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Task 8

MARYLAND

AN ASSESSMENT OF THE ENCROACHMENT OF WOODY VEGETATION INTO FIVE UNFORESTED DELMARVA BAYS AND FIVE COASTAL PLAIN BOGS BY ANALYSIS OF AERIAL PHOTOGRAPHY

Submitted to the
Coastal Resources Division
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by the
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INTRODUCTION

Delmarva bays and bogs are the most significant nontidal wetland habitats for rare plant species on Maryland's Coastal Plain. These two habitat types harbor more rare species than all other nontidal wetland types of coastal Maryland. In both bays and bogs, the majority of rare species occur within non-forested, herbaceous openings. Bogs also characteristically support low shrubs scattered throughout the herbaceous openings. Field observations by local naturalists and Natural Heritage Program Staff in the 1980s indicated that saplings and tall shrubs were encroaching on these openings and may threaten the rare, shade-intolerant, herbaceous species. To address this concern, this study was undertaken to determine the extent of change in size of herbaceous openings for five bays and five bogs known to harbor high concentrations of rare species (Appendix I). Vegetation cover was assessed from aerial photographs dating from the 1930s to the 1980s.

The results of the analysis of woody plant succession in bogs will assist in determining which bogs are to be studied in further detail in the field beginning in summer 1992. Knowledge gained from the field study and the study of historical change in bog size will be incorporated in the development of management plans for selected bogs.

As with all wetlands, hydrology influences the composition of vegetation in Delmarva bays. The duration of flooding appears to be the major influence limiting the establishment of trees in the herbaceous openings of Delmarva bays. Fire and grazing have been suggested as historical influences limiting woody encroachment; however, data has not substantiated these theories for Maryland's bays. Maintenance of the hydrologic regime therefore appears essential to the maintenance of the herbaceous openings that support rare plant species. Because land use practices influence hydrology, we initiated a study of surrounding land use in conjunction with the assessment of change in size of herbaceous openings for five Delmarva bays.

METHODS

A set of three historical aerial photographs was obtained for all Coastal Plain bogs and Delmarva bays that are listed as Geographical Areas of Particular Concern (GAPC's) in Maryland. The earliest available aerial photograph for each site (1930s-1940s) was obtained to serve as a baseline against which to compare vegetation changes in later photographs. These early photographs were U.S. Soil Conservation Service photos obtained in person from the National Archives and Records Administration in Alexandria, Virginia. We reviewed photographic reels, selecting the frame that offered the best resolution for each bay or bog.

The most recent aerial photography available commercially was generally at too small a scale to adequately resolve differences in vegetation type. Therefore we used the most recent photographs flown at an appropriate scale (1:24,000 or larger). These photographs were flown primarily in 1985 and were available in-house from the Water Resources Administration or the Natural Heritage Program (both Maryland Department of Natural Resources). A third set of photos of intermediate date (1957 - 1958) and appropriate scale, flown by SCS, were obtained by mail from the U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service in Utah. For two sites, additional, larger-scale historical photographs were available from Anne Arundel County. These were used to better understand and describe the vegetation history at those sites, but were omitted from the analysis of changes in area because large differences in scale made it hard to consistently interpret vegetation changes.

Based on the quality of available photos, site protection priorities, ownership patterns, and geographical distribution, five bays and five bogs were selected for analysis (Table I). Each photo was scanned using the Map and Image Processing System software (MIPS, by MicroImages, Inc., Lincoln, Nebraska, Version 3.x). Scanning was done at 400 dpi using a Howtek Scanmaster 3, Hewlett-Packard (HP) Vectra 486/25T personal computer, an HP 16" high-resolution UGA color monitor with Metheus 1228 UGA graphics board, and an HP VGA color monitor for text. The images were stored on optical disk using a Relax MO Plus, 600 MB Optical Drive.

Each photograph was examined under magnification to determine the boundary between the herbaceous opening and woody cover (bays) or between herbaceous/low shrub cover and tall woody cover (bogs). Open water was included in the measurement of herbaceous openings because it fluctuates seasonally and areas covered by open water in one season may support bay or bog

vegetation observable at another time of year. The area of the opening was calculated for each site in each year using the MIPS "planimeter" program. In order to assess the reliability of the results, each measurement was repeated a minimum of four times and the mean area was calculated. For each site, the significance of differences among mean areas in different years was assessed using the student's t-test.

We noted that the stated scale of the photographs was not always accurate. To correct for minor scale inconsistencies or image distortion, each bog photograph was calibrated by using the MIPS "calipers" program to measure the distance between two landmarks near the bog and common to all three photos. Differences in the measured distance were used to produce an area calibration factor for each photo, and area calculations were corrected accordingly. For bay sites, each photograph was registered against registered Land Sat spot imagery prior to analysis of surrounding land use patterns. Photo registration assisted in correcting for scale discrepancies and photo distortion.

Surrounding land use was analyzed for the five Delmarva bays at intervals of 30m, 60m, 100m, and 300m from the edge of the herbaceous opening outlined in the earliest available photo (1930s). For consistency, the 1930s herbaceous opening was used as the basis for these interval measurements for the 1950s and 1985 photos as well. The "vector buffer" function of MIPS was used to create polygons at these intervals around the herbaceous opening. Prints showing these polygons for Dorchester Pond were produced using an HP Paintjet XL printer and are included as Appendix II.

Within each distance interval, area was measured for the following classes of land use: cultivated fields, old fields, forest, and recently logged. Area was calculated with the MIPS "planimeter" function. The length of roads and ditches occurring within each interval was measured with the MIPS "calipers" function. The number of buildings present was recorded for each interval.

RESULTS

Coastal Plain Bogs

The size of herbaceous/low shrub openings at all bog sites declined significantly ($p < .005$) between the 1930's or 40's and the 1980's (Tables II and III). The greatest proportional decrease in size occurred at Suitland Bog, where the size of the opening in 1981 was only 6% of its size in 1937 (Table IV), an average rate of decline of 2.1% per year. The opening at Suitland Bog was the largest of all sites studied in the 1930's and 1940's (4.1 ha in 1937) but the second smallest by the 1980's (0.26 ha in 1981). Most of the loss occurred between 1937 and 1957, when opening size decreased by 81%.

