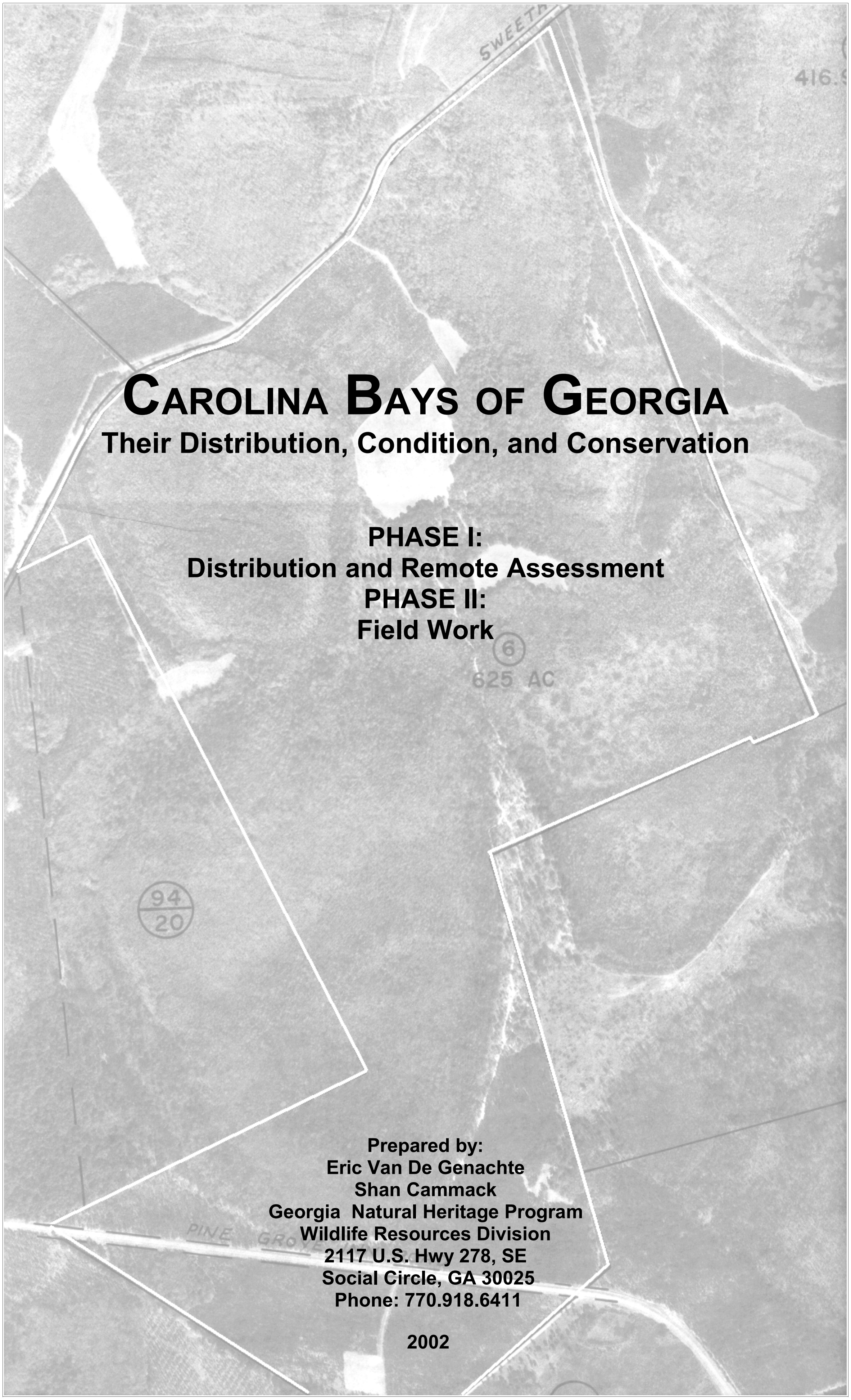


CAROLINA BAYS OF GEORGIA

Their Distribution, Condition, and Conservation

PHASE I:
Distribution and Remote Assessment
PHASE II:
Field Work

Prepared by:
Eric Van De Genachte
Shan Cammack
Georgia Natural Heritage Program
Wildlife Resources Division
2117 U.S. Hwy 278, SE
Social Circle, GA 30025
Phone: 770.918.6411

2002

CONSERVATION OF CAROLINA BAYS IN GEORGIA

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.

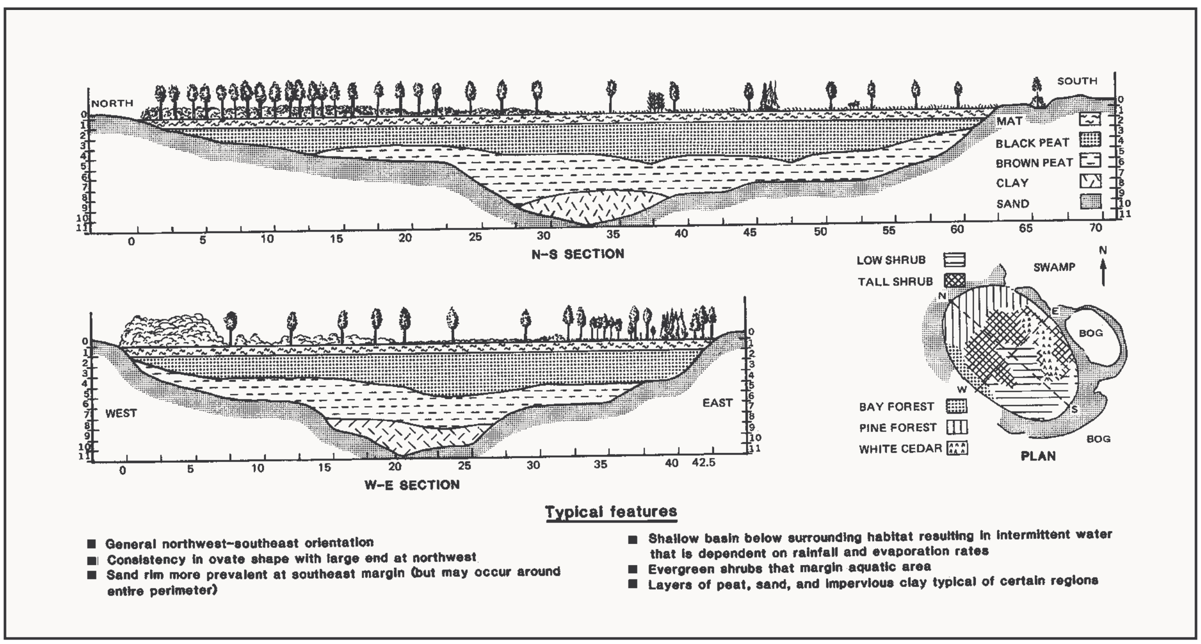


Figure 1. Cross section of a Carolina bay, indicating key morphological features, soil profiles, and vegetation types. Adapted from Sharitz and Gibbons (1982).

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.

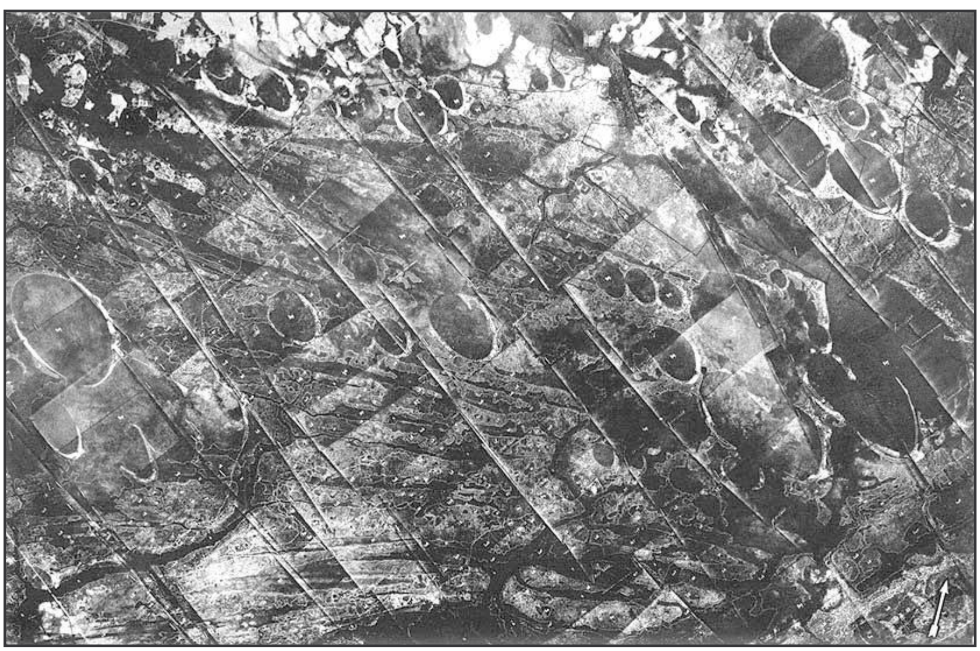


Figure 3. A 1930 aerial survey covering around five hundred square miles of coastal plain near Myrtle Beach in Horry County, South Carolina was undertaken by Fairchild Aerial Surveys for the Ocean Forest Company (Kobres 2001).

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.

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).

VALUES OF CAROLINA BAYS:

Habitat & Species Diversity
Amphibian Refugia
Rare Species
Wetland Functions

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.*).

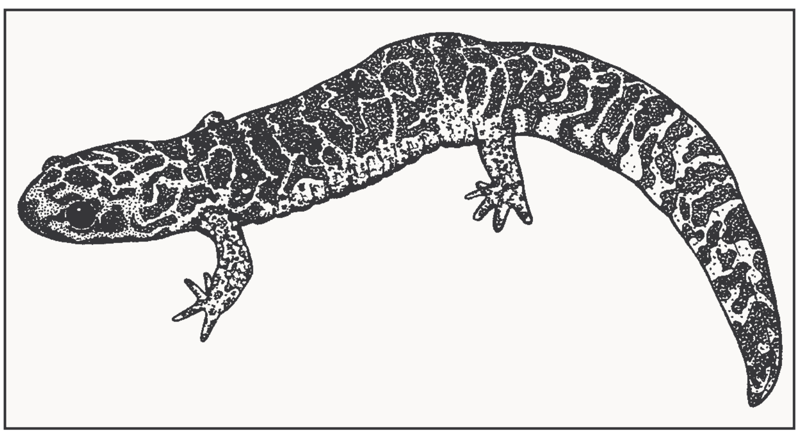


Figure 4. Illustration of a flatwoods salamander (*Ambystoma cingulatum*), one of the rare amphibians in Georgia that may use Carolina bays for breeding. Habitat loss has caused a serious demise for this species. Across its entire range, only about 10% of the historical sites still contain flatwoods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

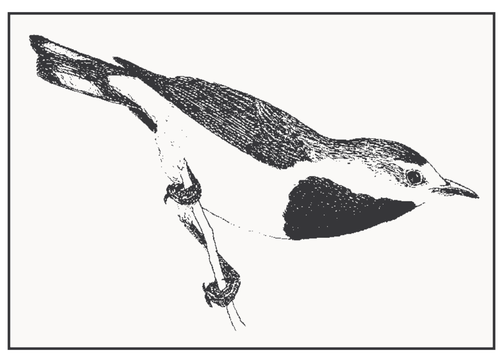


Figure 5. The Bachman's warbler, the rarest warbler in North America (believed by many to be extinct), has suffered tremendous habitat loss in both the U.S. and Cuban wintering grounds.

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).

