsh, a swamp forest, and a floodplain forest. The northern end of the preserve has a main access trail which ends in the Haul Road, a filled strip extending partway into the marsh. Because DMP is the last remaining upstream tidal freshwater marsh on the Potomac River, it probably provides the [only] habitat for several animal species: the Marsh Wren, Least Bittern, Rice Rat, and perhaps Willow Flycatcher and Swamp Sparrow. It also probably contains the remaining upstream populations of wild rice and some rare plants.

(6) The adjacent Potomac River has the potentiality of a negative effect on DMP. Construction of another Wilson Bridge might produce intolerable sediment loads, and any increase in pollution would also drastically affect stability of the preserve.

Several management plans have been suggested, and to some extent implemented, for DMP. Continued focus, diligence and monitoring should be given to:

1. protecting water quality in DMP, especially by working with municipalities and the boat marina. Poor water quality may pose the most significant threat to wildlife by causing negative impacts on food sources and community stability. Monitoring all pollution components, such as sewage effluents, oils, and debris, as well as sedimentation and wave actions, is essential. An important key to the future of DMP is implementation of improved soil erosion and pollution controls;

2. monitoring the invasion and spread of exotic plants and animals which assuredly will affect natural communities;

3. maintaining forested buffers abutting the marsh;

4. working with the National Park Service and other organizations to maintain and improve natural heritage values of this area.

ACKNOWLEDGMENTS

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LITERATURE CITED

- Abbott, J. M. ca. 1976. Wildlife recorded at Dyke Marsh, east Fairfax County, Virginia--mostly in the period 1946-1976. Mimeo., Friends of Dyke Marsh, Alexandria, VA
- Anonymous. 1996. Woodrow Wilson Bridge Improvement Study. Supplemental Draft. Environmental Impact Statement/Section 4(f) Evaluation.
- Anonymous. 1988. Potomac River dredged material placement site study. Final Report, Baltimore District, U.S. Army Corps of Engineers.
- Bailey, V. 1896. List of mammals of the District of Columbia. Proc. Biol. Soc. Wash. 10:93-101.
- Beetle, D. E. 1973. A checklist of the land and freshwater mollusks of Virginia. *Sterkiana* 49:21-35.
- Bent, A. C. 1953. Life histories of North American wood warblers. U. S. Natl. Museum, Bull. 203:28.
- Borror, D. J., and R. E. White. 1970. A Field Guide to the Insects of America North of Mexico. Houghton Mifflin Co., Boston, MA. 404 pp.
- Borror, D. J., C. A. Triplehorn, and N. F. Johnson. 1989. An Introduction to the Study of Insects. Sixth Ed. Saunders College Publishing, Philadelphia, PA. 875 pp.
- Briggs, S. A., ed. 1954. Washington, City in the Woods. Audubon Society of the District of Columbia, Washington, DC.
- Carter, V., and M. G. Haramis. 1980. Distribution and abundance of submersed aquatic vegetation in the tidal Potomac River--Implications for waterfowl. *Atl. Nat.* 33:14-19.
- Carter, V., and N. Rybicki. 1986. Resurgence of submersed aquatic macrophytes in the tidal Potomac River, Maryland, Virginia, and the District of Columbia. *Estuaries* 9(4B):366-375.
- Carter, V., N. B. Rybicki, R. T. Anderson, T. J. Trombley, and G. L. Zynjuk. 1985. Data on the distribution and abundance of submersed aquatic vegetation in the tidal Potomac River and transition zone of the Potomac estuary, Maryland, Virginia, and the District of Columbia, 1983 and 1984. Open-File Report 85-82, U.S. Geological Survey, Reston, VA. 61 pp.
- Carter, V., N. B. Rybicki, J. M. Landwehr, and M. Turtora. 1994. Role of weather and water quality in population dynamics of submersed macrophytes in the tidal Potomac River. *Estuaries* 17(2):417-426.

- Coues, E., and D. W. Prentiss. 1883. Avifauna Columbiana: being a list of birds ascertained to inhabit the District of Columbia, with the times of arrival and departure of such as are non-residents, and brief notices of habits, etc. 2nd ed. Government Printing Office, Washington, D.C. 133 pp.
- Council on Environmental Quality. 1996. Environmental Quality. The Twenty-fifth Anniversary Report of the Council on Environmental Quality, Washington, DC.
- Cummins, K. W., and R. W. Merritt. 1984. Ecology and distribution of aquatic insects. Pages 59-65 in R. W. Merritt and K. W. Cummins, eds. 1984. An Introduction to the Aquatic Insects of North America. Second Ed. Kendall/Hunt Publishing Co., Dubuque, IA.
- Danton, N. H. 1950. Configuration of the bedrock surface of the District of Columbia and vicinity, Geological Survey, Professional Paper 217.
- Davis, E. G. 1950. Birds of the Season. Atl. Nat.6(1):24-25.
- Division of Natural Heritage. n.d. Biological and Conservation Data System. Unpubl. data, Va. Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA.
- Division of Natural Heritage. 1991. Natural Heritage Resources inventory of Hunting Bay-Dyke Marsh, Virginia. Progress Report. Va. Dept. of Conservation and Recreation, Richmond, VA. 28 pp.
- Division of Natural Heritage. 1992. A Natural Heritage Resources inventory of Hunting Bay-Dyke Marsh, Alexandria City and Fairfax County, Virginia. Final Report. Va. Department of Conservation and Recreation, Richmond, VA. 30 pp.
- Division of Natural Heritage. 1994. A Natural Heritage inventory of Hunting Bay-Dyke Marsh, Alexandria City and Fairfax County, Virginia. Addendum. Va. Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. 7 pp.
- Gerberich, A. G. 1984. The endangered and threatened freshwater mollusks of Maryland. Pp. 245-266 in Threatened and Endangered Plants and Animals of Maryland, A. W. Norden, D. C. Forester, and G. H. Fenwick, eds. Maryland Natural Heritage Program, Special Publication 84-I, Maryland Department of Natural Resources.
- Gruending, G. K., and D. J. Bogucki. 1989. Fairfax County, Virginia, tidal wetland mapping project. Final report. Northern Virginia Planning District Commission.
- Halle, L. J. 1947. Spring in Washington. Johns Hopkins Univ. Press, Baltimore, MD. 234 pp.
- Hammerschlag, R. 1973. Dyke Marsh restoration-Project report. Unpublished report, R. Hammerschlag.
- Hammerschlag, R. 1984. Relationship of Hydrilla growth to Potomac water Quality. NPS Dyke Marsh Data-1984. Unpublished report, R. Hammerschlag.
- Hammerschlag, R. 1985. Ecology of *Hydrilla verticillata* at Dyke Marsh 1985. Unpublished report, R. Hammerschlag.
- Hammerschlag, R., S. Syphax, L. Williams, and T. Glenn. 1985. Ecology of *Hydrilla verticillata* at Dyke Marsh. Unpublished report, R. Hammerschlag.
- Haramis, G. M., and V. Carter. 1983. Distribution of submersed aquatic macrophytes in the tidal Potomac River. Aquatic Botany 15:65-79.
- Harper, J. D., and F. D. Heliotis. 1992. Dyke Marsh hydrological model. Unpublished report, George Mason University, Fairfax, VA.