The next largest proportional declines in opening size occurred at the two Eastern Shore sites. At Horsebridge Creek Bog in 1985 the opening had decreased to 24% of its 1938 size (1.6% decline per year). The total opening at Sharptown Bog had declined in 1985 to 31% of its 1938 size (1.5% per year). The real loss of bog vegetation at these two sites was probably even greater. At Horsebridge Creek Bog in 1938, a wide, herbaceous wetland opening surrounded both sides of Horsebridge Creek for more than 1/4 mile of its length. Between 1958 and 1985, the creek was channelized and a powerline right-of-way constructed across it; the only openings remaining in 1985 were the narrow stream channel and the artificially maintained right-of-way where the powerline crossed the bog. Most of this opening would not have been wet enough to support bog vegetation. All rare species reported in mid-1980's field surveys at this site were confined to two small boggy depressions under the powerline.

Sharptown Bog was already traversed by a powerline in 1938, but the right-of-way had not been recently cleared and most of the 0.5 ha opening measured in that year appeared to be a natural herbaceous opening along a stream. By 1958, the powerline right-of-way was cleared and the streamside opening was beginning to close in with woody vegetation. By 1985, the entire streamside opening outside of the powerline right-of-way had become forested.

Patterns of vegetation change were observed more closely at the two Anne Arundel County bogs due to the availability of large-scale photographs from intermediate years. In 1943, Gumbottom Wetland contained an apparently all-herbaceous opening of approximately .5 ha, clearly distinct from a very large adjacent shrub swamp. By 1952 and 1957 the distinction was less clear, as shrubs had begun to move into the herbaceous opening. By 1970, much of the opening was dominated by low shrubs, but it was still distinct from the taller shrub canopy of the shrub swamp. By 1984 and 1985, the size of the opening had decreased

to less than 1/3 hectare (.28 ha in 1985), and tall shrubs had penetrated into the interior of the opening in some locations. Gumbottom Wetland showed the lowest proportional decline in area of opening among the bog sites. In 1985, the size of the opening was 53% of its 1943 size. The decrease occurred much more rapidly between 1943 and 1957 (2.3% per year) than between 1957 and 1985 (0.5% per year).

North Gray's Bog had the largest herbaceous/shrub opening in 1985, with an area of 1.1 ha. Although it is known from field surveys that part of this opening is composed of an open water pond and emergent marsh, this portion is important because it represents area for potential bog expansion. This is the only site studied where the bog appears to be in the early stages of formation, with a thick peat mat gradually growing gradually out over the still water. North Gray's Bog showed the second lowest proportional decline in area, decreasing to 42% of its 1948 size by 1985. It was the only site in which the greater decline occurred between the 1950's and the 1980's (2.1% decline per year). The area of the opening at this site stayed the same between 1948 and 1957. Intermediate photos indicate that the decline had begun by 1970, when a tall shrub canopy had begun to penetrate the opening in the drier, eastern end of the site.

Delmarva Bays

Change in Area of Herbaceous Opening

The area of herbaceous openings declined significantly ($p < 0.01$) from the 1930s through 1985 for all five bays studied (see Tables V and VI). For all sites, the herbaceous openings consistently decreased in area from the 1930s to the 1950s and from the 1950s to the 1980s with one exception. Bridgetown Pond increased in area from 1958 to 1985; however, the herbaceous opening was significantly smaller in 1985 than it was in 1937 as a result of the significant decrease in area from 1937 to 1958.

The largest proportional decrease in size of herbaceous opening occurred at Jackson Lane. The mean area of the opening in 1985 was 29% of the mean area in 1937. By 1985, the herbaceous opening at Golts Pond had decreased to 55% of its size in 1937. By 1985 Black Bottom Pond had decreased to 73% of its area in 1936. The smallest decreases in area of herbaceous opening were recorded for Bridgetown Pond and Dorchester Pond. By 1985, both of these sites declined to 91% of the areas recorded for 1937 and 1938 respectively.

The decrease in area of herbaceous opening was larger from the 1930s to 1950s than in the subsequent period ending in 1985 for all sites with the exception of Dorchester Pond.

Land Use Analysis

Two of the five sites, Black Bottom Pond and Bridgetown Pond, experienced little change in land use from the 1930s to 1985 (Table VII). Over 80% of the surrounding land remained forested within 100m of the bays throughout the study period. Virtually no disturbance was evident within 60m of these bays during this period. Of the four relatively small bays, Black Bottom and Bridgetown also experienced the least encroachment of woody species during the study period.

The general trend in land usage observed from the 1930s to 1985 was of farm fields reverting to forest. At Dorchester Pond, Golts Pond, and Jackson Lane, 1/3 to 1/2 of the land within 100m of the bays was farmed in the 1930s. By 1985 all but 5% of this land had reverted to forest. In general, as fields reverted to forest, roads were abandoned so the length of roads present in all intervals generally declined during the study period. The exceptions to this were at Golts Pond and Dorchester Pond. Numerous residences occur within 300m of Golts Pond and a few new roads were constructed to increase access to these properties. At Dorchester Pond, as fields were abandoned, roads were maintained at the field edges to provide access to nearby fields that remained in cultivation. This gave the appearance of an increase in road length in the 60-100m interval.

No major ditches lie within 300m of the five bays studied. Field surveys revealed that small ditches are present at most of these bays, however, they are not visible in the aerial photographs. The forest canopy conceals these ditches, so this is not an effective method to evaluate the position and effect of ditches.

Logging was evident at both Dorchester Pond and Bridgetown Pond. At Dorchester, logging occurred in the 1930s in all intervals studied and beyond 300m to the south of the bay. At Bridgetown Pond, young irregular stands of pine along sand roads in the 1937 photo suggest that logging had recently occurred in the 100-300m interval. Areas of relatively open canopy in the 1958 photo suggest that logging occurred again in the 100-300m interval.