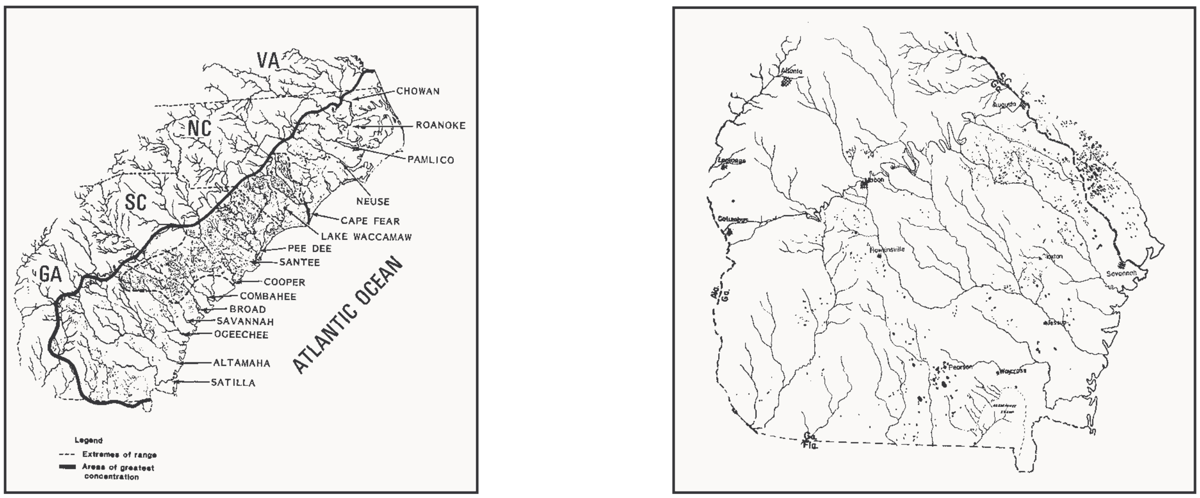


Figure 6. Distribution of Carolina bays in the Coastal Plain and in Georgia according to Prouty (1952). [Left] Range-wide map as modified by Sharitz and Gibbons (1982) and [Right] Georgia bays from the original Prouty (1952) map.

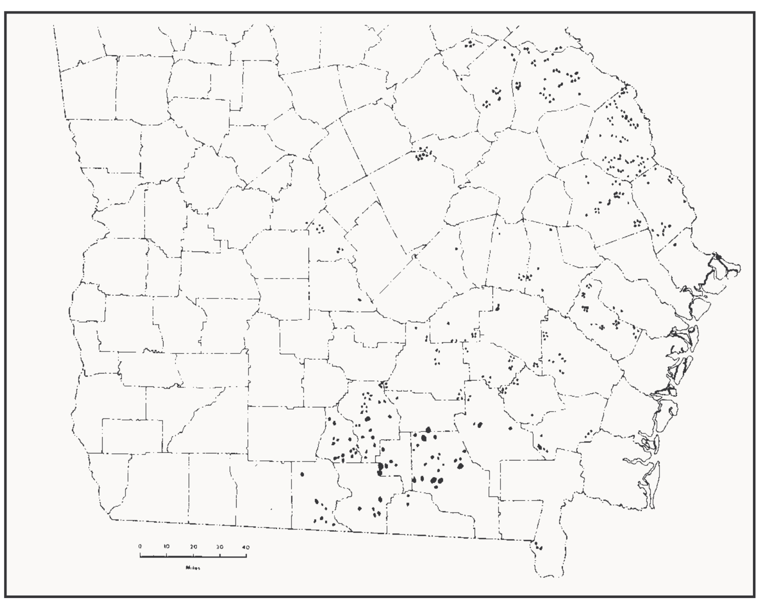


Figure 7. Distribution of Carolina bays in Georgia according to Wharton (1978). Notice that no bays are identified west of Brooks County.

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.

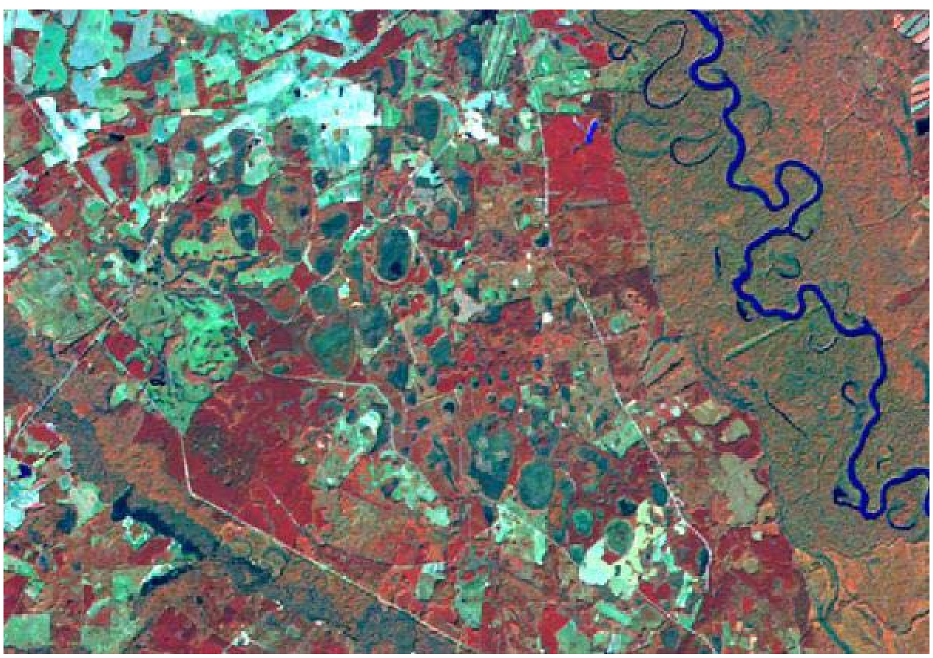
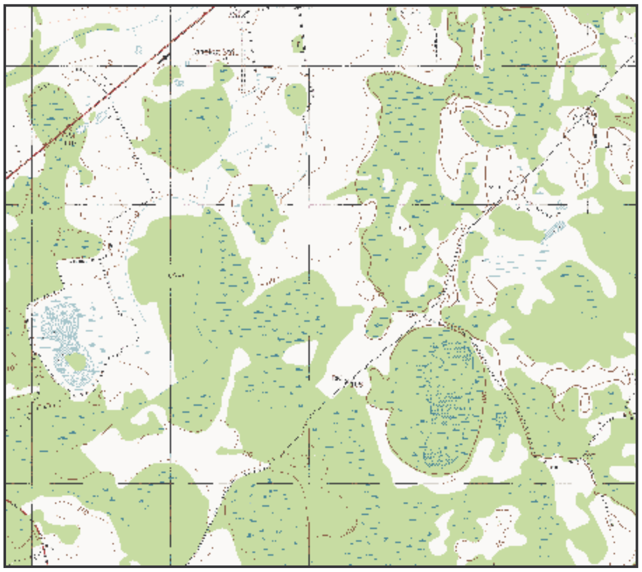


Figure 8. Example of satellite imagery used to define the macro study area. Note the Carolina bays in the center of the image. This image of Screven County shows the Savannah River to the east and Briar Creek to the Southwest.

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).



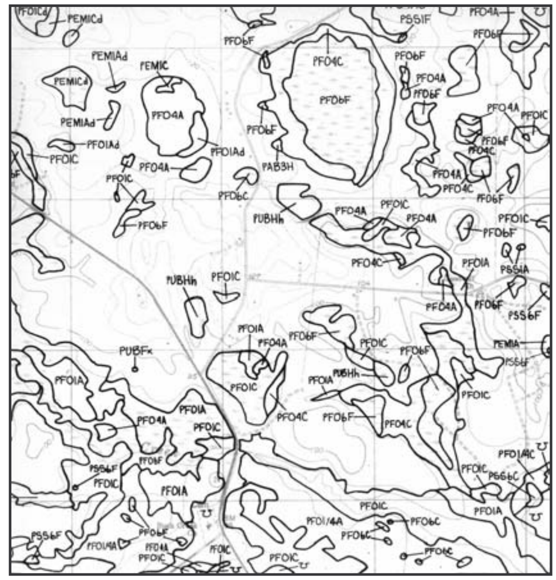


Figure 9. Examples of the USGS topographic maps (left) and USFWS NWI delineation maps (right) were used to define the macro study area. Both maps show a portion of Screven County. The topographic map is the Burton's Ferry quadrangle. The NWI map is for the Jacksonboro Bridge quadrangle.

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.

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.

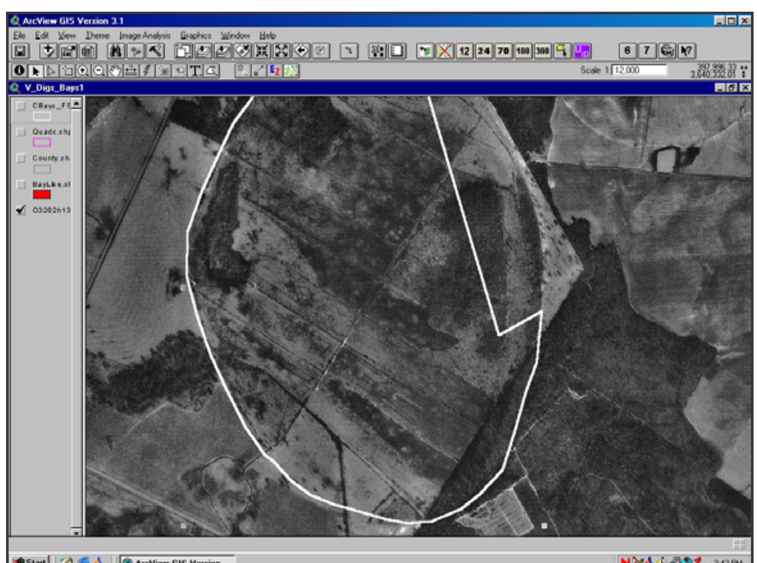


Figure 10. Example of screen digitizing from DOQQ imagery.

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.

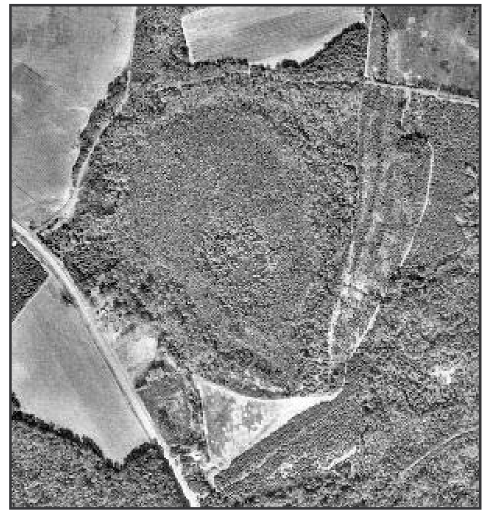


Figure 12. Integrity = 3 (Fair)
Bays that still perform their ecological services but have been impaired or limited in some manner are included in this ranking. Usually bays in this category are capable of being restored by simply allowing natural processes to play out. This bay rated more poorly because 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.

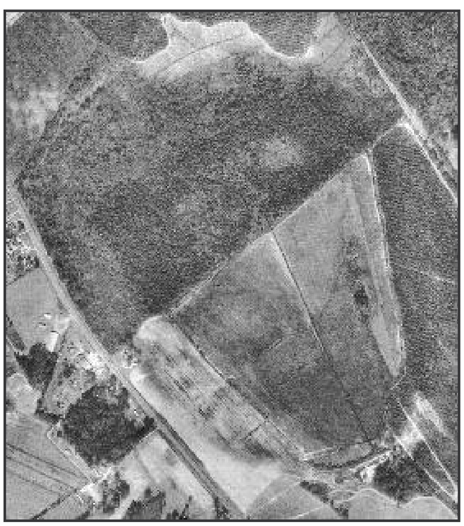


Figure 13. Integrity = 5 (Very Poor)
Bays in this category have been markedly disabled in their ability to provide important ecological services and are largely (but not entirely) degraded. Sites of this character can only be restored though an intensive and applied effort. This bay has been so ranked 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.

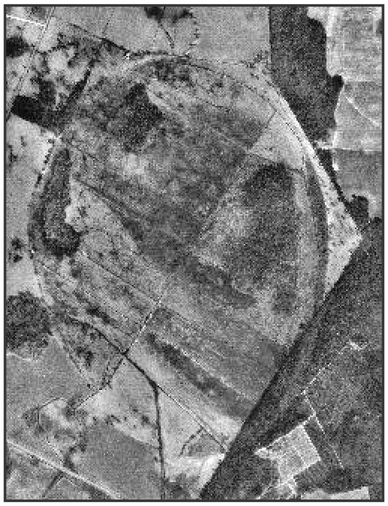


Figure 15. Ditching Intensity = 2 (Intense)
Although the outline of this Jenkins County bay can be deciphered, it no longer supports a natural hydrologic regime and no longer supports classic vegetation patterns of bays. There are multiple drainage canals evident in the photograph. The ditches have successfully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

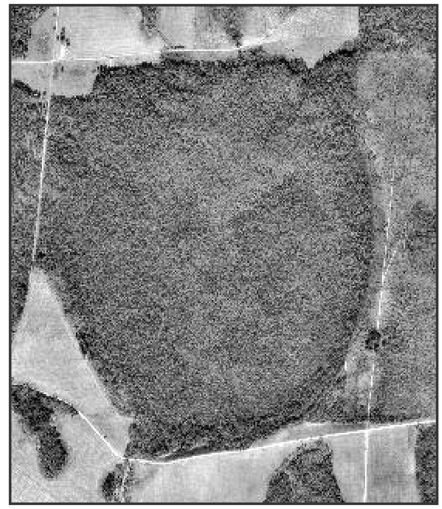


Figure 16. Rim Condition = 1 (Intact)
The rim of this bay is rated as intact. There are no roads built on the sand rim and no ditches appear to cut through it. The vegetation appears to be native and intact. This natural vegetation provides a buffer to the bay from adjacent land uses.