- Hay, W. P. 1902. A list of batrachians and reptiles of the District of Columbia. Proc. Biol. Soc. Wash. 15:121-145.
- Jenkins, R. E., and N. M. Burkhead. 1994. Freshwater Fishes of Virginia. American Fisheries Soc., Bethesda, MD. 1079 pp.
- Johnston, P. M. 1964. Geology and ground-water resources of Washington, D.C., and vicinity. Geological Survey, Water Supply Paper 1776.
- Kelso, D., Z. Xu, G. Marcella, and L. K. Thomas, Jr. 1993. A historical delineation of the Dyke Marsh vegetation. Report to the National Park Service. 8 pp.
- Lindholm, D. A. 1992. 1992 Dyke Marsh herbaceous plant study. George Mason University, Fairfax, VA. 27 pp.
- McAtee, W. L. 1918. A sketch of the natural history of the District of Columbia. Bull. Biol. Soc. Wash. No. 1, 142 pp.
- Myrick, R. M., and L. B. Leopold. 1963. Hydraulic geometry of a small tidal estuary. Geological Survey Professional Paper 422-B, U. S. Government Printing Office, Washington, DC. 18 pp.
- National Park Service. 1976. Environmental assessment of Dyke Marsh. National Capital Region, National Park Service, U. S. Department of the Interior. 52 pp.
- Oberholser, H. C. 1895. Mammals at Belle Haven 20-22 June 1895. U.S. Fish and Wildlife Ms, Smithsonian Archives, Washington, DC
- Odum, E. P. 1983. Wetlands and their values. J. Soil and Water Conser. 38(5):380.
- Odum, E. P. 1997. Ecology: A Bridge between Science and Society. Sinauer Associates Inc., Sunderland, MA. 331 pp.
- Odum, W. E. 1988. Comparative ecology of tidal freshwater and salt marshes. Ann. Rev. Ecol. Syst. 19:147-176.
- Orth, R., J. Simons, J. Capelli, V. Carter, A. Frisch, L. Hindman, S. Hodges, K. Moore, and N. Rybicki. 1987. Distribution of submersed aquatic vegetation in the Chesapeake Bay and tributaries-1985. Virginia Institute of Marine Science.
- Parsons, Brinckerhoff, Quade, and Douglas. 1976. Fairfax County, Virginia. Final Dogue-Little Hunting-Belle Haven Environmental Baseline Evaluation. Task Order 10.6
- Paschal, J. E., Jr., D. Miller, N. Bartow, and V. Carter. 1982. Submersed aquatic vegetation in the tidal Potomac River and estuary of Maryland, Virginia and the District of Columbia: Hydrologic Data Report, May 1978 to November 1981. U.S. Geological Survey Open-File Report 82-694.
- Slavik, W., and F. M. Uhler. 1951. The Potomac Basin. 3. Where are the ducks? Atl. Nat. 6(4):143-150.
- Steward, K. K., T. D. Van, V. Carter, and A. H. Pieterse. 1984. Hydrilla invades Washington D.C. and the Potomac. Am. J. Botany 71(1):162-163.
- Thomas, L. K., Jr. 1974. A short natural history of Dyke Marsh. Unpublished report, L. K. Thomas.
- Thomas, L. K. 1976. General vegetation composition of Dyke Marsh as compiled by Dr. L. K. Thomas. Appendix VIII In U. S. Department of the Interior, "Environmental Assessment of Dyke Marsh," George Washington Memorial Parkway, National Capital Region, National Park Service.
- Uhler, F. M. 1963. Plants and animals noted in Dyke Marsh and adjacent waters along the tidal Potomac River, Fairfax County, Virginia, with suggestions regarding

- developments for aquatic wildlife in that area. October 26 and November 19, 1963.
- Uhler, F. 1968. Statement on value of Dyke Marsh. H.R. 90th Congress. 2nd session (June 24, July 8,9, 1968), pp. 77-82 and 210-218.
- U.S. Army Corps of Engineers. 1988. Final report. Potomac River dredged material placement site study. Baltimore District, U.S. Army Corps of Engineers. 85 pp.
- U.S. Department of Transportation et al. 1996. Woodrow Wilson Bridge Improvement Study. Supplemental Draft Environmental Impact Statement/Section 4(f) Evaluation.
- Wester, H. V., and M. Sullivan. 1970. 1970 episode of air pollution damage to vegetation in Washington, D.C. area. Office of the Chief Scientist Annual Report, 1970, National Park Service, Washington, DC
- Wilson, E. M. 1991. Status of Virginia's rare birds at Dyke Marsh and Hunting Creek, Fairfax Co. Unpublished report to Division of Natural Heritage.
- Wilson, E. M. 1994. Birds of Fairfax County, Virginia. Mimeo. Friends of Dyke Marsh, Alexandria, VA
- Wray, D. W. 1967. Insects of North Carolina. 3rd Supplement. North Carolina Department of Agriculture, Division of Entomology, Raleigh, NC. 181 pp.
- Xu, Z. 1991. Final report on inventories of plant species and communities in Dyke Marsh, Alexandria, Virginia. George Mason University, Fairfax, VA. 68 pp.

APPENDIX A

PERTINENT LEGISLATION

SEE DETAILED ACCOUNT: "Dyke Marsh: Legislative history and intent."
19 May 1981. Friends of Dyke Marsh, Alexandria, Va

Act of May 23, 1928 (P.L. 493)

The Act of May 23, 1928 authorized and directed the United States Commission for the Celebration of the Two Hundredth Anniversary of the Birth of George Washington to take such steps as necessary to construct a suitable memorial highway to connect Mount Vernon with the south end of Memorial Bridge, then under construction. It also authorized the Secretary of Agriculture to cooperate with the Commission in carrying out the provisions of this act. The Secretary was authorized to acquire land, and when constructed to maintain and control pedestrian and vehicular traffic so that it did not interfere with the current jurisdiction of the State of Virginia.... As a result of this act the northern area of Dyke Marsh/Belle Haven was acquired through condemnation on November 23, 1933.