New powerlines were constructed between 1957 and 1985 crossing the 100-300m intervals at Golts Pond and Black Bottom Pond. Of the five bays studied, only Golts Pond had more than two buildings present within 300m of the bay. The bays occur in rural areas where lots tend to be large and houses widely dispersed. However Golts Pond lies near a small town center. In 1936, 24 buildings were located within 300m of the bay. Half of these were abandoned and by 1985 just 11 buildings remained.

DISCUSSION

Coastal Plain Bogs

The encroachment of woody species into Coastal Plain bogs is a natural process of vegetation succession in which unforested bogs slowly become dominated by trees. Historically, new sites developed that were suitable for colonization by shade intolerant bog vegetation, such as the edges of beaver ponds, old stream meanders, and openings in swamps created by fire during dry years. Today, a large portion of the landscape has been converted to residential, industrial, commercial, or agricultural uses, and most of Maryland's Coastal Plain bogs, many of which were located in counties now heavily urbanized, have been destroyed. Potential sites for new bog formation have also been destroyed, and the disturbances which created them, such as fire and flooding, have been suppressed. Because the natural development of new sites for bog formation can no longer keep pace with the accelerated loss of Maryland's few remaining bogs, the natural succession of woody species into those bogs threatens the survival of this unusual habitat. If unique Coastal Plain bog plant communities are to survive, active management to curtail woody encroachment into bogs may be required at some sites.

Potential methods of woody species control include prescribed burns, flooding by blocking drainage ditches or reconstructing old dams, selective herbicide use, and removing tree saplings by hand. Each method has advantages and drawbacks. Burning and flooding may best mimic natural disturbances that maintained bog openings, but fire may not be feasible in urban/suburban landscapes and flooding may have direct negative impacts on existing rare species. Herbicide use would have to be planned and executed with extreme caution to avoid damaging rare species or contaminating water or soil. Hand removal may be the most prudent and conservative choice, but even this choice requires caution and careful timing of work to minimize trampling fragile bog habitats. Decisions regarding vegetation management should be made after on-site research to evaluate such factors as the rate of woody encroachment into the bog, surrounding land use, and hydrology.

The Maryland Natural Heritage Program has contracted to establish permanent plots at two bogs to measure the rate of tree sapling encroachment over time and to provide management plans to control woody invasion at these sites. Together with a knowledge of ownership patterns and management history, the analyses of historical aerial photos provided information useful in determining which sites can profit most from on-site evaluation and control of woody encroachment.

Of the five bogs examined, Suitland Bog exhibited the highest rate of decline in size of opening. However, it may be least in need of intervention by the Natural Heritage Program because the site is owned and managed by the Maryland-National Capital Park and Planning Commission, which is actively working to protect it. The site's hydrology has been studied and the aquifer that feeds it has been purchased to protect the source of water. Berms, a boardwalk and a chain link fence around the major bog opening have been constructed to curtail erosion, trampling and dirt bike use. Efforts are underway by park staff to educate the public and to control woody encroachment manually. Thus Suitland Bog already receives the greatest degree of protection and management of any of the five sites studied.

Since the only openings remaining at Sharptown Bog and Horsebridge Creek Bog are within powerline rights-of-way, power company officials have instituted their own programs to control woody encroachment. At these sites, the Natural Heritage Program's most profitable role will be maintaining continued landowner contact, particularly continued involvement in the development of management plans for the sites. We have provided the owners with maps and rare species reports and they have agreed to omit the bogs from broadcast herbicide application. Continued contact is essential to ensure that this agreement is followed. We also need to work with adjacent owners to preserve a forested buffer and to avoid repetition of the disastrous dragging of timber through the powerline opening that destroyed much of Sharptown Bog in the 1980s. At both Sharptown and Horsebridge Creek Bogs, monitoring of rare species and of exotic species is needed.

The two sites with the greatest potential to benefit from tracking the encroachment of woody species and developing vegetation management plans are Gumbottom Wetland and North Gray's Bog. These sites currently support the largest herbaceous openings and they experienced the smallest decrease in area over the study period. (The total opening at Horsebridge Creek is larger than at Gumbottom, but only a small portion of it supports bog vegetation.) They have the largest forested buffers, the least deleterious land use in the immediate vicinity and probably the lowest rate of invasion by non-native, weedy species. Permission to study and eventually manage both sites, if needed, should be easier to obtain at these two sites than at most bogs. Gumbottom Wetland is owned by the Maryland Department of Natural Resources. The homeowner's association that owns North Gray's Bog has registered the bog and its buffer, encouraged scientific research by the Natural Heritage Program, and requested that Natural Heritage develop a management plan for the site. Lastly, woody vegetation that is likely to eventually threaten bog species has been observed on site at both Gumbottom and North Gray's Bog, so both sites would benefit from the monitoring and control of woody encroachment.

Delmarva Bays

The two bays experiencing the greatest decrease in size of herbaceous opening, Golts Pond and Jackson Lane, were both nearly surrounded by agricultural fields in the 1930's that reverted to forest by the 1950s. This suggests that agricultural activity may have contributed to maintaining the herbaceous opening at these sites. For example, these areas may have been maintained for grazing. It is also possible that the decrease in the herbaceous openings is associated with natural succession of the abandoned agricultural fields. Evapotranspiration is particularly high in the early years of succession when young trees of colonizing species grow most rapidly. This high rate of evapotranspiration may have reduced the water available to the bays and shortened the duration of flooding along the bay perimeter. With less flooding, woody species would establish more readily. This scenario is further supported by the slower decrease in size of herbaceous opening that occurred from the 1950s to 1985, when both the growth rate and evaporatranspiration of the young forest would have slowed.