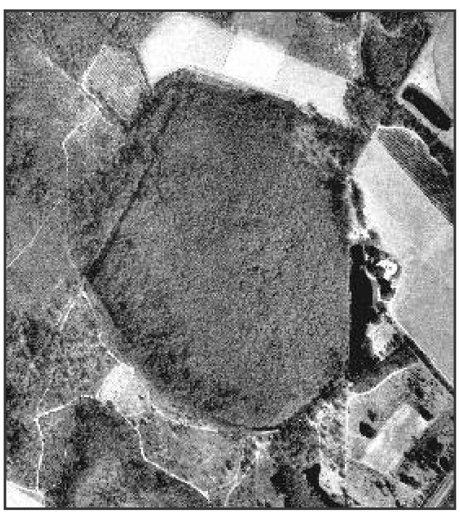


Figure 17. Buffer Condition= 0 (None)
This bay has no natural buffer left. It is surrounded by pastures, pine plantations, and agricultural fields. With this lack of buffer, run-off and sedimentation could threaten the integrity of the bay. The numerous roads also found near the bay further fragment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

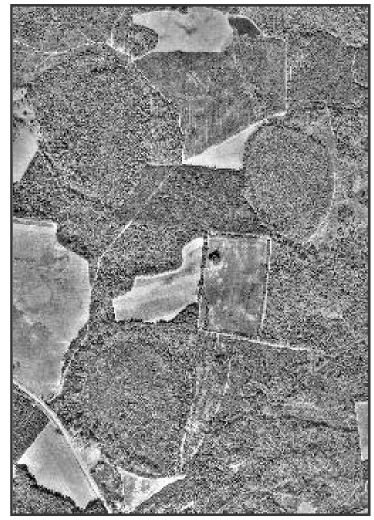


Figure 20. Vegetation = 1 (Woody)
All three bays in this Screven County photograph can be characterized as being "woody." The term "woody" also encompasses a wide variety of habitat types, including scrub/shrub, seasonally flooded palustrine hardwoods, cypress-gum swamps, etc. These habitat types are 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.

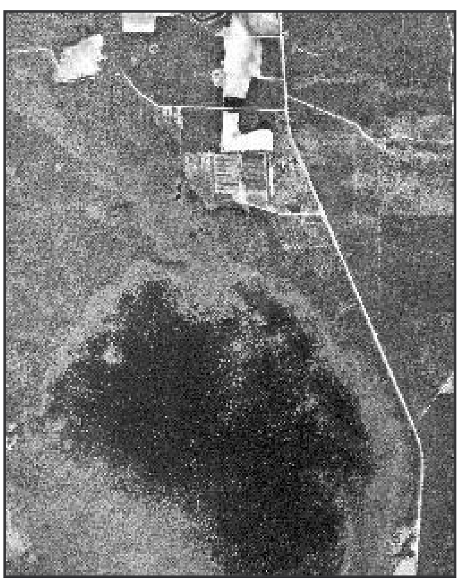


Figure 21. Hydrology = 3 (Fully Connected)
Close inspection of the northern portion of the bay reveals that the bay is connected with a linear wetland (i.e. a slough or stream). This connectivity represents part of the problem in defining a "true" Carolina bay.

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.

RESULTS AND DISCUSSIONS

Carolina Bays

A total of 1,194 DOQQs (digital orthographic quarter quadrangles) were visually surveyed for Carolina bays in 34 counties of the Georgia Coastal Plain. Five hundred twenty-eight Carolina bays were recognized and digitized, covering over 27,000 hectares. Figure 23 shows a distribution map of the currently recognized Carolina bays. Screven County contained the highest number (156) while Liberty County only contained one Carolina bay.

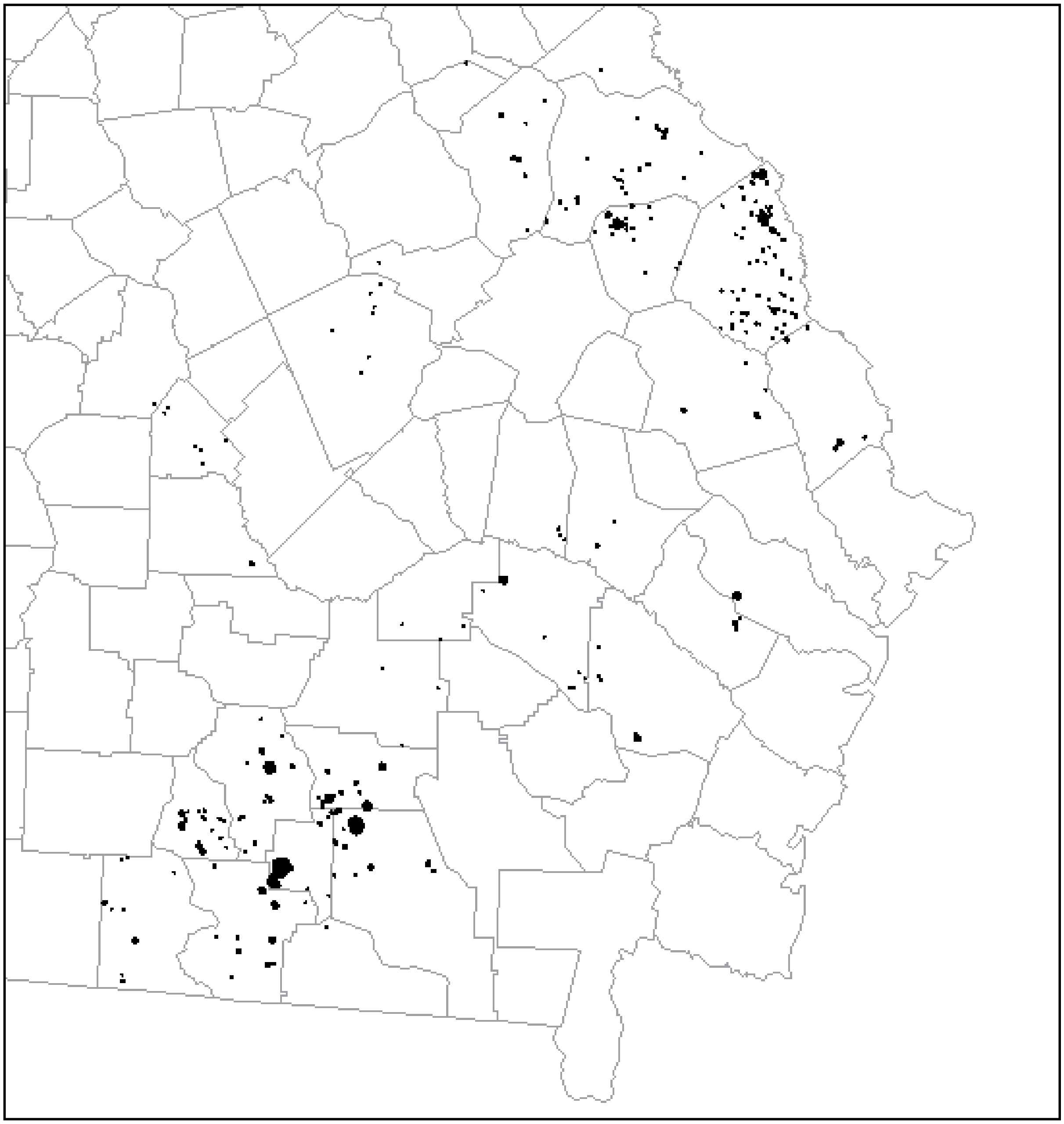


Figure 23. Distribution of Carolina bays as recognized by this project.

An additional 969 polygons were digitized during the review of the DOQQs representing wetlands that were similar to Carolina bays, but were ultimately not identified as such. As previously mentioned, Carolina bays are not defined by a single characteristic, but by several features and since not all Carolina bays possess all of the identifying features, distinguishing bays from other kinds of wetlands can be difficult.

Polygons for these non-Carolina bay wetlands were digitized for two reasons. First, it was anticipated that doing so might shed some light on the formation and variability of Carolina bays. Secondly, it was recognized that isolated wetlands can play an important role in the conservation of herptofauna. Attempting to capture these wetlands digitally, even in a haphazard fashion, would be valuable to those working to protect reptiles and amphibians. This goal was realized when another DNR staff member, Thomas Floyd, used the supplementary dataset of 969 polygons to identify potential habitats for the federally-listed flatwoods salamander (*Ambystoma cingulatum*).

The majority of *bona fide* Carolina bays were remotely assessed for the seven aforementioned parameters. The values for the "General Integrity" parameter were later used to prioritize bays for field assessments. A large majority of the bays (about 70%) were observed during aerial surveys. Actual field surveys occurred in about 10% of these Carolina bays.

In several instances, there are unique patterns that emerge in the distribution and orientation of the bays (see Figure 24). If these patterns help explain the genesis of Carolina bays, it was not made clear to the authors. In addition to the clustering of bays as seen in Figure 24, there are instances (e.g. Burke County) where Carolina bays or bay-like formations were distributed at regular intervals along a common axis, like islands of an archipelago. Often these "archipelagos" paralleled stream systems.

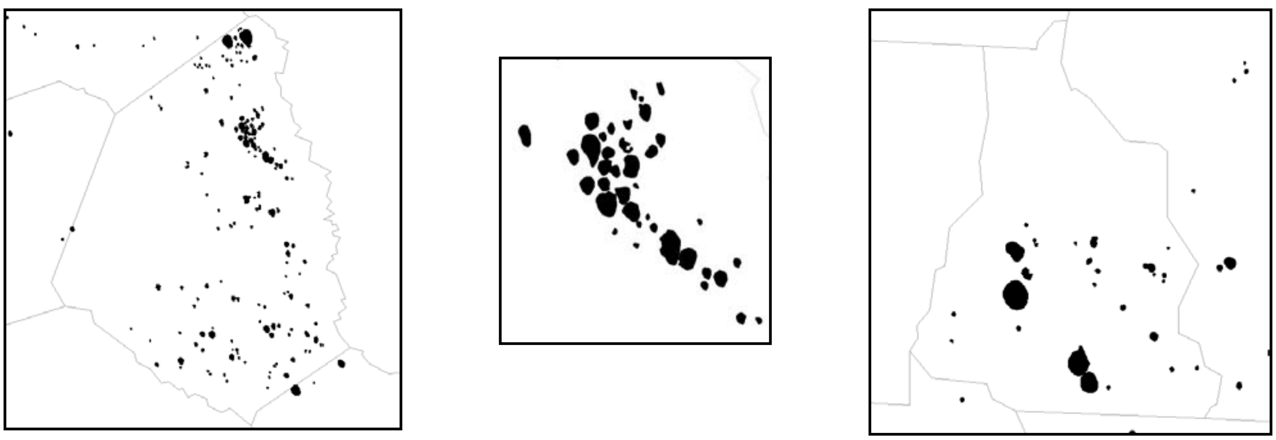


Figure 24. Pattern of distribution in Screven County (left and center close-up) and Cook County (right).

Size Distribution

This study focused on Carolina bays at or above 4 ha (10 ac). The 4 ha limit was based on an assumption that bays with less area would be perceived as being too small to warrant preservation efforts. Determining the area of bays was calculated in ArcView (ESRI) based on the extent of the polygons digitized for each of them. The area reported for bays is typically somewhat larger than the actual area of wetlands because the eastern sand rim was included when digitizing bays. Therefore, each polygon includes not only the wetland proper, but the perimeter hardwood "bay" forests, and the sand rim as well.