Capper-Cramton Act of May 29, 1930 (P.L. 71-284)

This act provided for the acquisition, establishment, and development of the George Washington Memorial Parkway along the Potomac River from Mount Vernon and Fort Washington to Great Falls, and provided for acquisition of lands in the States of Maryland and Virginia requisite to the comprehensive park, parkway and playground system of the Nations Capital.

Act of June 11, 1959 (P.L. 86-41)

This act provided for the acquisition of certain lands belonging to the Smoot Sand and Gravel Corporation (SSGC), in exchange for certain dredging and other rights on land already owned by the United States on the east side of the Mount Vernon Memorial Highway in Fairfax County, Virginia, in order to protect the Mount Vernon Memorial Highway, to add further to its memorial character, and in order to acquire an area of irreplaceable wetlands near the Nation's Capital which is valuable for the production and preservation of wildlife.

Agreement between Charles and Elizabeth Fairchild and The Secretary of Interior, June 30, 1970

This agreement between the Fairchild and the Secretary of Interior was signed on June 30, 1970 and deeded approximately 28 acres to the United States for a cost of \$10.00. This agreement was signed after permission was granted in an agreement signed by the Secretary of Interior on June 5, 1970, to construct an access on 1.3 acres of government property adjacent to the forty-two acre tract owned by RF & P Railroad company, and leased by Fairchild Co., Inc.

APPENDIX B

Beetle (1973) provided a checklist of the land and freshwater mollusks of Virginia and therein identified 35 species known from Fairfax County at that time. These species should be looked for in DMP and the surrounding areas.

<i>Alasmidonta undulata</i>	<i>Alasmidonta varicosa</i>
<i>Lasmigona subviridis</i>	<i>Elliptio lanceolata</i>
<i>Lampsilis cariosa</i>	<i>Lampsilis radiata</i>
<i>Viviparus georgianus</i>	<i>Lioplax subcarinata</i>
<i>Valvata tricarinata perconfusa</i>	<i>Lyogyrus granum</i>
<i>Ammicola limosa</i>	<i>Cochliopa virginica</i>
<i>Gillia altilis</i>	<i>Pomatiopsis lapidaria</i>
<i>Bithynia tentaculata</i>	<i>Goniobasis virginica</i>
<i>Physa ancillaria</i>	<i>Physa acuta</i>
<i>Physa heterostropha</i>	<i>Stagnicola caperata</i>
<i>Pseudosuccinea columella</i>	<i>Helisoma trivolvis</i>
<i>Planorbula armigera</i>	<i>Gyraulus deflectus</i>
<i>Menetus dilatatus</i>	<i>Ferrissia parallela</i>
<i>Ferrissia rivularis</i>	<i>Carychium exiguum</i>
<i>Gastrocopta cristata</i>	<i>Vertigo milium</i>
<i>Strobilops aenea</i>	<i>Strobilops labyrinthica</i>
<i>Philomycus carolinianus flexuolaris</i>	<i>Discus patulus</i>
<i>Anguispira alternata angulata</i>	<i>Anguispira a. fergusonii</i>
<i>Anguispira a. mordax</i>	<i>Punctum vitreum</i>
<i>Glyphyalinia rhoadsi</i>	<i>Stenotrema barbatum</i>
<i>Stenotrema fraternum</i>	<i>Triodopsis fallax</i>
<i>Triodopsis juxtidentis</i>	<i>Triodopsis denotata</i>

APPENDIX C

Table C-1. The number of hexapod taxa found in 1998 and expected in the DMP. Data from E. Barrows.

Subclass, order	Number of species	
	found ¹	expected ²
Subclass Entognatha		
(Entognathan Hexapods)		
Collembola (Springtails)	0	81
Diplura (Diplurans)	0	1
Protura (Proturans)	0	1
Subclass Insecta (Insects)		
Blattaria (Cockroaches)	0	1
Coleoptera (Beetles)	59	1,606
Dermaptera (Earwigs)	1	1
Diptera (Flies)	60	1,243
Ephemeroptera (Mayflies)	1	58
Embiidina (Webspinners)	0	0
Grylloblattaria (Rock Crawlers)	0	0
Hemiptera (Stink Bugs and kin)	8	272
Homoptera (Aphids and kin)	10	364
Hymenoptera (Ants, Bees, Wasps)	102	1,190
Isoptera (Termites)	1	1
Lepidoptera (Butterflies, Moths)	29	684
Mantodea (Mantids)	0	4
Mecoptera (Scorpionflies)	1	5
Microcoryphia (Bristletails)	0	1
Neuroptera (Lacewings and kin)	3	33
Odonata (Damselflies, Dragonflies)	6	71
Orthoptera (Grasshoppers and kin)	3	110
Phasmida (Walkingsticks)	0	1
Plecoptera (Stoneflies)	5	45
Psocoptera (Bark Lice)	0	18
Pthiraptera (Lice)	0	37
Siphonaptera (Fleas)	0	7
Strepsiptera		
(Twisted-wing Parasites)	0	5
Thysanoptera (Thrips)	0	33
Thysanura (Silverfish)	0	2
Trichoptera (Caddisflies)	3	17
Zoraptera (Zorapterans)	0	0
Total	292	6,000
(ca. 5%)		

¹ These numbers are from a preliminary examination of 8 of the 21 sets of specimens and field examinations of living hexapods in the Preserve.

² These numbers are based on an extrapolation of a count of 12,520 hexapod species in North Carolina (Wray 1967). It is hypothesized that there are 6,000 hexapod species in the Preserve because of its general geographic location, habitats, and my experience with the number of hexapods in the Washington, DC, area. Some of these orders (e.g., Collembola, Diplura) are infrequently captured in Malaise traps.

Table C-2. Hexapod orders found in the DMP and their foods. All hexapods consume bacteria and protists when these organisms are on their usual foods. Species often have unique diets and some change their diets as they develop. Data are from Borror and White (1970), Borror et al. (1989), Cummins and Merritt (1984), and Edward Barrows (pers. obs.).

Subclass Entognatha

(Entognathan Hexapods)

Collembola (Springtails): algae, arthropod feces, bacteria, dead organic matter, fungi, pollen

Diplura (Diplurans): probably dead organic matter

Protura (Proturans): dead organic matter, fungus spores

Subclass Insecta (Insects)

Blattaria (Cockroaches): dead organic matter, fruit

Coleoptera (Beetles): all kinds of organic matter

Dermaptera (Earwigs): dead and living plant parts, other living insects

Diptera (Flies): all kinds of organic matter

Ephemeroptera (Mayflies): chiefly algae and detritus in bodies of water

Hemiptera (Stink Bugs and kin): dead and living plant parts, living insects

Homoptera (Aphids and kin): living plants

Hymenoptera (Ants, Bees, Wasps): organic matter.