Of the five bays, Dorchester Pond was the exception in experiencing a more rapid decrease in the herbaceous opening from the 1950s to 1985 despite extensive logging in the 1930s and its proximity to reverting agricultural fields. According to recent findings of the U.S. Geological Survey (Pat Phillips, personal communication), the four smaller bays in Caroline and Kent Counties lie in the same hydrogeologic region, meaning they share similar patterns of groundwater and surface water movement due to similarities in elevational gradient, soil type, and geology. However, Dorchester Pond is in a different region with different hydrological characteristics and therefore may respond differently to changes in land use. It may also be of significance that a large portion of forested land within 100m of Dorchester Pond was converted to pine plantation between the 1950s and 1985. These evergreens have a higher total annual transpiration rate than deciduous trees. The presence of a high density of pine close to the bay may reduce the available water and thus shorten the duration of flooding in the bay and promote woody succession along the bay perimeter.

Field observations indicate that the slight increase in size of the herbaceous opening at Bridgetown Pond may be the result of oaks dying from gypsy moth defoliation.

Additional bays must be studied so that the sample size is larger in order to develop conclusive evidence of the effects of land use practices on Delmarva bays. However, the results of this study suggest that maintenance of mature, natural forest cover, especially within 100m of a bay, may contribute to maintaining the herbaceous openings and the rare species they harbors.

The bays experiencing the most rapid decrease in size of herbaceous opening, Jackson Lane and Golts Pond should be carefully monitored to determine the status of rare species populations. While monitoring of plant communities is underway at Jackson Lane, there has been no effort to monitor the rare plant populations at either site. Removal of woody vegetation from the Jackson Lane bay should be seriously considered. At the present rate of succession, this bay will be completely forested in 30 years. It is likely that the rare species would be lost much sooner as they are gradually shaded.

It is likely that land use activities beyond 300m from the bays influence the flora of the bays. For example, large tax ditches may draw down water over 1000 ft from the ditch. In addition, this study of aerial photographs proved ineffective in locating ditches. Information concerning the location and time of construction of ditches should be sought from the Soil Conservation Service. If possible, this information should be mapped and included in further analyses of land use around Delmarva bays. Further analyses should explore land use up to 600m from bays and should include at least 20 bays to obtain more conclusive results.

Table I. Inventory of aerial photography used to assess size of herbaceous/shrub opening.

Legend for photographic sources: **AACo** = Anne Arundel County Planning and Zoning Department; **MDNHP** = Maryland Natural Heritage Program, Department of Natural Resources; **SCS** = U.S. Soil Conservation Service; **WRA** = Water Resources Administration, Maryland Department of Natural Resources.

A. **COASTAL PLAIN BOGS**

Site	Year	Source	Scale
Gumbottom Wetland			
Anne Arundel County			
USGS Quad: Round Bay	1943	SCS	1:20,000
	1952	AACo	1:4800[1]
	1957	SCS	1:20,000
	1970	AACo	1:12,000[1]
	1984	AACo	1:2400[1]
	1985	WRA	1:12,000
Horsebridge Creek Bog			
Wicomico County			
USGS Quad: Wango			
	1938	SCS	1:20,000
	1958	SCS	1:20,000
	1985	WRA	1:12,000
North Gray's Bog			
Anne Arundel County			
USGS Quad: Gibson Island			
	1948	SCS	1:20,000
	1952	AACo(SCS)	1:4800[1]
	1957	SCS	1:20,000
	1970	AACo	1:12,000[1]
	1984	AACo	1:2400[1]
	1985	WRA	1:12,000
Sharptown Bog			
Wicomico County			
USGS Quads: Hebron, Sharptown			
	1938	SCS	1:20,000
	1958	SCS	1:20,000
	1985	WRA	1:12000
Suitland Bog			
Prince George's County			
USGS Quad: Anacostia			
	1937	SCS	1:20,000
	1957	SCS	1:20,000
	1981	MNHP	1:24,000

[1] Used to assist in interpretation of the three primary photos; area calculations were not based on these photos.

B. **DELMARVA BAYS**

Site	Year	Source	Scale
Black Bottom Pond			
Kent County			
USGS Quad: Millington			
	1936	SCS	1:20,000
	1957	SCS	1:20,000
	1985	WRA	1:12,000
Bridgetown Pond			
Caroline County			
USGS Quad: Goldsboro			
	1937	SCS	1:20,000
	1958	SCS	1:20,000
	1985	WRA	1:12,000
Dorchester Pond			
Dorchester County			
USGS Quad: East New Market			
	1938	SCS	1:20,000
	1958	SCS	1:20,000
	1985	WRA	1:12,000
Golts Pond			
Kent County			
USGS Quad: Millington			
	1936	SCS	1:20,000
	1957	SCS	1:20,000
	1985	WRA	1:12,000
Jackson Lane			
Caroline County			
USGS Quad: Goldsboro			
	1937	SCS	1:20,000
	1958	SCS	1:20,000
	1985	WRA	1:12,000

TABLE II. Area of herbaceous and/or low shrub opening in each Coastal Plain bog site for each year, reported as mean ± standard error of repeated measurements. Means for a site with the same superscript are not statistically different according to Students two-sample t-test values in Table IV.

		AREA OF OPENING (hectares)		
SITE	MO/YR	MEAN		STANDARD ERROR
Gumbottom Wetland	4/1943	0.527[a]	±	0.067
	8/1957	0.362[b]	±	0.060
	9/1985	0.280[c]	±	0.051
Horsebridge Creek Bog	6/1938	2.800[a]	±	0.161
	6/1958	0.497[b]	±	0.070
	9/1985[1]	0.678[c]	±	0.098
North Gray's Bog	12/1948	2.592[a]	±	0.117
	7/1957	2.596[a]	±	0.158
	9/1985	1.090[b]	±	0.054
Suitland Bog	5/1937	4.148[a]	±	0.155
	6/1957	0.800[b]	±	0.070
	4/1981	0.257[c]	±	0.035
Sharptown Bog				
Natural Herbaceous Wetland Opening				
	5/1938	0.491[a]	±	0.078
	7/1958	0.176[b]	±	0.050
	9/1985	0[c]		
Opening Under Powerline Right-of-way				
	5/1938	0.030[a]	±	0.028
	7/1958	0.171[b]	±	0.044
	9/1985	0.164[b]	±	0.040
Total Opening[2]				
	5/1938	0.521		
	7/1958	0.347		
	9/1985	0.164		

[1]The stream at this site had been channelized by 1985. The only opening remaining is that maintained artificially for a powerline right-of-way; most of opening is probably not wetland, and thus is incapable of supporting bog vegetation.

