Executive Summary

Carolina bays are unique wetland landforms present in several states along the Atlantic Coastal Plain. As suggested by their name, most bays are found in the states of North and South Carolina. Each of those states conducted systematic inventories of their bays during the 1980s (Nifong 1982, Sarsony 1991, Weakley 1982, and Bennett and Nelson 1991). It was important for Georgia to follow suit and investigate the status of Carolina bays within its borders. The results of this study are particularly poignant considering the 2001 US Supreme Court decision on SWANCC vs. USACE which enervated legal protections for isolated wetlands under the Clean Water Act.

Because degradation of isolated wetlands could occur at an accelerated pace, it was important to find out where these bays are, the status of their condition, and to spread the word of their importance.

Five-hundred twenty-eight (528) bays covering over 27,000 hectares (ha) were identified and digitized into a GIS coverage. These bays were remotely assessed via recent oblique color aerial photographs taken by the USDA Farm Services Agency. Each bay was assessed for seven parameters, including General Integrity, Ditching Intensity, Rim Condition, Buffer Condition, Dominant and Secondary Vegetation Types, and Natural Hydrologic Connectivity.

The values generated under this remote assessment were used to prioritize sites for aerial and ground surveys in the second phase of the project. Unfortunately, the second phase of the project revealed that the remote assessments generally depicted bays as being in a better condition than experienced on the ground. The assessment values also guided protection efforts. Biologists facilitated the acquisition of a 120+ ha Carolina bay in Screven County (Dixon Bay).

By demonstrating the degraded condition of bays in Georgia, it is hoped that the results of this report will encourage conservation of this important resource and will prompt further protection.

INTRODUCTION

Purpose

The purpose of this project is to assess the distribution, status, and diversity of Carolina bays in Georgia and to promote their conservation through landowner collaboration, acquisition, easements, and educational outreach.

The tasks of the first phase of the project were to create a GIS coverage of Carolina bays throughout the state and to assess their condition remotely by reviewing recent aerial photography. The second phase of the project was largely field-based and included aerial surveys, site visits to select bays, and collaborating with landowners to conserve and restore wetlands. Another aspect of the second phase was to gauge the accuracy of the remote assessment effort through ground-checks.

This project was funded in part by the U.S. Fish and Wildlife Service through Section 6 of the Endangered Species Act of 1973. Funding was provided specifically to assess the condition of habitats supporting several federally listed species including Canby dropwort (*Oxypolis canbyi*), pondberry (*Lindera melissifolia*), woodstork (*Mycteria americana*), among others.

Background

Carolina bays are elliptical wetlands found along the Atlantic Coastal Plain that typically share a suite of features including an oval or tear-drop shape, orientation along a NW-SE axis, a raised sand rim along the south and east margins, a depth profile that often increases from the NW to the SE, and fluctuating water levels.

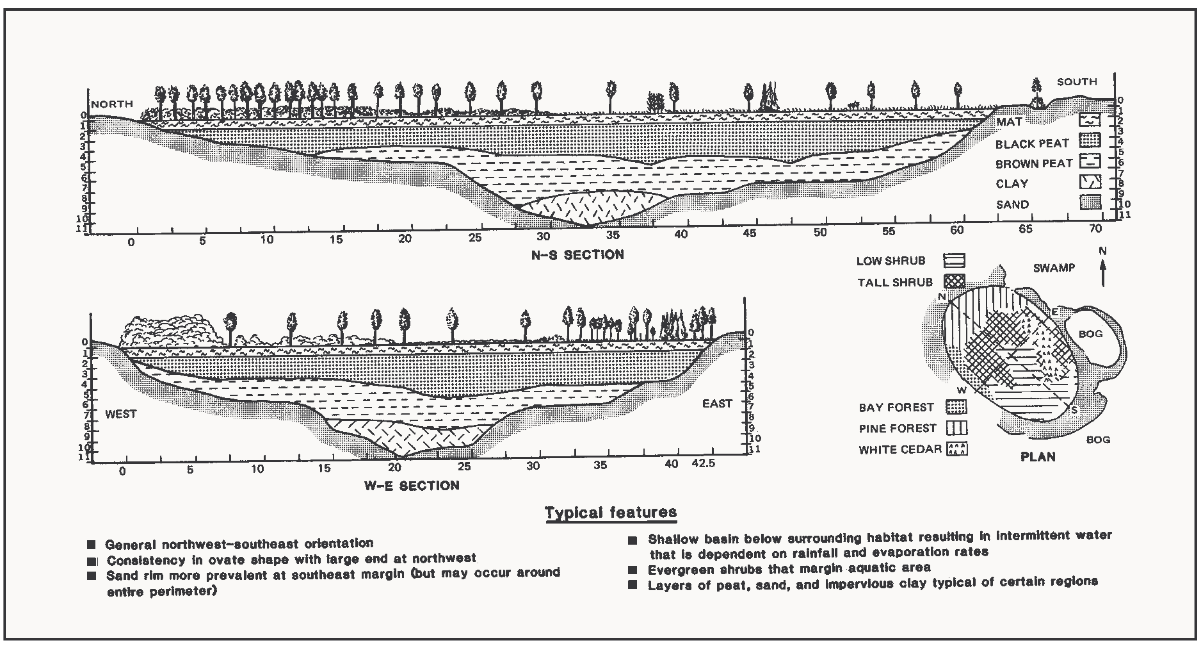

Figure 1. Cross section of a Carolina bay, indicating key morphological features, soil profiles, and vegetation types. Adapted from Sharitz and Gibbons (1982).

The uniformity of features found in Carolina bays has challenged theorists to propose a single mechanism for their development or creation. The challenge has spawned over a dozen theories on Carolina bay formation ranging from the plausible (e.g. subsidence features and wind events) to the fanciful (e.g. extra-terrestrial landing pads and ancient fish redds). Ultimately, there is no single accepted theory on their formation. In the scientific community, the most popular are those that attribute a complex of factors to bay formation and are typically based on combination of impacts from winds (Pleistocene storms) and water flow (Brooks *et al.*, 2001).