Isoptera (Termites): dead and living plant parts

Lepidoptera (Butterflies, Moths): usually living plant parts, sometimes dead animal and plant parts, beeswax, living insects, pollen

Mantodea (Mantids): living insects, sometimes small birds

Mecoptera (Scorpionflies): chiefly dead and living insects, mosses

Microcoryphia (Bristletails): chiefly algae, but also decaying fruits, lichens, and mosses

Neuroptera (Lacewings and kin): freshwater sponges, living insects, spider eggs

Odonata (Damselflies, Dragonflies): other living insects, sometimes aquatic vertebrates

Orthoptera (Grasshoppers and kin): dead and living plant parts, other living insects

Phasmida (Walkingsticks): living plant parts

Plecoptera (Stoneflies): carrion, detritus, fungi, other living insects, dead and living plant parts, seeds, whole small plants.

Psocoptera (Barklice): algae, cereals, dead insects and plants, lichens, molds, pollen.

Pthiraptera (Lice): vertebrate tissues

Siphonaptera (Fleas): vertebrate tissues

Strepsiptera (Twisted-wing Parasites): bees

Thysanoptera (Thrips): fungus spores, living insects, chiefly living plants

Thysanura (Silverfish): dead organic matter.

Trichoptera (Caddisflies): detritus, fungi, other living insects, dead and living plant parts, seeds, whole small plants.

APPENDIX D

Fish species reported from DMP and the adjacent Potomac River with documentation from Jenkins and Burkhead (*) and from Wayne Starnes (**, pers. comm.). Data on residency and feeding habits were supplied by Wayne Starnes. The fish species reported by Parsons et al. (1976) from the Belle Haven estuary are all included except for the banded killifish.

SPECIES	RESIDENCY	FEEDING HABIT
Lampreys:		
<i>Petromyzon marinus</i> (Sea lamprey)	anadromous	external parasite
Sturgeons:		
* <i>Acipenser brevirostrum</i> (Shortnose sturgeon)	apparently extirpated	
* <i>Acipenser oxyrhynchus</i>	very rare	
Gars:		
* <i>Lepisosteus osseus</i> (Longnose gar)	migratory	predator
Bowfins:		
* <i>Amia calva</i>		predator
Freshwater eels:		
* <i>Anguilla rostrata</i> ¹ (American eel)	catadromous (omnivore)	predator
Herrings:		
* <i>Dorosoma cepedianum</i> (Gizzard shad)	permanent, breeding	filter-feeding
* <i>Dorosoma petenense</i> (Threadfin shad)		filter-feeding
* <i>Alosa aestivalis</i> ¹ (Blueback herring)	migratory, breeding	filter-feeding
* <i>Alosa pseudoharengus</i> ¹ (Alewife)	migratory, larvae	filter-feeding
* <i>Alosa mediocris</i> (Hickory shad)	migratory, breeding very rare	predator
* <i>Alosa sapidissima</i> (American shad)	migratory, breeding becoming rare	predator
Pikes:		
* <i>Esox niger</i> (Chain pickerel)	predator	

continued

APPENDIX D continued

SPECIES	RESIDENCY	FEEDING HABIT
Minnows:		
* <i>Cyprinus carpio</i> ¹ (Common carp)	permanent, breeding	omnivore
* <i>Carassius auratus</i> (Goldfish)		omnivore
* <i>Notemigonus crysoleucas</i> (Golden shiner)		predator on small inverts.
* <i>Clinostomus funduloides</i> (Rosyside dace)		predator on small inverts.
* <i>Rhinichthys cataractae</i> (Longnose dace)		predator on small inverts.
* <i>Rhinichthys atratulus</i> (Blacknose dace)		predator on small inverts.
* <i>Semotilus atromaculatus</i> (Creek chub)		omnivore
* <i>Cyprinella analostana</i> (Satinfin shiner)		predator on small inverts.
* <i>Cyprinella spiloptera</i> (Spotfin shiner)		predator on small inverts.
* <i>Luxilus cornutus</i> (Common shiner)		predator on small inverts.
* <i>Notropis rubellus</i> (Rosyface shiner)		predator on small inverts.
* <i>Notropis amoenus</i> (Comely shiner)		predator on small inverts.
* <i>Notropis hudsonius</i> ¹ (Spottail shiner)	permanent, breeding	predator on small inverts.
* <i>Notropis procne</i> (Swallowtail shiner)		predator on small inverts.
* <i>Notropis bifrenatus</i> (Bridle shiner)		predator on small inverts.
* <i>Pimephales notatus</i> (Bluntnose minnow)		predator on small inverts.
Suckers:		
* <i>Carpiodes cyprinus</i> (Quillback)		predator on small inverts. detritus
* <i>Erimyzon oblongus</i> (Creek chubsucker)		plankton

continued

APPENDIX D continued

SPECIES	RESIDENCY	FEEDING HABIT
* <i>Hypentelium nigricans</i> (Northern hogsucker)		predator on small inverts.
* <i>Moxostoma macrolepidotum</i> (Shorthead redhorse)		predator on small inverts. detritus
* <i>Catostomus commersoni</i> (White sucker)		predator on small inverts. detritus
Bullhead catfishes:		
* <i>Ictalurus furcatus</i> (Blue catfish)	rare	predator on inverts., fish
* <i>Ictalurus punctatus</i> ¹ (Channel catfish)	permanent, breeding	predator on inverts., fish
* <i>Ameiurus catus</i> ¹ (White catfish)	permanent, breeding	omnivore
* <i>Ameiurus natalis</i> (Yellow bullhead)		omnivore
* <i>Ameiurus nebulosus</i> ¹ (Brown bullhead)	permanent, breeding	omnivore
* <i>Noturus gyrinus</i> (Tadpole madtom)		omnivore
Killifishes:		
* <i>Fundulus diaphanus</i> ¹ (Banded killifish)	permanent, breeding	predator on small inverts.
Livebearers:		
* <i>Gambusia holbrooki</i> ¹ (Eastern mosquitofish)	permanent, breeding	predator on small inverts.
Striped basses:		
* <i>Morone americana</i> ¹ (White perch)	migratory, breeding	predator on small inverts, fish
* <i>Morone saxatilis</i> ¹ (Striped bass)	migratory, breeding	predator on inverts., fish
Sunfishes:		
* <i>Pomoxis nigromaculatus</i> (Black crappie)		predator on inverts., fish
* <i>Pomoxis annularis</i> (White crappie)		predator on inverts., fish
* <i>Enneacanthus gloriosus</i> (Bluespotted sunfish)		predator on small inverts.