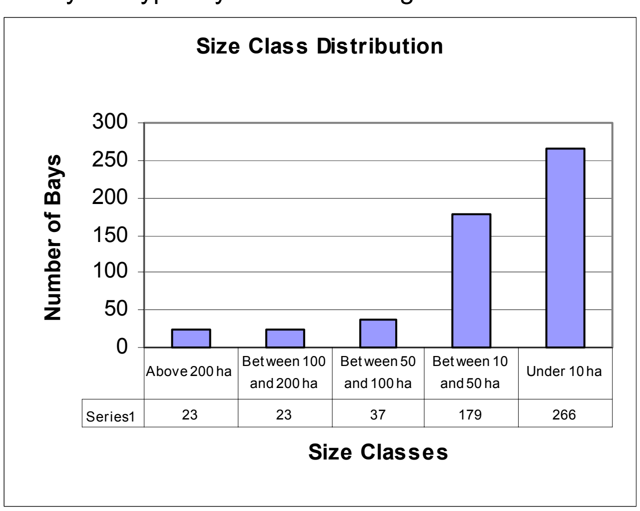


Figure 25. Size Class Distribution of bays.

The majority of bays delineated were small, with 445 under 50 hectares. Collectively, these smaller bays account for only 5,637 ha. Only 46 bays were above 100 ha, but represented a collective total of 16,820 ha. The largest is Banks Lake in Lanier County which contains almost 3,000 ha.

As Figure 25 shows, a large portion of bays in Georgia are small (< 10 ha) and most are no larger than 50 ha. Above 50 ha, there is a sharp drop in the number of bays in each of the larger size class, despite wider intervals in larger size classes. Surprisingly, although there are fewer bays in the three largest size classes, the relative number of bays in each of those classes remains remarkably similar.

Remote Assessment

General Integrity
Most bays were given an Integrity Index of either "Good" or "Fair," or were classified as being "Destroyed" (Figure 26). Less than two percent of the bays were rated as "Great." Areas for these bays ranged from 23 ha to the largest bay at 2,788 ha.

When there is a pronounced disparity between the percent of all bays and the percent of total area for each index rating, it is possible to surmise how very large or very small bays generally faired. For example, only a small percentage of bays qualified under the index rating of "Great," but those that did were likely large bays since it constitutes a large percentage of the total area of bays. In fact, 45.7% of bays above 100 ha were rated as “Great” or “Good” while only one fifth (19.9 percent) of the bays under 10 ha were so rated.

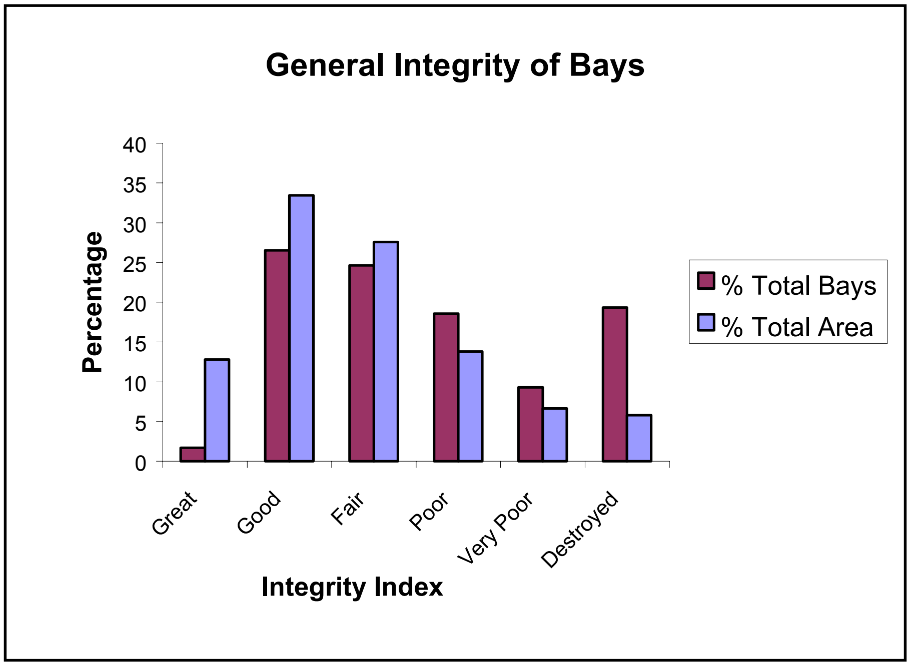


Figure 26. Integrity Index

Likewise, a large percentage of bays were rated as "Destroyed," but it represents only a small percentage of the total area of all bays. Only 28.2% of the larger bays were rated as "Poor," "Very Poor," or "Destroyed," while over half (52.3%) of the smallest bays were so rated. Of the 199 bays that were recognized as "Destroyed," 82% were under 50 ha. There was only one bay above 100 ha which was recognized as destroyed.

There is an additional degree of subjectivity when classifying bays as being "Destroyed" since it is only possible to assess the bays at a single point in time; that is, after their demise. Often, bays that have been destroyed appear on aerial photographs only as dark, elliptical stains on the ground. One might argue that bays that have been completely destroyed might not even produce such dark stains. Likewise, any drained wetland or pond leaving a dark, elliptical stain might have been misidentified as a expired Carolina bay. Arguably, any misidentifications were attributed to small bays more so than larger ones. Despite a bias toward overestimating the number of small bays destroyed, the authors believe that the data represent the true number as accurately as possible.

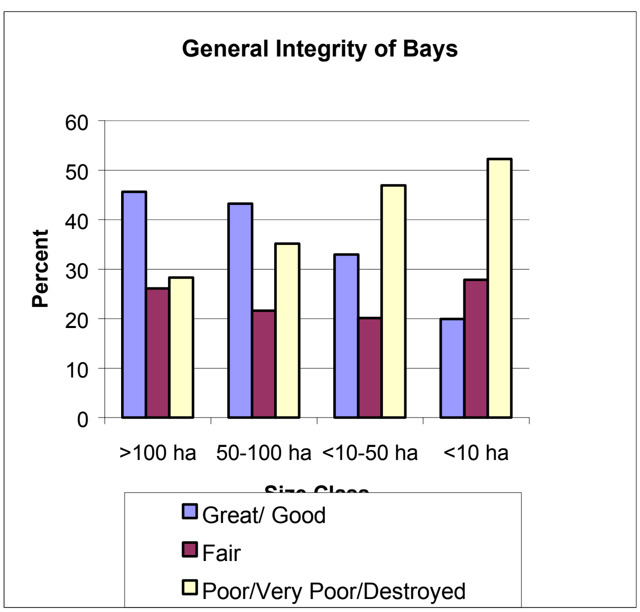


Figure 27 reveals that most bays greater than 50 ha were classified under General Integrity as being "Great" or "Good." Most bays 50 ha and less were classified as "Poor," "Very Poor," or "Destroyed." It is only in the smallest size class where the number of bays rated "Fair" was greater than the number rated "Good" or "Great."

This analysis recapitulates that many of the smaller bays have been intensively impacted and many of the larger bays remain better preserved.

Figure 27. Integrity Index by Size Class (Note that some ratings were concatenated in this graph).

Figure 28 on the following page represents the distribution of Carolina bays in Screven County as color coded by their "General Integrity " values. Maps of this nature were produced for all 34 study area counties (reference Table 4).

Table 4. All study area counties listed in alphabetical order for which maps depicting General Integrity values were produced.

1. Appling	18. Jenkins
2. Atkinson	19. Johnson
3. Bacon	20. Lanier
4. Berrien	21. Laurens
5. Brantley	22. Liberty
6. Brooks	23. Long
7. Bulloch	24. Lowndes
8. Burke	25. Pierce
9. Charlton	26. Pulaski
10. Clinch	27. Richmond
11. Coffee	28. Screven
12. Cook	29. Tattnall
13. Echols	30. Toombs
14. Effingham	31. Ware
15. Glascock	32. Wayne
16. Jeff Davis	33. Wheeler
17. Jefferson	34. Wilcox

Note that the fate of large bays in Screven County is somewhat atypical in that several have been intensively impacted (i.e. red fill coloration). These results were provided to demonstrate a contrast to land use patterns seen statewide. It may be that the presence of several large bays in a given area (like Screven County) warranted the development of an infrastructure (e.g. ditching equipment, etc.) to convert the wetlands to more "productive" uses.

There appears to be a lack of any geographic pattern in General Integrity values beyond bay size. In other words, there is little evidence that bays in one portion of the county were better preserved than in any other. This is a trend that tends to be true for most other counties.

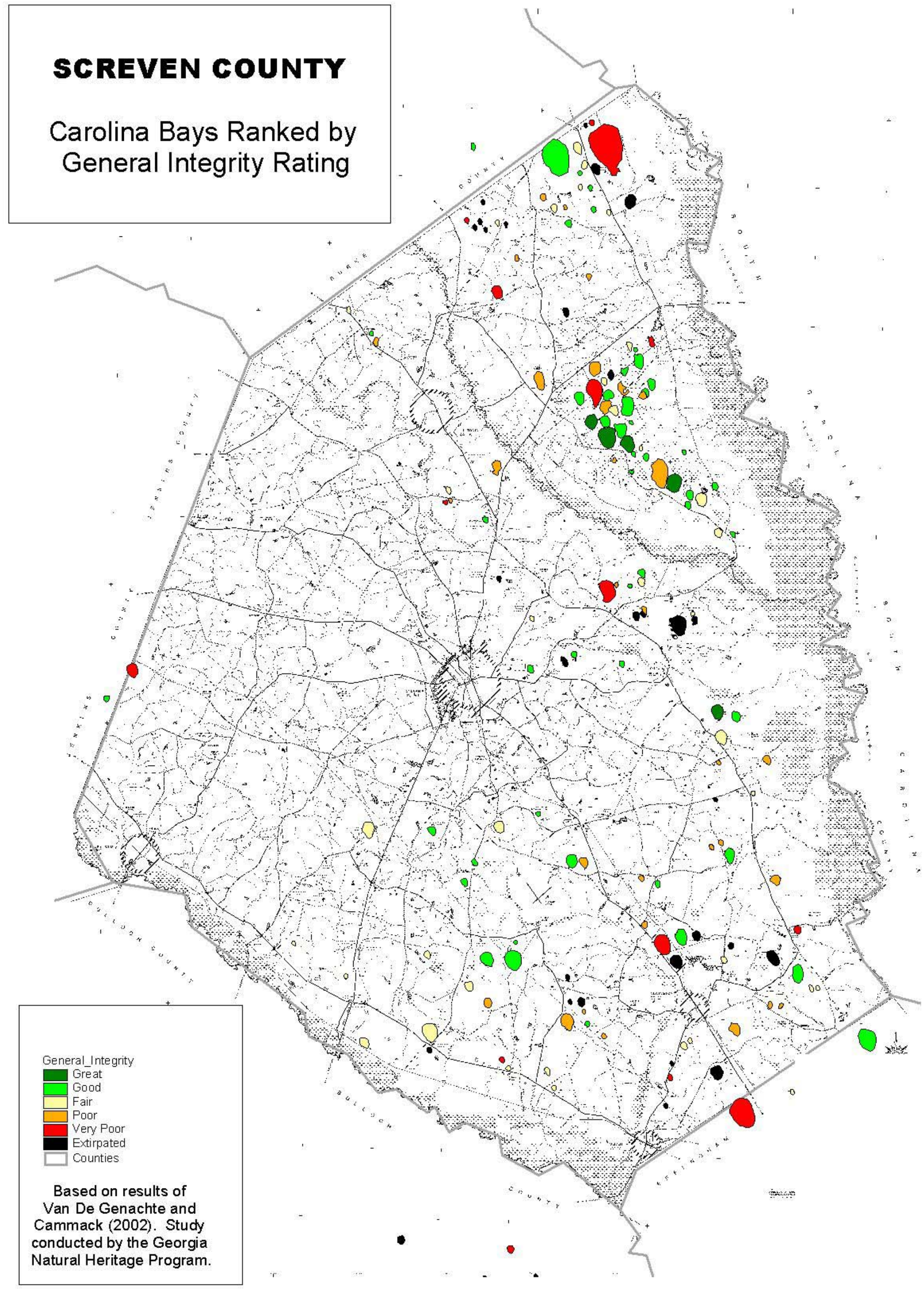


Figure 28. General Integrity of the Carolina bays in Screven County

Ditching Intensity

More than half of all bays (61.9%) showed at least some evidence of ditching (Figure 29). Almost three fourths of the largest bays (above 200 ha) exhibited at least some evidence of ditching.