Not only is their formation a subject of some controversy, but even their name, "Carolina bay," causes some speculation. One might assume that Carolina bays are so called because they serve as an embayment of water, but it is widely believed that the name is derived from the fact that several plant species generally known as "bays" inhabit the margins of these wetlands. These include species like sweet bay (*Magnolia virginiana*), loblolly bay (*Gordonia lasianthus*), and red bay (*Persea palustris*).

sweet bay (*Magnolia virginiana*)

loblolly bay (*Gordonia lasianthus*)

red bay (*Persea palustris*).

Figure 2. Line drawings of species of "bay." From left to right: sweet bay (*Magnolia virginiana*), loblolly bay (*Gordonia lasianthus*), and red bay (*Persea palustris*) [modified from Godfrey (1998)].

While the presence of elliptical wetlands were recognized by early European settlers, Carolina bays were probably not fully appreciated (or so contentiously discussed) until aerial photography was first made available in the 1930's. It was then that the regularity of shape and orientation of bays prompted many to start investigating this phenomenon.

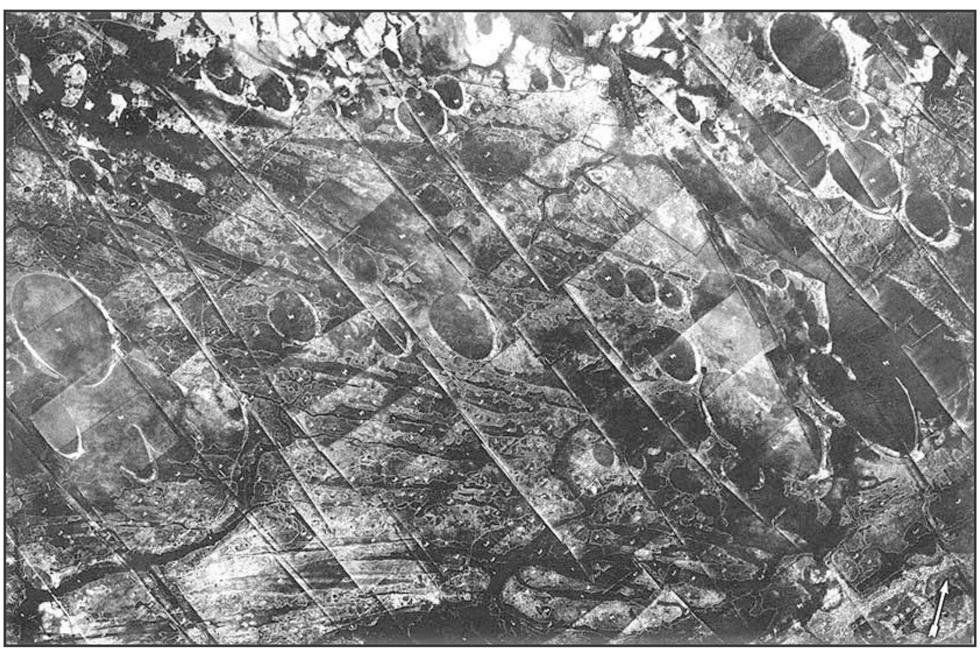

Figure 3. A 1930 aerial survey covering around five hundred square miles of coastal plain near Myrtle Beach in Horry County, South Carolina was undertaken by Fairchild Aerial Surveys for the Ocean Forest Company (Kobres 2001).

CONSERVATION OF CAROLINA BAYS IN GEORGIA

Beyond the aesthetic curiosity that Carolina bays provide, bays are ecologically valuable for a myriad of reasons, some of which are illustrated below.

VALUES OF CAROLINA BAYS:

Habitat & Species Diversity
Amphibian Refugia
Rare Species
Wetland Functions

Support Wide Range of Habitats: The very gradual wetland gradient present in many bays provides for a wide range of habitats from ephemerally flooded shrub lands to perennially flooded emergent vegetation ponds. Moreover, since many bays also contain sand rims along their southeastern margin, a variety of xeric habitats and species associates can be found.

Provide Amphibian Refugia: Many Carolina bays typically fill with water in winter but then dry up periodically in summer. This dry period tends to exclude fish, thus providing a safe environment for breeding amphibians. The rare flatwoods salamander may find refugia in Carolina bays (Figure 4).

Provide Habitat for Rare Species: Dozens of rare species in addition to the federally-listed species previously mentioned inhabit the environments of Carolina bays. Reference Tables 1 and 2 for lists of rare plant and animal species potentially occurring in the Carolina bays of Georgia. These were the targets of Phase II of this project. Table 3 lists animals that are now extirpated or extinct which may have used these habitats.

Provide Some Wetland Functions: Like other wetlands, bays can purify water through physical filtering, heavy metal adhesion to organic substrates, microbiological processing, and plant uptake of nutrients and heavy metals. Bays can also store stormwater.

One might suspect that Carolina bays would be centers of endemism based on their uniformity of character, relative hydrologic isolation, and clustered distribution. In actuality, few endemic species have been identified. The exception to this rule is Lake Waccamaw, a 3,600 ha (9,000 ac) bay in North Carolina with an unusually high pH. A couple species of mussel, snail, and fish are recognized as being endemic. These include the Waccamaw spike (*Elliptio waccamawensis*), Waccamaw fatumucket (*Lampsilis fullerkati*), the undescribed Waccamaw snail (*Amnicola* sp. 1) and Waccamaw silt snail (*Cincinnatia* sp. 1), Waccamaw silverside (*Menidia extensa*), and Waccamaw darter (*Etheostoma perlongum*) (LeGrande, *pers. comm.*).