[2]Total area of opening at Sharptown Bog is not a mean but rather the sum of means of two component measurements; thus no standard error is given.

Table III. Student's two-sample t-test for comparisons of mean area of herbaceous openings between years at Coastal Plain Bogs. *** = p, < 0.005. No asterisk indicates means are not statistically different.

Site	Years Compared	df	Common Variance	t Value
Gumbottom	1943 & 1957	8	0.020	12.89***
Wetland	1957 & 1985	8	0.016	8.25***
Horsebridge	1958 & 1985	13	0.019	-16.45***
Creek Bog	1938 & 1985	7	0.102	80.60***
North Gray's	1948 & 1957	7	0.100	- 0.07
Bog	1948 & 1985	6	0.037	56.66***
Suitland Bog	1937 & 1957	6	0.070	67.62***
	1957 & 1981	7	0.014	59.95***
Sharptown Bog				
Natural Opening				
	1938 & 1958	12	0.025	21.03***
Powerline Opening				
	1938 & 1958	7	0.008	-27.43***
	1958 & 1985	9	0.009	1.24
	1938 & 1985	8	0.007	-28.55***

TABLE IV. Percentage of historical opening remaining open, as compared to the size of the opening in the earliest year examined.

SITE	YEAR	PROPORTION OF HISTORICAL OPENING REMAINING OPEN
Gumbottom Wetland		
	1943	100%
	1957	67%
	1985	53%
Horsebridge Creek Bog		
	1938	100%
	1958	18%
	1985	24%[1]
North Gray's Bog		
	1948	100%
	1957	100%
	1985	42%
Suitland Bog		
	1937	100%
	1957	19%
	1981	6%
Sharptown Bog		
Natural Opening		
	1938	100%
	1958	36%
	1985	0%
Opening Under Powerline Right-of-way		
	1938	100%
	1958	585%
	1985	547%
Total Opening		
	1938	100%
	1958	66%
	1985	31%

[1]Only opening remaining in 1985 was that maintained artificially for powerline right-of-way; most of opening was probably not wetland and thus would not be expected to support bog vegetation.

Table V. Area of herbaceous opening for Delmarva bays as calculated from aerial photos.

Site Name	Mo/Yr	Mean Area x (m^2)	Variance s	Standard Error (SE)
Black Bottom Pond	8/36	1,054	31	13
	8/57	761	36	15
	9/85	766	3	1
Bridgetown Pond	10/37	4,532	83	34
	5/58	3,905	52	21
	8/85	4,106	64	26
Dorchester Pond	5/38	64,972	136	56
	5/58	62,281	239	98
	9/85	58,755	46	19
Golts Pond	10/36	6,172	102	42
	8/57	4,551	99	40
	9/85	3,396	83	34
Jackson Lane	10/37	11,516	96	39
	5/58	5,247	88	36
	9/85	3,295	32	13

Table VI. Student's t test for difference between mean area of openings of Delmarva bays. Common df=10.

Site Name	Years Compared	Common Variance	T Value	Significant difference p=0.01
Bridgetown Pond	1937 & 1958	76	14.3	Yes
	1958 & 1985	64	5.4	Yes
	1937 & 1985	81	9.1	Yes
Black Bottom Pond	1936 & 1957	37	13.7	Yes
	1957 & 1985	28	0.5	No
Dorchester Pond	1938 & 1958	213	21.9	Yes
	1958 & 1985	188	32.0	Yes
Golts Pond	1936 & 1957	110	25.5	Yes
	1957 & 1985	100	20.0	Yes
Jackson Lane	1937 & 1958	101	108	Yes
	1958 & 1985	73	46	Yes

Table VII. Land usage within four intervals of distance from the herbaceous openings of five Delmarva bays. Proportion of area within each interval for each land use is identified by percent area in use within the interval. The length (m) of roads and ditches within each interval is given.

BLACK BOTTOM POND

	Bay Edge-30m			30-60m			60-100m			100-300m		
	1936	1957	1985	1936	1957	1985	1936	1957	1985	1936	1957	1985
farmed (%)	---	---	---	---	---	---	---	---	---	11	10	14
oldfield (%)	---	---	---	5	---	---	9	---	---	8	5	---
forested (%)	100	100	100	95	100	100	91	100	100	80	85	81
powerline (%)	---	---	---	---	---	---	---	---	---	---	---	5
roads (m)	---	---	---	---	---	---	---	---	---	---	---	---
ditches (m)	---	---	---	---	---	---	---	---	---	---	---	---

BRIDGETOWN POND

	Bay Edge-30m			30-60m			60-100m			100-300m		
	1937	1958	1985	1937	1958	1985	1937	1958	1985	1937	1958	1985
farmed (%)	---	---	---	---	---	---	6	6	---	18	15	13
oldfield (%)	---	---	---	---	---	---	12	---	---	18	1	---
forested (%)	100	100	100	100	100	100	82	94	100	61	75	83
roads (m)	---	---	---	---	---	---	---	---	---	694	430	---
ditches (m)	---	---	---	---	---	---	---	---	---	159	173	105
other bays (%)	---	---	---	---	---	---	---	---	---	3	4	4
logged (%)	---	---	---	---	---	---	---	---	---	---	4	---