continued

APPENDIX D continued

SPECIES	RESIDENCY	FEEDING HABIT
* <i>Micropterus dolomieu</i> (Smallmouth bass)		predator on inverts., fish
* <i>Micropterus salmoides</i> (Largemouth bass)	permanent, breeding	predator on inverts., fish
* <i>Lepomis gulosus</i> (Warmouth)	permanent, breeding	predator on inverts., fish
* <i>Lepomis cyanellus</i> (Green sunfish)	permanent, breeding	predator on small inverts.
* <i>Lepomis auritus</i> (Redbreast sunfish)	permanent, breeding	predator on small inverts.
* <i>Lepomis macrochirus</i> (Bluegill)	permanent, breeding	predator on insects
* <i>Lepomis gibbosus</i> ¹ (Pumpkinseed)	permanent, breeding	predator on small inverts.
Perches:		
* <i>Perca flavescens</i> ¹ (Yellow perch)	migratory and permanent, breeding	predator on inverts., fish
* <i>Percina caprodes</i> (Logperch)	rare	predator on inverts.
* <i>Percina maculata</i> (Blackside darter)	rare	predator on insects
* <i>Etheostoma olmstedii</i> (Tesselated darter)	permanent, breeding	predator on small inverts.
Other:		
** <i>Brevoortia tyrannus</i> ¹ (Atlantic menhaden)	migratory, breeding	filter-feeding (omnivore)
** <i>Menidia beryllina</i> (Tidewater silverside)	permanent, breeding	predator on small inverts.
** <i>Fundulus heteroclitus</i> (Mummichog)	permanent, breeding	predator on small inverts.
<i>Hyboganthus regius</i> ¹ (E. Silvery minnow)	permanent, breeding	detritus

¹ Listed as sport/commercial fish found near DMP (National Park Service 1976)

APPENDIX E

Amphibians and reptiles reported from DMP by Walter Bulmer (1996-1999) and from nearby sites as indicated.

AMPHIBIANS

Salamanders

- Eurycea bislineata* (Two-lined salamander) common, woodland
Plethodon cinereus (Red-backed salamander)^{2, 3} common, woodland¹
Notophthalmus viridescens (E. newt)^{2, 3} uncommon, forest ponds

Frogs and toads

- Bufo americanus* (American toad)^{2, 3} common, woodland, marsh
Bufo woodhousei (Fowler's toad)³ uncommon, woodland
Acris crepitans (N. Cricket frog)^{2, 3} uncommon, woodland, marsh
Hyla cinerea (Green treefrog)³ uncommon, marsh
Hyla versicolor (E. Gray treefrog)³ common, woodland
Pseudacris crucifer (Spring peeper)^{2, 3} uncommon, woodland
Rana clamitans (Green frog)^{2, 3} common, marsh, woodland
Rana catesbeiana (Bullfrog)^{2, 3} common, marsh
Rana palustris (Pickerel frog)³ common, marsh, woodland
Rana sphenoccephala (S. Leopard frog)^{2, 3} uncommon, marsh

REPTILES

Turtles

- Chelydra serpentina* (Snapping turtle)^{2, 3} common, marsh
Chrysemys picta (Painted turtle)^{2, 3} common, marsh
Pseudemys concinna (River cooter) uncommon, marsh
Pseudemys rubiventris (Red-bellied turtle) common, marsh
Terrapene carolina (Box turtle) common, woodland
Trachemys scripta (Red-eared turtle)² common, marsh
Kinosternon subrubrum (Mud turtle)^{2, 3} common, marsh
Stenotherus odoratus (Musk turtle)^{2, 3} common, marsh

Lizards

- Scincella lateralis* (Ground skink)^{2, 3} common, woodland
Eumeces fasciatus (Five-lined skink)^{2, 3} common, woodland

Snakes

- Carphophis amoenus* (Worm snake)³ uncommon, woodland
Coluber constrictor (Black racer)^{2, 3} common, marsh, woodland
Diadophis punctatus (Ring-neck snake)³ common, woodland
Elaphe obsoleta (Black rat snake)² common, woodland
Nerioda sipedon (N. water snake)^{2, 3} common, marsh, woodland
Opheodrys aestivus (Rough green snake) uncommon, marsh, woodland
Regina septemvittata (Queen snake)³ uncommon, marsh, woodland
Storeria dekayi (N. brown snake)³ uncommon, marsh, woodland
Thamnophis sauritus (E. ribbon snake)³ uncommon, marsh, woodland
Thamnophis sirtalis (E. garter snake)^{2, 3} common, marsh, woodland

¹ woodland refers to a combination of swamp and floodplain forests.

² species reported in an unpublished list by David Abbott et al. (ca. 1976). These authors also reported Spotted salamander, Dusky salamander, Wood frog, Spotted turtle, Broad-headed skink, and Corn snake.

³ species reported in nearby watersheds (Belle Haven, Little Hunting Creek, Dogue Creek) by Parsons et al. (1976). They also reported other species perhaps not all from DMP: Jefferson salamander, Spotted salamander, Marbled salamander, Dusky salamander, Two-lined salamander, Three-lined salamander, Four-toed salamander, Slimy salamander, Mud salamander, Red salamander, Chorus frog, Wood frog, Spotted turtle, Wood turtle, Diamondback terrapin, Florida cooter, Fence lizard, Broad-headed skink, Corn snake, Hognose snake, Mole snake, King snake, Milk snake, Red-bellied snake, Smooth earth snake.

APPENDIX F

Birds of the DMP, adapted from a field check-list, "Birds of Dyke Marsh," National Park Service (1993), and updated to 2000 by Kurt Gaskill. Also includes Hunting Creek and Bay. Principal season of occurrence: P=resident, W=winter, S=summer, M=spring and/or fall migration. Breeding status (B=breeds or has bred) taken chiefly from the recent Breeding Bird Surveys. List does not include historical records: American Woodcock, Ruffed Grouse, Red Crossbill, White-winged Crossbill. Species marked with an asterisk (*) have not been seen since 1985.