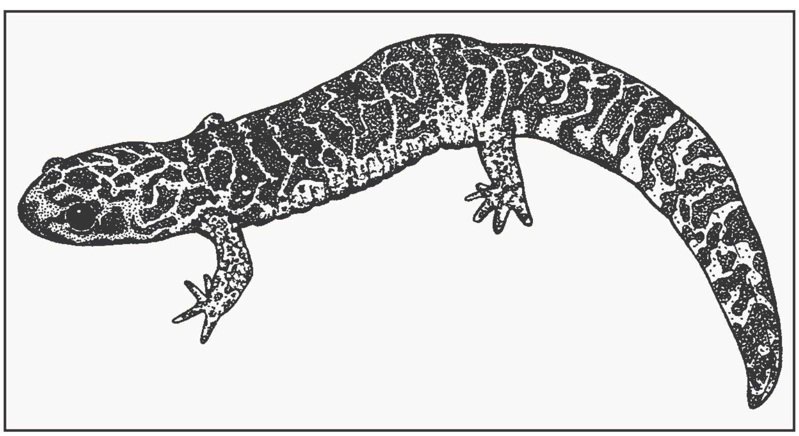

Figure 4. Illustration of a flatwoods salamander (*Ambystoma cingulatum*), one of the rare amphibians in Georgia that may use Carolina bays for breeding. Habitat loss has caused a serious demise for this species. Across its entire range, only about 10% of the historical sites still contain flatwoods salamanders.

Table 1. Rare plant species potentially in the habitats associated with Carolina bays in Georgia.

Scientific name	Common name		Scientific name	Common name
Agalinis filicaulis	spindly purple foxglove		*Panicum neuranthum*	panic grass
Andropogon mohrii	bog bluestem		*Panicum tenerum*	panic grass
Carex fissa var aristata	sedge		*Paspalum dissectum*	Walter's paspalum
Carex reniformis	reniform sedge		*Pentodon pentandrus*	pentodon
Cirsium lecontei	Leconte thistle		*Plantago sparsiflora*	pineland plantain
Cirsium virginianum	Virginia thistle		*Platanthera integra*	yellow fringeless orchid
Croton elliottii	Elliott croton		*Polygala balduinii*	white milkwort
Cyperus lecontei	Leconte flatsedge		*Ptilimnium nodosum*	mock bishop-weed
Drosera tracyi	threadleaf sundew		*Rhexia aristosa*	awned meadowbeauty
Eriocaulon texense	Texas pipewort		*Rhynchospora harperi*	Harper's beaksedge
Helianthus heterophyllus	wetland sunflower		*Rhynchospora oligantha*	feather-bristle beaksedge
Hypericum denticulatum	St. Johnswort		*Rhynchospora punctata*	pineland beaksedge
Ilex amelanchier	serviceberry holly		*Rhynchospora torreyana*	Torrey beakrush
Iris tridentata	Savannah iris		*Sarracenia minor*	hooded pitcherplant
Isoetes flaccida	white-spored quillwort		*Sarracenia psittacina*	parrot pitcherplant
Isoetes flaccida var alata	wingleaf white-spored quillwort		*Schoenolirion elliottii*	white sunnybell
Lindera melissifolia	pondberry		*Schwalbea americana*	chaffseed
Litsea aestivalis	pondspice		*Scirpus erismanae*	bulrush
Lobelia boykinii	Boykin lobelia		*Spermacoce glabra*	smooth buttonweed
Mecardonia acuminata var. *microphylla*	little-leaf mecardonia		*Spiranthes brevilabris* var *floridana*	ladies-tresses
Mitreola angustifolia	narrowleaf miterwort		*Sporobolus pinetorum*	pineland dropseed
Myriophyllum laxum	lax water-milfoil		*Sporobolus teretifolius*	wire-leaf dropseed
Oldenlandia boscii	bluets		*Vaccinium crassifolium*	evergreen lowbush blueberry
Oxypolis canbyi	Canby dropwort		*Zenobia pulverulenta*	zenobia
Oxypolis ternata	Savanna cowbane		*Zephyranthes simpsonii*	Simpson rain lily

Table 2. Rare animal species potentially in the habitats associated with Carolina bays in Georgia.

Scientific Name	Common name
Alligator mississipiensis	American alligator
Ambystoma cingulatum	flatwoods salamander
Amphiuma pholeter	one-toed amphiuma
Clemmys guttata	spotted turtle
Corynorhinus rafinesquii	Rafinesque's big-eared bat
Drymarchon couperi	Eastern indigo snake
Enneacanthus chaetodon	blackbanded sunfish
Gopherus polyphemus	gopher tortoise
Haliaeetus leucocephalus	bald eagle
Mycteria americana	wood stork
Necturus maculosus	mudpuppy
Necturus punctatus	dwarf waterdog
Necturus sp. cf. beyeri	Gulf coast waterdog
Neofiber alleni	round-tailed muskrat
Notophthalmus perstriatus	striped newt
Pseudobranchus striatus	dwarf siren
Rana capito	gopher frog
Rana virgatipes	carpenter frog

Table 3. Species believed to use Carolina bays which have presumably been driven to extirpation or extinction.

Scientific Name	Common name
Campephilus principalis	ivory-billed woodpecker
Conuropsis carolinensis	Carolina parakeet
Felix concolor coryi	Florida panther
Vermivora bachmanii	Bachman's warbler

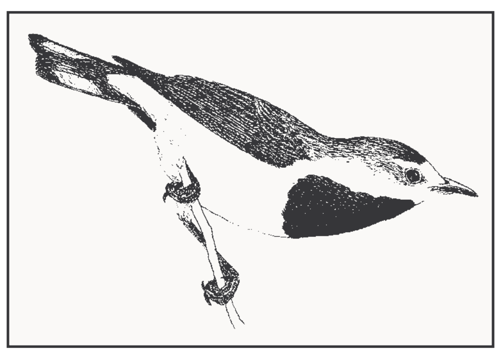

Figure 5. The Bachman's warbler, the rarest warbler in North America (believed by many to be extinct), has suffered tremendous habitat loss in both the U.S. and Cuban wintering grounds.

METHODOLOGY

The methodology of the first phase of the project involved defining a study area, digitizing the Carolina bay formations within the study area, and remotely qualifying their features and conditions based on recent aerial photography. The methodology of the second phase of the project involved aerial surveys of bays by helicopter as well as ground visits.