DORCHESTER POND

	Bay Edge-30m			30-60m			60-100m			100-300m		
	1938	1958	1985	1938	1958	1985	1938	1958	1985	1938	1958	1985
farmed (%)	---	---	---	34	19	---	29	21	2	36	22	17
logged (%)	8	---	---	49	---	---	27	---	---	17	---	---
forested (%)	92	100	100	17	81	100	43	79	98	48	78	83
roads (m)	---	---	---	---	---	244	272	435	533	1437	1137	881
ditches (m)	---	---	---	---	---	---	---	---	---	---	---	---

GOLTS POND

	Bay Edge-30m			30-60m			60-100m			100-300m		
	1936	1957	1985	1936	1957	1985	1936	1957	1985	1936	1957	1985
farmed (%)	4	1	---	35	30	3	40	22	3	60	45	40
oldfield (%)	96	---	---	51	---	---	39	---	15	25	5	2
forested (%)	---	99	100	14	70	97	21	78	82	5	55	55
*roads (m)	---	---	---	26	26	---	302	302	345	2046	2046	2472
ditches (m)	---	---	---	---	---	---	---	---	---	---	---	---
powerline (%)	---	---	---	---	---	---	---	---	---	---	---	3

*includes railroad

JACKSON LANE

	Bay Edge-30m			30-60m			60-100m			100-300m		
	1937	1958	1985	1937	1958	1985	1937	1958	1985	1937	1958	1985
farmed (%)	25	---	---	58	---	---	41	3	---	30	5	---
oldfield (%)	---	---	---	---	---	---	---	5	---	7	15	---
forested (%)	75	100	100	42	100	100	59	92	100	63	80	96
other bays (%)	---	---	---	---	---	---	---	---	---	4	4	4
roads (m)	---	---	---	40	40	---	---	40	---	1035	412	101
ditches (m)	---	---	---	---	---	---	---	---	---	---	---	---

APPENDIX I. Rare species occurring at each Coastal Plain bog and Delmarva bay site studied.

RARE SPECIES SUMMARY TABLE

Site Name: Gumbottom Wetland

County: Anne Arundel

USGS Quad: Round Bay

Scientfic Name	Common Name	Status
Carex exilis	Coast Sedge	Endangered
Carex bullata	Button Sedge	Threatened
Chamaedaphne calyculata	Leatherleaf	Threatened
Platanthera ciliaris	Yellow-fringed Orchid	Threatened
Sarracenia purpurea	Northern Pitcher Plant	Threatened
Bartonia paniculata	Twining Bartonia	Watch List
Carex atlantica	Eastern Sedge	Watch List
Drosera rotundifolia	Round-leaved Sundew	Watch List
Eriophorum virginicum	Tawny Cottongrass	Watch List
Rhynchospora alba	White Beakrush	Watch List
Vaccinium macrocarpon	Large Cranberry	Watch List

RARE SPECIES SUMMARY TABLE

SITE NAME: Horsebridge Creek Bog

COUNTY: Wicomico

USGS QUAD: Wango

Scientific name	Common name	Status
Sclerolepis uniflora	Pink Bog-button	Endangered
Sarracenia purpurea	Northern Pitcher-plant	Threatened
Sagittaria engelmanniana	Engelmann's Arrowhead	Threatened
Eriocaulon compressum	Flattened Pipewort	Rare
Drosera rotundifolia	Round-leaved Sundew	Watch List

The following additional rare species were reported from this site in the early 1980's and may persist at the site:

Amphicarpum purshii
Bartonia paniculata
Psilocarya scirpoides
Utricularia fibrosa
Xyris fimbriata
Xyris smalliana

RARE SPECIES SUMMARY TABLE

SITE NAME: North Gray's Bog

COUNTY: Anne Arundel

USGS QUAD: Gibson Island

Scientific name	Common name	Status
Carex exilis	Coast Sedge	Endangered
Arundinaria gigantea	Giant Cane	Threatened
Chamaedaphne calyculata	Leatherleaf	Threatened
Eleocharis olivacea	Green Spikerush	Watch List
Eriophorum virginicum	Tawny Cottongrass	Watch List
Rhynchospora alba	White Beakrush	Watch List
Vaccinium macrocarpon	Large Cranberry	Watch List

RARE SPECIES SUMMARY TABLE

SITE NAME: Sharptown Bog

COUNTY: Wicomico

USGS QUAD: Sharptown, Hebron

Scientific name	Common name	Status
Cleistes divaricata	Spreading Pogonia	Endangered
Eleocharis robbinsii	Robbins' Spikerush	Endangered
Fuirena pumila	Smooth Fuirena	Endangered
Polygala cruciata	Cross-leaved Milkwort	Endangered
Psilocarya nitens	Short-beaked Baldrush	Endangered
Rhynchospora glomerata	Clustered Beakrush	Endangered
Scirpus subterminalis	Water Clubrush	Endangered
Sclerolepis uniflora	Pink Bog-button	Endangered
Sarracenia purpurea	Northern Pitcher-plant	Threatened
Drosera rotundifolia	Round-leaved Sundew	Watch List
Pogonia ophioglossoides	Rose Pogonia	Watch List
Utricularia radiata	Small Swollen Bladderwort	Watch List

RARE SPECIES SUMMARY TABLE

SITE NAME: Suitland Bog

COUNTY: Prince George's

USGS QUAD: Anacostia

Scientific name	Common name	Status
Asclepias rubra	Red Milkweed	Endangered
Polygala cruciata	Cross-leaved Milkwort	Endangered
Rhynchospora glomerata	Clustered Beakrush	Endangered
Sarracenia purpurea	Northern Pitcher-plant	Threatened
Thelypteris simulata	Bog Fern	Threatened
Eleocharis tortilis	Twisted Spikerush	State Rare
Eriocaulon decangulare	Ten-angled Pipewort	State Rare
Aronia prunifolia	Purple Chokeberry	Watch List
Eriophorum virginicum	Tawny Cottongrass	Watch List
Melanthium virginicum	Virginia Bunchflower	Watch List
Pogonia ophioglossoides	Rose Pogonia	Watch List
Quercus prinoides	Dwarf Chestnut Oak	Watch List
Rhododendron atlanticum	Dwarf Azalea	Watch List
Rhynchospora alba	White Beakrush	Watch List
Senecio pauperculus	Balsam Ragwort	Watch List
Utricularia subulata	Zig-zag Bladderwort	Watch List