-
- Red-throated Loon (*Gavia stellata*). W
 Common Loon (*Gavia immer*). M, W
 Pied-billed Grebe (*Podilymbus podiceps*). B, M
 Horned Grebe (*Podiceps auritus*). M
 Double-crested Cormorant (*Phalacrocorax auritus*). S, M
 Great Cormorant (*Phalacrocorax carbo*). M
 American Bittern (*Botaurus lentiginosus*). M
 Least Bittern (*Ixobrychus exilis*). S, B, M
 Great Blue Heron (*Ardea herodias*). P
 Great Egret (*Casmerodius albus*). P
 Snowy Egret (*Egretta thula*). S, M
 Little Blue Heron (*Egretta caerulea*). S, M
 Tricolored Heron (*Egretta tricolor*). M
 Cattle Egret (*Bubulcus ibis*). M
 Green Heron (*Butorides virescens*). S, M
 Black-crowned Night-heron (*Nycticorax nycticorax*). S, B, M
 Yellow-crowned Night-heron (*Nyctanassa violaceus*). S, M *
 White Ibis (*Eudocimus albus*). M *
 Black Vulture (*Coragyps atratus*). S, M
 Turkey Vulture (*Cathartes aura*). P
 Snow Goose (*Chen caerulescens*). M, W
 Canada Goose (*Branta canadensis*). B, P
 Mute Swan (*Cygnus olor*). S, M
 Tundra Swan (*Cygnus columbianus*). M, W
 Wood Duck (*Aix sponsa*). B, P
 Green-winged Teal (*Anas crecca*). M
 American Black Duck (*Anas rubripes*). B, M, W

Mallard (*Anas platyrhynchos*). B, P
Northern Pintail (*Anas acuta*). M
Blue-winged Teal (*Anas discors*). M
Northern Shoveler (*Anas clypeata*). M
Gadwall (*Anas strepera*). M, W
Eurasian Wigeon (*Anas penelope*). W
American Wigeon (*Anas americana*). M
Canvasback (*Aythya valisineria*). M, W
Redhead (*Aythya americana*). M
Ring-necked Duck (*Aythya collaris*). M
Greater Scaup (*Aythya marila*). M
Lesser Scaup (*Aythya affinis*). M, W
Oldsquaw (*Clangula hyemalis*). M
Common Goldeneye (*Bucephala clangula*). M
Bufflehead (*Bucephala albeola*). M, W
Hooded Merganser (*Lophodytes cucullatus*). M, W
Common Merganser (*Mergus merganser*). M, W
Red-breasted Merganser (*Mergus serrator*). M
Ruddy Duck (*Oxyura jamaicensis*). M, W
Osprey (*Pandion haliaetus*). S, B, M
Bald Eagle (*Haliaeetus leucocephalus*). P
Northern Harrier (*Circus cyaneus*). M
Sharp-shinned Hawk (*Accipiter striatus*). M, W
Cooper's Hawk (*Accipiter cooperii*). M, W
Red-shouldered Hawk (*Buteo lineatus*). P
Broad-winged Hawk (*Buteo platypterus*). M
Red-tailed Hawk (*Buteo jamaicensis*). P
American Kestrel (*Falco sparverius*). P
Merlin (*Falco columbarius*). M
Peregrine Falcon (*Falco peregrinus*). M
Northern Bobwhite (*Colinus virginianus*). S, P?
King Rail (*Rallus elegans*). S, M
Virginia Rail (*Rallus limicola*). S, M
Sora (*Porzana carolina*). M
Common Moorhen (*Gallinula chloropus*). B, M
American Coot (*Fulica americana*). M, W
Sandhill Crane (*Grus canadensis*). M
Black-bellied Plover (*Pluvialis squatarola*). M
American Golden-plover (*Pluvialis dominica*). M
Semipalmated Plover (*Charadrius semipalmatus*). M
Killdeer (*Charadrius vociferus*). P
American Avocet (*Recurvirostra americana*). M
Greater Yellowlegs (*Tringa melanoleuca*). M
Lesser Yellowlegs (*Tringa flavipes*). M
Solitary Sandpiper (*Tringa solitaria*). M
Willet (*Cataptrophorus semipalmatus*). M

- Spotted Sandpiper (*Actitis macularia*). M
 Hudsonian Godwit (*Limosa haemastica*). M
 Marbled Godwit (*Limosa fedoa*). M
 Ruddy Turnstone (*Arenaria interpres*). M
 Red Knot (*Calidris canutus*). M
 Sanderling (*Calidris alba*). M
 Semipalmated Sandpiper (*Calidris pusilla*). M
 Western Sandpiper (*Calidris mauri*). M
 Least Sandpiper (*Calidris minutilla*). M
 White-rumped Sandpiper (*Calidris fuscicollis*). M
 Baird's Sandpiper (*Calidris bairdii*). M
 Pectoral Sandpiper (*Calidris melanotos*). M
 Dunlin (*Calidris alpina*). M
 Stilt Sandpiper (*Calidris himantopus*). M
 Ruff (*Philomachus pugnax*). M
 Short-billed Dowitcher (*Limnodromus griseus*). M
 Long-billed Dowitcher (*Limnodromus scolopaceus*). M
 Common Snipe (*Gallinago gallinago*). M, W
 Wilson's Phalarope (*Phalaropus tricolor*). M
 Red-necked Phalarope (*Phalaropus lobatus*). M
 Parasitic Jaeger (*Stercorarius parasiticus*). M
 Laughing Gull (*Larus atricilla*). S, W
 Franklin's Gull (*Larus pipixcan*). M
 Little Gull (*Larus minutus*). M
 Bonaparte's Gull (*Larus philadelphia*). M
 Ring-billed Gull (*Larus delawarensis*). S, W
 Herring Gull (*Larus argentatus*). S, W
 Lesser Black-backed Gull (*Larus fuscus*). M
 Great Black-backed Gull (*Larus marinus*). S, W
 Caspian Tern (*Sterna caspia*). S, M
 Royal Tern (*Sterna maxima*). S, M
 Common Tern (*Sterna hirundo*). M
 Forster's Tern (*Sterna forsteri*). S, M
 Least Tern (*Sterna antillarum*). S
 Black Tern (*Chlidonias niger*). M
 Black Skimmer (*Rynchops niger*). M
 Rock Dove (*Columba livia*). P
 Mourning Dove (*Zenaida macroura*). B, P
 Black-billed Cuckoo (*Coccyzus erythrophthalmus*). S, M
 Yellow-billed Cuckoo (*Coccyzus americanus*). S, B, M
 Eastern Screech-Owl (*Otus asio*). P *
 Great Horned Owl (*Bubo virginianus*). B, P
 Barred Owl (*Strix varia*). P
 Common Nighthawk (*Chordeiles minor*). M
 Whip-poor-will (*Caprimulgus vociferus*). M *
 Chimney Swift (*Chaetura pelagica*). S, M