Accuracy in determining the presence (and impact of) ditches in Carolina bays from aerial photography is compromised by several factors. For example, many older ditches can be obscured by canopy coverage. In some instances, a ditch may appear very prominently on an aerial photograph but may actually be non-functional on the ground, either because the ditch was insufficiently deep or because the sandy walls of the ditch simply collapsed, retarding water flow. Even artifacts in the photograph itself, like shadows or linear strips of vegetation can create a remarkably credible mirage of a ditch that never actually exists.

All these caveats notwithstanding, it is evident from these findings and from field surveys that most Carolina bays have been affected by ditching.

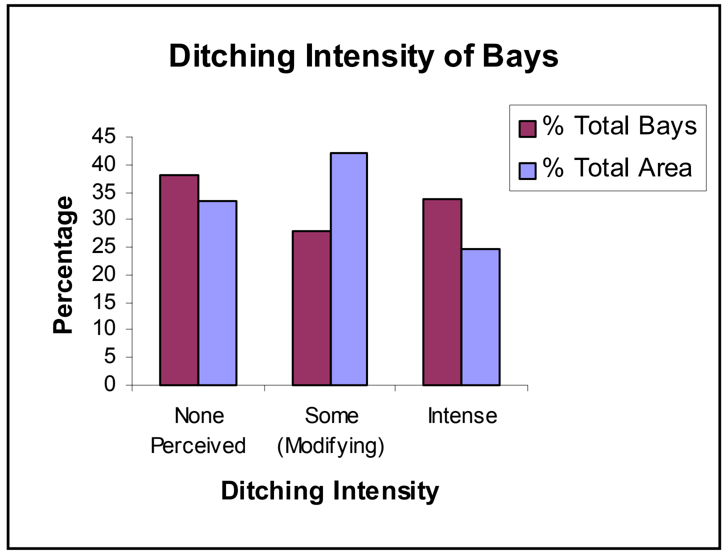


Figure 29 Intensity of ditching on the Carolina bays of Georgia.

Carolina bays are typically ditched in order to extract timber or peat or to render the land more economically valuable by converting it to row crop, pine plantation, or pasture land-uses. Field and aerial surveys document the degree to which ditching (in the form of crown-and-ditch roads) to facilitate timber extraction has been employed during the drought of the late 1990s and early 2000's.

The U.S. Supreme Court decision SWANCC v USACE, which established that isolated wetlands may not be recognized as "waters of the United States" and therefore not protected under the Clean Water Act, may result in intensified efforts to drain Carolina bays and result in detrimental impacts.

Rim Condition

One of the diagnostic features of a Carolina bay is the presence of a sandy rim along its eastern and southeastern margin. Although this is a feature common to many Carolina bays, not all bays have sand rims. Our results reveal that about half (52.7%) of the bays assessed have no recognizable sand rim. However, most of the bays with no rim were also the smaller bays as evidenced in Figure 28. Notice that although the percentage of bays with no sand rim is high, the total area of bays represented in this category is low (< 20%). In fact, of the 278 bays with no rim, 197 (or 70.9%) were smaller than 10 ha. Although larger bays tended to have discernable sand rims, the vast majority of them had at least some evidence of disturbance. Unfortunately, only 35 Carolina bays (representing 6.6%) had sand rims considered to be "intact."

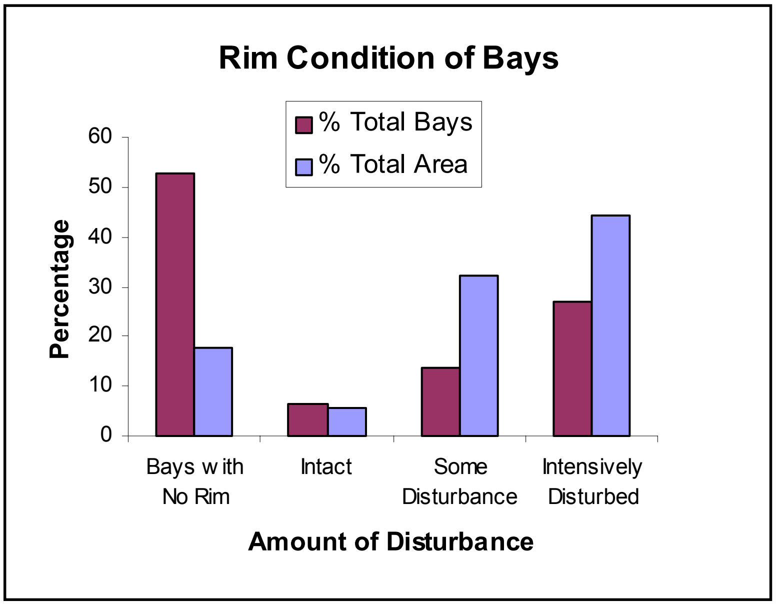


Figure 28 Condition of sand rims on Carolina bays of Georgia.

The types of disturbances suffered by sand rims varied little and typically included trail or road development, silvicultural activities, residential development, and in some cases agriculture. Although there is evidence from field surveys suggesting that the sand rims of some bays were mined, this appears to have been a relatively rare impact on bays. The impact of historical timbering can be difficult to assess remotely due to the redundancy in the vegetative signatures for the naturally sparse scrub-oak communities of deep, xeric sand rims and the regenerating forests of shallow, less xeric sand rims. Field surveys on these sand rims typically reveals heavy scrub oak communities with scattered remnants of pine stumps and bole cavities in the soil – presumably from longleaf pine (*Pinus palustris*).

Field surveys also revealed that areas of historical impact could be surmised based on the color and composition of the sands. Areas of the sand rim with the following characteristics presumably suffered few impacts: sands which were darker in color, contained an abundance of fine organic material, had little micro-site relief (i.e. were flat), moderately compacted, capable of sustained foot traffic without mixing, sustaining a diversity of herbaceous flora. On the other hand, areas of the sand rim with the following characteristics presumably suffered impacts, at least historically: bright white sands, little or no organic matter, considerable micro-site relief (i.e. were bumpy), loose, suffered mixing with foot traffic, sparse vegetation and low diversity. Although this might sound somewhat intuitive, there are areas with apparently robust vegetation, that on closer inspection reveal that historically, aggressive land practices were applied.

As would be expected, the size of a sand rim is at least roughly proportional to the size of the bay itself. Therefore, there is a likelihood that the small bays have sand rims that were so narrow that they were largely imperceptible from aerial photography. One would also expect that the likelihood of finding rare species on such sand rims would be low, despite the fact that they may be less impacted.

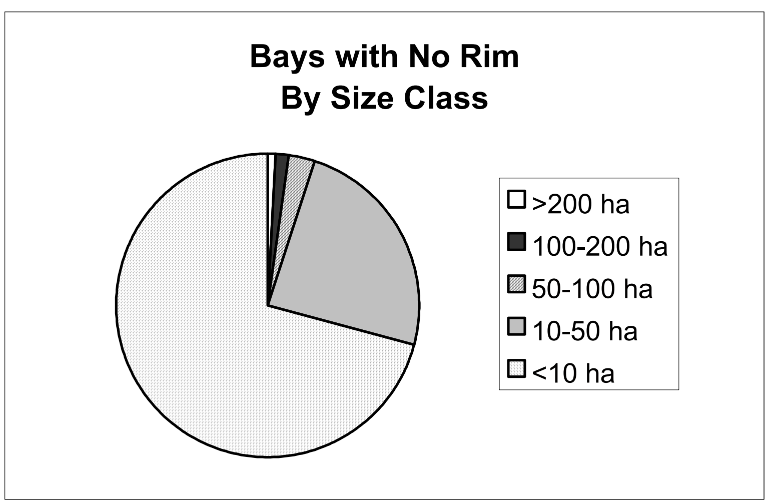


Figure 29 Carolina bays with no sand rim organized by size class.

Buffer Condition

Natural buffers were absent in many of the bays (Figure 30). Less than three percent of the bays (2.7%) were rated as having Substantial Buffers. In fact, almost three fourths of the bays did not have buffers. A buffer of natural vegetation around any habitat type, wetlands in particular, is important for satisfying the suit of resource needs by both aquatic and terrestrial fauna, amphibious fauna in particular.

A classic example is that identified by Burke and Gibbons (1995), who revealed that turtles inhabiting Carolina bays required nesting and hibernation sites that were well outside the perimeter of the bay itself (73 m to 275 m) and into the uplands. Another example, by Semlitsch (1998) identifies that salamanders were typically found in areas about 125 m from the margin of wetlands. In addition to providing individual animals with the complete suite of resources needed to survive, natural buffers maintain demographically and genetically healthy populations by permitting the regular migration.

Besides providing animals with necessary resources and travel corridors, natural buffers mitigate for abiotic influences outside the bay. Temperature extremes, over-land drainage rates, sedimentation (including aeolian deposition), chemical and nutrient run-off, soil moisture gradients, and other impacts are ameliorated by the presence of natural buffers. Recognizing that so few bays have substantial natural buffer is an omen to the long-term ecological health of these isolated wetlands.

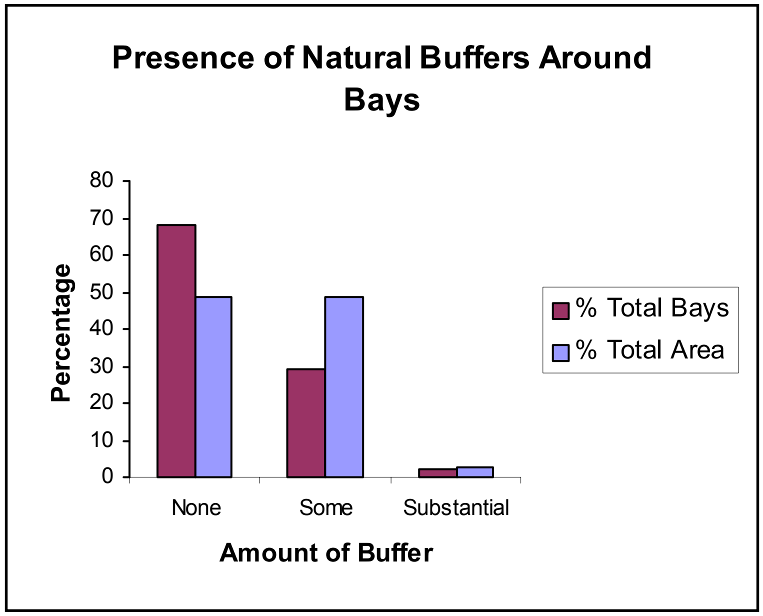


Figure 30 Percentage of Carolina bays with varying degrees of natural vegetative buffer.

As with many of the impacts reviewed previously, the absence of natural buffers was more prevalent in smaller Carolina bays than in larger bays. This is particularly significant due to the fact that the degree of buffer assigned to a bay during assessment was relative to the size of the bay. In other words, for a small bay to be rated as having substantial natural buffer requires only a fraction of the area necessary for a larger bay to be similarly rated.

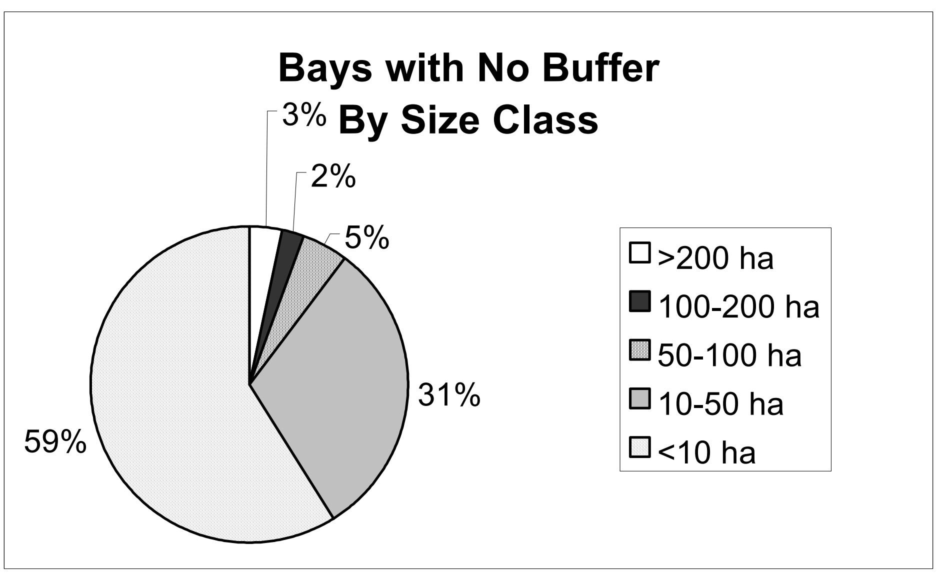


Figure 31. Carolina bays with no natural buffer organized by size class.