In addition, the following rare crustacean may occur here (because hybrids of this species with Stygobromus tenuis [Watch List species] have been reported historically from "near Suitland"):

Stygobromus hayi	Hay's Spring Amphipod	Federally Endangered

RARE SPECIES SUMMARY TABLE

SITE NAME: Black Bottom Pond

COUNTY: Kent

USGS QUAD: Millington

Scientific name	Common name	Status
Bidens discoidea	Small Beggar-ticks	Endangered
Carex gigantea	Giant Sedge	Endangered
Fimbristylis perpusilla	Harper's Fimbristylis	Endangered
Hottonia inflata	Featherfoil	Endangered
Rhynchospora corniculata	Short-bristled Hornedrush	Endangered
Oldenlandia uniflora	Clustered Bluets	State Rare

SITE NAME: Bridgetown Pond

COUNTY: Caroline

USGS QUAD: Goldsboro

Scientific name	Common name	Status
Ambystoma tigrinum	Eastern Tiger Salamander	Endangered
Hyla gratiosa	Barking Treefrog	Endangered
Psilocarya scirpoides	Long-beaked Baldrush	Endangered
Carex bullata	Button Sedge	Threatened
Sagitaria engelmanniana	Engelmann's Arrowhead	Threatened
Scleria reticularis	Reticulated Nutrush	Rare
Rana virgatipes	Carpenter Frog	In Need of Conservation
Panicum hemitomon	Maidencane	Watch List

RARE SPECIES SUMMARY TABLE

SITE NAME: Dorchester Pond

COUNTY: Dorchester

USGS QUAD: East New Market

Scientific name	Common name	Status
Eleocharis robbinsii	Robbins' Spikerush	Endangered
Hypericum adpressum	Creeping St. John's-wort	Endangered
Lachnanthes caroliniana	Red-root	Endangered
Psilocarya scirpoides	Long-beaked Baldrush	Endangered
Rhynchospora inundata	Drowned Hornedrush	Endangered
Xyris smalliana	Small's Yelloweyed-grass	Endangered
Utricularia purpurea	Purple Bladderwort	Threatened
Podilymbus podiceps	Pied-bill Grebe	Rare
Scleria reticularis	Reticulated Nutrush	Rare
Rana virgitipes	Carpenter Frog	In Need of Conservation

RARE SPECIES SUMMARY TABLE

SITE NAME: Golts Pond

COUNTY: Kent

USGS QUAD: Millington

Scientific name	Common name	Status
Carex gigantea	Giant Sedge	Endangered
Fimbristylis perpusilla	Harper's Fimbristylis	Endangered
Bartonia paniculata	Twining Bartonia	Watch List