- Ruby-throated Hummingbird (*Archilochus colubris*). S, B, M
 Belted Kingfisher (*Ceryle alcyon*). B?, P
 Red-headed Woodpecker (*Melanerpes erythrocephalus*). M
 Red-bellied Woodpecker (*Melanerpes carolinus*). B, P
 Yellow-bellied Sapsucker (*Sphyrapicus varius*). W
 Downy Woodpecker (*Picoides pubescens*). B, P
 Hairy Woodpecker (*Picoides villosus*). B, P
 Northern Flicker (*Colaptes auratus*). B, P
 Pileated Woodpecker (*Dryocopus pileatus*). B, P
 Eastern Wood-pewee (*Contopus virens*). S, M
 Yellow-bellied Flycatcher (*Empidonax flavescens*). M
 Acadian Flycatcher (*Empidonax virescens*). S, M
 Willow Flycatcher (*Empidonax traillii*). S, M
 Least Flycatcher (*Empidonax minimus*). M
 Eastern Phoebe (*Sayornis phoebe*). S, M
 Great Crested Flycatcher (*Myiarchus crinitus*). S, B, M
 Eastern Kingbird (*Tyrannus tyrannus*). S, B, M
 White-eyed Vireo (*Vireo griseus*). S, B, M
 Blue-headed Vireo (*Vireo solitarius*). M
 Yellow-throated Vireo (*Vireo flavifrons*). S, M
 Warbling Vireo (*Vireo gilvus*). S, B, M
 Philadelphia Vireo (*Vireo philadelphicus*). M
 Red-eyed Vireo (*Vireo olivaceus*). S, B, M
 Blue Jay (*Cyanocitta cristata*). B, P
 American Crow (*Corvus brachyrhynchos*). B, P
 Fish Crow (*Corvus ossifragus*). P
 Horned Lark (*Eremophila alpestris*). M *
 Purple Martin (*Progne subis*). S, B, M
 Tree Swallow (*Tachycineta bicolor*). S, B, M
 Northern Rough-winged Swallow (*Stelgidopteryx serripennis*). S, B, M.
 Bank Swallow (*Riparia riparia*). M
 Cliff Swallow (*Hirundo pyrrhonota*). M
 Barn Swallow (*Hirundo rustica*). S, B, M
 Black-capped Chickadee (*Poecile atricapillus*). W *
 Carolina Chickadee (*Poecile carolinensis*). B, P
 Tufted Titmouse (*Baeolophus bicolor*). B, P
 Red-breasted Nuthatch (*Sitta canadensis*). M *
 White-breasted Nuthatch (*Sitta carolinensis*). S, P
 Brown Creeper (*Certhia americana*). W
 Carolina Wren (*Thryothorus ludovicianus*). B, P
 House Wren (*Troglodytes aedon*). S, M, W
 Winter Wren (*Troglodytes troglodytes*). W
 Marsh Wren (*Cistothorus palustris*). B, M
 Golden-crowned Kinglet (*Regulus satrapa*). M, W
 Ruby-crowned Kinglet (*Regulus calendula*). M, W
 Blue-gray Gnatcatcher (*Poliophtila caerulea*). S, B, M

- Eastern Bluebird (*Sialia sialis*). S, M
 Veery (*Catharus fuscescens*). M
 Gray-cheeked Thrush (*Catharus minimus*). M *
 Swainson's Thrush (*Catharus ustulatus*). M
 Hermit Thrush (*Catharus guttatus*). M, W
 Wood Thrush (*Hylocichla mustelina*). S, M
 American Robin (*Turdus migratorius*). S, B, M
 Gray Catbird (*Dumetella carolinensis*). S, B, M
 Northern Mockingbird (*Mimus polyglottos*). B, P
 Brown Thrasher (*Toxostoma rufum*). S, P
 European Starling (*Sturnus vulgaris*). B, P
 American Pipit (*Anthus rubescens*). W
 Cedar Waxwing (*Bombycilla cedrorum*). S, B, M
 Blue-winged Warbler (*Vermivora pinus*). M
 Golden-winged Warbler (*Vermivora chrysoptera*). M *
 Tennessee Warbler (*Vermivora peregrina*). M
 Orange-crowned Warbler (*Vermivora celata*). M, W *
 Nashville Warbler (*Vermivora ruficapilla*). M
 Northern Parula (*Parula americana*). S, B, M
 Yellow Warbler (*Dendroica petechia*). S, B, M
 Chestnut-sided Warbler (*Dendroica pensylvanica*). M
 Magnolia Warbler (*Dendroica magnolia*). M
 Cape May Warbler (*Dendroica tigrina*). M
 Black-throated Blue Warbler (*Dendroica caerulescens*). M
 Yellow-rumped Warbler (*Dendroica coronata*). M, W
 Black-throated Green Warbler (*Dendroica virens*). M
 Blackburnian Warbler (*Dendroica fusca*). M
 Yellow-throated Warbler (*Dendroica dominica*). M
 Pine Warbler (*Dendroica pinus*). M
 Prairie Warbler (*Dendroica discolor*). M
 Palm Warbler (*Dendroica palmarum*). M
 Bay-breasted Warbler (*Dendroica castanea*). M
 Blackpoll Warbler (*Dendroica striata*). M
 Black-and-white Warbler (*Mniotilta varia*). S, M
 American Redstart (*Setophaga ruticilla*). S, M
 Prothonotary Warbler (*Protonotaria citrea*). S, B, M
 Worm-eating Warbler (*Helmitheros vermivorus*). M
 Ovenbird (*Seiurus aurocapillus*). M
 Northern Waterthrush (*Seiurus noveboracensis*). M
 Louisiana Waterthrush (*Seiurus motacilla*). S, M
 Kentucky Warbler (*Oporornis formosus*). S, M
 Mourning Warbler (*Oporornis philadelphia*). M *
 Common Yellowthroat (*Geothlypis trichas*). S, M, P?
 Hooded Warbler (*Wilsonia citrina*). M
 Wilson's Warbler (*Wilsonia pusilla*). M
 Canada Warbler (*Wilsonia canadensis*). M