Dominant Vegetation

The definitions of Dominant and Secondary Vegetation parameters can be referenced under Methodology. The most common Dominant Vegetation classification for most bays Woody, meaning that means that the vegetation type of most bays was either forested and/or composed of heavy shrub-scrub. Large bays in particular are likely to be classified under the Woody vegetation type. Within size classes, the Woody categorization typically represented better than 40% of the total number of bays.

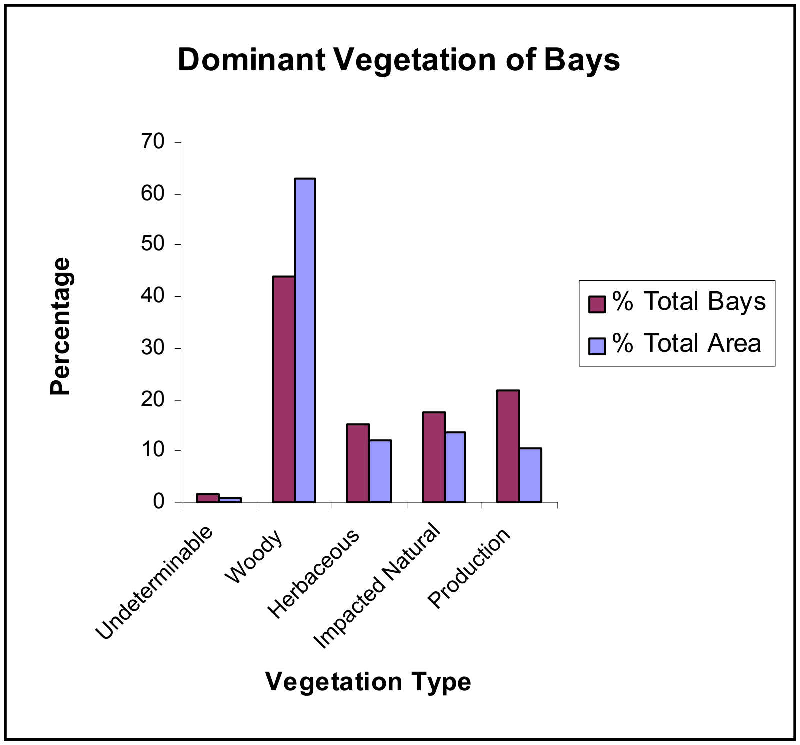


Figure 32. Percentage of bays classified by various Dominant Vegetation categories.

Unfortunately, the next two most frequent categories were Production and Impacted Natural, each accounting for approximately 20% of all bays.

It appears that the percentage of bays classified under Production increases somewhat as size class decreases – maximizing at almost 28% in the smallest size class (Figure 33). This might be suspected considering that the smallest bays have been those most impacted by other disturbances (e.g. ditching). Moreover, one would surmise that smaller bays are easier to convert than larger bays. The statistical significance of this trend has not yet been ascertained. No such trend is visually evident for the category Impacted Natural.

Considering the Production category represents bays converted to row crops, grazing, pine plantation and other intensive land uses and that Impacted Natural represents bays that have been clear cut, it is evident that a significant portion of all bays have been intensively impacted for economic return.

Although the Herbaceous category was much less common overall than the other natural vegetation type (Woody) it maintained a remarkably consistent proportion of bays within size classes. Between 10% and 20% of the total number of bays in any given size class were classified as Herbaceous. Project investigators were particularly interested in this value considering that the federally listed Canby dropwort (*Oxypolis canbyi*) would occupy habitats classified under this vegetation.

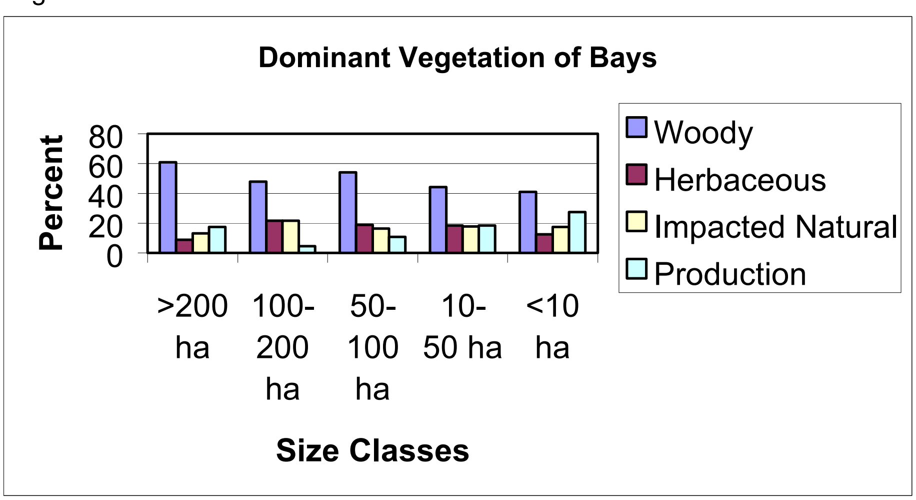


Figure 33. Percent of Carolina bays classified by various Dominant Vegetation types according to size class.

Secondary Vegetation

The parameter Secondary Vegetation identifies the second most abundant vegetation type (reference Methodologies for more detailed definition). Determining the second most extensive habitat was important in part because *Oxypolis canbyi* (Canby dropwort) was a primary target of this project and occurs in habitats that would be classified in this study as Herbaceous. Realizing that most bays are not completely herbaceous, it was important to be able to identify which bays contained at least *some* herbaceous cover that might serve as potential habitat for this species.

Consistent with the values found for the parameter Dominant Vegetation, most bays had Woody as the most frequently attributed Secondary vegetation type. Thereafter Impacted Natural (~20%) followed by Herbaceous and Production each accounting for approximately 10%. There were slightly more bays that could not be adequately assessed for Secondary Vegetation than for the Dominant Vegetation parameter.

The disparity between the two metrics (percent total bays and percent total area) for the secondary vegetation type Production, implies that smaller bays were more frequently impacted by intensive land use than larger bays. This suggestion is clarified by the results presented in Figure 35.

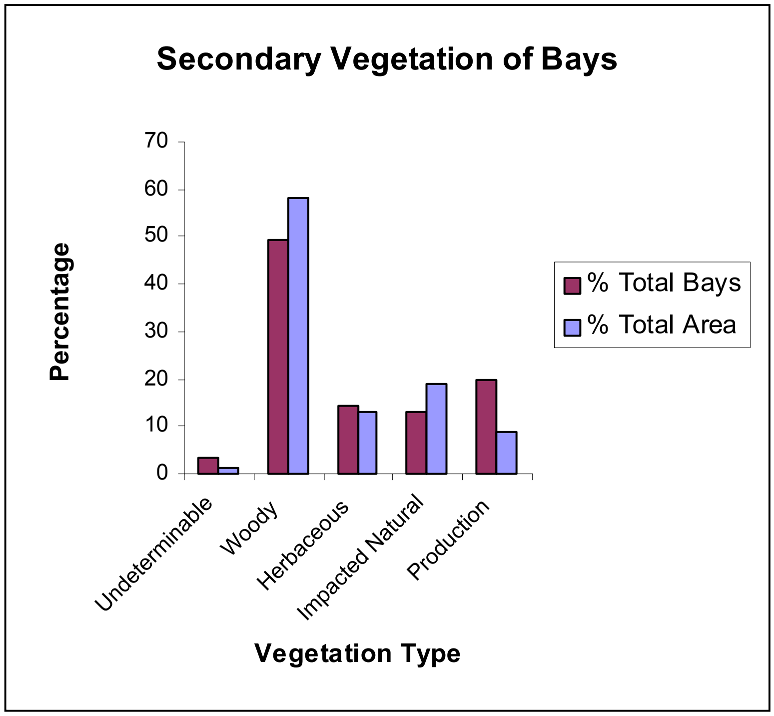


Figure 34. Percentage of bays classified by various Secondary Vegetation categories.

Figure 35 identifies that, in particular, bays less than 50 ha were much more likely to have been impacted by Production land uses. The reversing trend for the largest bays is unexplained by this data, but may be a function of several factors including few bays in that size class, the depth-profile of large bays, or the fact that the largest bays were targeted for conversion due to potentially greater return on investment for ditching efforts. Whereas the smaller bays were likely to be converted to Production, the mid-sized and larger bays were more likely to have been timbered for their hardwoods according to the percentage listed under Impacted Natural. Generally speaking, fifty percent of each size class was categorized as Woody. Larger bays with a little more than fifty and smaller bays (<50 ha) somewhat less. Bays between 10 ha and 100 ha were nearly twice as likely as other bays to have their Secondary Vegetation classified as Herbaceous.

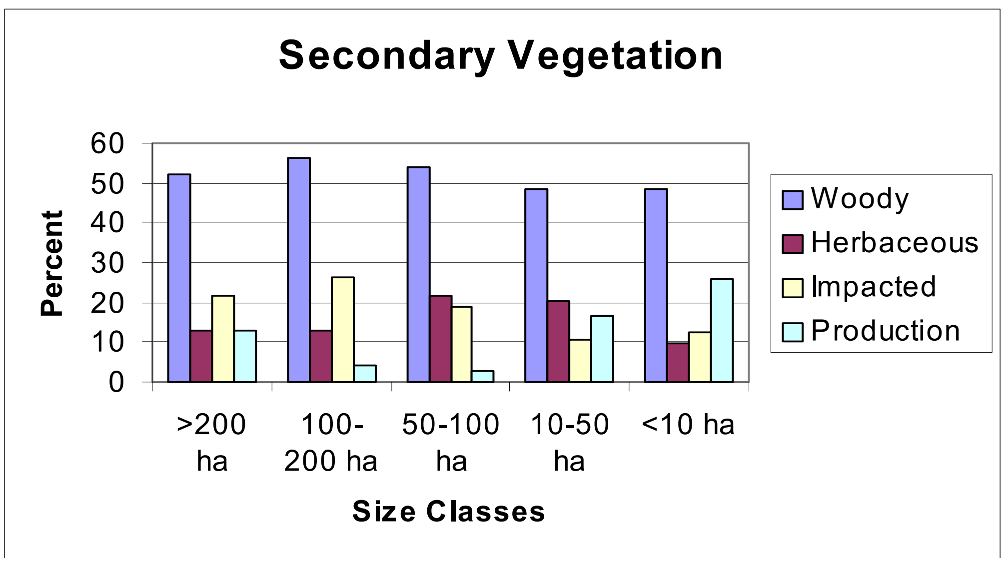


Figure 35. Percent of bays classified by Dominant Vegetation types according to size class.

Natural Hydrologic Connectivity

Consistent with the classical definition for Carolina bays, most bays assessed during this study were categorized as being naturally hydrologically isolated. Only 10 bays (less than 2% of the total number) were rated as being fully connected with another fluvial or lacustrine systems. The disparity between the percent of total bays and percent of total area suggests that there may be trends regarding hydrological connectivity related to the size of bays.

A closer review of Natural Hydrologic Connectivity in Figure 36 reveals those trends.