SITE NAME: Jackson Lane

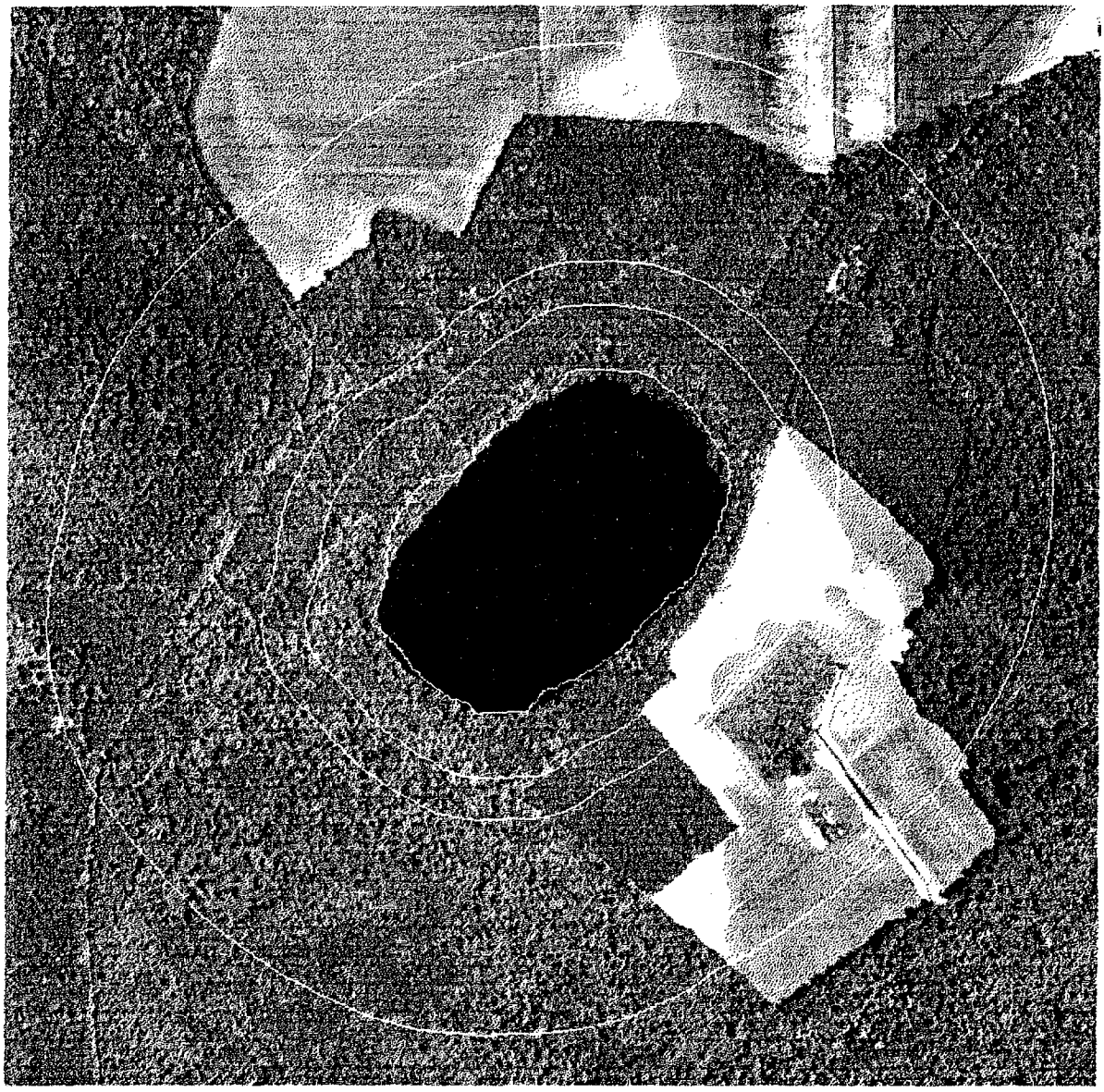
COUNTY: Caroline

USGS QUAD: Goldsboro

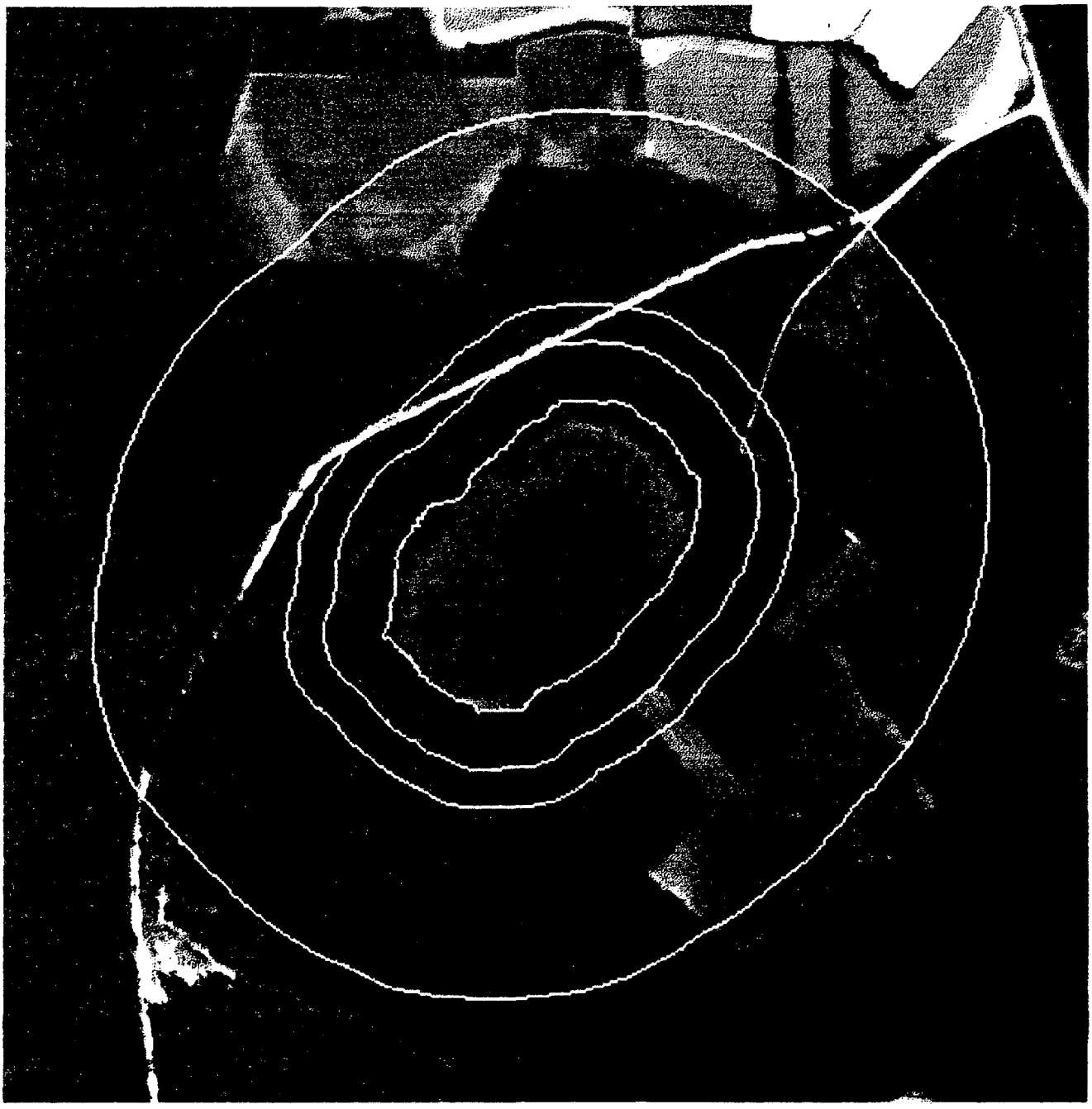
Scientific name	Common name	Status
Fimbristylis perpusilla	Dwarf Fimbristylis	State Endangered; Federal Candidate (C-2)
Eleocharis melanocarpa	Black-fruited Spike-rush	Endangered
Hottonia inflata	Featherfoil	Endangered
Panicum hemitomon	Maidencane	Watch List

APPENDIX II. Dorchester Pond 1938 (a), 1958 (b), and 1985 (c) aerial images produced by MIPS at approximate scale 1:6000 with 1938 herbaceous opening, 60m, 100m, and 300m buffers shown in white.

Appendix II a. Dorchester Pond 1938 aerial image. Approximate scale 1:6000 with herbaceous opening, 60m, 100m, and 300m buffers in white.



Appendix II b. Dorchester Pond 1958 aerial image. Approximate scale 1:6000 with herbaceous opening, 60m, 100m, and 300m buffers in white.



Appendix II c. Dorchester Pond 1985 aerial image. Approximate scale 1:6000 with 1938 herbaceous opening, 60m, 100m, and 300m buffers in white.