Determining the Macro Study Area

To determine the appropriate study area, a variety of methods was employed, including referencing existing works, reviewing LandSat imagery, and inspecting USGS topographic maps. Notable documents referenced include Prouty (1952) and an unpublished map by Sam Pickering that was later presented in Wharton (1978). As seen in Figures 6 and 7, Prouty (1952) was more inclusive in his definition of an acceptable Carolina bay and Pickering more exclusive. Prouty (1952) recognized bays occurring throughout the Georgia Coastal Plain as far west as Seminole County and even made mention of bay-like formations occurring in the Piedmont physiographic region (Jasper County, GA).

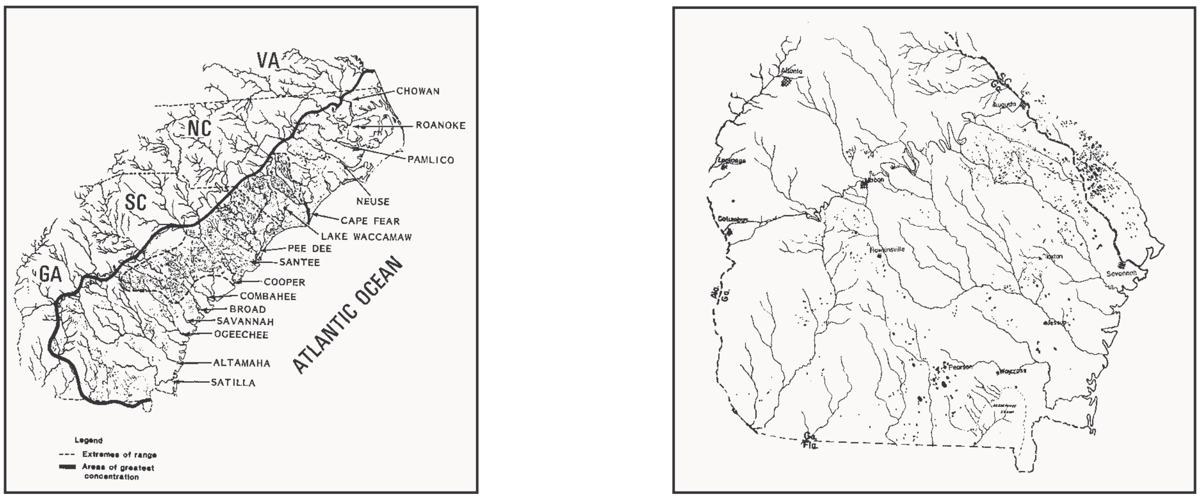

Figure 6. Distribution of Carolina bays in the Coastal Plain and in Georgia according to Prouty (1952). [Left] Range-wide map as modified by Sharitz and Gibbons (1982) and [Right] Georgia bays from the original Prouty (1952) map.

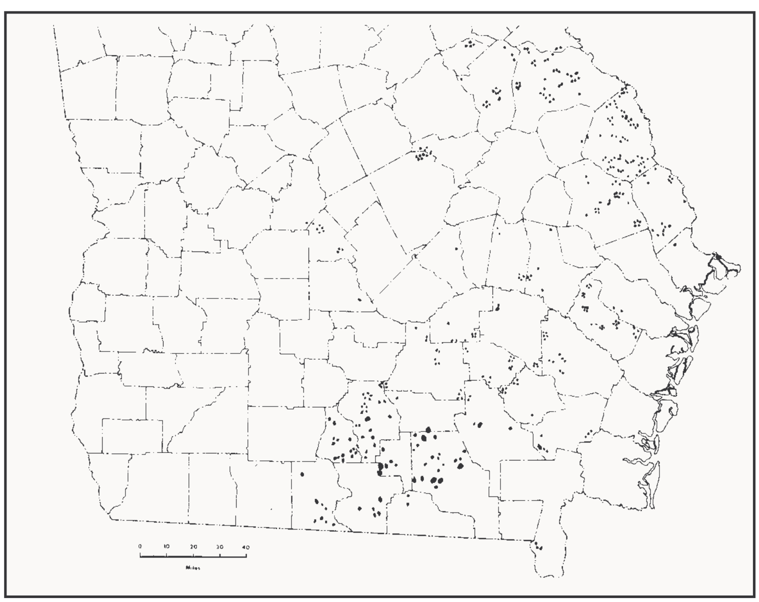

Figure 7. Distribution of Carolina bays in Georgia according to Wharton (1978). Notice that no bays are identified west of Brooks County.

If the distribution of Carolina bays had already been documented by two authors, why repeat the process? The answer is three-fold and is based on accuracy, detail, and reproducibility. ACCURACY: When either the Wharton or Prouty maps are super-imposed aerial photographs, it is clear that the bays identified on the distribution maps do not over-lay well on those bays evident in the photography and vice versa. DETAIL: Neither author conducted assessments of individual bays so their ecological status is unknown. Based on the intensifying impacts due to changes in regulatory interpretation (SWANCC v. USACE) and weather (droughts facilitate timbering in wetlands), it is important to establish baselines on the condition of Carolina bays in the state. REPRODUCIBILITY: Since GIS technology was not available to the authors during their investigations, it was impossible to create maps that were immediately reproducible at multiple scales with today's precision and to display those data based on any suite of attributes like size, condition, etc. In fact, the hardcopies of the Pickering map are no longer known to exist and the map is only represented on a small scale in Wharton (1978). For these and other reasons related to initiating protection and conservation efforts for bays and the rare species they support, conducting this investigation was warranted.

LandSat satellite imagery was also used to define the macro study area by recognizing wetland features with elliptical outlines. The satellite imagery used was captured in the winter of 1997 and 1998. Bands 4, 5, and 3 were mapped as red, green, and blue respectively to highlight wetland habitats. If a county was interpreted as having had at least one Carolina bay, it was included in the macro study area. Originally, there were 34 counties in the study area. Two counties were later dropped because no bays were observed in the current aerial photography. A third county was dropped because current aerial photography was unavailable at the time of remote assessment.