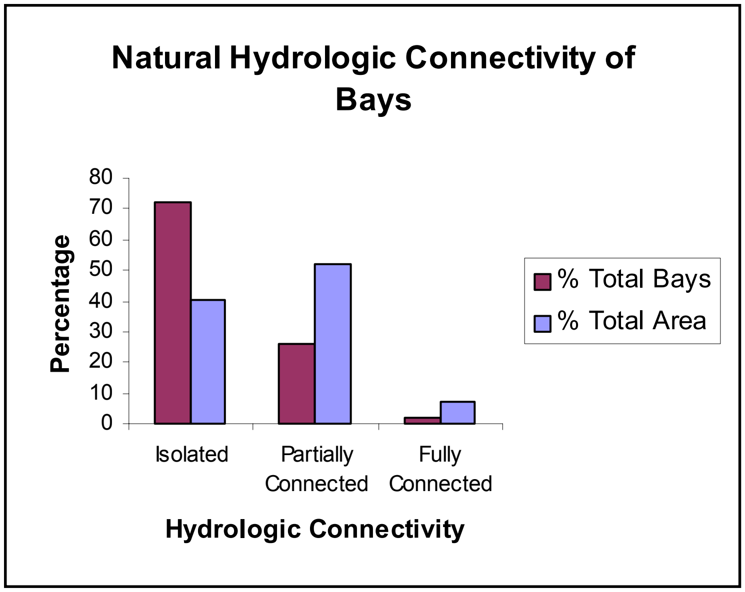


Figure 36. Percent of Carolina bays classified by degree of hydrologic connectivity.

The data in Figure 37 demonstrate a strong direct relationship between the size of the bay and the probability that it is grossly (or fully) connected to other water bodies. Although most bays less than 100 ha are isolated, only about a third of larger bays are. Because there are so few bays categorized as being grossly connected, one would expect that a mirror relationship exists for bays classified as being partially connected to other waters. Indeed, that assumption is revealed: most bays above 100 ha are at least partially connected whereas most smaller bays are not.

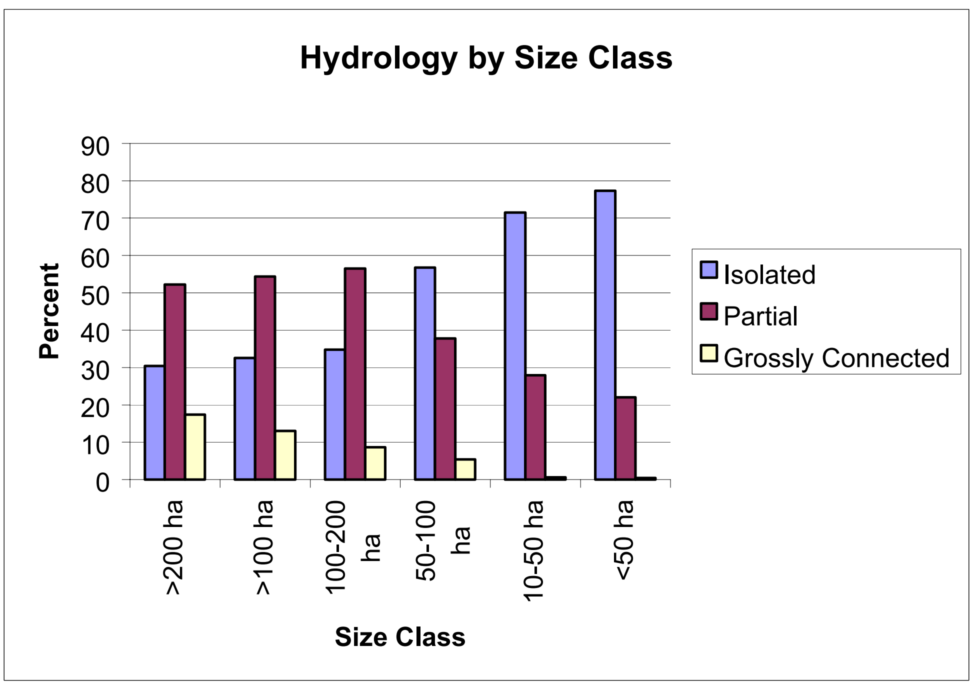


Figure 37. Percentage of Carolina bays classified by hydrologic connectivity according to size class.

Field Work

Field surveys were conducted throughout the study area. A bay's rating for General Integrity and its size were some of the factors considered in choosing bays to ground-survey. Roughly 10% of the bays digitized were visited.

As might be expected, ground surveys are comparatively more expensive to conduct, not only in terms of travel and lodging, but in terms time as well. Finding information on landowners, contacting them, building a rapport, and obtaining consent to walk the property requires substantial time and patience. Once access to the bay is acquired, physically walking through a single large bay can take between several hours to all day to complete. In a field survey, the data acquired is often only qualitative and may or may not be comparable to other bays.

Despite these costs, there is arguably no better way to more precisely determine the condition and history of a bay than to physically walk through it. This was especially true during this project's field season since it coincided with a significant drought period, permitting biologists to enter the interior of bays that would have otherwise been too difficult or too dangerous to access. Admittedly, the disadvantage of the drought was that the vegetative communities were not representative of normal conditions. This was particularly true of the herbaceous community.

Although assessments based on aerial photography were often confirmed by observations made on the ground, there were several occasions when field surveys invalidated the assessments made remotely. For example, there were a couple occasions when a Carolina bay was rated highly and remotely assessed as being intact and having a continuous forest canopy. During the ground surveys, however, the presence of low species diversity, dense shrub layer, abundance of lianas, and remarkable consistency in tree diameter (i.e. age) suggested that the site had historically been clear-cut and that the current forested community was roughly 25 years into its regeneration. Ecologically, this bay does not behave as would an older growth forest community (>150 yrs) that might have had higher species richness, a complex canopy structure, and capable of providing a more diverse suite of niches for other flora and fauna. Had this information been apparent in the photograph, I (EEV) would have rated such bays less highly. On other occasions, some "open-water" bays that were rated highly during the remote assessment were later suspected during field surveys to have historically been mined for peat. Again, a fact that would have rated them less highly.

On the positive side, there were also occasions when a bay was assessed as being ecologically compromised by the presence of a ditch, only to find during the field surveys that the ditch was largely ineffective because it had collapsed in on itself and served more like a slow seepage than a flowing canal. Such ditches might still function during high water periods and effectively change the hydric condition of the bay to some degree, but probably no longer grossly affected the plant communities as it once might have.

Providing in this report a litany of specific field observations for each bay visited would not be practical and may even violate landowner confidentiality and privacy standards and therefore are not presented here. In lieu of such data, commentary is provided throughout the Results section of this report. In retrospect, it would have been useful to analyze the field surveys and to include field survey assessments in the GIS coverage so that comparisons could more easily be made.

In general, it can be said that bays were often over-rated during the remote assessment relative to the ratings biologists would have assigned to bays following ground surveys. Ground surveys revealed more ditches, roads, soil disturbance, evidence of logging and mining, more communities in early regenerative phases, exotic species, encroachment of intensive land use on wetland margins, and other general anomalies in natural communities.

To address some of the concerns and costs associated with field surveys that were previously mentioned, aerial surveys were conducted over 90% of the study area during the summer of 2002. Digital still photography, slides, and videography were taken on each of the three flights. Although aerial surveys are still remote in nature, they provide an improved perspective for assessing the condition of bays and permit biologists to collect more current imagery of bays from multiple levels and from several angles. In comparison to field visits, aerial surveys permitted biologists to assess literally hundreds of acres in just a matter of hours. Several of the bays that were in relatively good condition and contained vegetation types classified here as "Herbaceous" were targeted for subsequent surveys for *Oxpolis canbyi* and *Lindera melissifolia*.

Education and Outreach Efforts

There are four primary educational products from this project. One is a website, in PDF format, based on this report. The second was a 70-page booklet, known as an "Access Guide," identifying important features of bays. The third was an annotated MS PowerPoint presentation and the fourth was a episode of Georgia Public Television's Georgia Outdoors magazine. A fifth educational element, a poster, was not been completed before printing this report.

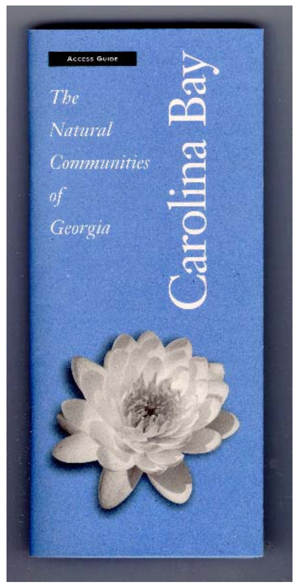
Website

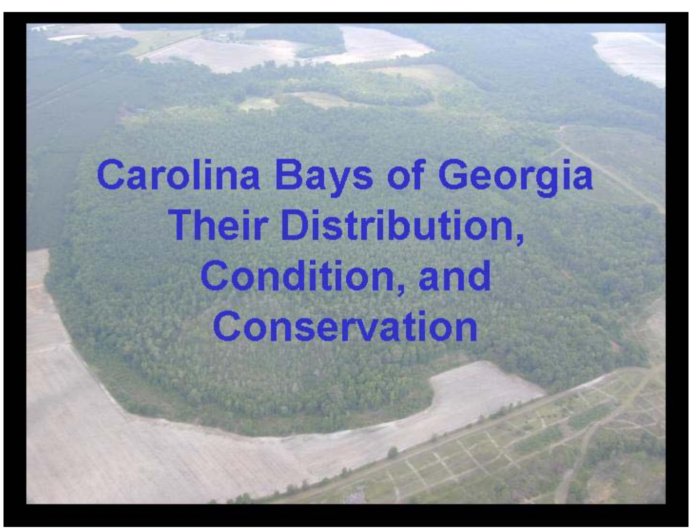
To make these findings more widely available, the report was divided into chapters and converted into a PDF format and posted on the DNR website. It is available by visiting www.georgiawildlife.com and navigating to the Carolina Bay report.

Access Guide Booklet

In collaboration with other DNR offices and agencies, project investigators contributed to the development of a 70-page booklet defining many of the important aspects of Carolina bays including their flora, fauna, ecological processes, and conservation importance. The Access Guide is primarily targeted for audiences like students, amateur naturalists, and visitors to protected Carolina bays. It is available from the DNR by contacting: .Robin Hill, 2117 U.S Hwy 278, SE; Social Circle, GA 30025.

Provided to the right are representations of the front cover and sample text of the Access Guide.





Presentation

An annotated digital slide presentation was developed in the software Microsoft PowerPoint and is included with this report on the attached CD ROM.

This slide presentation does not follow the outline of this report in detail, but presents a more general overview of Carolina bays and addresses the purposes and selected findings of this report in coarse summary.

This slide presentation is targeted for school and non-profit groups (e.g. Audubon Society Chapters, etc.).

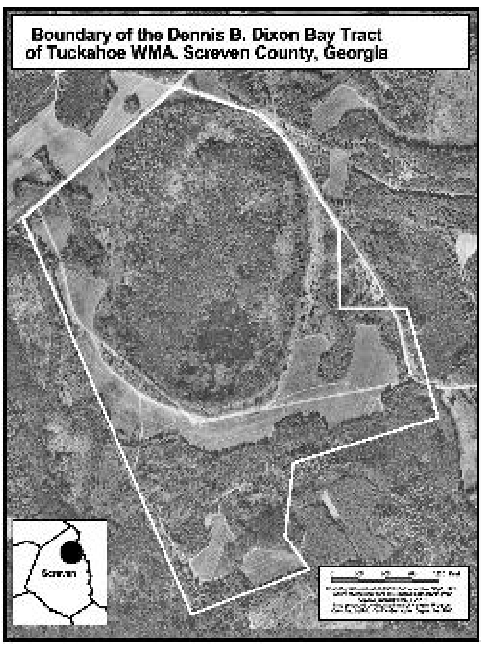
CONSERVATION OF CAROLINA BAYS IN GEORGIA

Television Program

In conjunction with Georgia Public Television (GPTV), the Department of Natural Resources produced an episode of Georgia Outdoors focusing on Carolina bays in the state. One author (EEV) participated in the production of that program by providing general information, graphics, as well as an interview with the program host. [Copies of this program can be obtained from Georgia Public Television, 260 14th St., NW, Atlanta, GA 30319-5306 (1.800.222.6006) – request Georgia Outdoors episode number 1206, "Blackwater Canoe."]

Protection Efforts

As a result of the efforts applied in this project one property has been permanently protected and another is being actively pursued. The two properties are Dixon Bay in Screven County and Neyami Savanna in Lee County.