Yellow-breasted Chat (*Icteria virens*). M
Summer Tanager (*Piranga rubra*). M
Scarlet Tanager (*Piranga olivacea*). S, B, M
Eastern Towhee (*Pipilo erythrophthalmus*). S, M
American Tree Sparrow (*Spizella arborea*). W
Chipping Sparrow (*Spizella passerina*). S, M
Field Sparrow (*Spizella pusilla*). S, M
Savannah Sparrow (*Passerculus sandwichensis*). M, W
Fox Sparrow (*Passerella iliaca*). M
Song Sparrow (*Melospiza melodia*). B, M
Lincoln's Sparrow (*Melospiza lincolni*). M
Swamp Sparrow (*Melospiza georgiana*). S, B, M
White-throated Sparrow (*Zonotrichia albicollis*). M, W
White-crowned Sparrow (*Zonotrichia leucophrys*). M, W
Dark-eyed Junco (*Junco hyemalis*). W
Snow Bunting (*Plectrophenax nivalis*). W
Northern Cardinal (*Cardinalis cardinalis*). B, P
Rose-breasted Grosbeak (*Pheucticus ludovicianus*). M
Blue Grosbeak (*Guiraca caerulea*). M
Indigo Bunting (*Passerina cyanea*). S, M
Bobolink (*Dolichonyx oryzivorus*). M
Red-winged Blackbird (*Agelaius phoeniceus*). B, P
Eastern Meadowlark (*Sturnella magna*). M
Rusty Blackbird (*Euphagus carolinus*). M, W
Common Grackle (*Quiscalus quiscula*). S, B, M
Brown-headed Cowbird (*Molothrus ater*). S, B, M
Orchard Oriole (*Icterus spurius*). S, B, M
Baltimore Oriole (*Icterus galbula*). S, B, M
Purple Finch (*Carpodacus purpureus*). W
House Finch (*Carpodacus mexicanus*). B, W
Pine Siskin (*Carduelis pinus*). M, W *
American Goldfinch (*Carduelis tristis*). B, P
Evening Grosbeak (*Coccothraustes vespertinus*). M *
House Sparrow (*Passer domesticus*). B, P

APPENDIX G

Mammals reported from DMP and nearby areas.

	Abbott 1976 ¹	Parsons et al. 1977	Bulmer 1996- 1999 ³
Virginia Opossum (<i>Didelphis virginiana</i>)	X	X	X
Northern Short-tailed Shrew (<i>Blarina brevicauda</i>)	X	X	X
Eastern Mole (<i>Scalopus aquaticus</i>)		X	X
Star-nosed Mole (<i>Condylura cristata</i>)			X
Little Brown Myotis (<i>Myotis lucifugus</i>)	X	X	
Northern Red Bat (<i>Lasiurus borealis</i>)	X	X	
Hoary Bat (<i>Lasiurus cinereus</i>)	X	X	
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)		X	
Eastern Pipistrelle (<i>Pipistrellus subflavus</i>)		X	
Big Brown Bat (<i>Eptesicus fuscus</i>)	X	X	
Evening Bat (<i>Nycticeius humeralis</i>)		X	
Eastern Cottontail (<i>Sylvilagus floridanus</i>)	X	X	X
Eastern Chipmunk (<i>Tamias striatus</i>)	X	X	X
Woodchuck (<i>Marmota monax</i>)			X
Eastern Gray Squirrel (<i>Sciurus carolinensis</i>)	X	X	X
Southern Flying Squirrel (<i>Glaucomys volans</i>)	X	X	X
American Beaver (<i>Castor canadensis</i>)	X	X	X
Marsh Rice Rat (<i>Oryzomys palustris</i>)	X		
Eastern Harvest Mouse (<i>Reithrodontomys humulis</i>)	X		
White-footed Mouse (<i>Peromyscus leucopus</i>)	X	X	X
Deer Mouse (<i>Peromyscus maniculatus</i>)	X		
Eastern Woodrat (<i>Neotoma floridana</i>) ²	X		
House Mouse (<i>Mus musculus</i>)			X
Norway Rat (<i>Rattus norvegicus</i>)	X		
Black Rat (<i>Rattus rattus</i>)	X	X	
Meadow Vole (<i>Microtus pennsylvanicus</i>)	X	X	X
Common Muskrat (<i>Ondatra zibethicus</i>)	X	X	X
Red Fox (<i>Vulpes vulpes</i>)	X	X	X
Common Gray Fox (<i>Urocyon cinereoargenteus</i>)	X	X	X
Common Raccoon (<i>Procyon lotor</i>)	X	X	X
Mink (<i>Mustela vison</i>)		X	
Striped Skunk (<i>Mephitis mephitis</i>)	X	X	X
Northern River Otter (<i>Lutra canadensis</i>)	X	X	
White-tailed Deer (<i>Odocoileus virginianus</i>)	X		X

¹observations from 1968-1976²unlikely³not found currently but expected: Southeastern Shrew (*Sorex longirostris*), Least Shrew (*Cryptotis parva*), Little Brown Myotis, Silver-haired Bat, Eastern Pipistrelle, Red Bat, Hoary Bat, Marsh Rice Rat, Norway Rat, Meadow Jumping Mouse (*Zapus hudsonius*), Long-tailed Weasel (*Mustela frenata*), Mink, River Otter.



VERA B. REMSBURG

(1920-2000)

The Officers and Council of the Virginia Academy of Science sadly note the death of Vera Baron Remsburg, past president of the Academy. Vera was born, 1920, in Raleigh, West Virginia and expired after a protracted illness on December 26, 2000 at the home of her sister, Mrs Josephine B. DeShazo in Spencer, Va.

Vera was a long-time and very active member of the Academy, serving on many committees, including the Junior Academy Committee, where her career as a public school science teacher came to bear on her dedication to science education. Vera was also active in the formation of the Virginia Association of Science Teachers (VAST) and served as president of that organization 1960-1962. In the early 60's she worked with the American Institute of Biological Sciences in promoting the Biological Sciences Curriculum Study (BSCS) in the state of Virginia. She was one of the first biology science teachers to instruct using the "Green Version" of BSCS.

In 1975 Vera was elevated to Fellow status in the VAS (along with Horton H. Hobbs, her graduate school mentor from The University of Virginia). Vera was elected 1979 as the 57th president of the VAS and, in 1986, her tireless work for the Academy was recognized by the Ivey F. Lewis Distinguished Service Award.

Vera worked with president, Roscoe D. Hughes in building the groundwork for what has become the Science Museum of Virginia (SMV). Vera served (1985-1995) as a Trustee of the SMV, while maintaining focus on the many programs of the VAS, including a long tenure on VAS Council.

After retirement from public school teaching in northern Virginia, Vera and her husband, Brent Remsburg, moved to Abingdon, Va. where she resumed teaching, pursued gardening and served in officership roles in many community organizations (Book-lovers Club of Abingdon, Abingdon Garden Club, Abingdon Tree Committee, Barter Theater for the Shakespearean Garden, Virginia Highlands Festival Board, Eashington County Retired Teachers Association, Va, Federation of Garden Clubs). She was a member of the Alpha Zeta Chapter of Delta Gamma International Honorary Society of Women Educators. In 1981 Longwood College Alumni Association presented her with their Distinguished Alumnus Service Award.

Once in awhile there comes to the Virginia Academy of Science an activist with conservative bent and great energy who relentlessly strives for improvement towards perfection of our organization. Such a person was Vera Baron Remsburg.



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