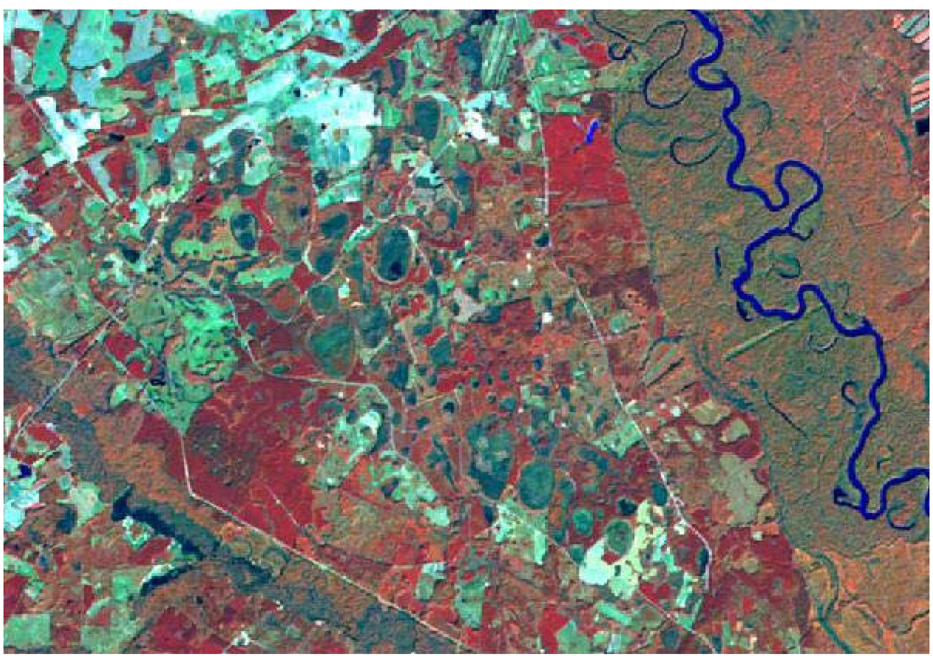

Figure 8. Example of satellite imagery used to define the macro study area. Note the Carolina bays in the center of the image. This image of Screven County shows the Savannah River to the east and Briar Creek to the Southwest.

Lastly, a review of topographic maps by the U.S. Geologic Survey and National Wetland Inventory delineation maps (NWI) by the U.S. Fish and Wildlife Survey provided insights into the statewide distribution of Carolina bays (see Figure 9). The topographic maps were particularly useful during the digitizing phase (described later).

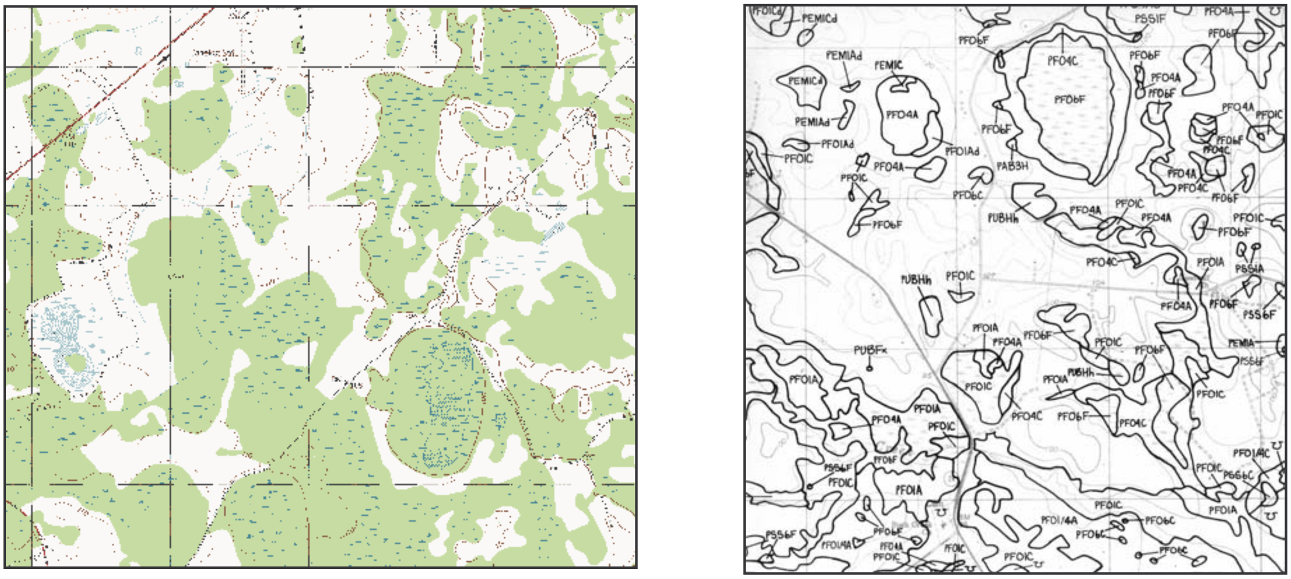

Figure 9. Examples of the USGS topographic maps (left) and USFWS NWI delineation maps (right) were used to define the macro study area. Both maps show a portion of Screven County. The topographic map is the Burton's Ferry quadrangle. The NWI map is for the Jacksonboro Bridge quadrangle.

Digitizing Carolina Bays

The GIS database of Carolina bays was developed in ArcView version 3.1 (ESRI corporation). Aerial photographs that were digitally rendered and orthographically rectified were projected at a scale of 1:12,000 for screen digitizing. Using the standard digitizing tools, the margins of Carolina bays (including the sand rim) were digitized in the graphics layer and subsequently transferred into a feature theme (shapefile) using a customized extension (Krakow, 2001a) named "StufShap.avx" (available on CD ROM). Figure 10 shows an example of a Carolina bay in the process of being digitized.

Figure 10. Example of screen digitizing from DOQQ imagery.

Navigating around the digital aerial photographs was facilitated by the development of customized script by Krakow (2001b) called "Pan95.ave" (available on CD ROM). The script pans the features in the View window 95% in one of four cardinal directions (up, down, left, right) depending on the combination of keys engaged when the button is clicked. This scripted ensured that all areas of a photograph were visually scanned for Carolina bays and reduced repetitive strain on the personnel doing the scanning.

Most of the supporting GIS datasets used during the project were acquired from the Georgia GIS Data Clearinghouse, such as the 1993 aerial photos from the National Aerial Photography Program (digital orthophotograph quarter quads or DOQQ) and Georgia County Road Maps (digital raster graphics or DRG) as well as feature theme data like county boundaries and rivers. The website to the Georgia GIS clearinghouse is:

http://gis.state.ga.us/Clearinghouse/Data_Library/data_library.html

Many other data sets, however, were created and maintained by the Georgia Natural Heritage Program including 7.5' topographic quadrangle (and quarter quad) boundaries, DNR property boundaries, rare species locations, and others.

Remotely Assessing Carolina Bays

The condition of Carolina bays was remotely assessed by reviewing aerial photography. The most contemporary imagery available for the study area was acquired from county offices of USDA Farm Services Agency (FSA) as part of their crop compliance program. The FSA imagery is low-level, true-color, oblique aerial photography (usually as slides) that is acquired at least once every year (often twice a year) and typically covers a majority of each county.

Each of the FSA offices that had slides was visited. Slides were projected onto FSA compliance tables using a standard slide projector (and sometimes a magnifying lens). Using this set-up, Carolina bays were remotely assessed for seven parameters

The seven parameters were: General Integrity, Ditching Intensity, Rim Condition, Buffer Condition, Dominant And Secondary Vegetation Types, and Natural Hydrologic Connectivity.

PARAMETERS & METRICS BY WHICH CAROLINA BAYS WERE ASSESSED

General Integrity
1 Great
2 Good
3 Fair
4 Poor
5 Very Poor
6 Destroyed

Ditching Intensity
0 None Perceived
1 Some
2 Intense

Rim Condition
0 No Rim
1 Intact
2 Some Disturbance
3 Intensively Disturbed

Buffer Condition
0 None
1 Some
2 Substantial

Dominant and Secondary Vegetation Types
0 Undeterminable
1 Woody
2 Herbaceous
3 Impacted Natural
4 Production

Natural Hydrologic Connectivity
1 Isolated
2 Partially Connected
3 Fully Connected

The metrics for these parameters were necessarily coarse due to the high variability in their expression and due to the quality and interpretability of imagery and the time available during this project to assess each bay (See inset box above). It was not practical, for example, for the investigators to measure the extent of ditches in each of the bays. Gauging many of these parameters is done relative to the size of the Carolina bay. Whereas an impact on a small bay might be considered intense, an impact of the same magnitude on a much larger bay might be considered inconsequential. An explanation of these parameters and examples are provided on the following pages.

Definition of Parameters with Examples

A brief explanation of the parameters is provided below. Reference Figures 11 through 22 for visual examples of how parameters were interpreted. Please note that while the examples provided are from 1993 black and white aerial photography, the actual assessment was conducted using photography from the offices of the USDA FSA previously described. Also note that the scale used in these examples is variable. These figures are intended to offer insight into how the parameters were rated.

General Integrity rates general ecological functioning and "naturalness." This parameter qualifies the condition of a bay considering a wide variety of factors, including but not limited to the other parameters. Values ranged from “Great” to “Very Poor” to “Destroyed.” This parameter was considered the primary rating for the bays and was used extensively in analysis and field surveys. It essentially captures and represents the investigator's overall "feel" for the bay.

Ditching Intensity qualifies the impact or intensity of ditching on the wetland. A large bay with a single ditch, for example 15 m long, might be rated as having "Some (ditching impact)" whereas a similar ditch in a smaller bay might be rated as having "Intense (ditching impact)" simply because the ditch is proportionately greater and presumably more effective in a smaller bay.

Rim Condition serves two functions: it first identifies whether a bay has a rim at all and secondly qualifies the degree to which the rim has been impacted. The sand rim of a bay that was impacted by a logging road or a small jeep trail might be rated has having "Some Disturbance," whereas the presence of a paved road, buildings, or pine plantation would be rated as being "Intensively Disturbed."

Buffer Condition qualifies whether the bay is surrounded by natural habitats. Although some bays may technically be surrounded by natural vegetation, if that buffer is narrow and effectively non-functional, the rating may be “None” or “Some.” It is not necessarily the absolute extent of buffer, but its proportion to the bay. A buffer of native vegetation in natural composition is important for several factors including temperature mediation, "edge" effects, water quality, and the needs of the fauna. Burke and Gibbons (1995), for example, provides an illustrative example of how turtles inhabiting Carolina bays require upland buffers between 73 m and 275 m from the margin of the bay to find suitable nesting and hibernation sites.

Dominant and Secondary Vegetation Types were assessed by classes rather than by the species composition, since specific vegetation types could not be accurately determined consistently. "Woody" included forested and shrub vegetation types and cypress savannahs with heavy tree cover. "Herbaceous" included true herbaceous cover, open cypress or shrub savannahs, and open water. The "Impacted Natural" class captured vegetation types like clear-cut areas, that were still composed largely of native species that were regenerating. "Production" included vegetation types like row crops, pine plantations, and pastures, or areas so intensively impacted by human activities that they no longer possessed natural wetland vegetation. There was an “Undeterminable” class for those with poor coverage or interpretability.

Natural Hydrologic Connectivity identifies whether a bay has any visible indication of being naturally connected to nearby fluvial systems (e.g. presence of hardwood strands). The key element of this parameter is the concept of being naturally connected. For example, if a Carolina bay is ditched and forced to drain into a nearby stream, that bay would still be characterized as being naturally hydrologically isolated because its connection to the stream was due to human efforts. This parameter is important to segregate from Ditching Intensity, because it identifies the degree to which bays are naturally isolated and provides some indication of the impact that the U.S. Supreme Court decision of SWANCC v USACE might have on wetlands of this type.

Figure 11. Integrity = 1 (Great)
Bays that appear able to support their ecological functions largely uninhibited are included in this ranking. This bay rated highly because it is large, with a majority of its margin is surrounded by relatively natural habitats. It also has no clear evidence of ditching, contains a variety of vegetation types, and shows little evidence of recent logging.

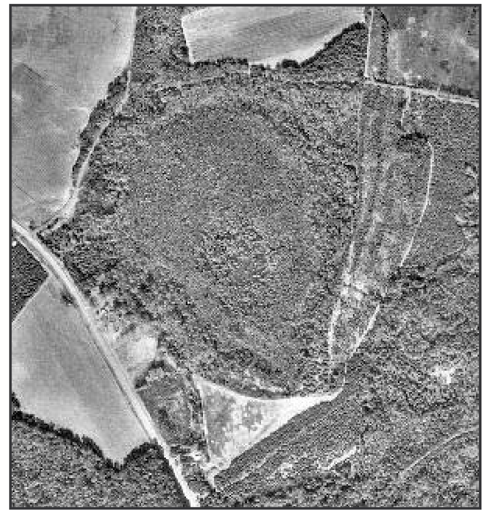

Figure 12. Integrity = 3 (Fair)
Bays that still perform their ecological services but have been impaired or limited in some manner are included in this ranking. Usually bays in this category are capable of being restored by simply allowing natural processes to play out. This bay rated more poorly because it is more isolated from connecting habitats, it appears to have a drainage ditch in the SW portion that appears to only be moderately effective, it is surrounded by roads, and its rim has been impacted by silvicultural activities.

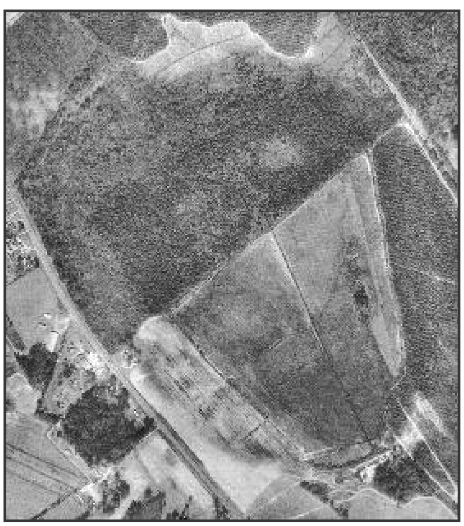

Figure 13. Integrity = 5 (Very Poor)
Bays in this category have been markedly disabled in their ability to provide important ecological services and are largely (but not entirely) degraded. Sites of this character can only be restored though an intensive and applied effort. This bay has been so ranked due to the intensity of ditching, removal of natural vegetation, relative isolation from surrounding habitats, proximity of large roads, intensity of impacts on the rim, and other factors.

Figure 14. Integrity = 6 (Destroyed)
Bays that are no longer capable of supporting any of their ecological functions and no longer support natural vegetation are classified as "destroyed." The effort required to restore such a bay would likely be cost prohibitive, if possible at all. Often, these bays appear on aerial photographs only as dark "stains" on the soil. These dark stains show up well in cultivated lands.

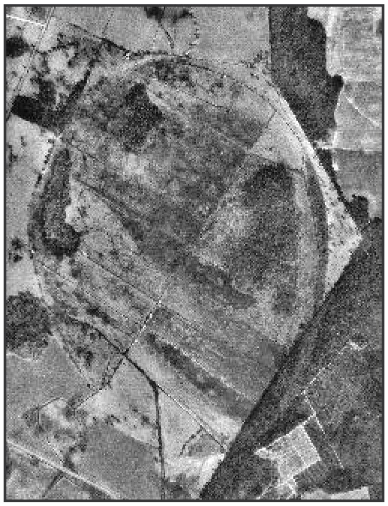

Figure 15. Ditching Intensity = 2 (Intense)
Although the outline of this Jenkins County bay can be deciphered, it no longer supports a natural hydrologic regime and no longer supports classic vegetation patterns of bays. There are multiple drainage canals evident in the photograph. The ditches have successfully drained this wetland.

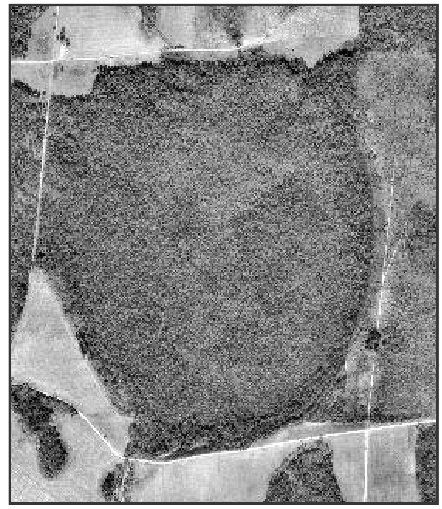

Figure 16. Rim Condition = 1 (Intact)
The rim of this bay is rated as intact. There are no roads built on the sand rim and no ditches appear to cut through it. The vegetation appears to be native and intact. This natural vegetation provides a buffer to the bay from adjacent land uses.

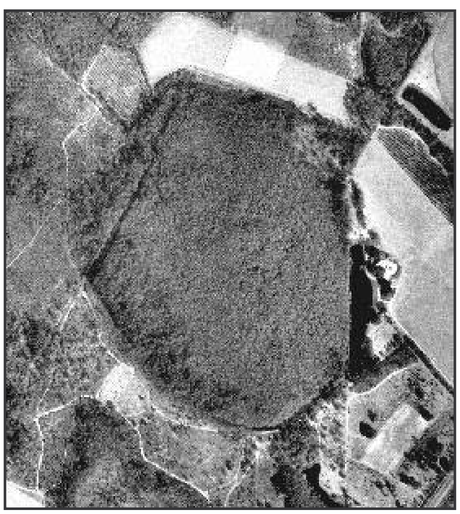

Figure 17. Buffer Condition= 0 (None)
This bay has no natural buffer left. It is surrounded by pastures, pine plantations, and agricultural fields. With this lack of buffer, run-off and sedimentation could threaten the integrity of the bay. The numerous roads also found near the bay further fragment the landscape.

Figure 18. Buffer Condition= 2 (Substantial)
Although a pine plantation can be seen as dark-colored vegetation in the lower left portion of the photo and a road encircles the lower portion of the bay, much of the margin of the bay has a continuous gradient between the wetlands of the bay and forested communities surrounding the bay. This Clinch County bay rated “Substantial” for Buffer Condition.

Figure 19. Vegetation = 2 (Herbaceous)
Both the medium-sized bay in the upper right corner and the larger bay in the lower right corner characterize the range of vegetation types that were collectively identified as "herbaceous." “Herbaceous" encompasses a wide range of habitats, including open water, truly herbaceous, and savannah. Part of the bay in the upper left corner has an open water condition, whereas the larger bay in the lower right represents a savannah type habitat. The savannah is recognized as having a light-colored and creamy textured field punctuated by the dark canopies of isolated trees. These bays are in Jefferson County.

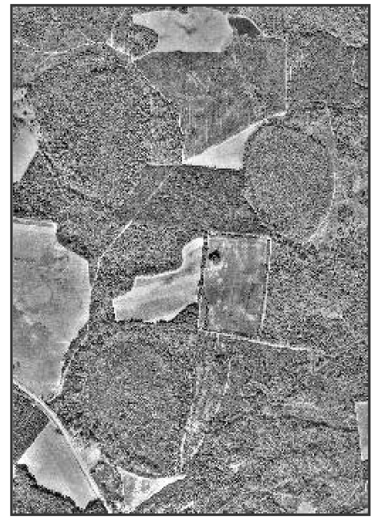

Figure 20. Vegetation = 1 (Woody)
All three bays in this Screven County photograph can be characterized as being "woody." The term "woody" also encompasses a wide variety of habitat types, including scrub/shrub, seasonally flooded palustrine hardwoods, cypress-gum swamps, etc. These habitat types are interpreted from the aerial photograph by a range of characteristics, but usually show-up medium to dark gray with ample stippling of light and dark punctuations, creating a moderately well-defined texture.

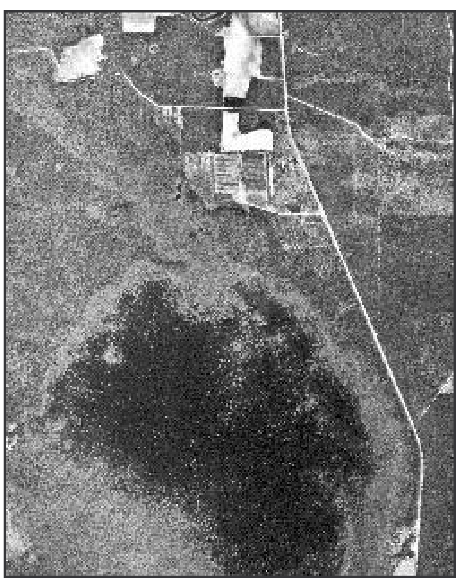

Figure 21. Hydrology = 3 (Fully Connected)
Close inspection of the northern portion of the bay reveals that the bay is connected with a linear wetland (i.e. a slough or stream). This connectivity represents part of the problem in defining a “true” Carolina bay.

Figure 22. Hydrology = 1 (Isolated)
Despite the fact that a ditch can clearly be seen in the five o'clock position, the bay was likely isolated, in its natural state, from other major water systems and wetlands. Incidentally, based on a field observation, one author reports that this ditch probably does not function effectively because it has collapsed. One might not guess as much by simply reviewing this photography.

While reviewing photos in the offices of the USDA FSA, data were entered directly into a laptop computer that displayed each bay in a GIS format. Data entry was facilitated by the development of a special ArcView extension developed by Krakow (2001c). The first time a user employs this extension, the Easy Field Entry extension, they hold down the Control button prior to clicking a feature. These keystrokes initiate a kind of "set-up screen" which asks the user to identify the fields for which data will be entered. From that point on, the user simply has to click on one of the features in the bay shapefile to bring up a dialog box with only the selected fields presented to receive data. This facilitates data entry by avoiding the need to open the Attributes Table, find the appropriate record, enter data cell-by-cell, then save the changes and close the Attribute Table.

To ensure that the investigators were properly orientated, 1993 DOQQs were displayed on the laptop along with the feature theme. Assessing bays in this fashion required as little as a half hour in counties with a small number of bays to an entire day in places like Screven County.

Unfortunately, the imagery available at all FSA offices was not of comparable quality. Some slides were out of focus, had obscuring cloud cover, or were improperly flown resulting in duplicate coverage in some areas and deficits in others. Moreover, there were instances where Carolina bays could not be assessed because portions of a given county had not been flown.

Field Surveys

During the second phase of the project, ground-truthing and field reviews of selected Carolina bays were conducted in nearly all of the 34 study-area counties. Investigators simply walked the property and visually inspected it for impacts and ecological signatures. Some impacts (e.g. ditching) are easy to identify whereas others (e.g. species composition or uniform age class structure) are much more subtle. Unfortunately, there was little time to conduct field reviews as detailed as the investigators would have preferred considering that there are some 27,000 ha of Carolina bay habitat to assess. Therefore, the results from these surveys were largely qualitative and serve to enhance the findings of the remote assessment.

Pictured to the right is a bay in Cook County, one of dozens of bays that was visited. This particular site is owned by the County in conjunction with part of a land-application water treatment system. Although this bay continues to support important ecological functions for wildlife, there is evidence (not shown here) that portions of the bay may be impacted by nutrient inputs.

Aerial Reviews

In order to field-assess a larger portion of the Carolina bays habitat, aerial surveys by helicopter were employed. On three occasions, DNR piloted helicopters surveyed most of the Carolina bays rated as Good or Great in most of the study-area counties. During the helicopter surveys, video along with still digital footage was captured. Several dozen slides, digital photographs and nearly six hours of digital video (3 CCD broadcast quality, 3:4, NTSC, 48 kHz) are available. Information from these flights also serves to enhance the findings of the remote assessment.