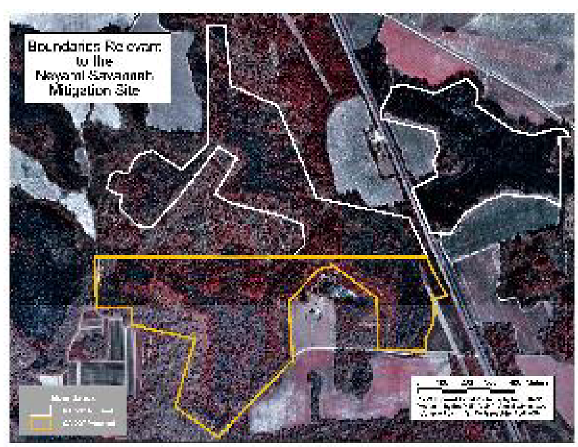
Dixon Bay

The DOT purchased Dixon Bay and has permanently protected it as part of a mitigation program for wetlands impacted during road construction. Dixon bay is a 135.2 ha (333.9 ac) property in Screven County that includes a 62.82 ha (155.2 ac) Carolina bay. The DOT and DNR have joined into a fifty- Memorandum of Agreement to have the DNR manage the property. The DOT provided stewardship funds to assist the DNR. Active management on this site will include restoring portions of the upland habitats from its current state as a pine plantation into a natural longleaf pine (*Pinus palustris*) forest.

Dixon bay is an ecologically valuable wetland for several reasons. Due to both natural and human disturbances, a variety of habitat types have developed - from black gum (*Nyssa biflora*) swamps, to a pond cypress (*Taxodium ascendens*) and sedge (*Rhynchospora careyana*) savannas, and even an open water area populated with a couple species of pond lilies. Although no resident rare species have been identified, wood storks (*Mycteria americana*) have been documented feeding in the bay and suitable habitat appears to exist for the Canby dropwort (*Oxypolis canbyi*).

Neyami Savanna

Located in Lee County, the Neyami Savanna site is not actually a Carolina bay, but is an extremely important site for the federally listed Canby dropwort (*Oxypolis canbyi*) for which project funding was partially justified. Like Dixon Bay, this site was purchased by the DOT for mitigation purposes. In this case, however, it was to mitigate for impacts to the federally listed Canby dropwort. The DOT has already purchased two tracts (24.5 ha and 35 ha) and is currently pursuing a conservation easement on a third tract (49 ha) to the south.



Investigators have visited the property to assess management needs and to prepare an easement deed and Memorandum of Agreement with the DOT.

REFERENCES

Bennett, Stephen H. and John B. Nelson. 1991. Distribution and status of Carolina Bays in South Carolina. South Carolina Wildlife & Marine Resources Department. 1:1-88.

Brooks, M.J., B.E. Taylor, P.A. Stone, L.R. Gardner. 2001. Pleistocene encroachment of the Wateree River sand sheet into Big Bay on the Middle Coastal Plain of South Carolina. Southeastern Geology. 40(4):241-257.

Burke, V.J. and J.W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. Conservation Biology. 9(6):1365-1369.

Godfrey, R. K. 1988. Trees, shrubs, and woody vines of northern Florida and adjacent Georgia. University of Georgia Press, Athens, GA. 734 pp.

Krakow, Greg. 2001a. StuffShp.ave. (Avenue Scripting Language). GA-DNR Georgia Natural Heritage Program: Social Circle, GA

Krakow, Greg. 2001b. Pan95.ave. (Avenue Scripting Language). GA-DNR Georgia Natural Heritage Program: Social Circle, GA

Krakow, Greg. 2001c. EasyEntry.avx. (Avenue Scripting Language). GA-DNR Georgia Natural Heritage Program: Social Circle, GA

Krakow, Greg. 2001d. UniqueID.avx. (Avenue Scripting Language). GA-DNR Georgia Natural Heritage Program: Social Circle, GA

Kobres, Bob. website: http://abob.libs.uga.edu/bobk/cbaymbsc.html. October 16, 2001.

LeGrange, Harry. *pers. comm*. October 26, 2001. North Carolina Heritage Program.

Nifong, Timothy D. 1982. The "Clay Subsoil" Carolina Bays of North Carolina. Department of Botany, The University of North Carolina. 7pp.

Prouty, W. F. 1952. Carolina Bays and their origin. Geological Society of America Bulletin. 63:167-224.

Sarsony, E. Christopher. 1991. An ecological assessment of Carolina bay wetlands south of the Cape Fear River in Bladen County. Masters Thesis: School of Forestry and Environmental Studies, Duke University.

Semlitsch. R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology. 12(5):1113-1119.

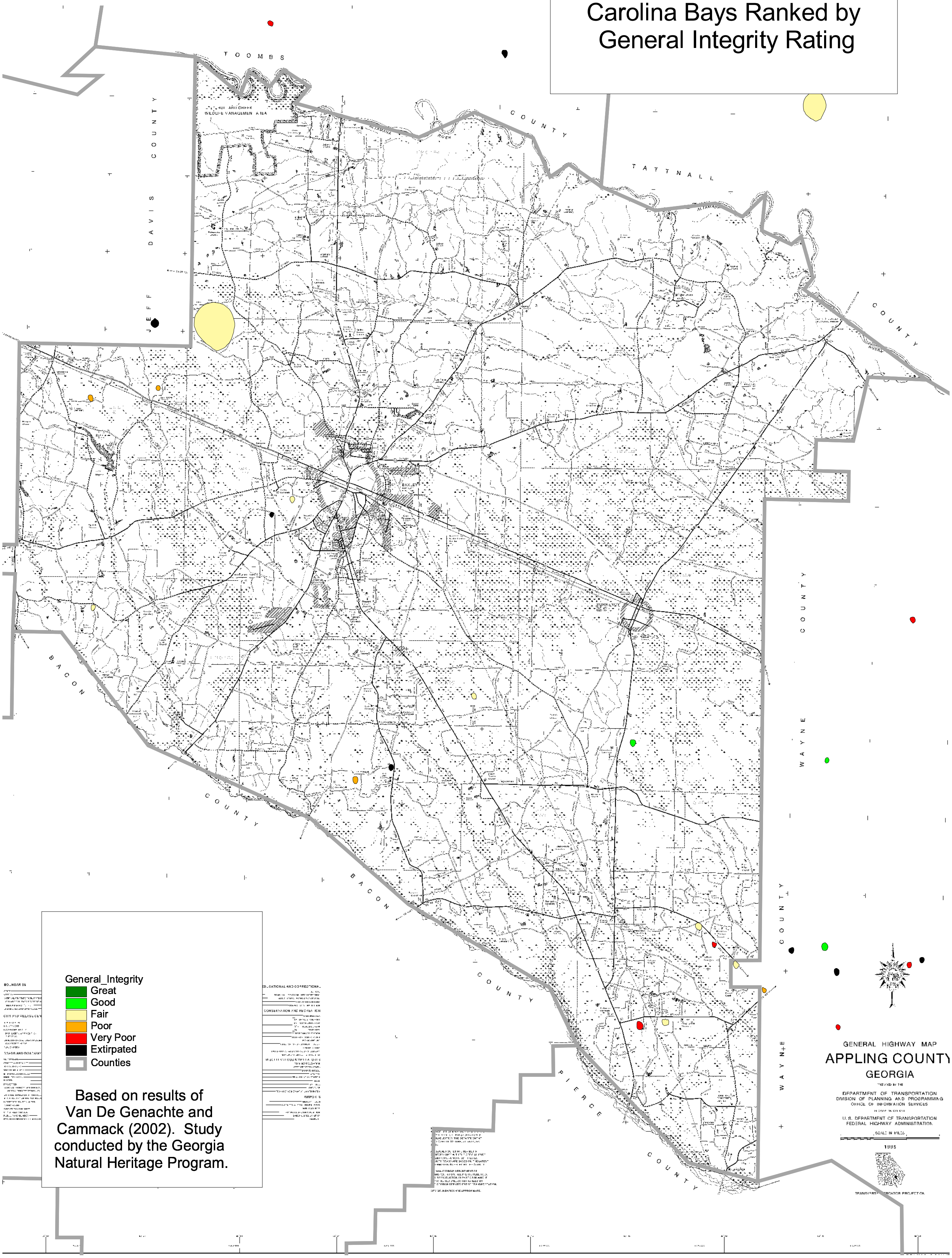
Sharitz, R. R. and Gibbons, J. W. 1982. The ecology of southeastern shrub bogs (Pocosins) and Carolina bays: a community profile. DOI-USFWS: Washington, DC. FWS/OBS-82-04.

Weakley, Alan. 1982. Natural features summary and preserve design for Carolina bays in Bladen and Cumberland counties.

Wharton, C.H. 1978. The natural environments of Georgia. Georgia Department of Natural Resources. Atlanta, GA. 227 pp.

APPLING COUNTY

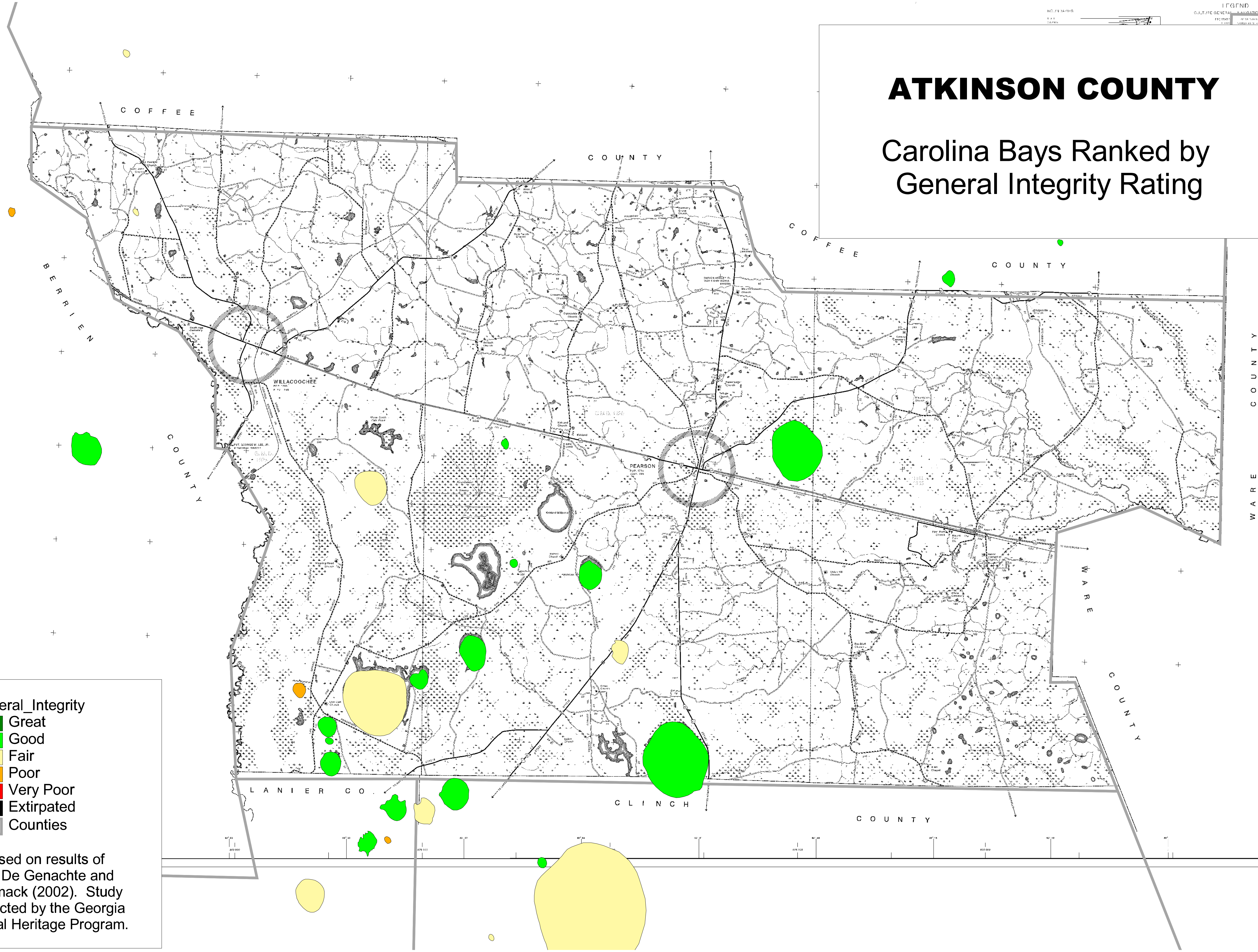
Carolina Bays Ranked by General Integrity Rating



Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

ATKINSON COUNTY

Carolina Bays Ranked by General Integrity Rating

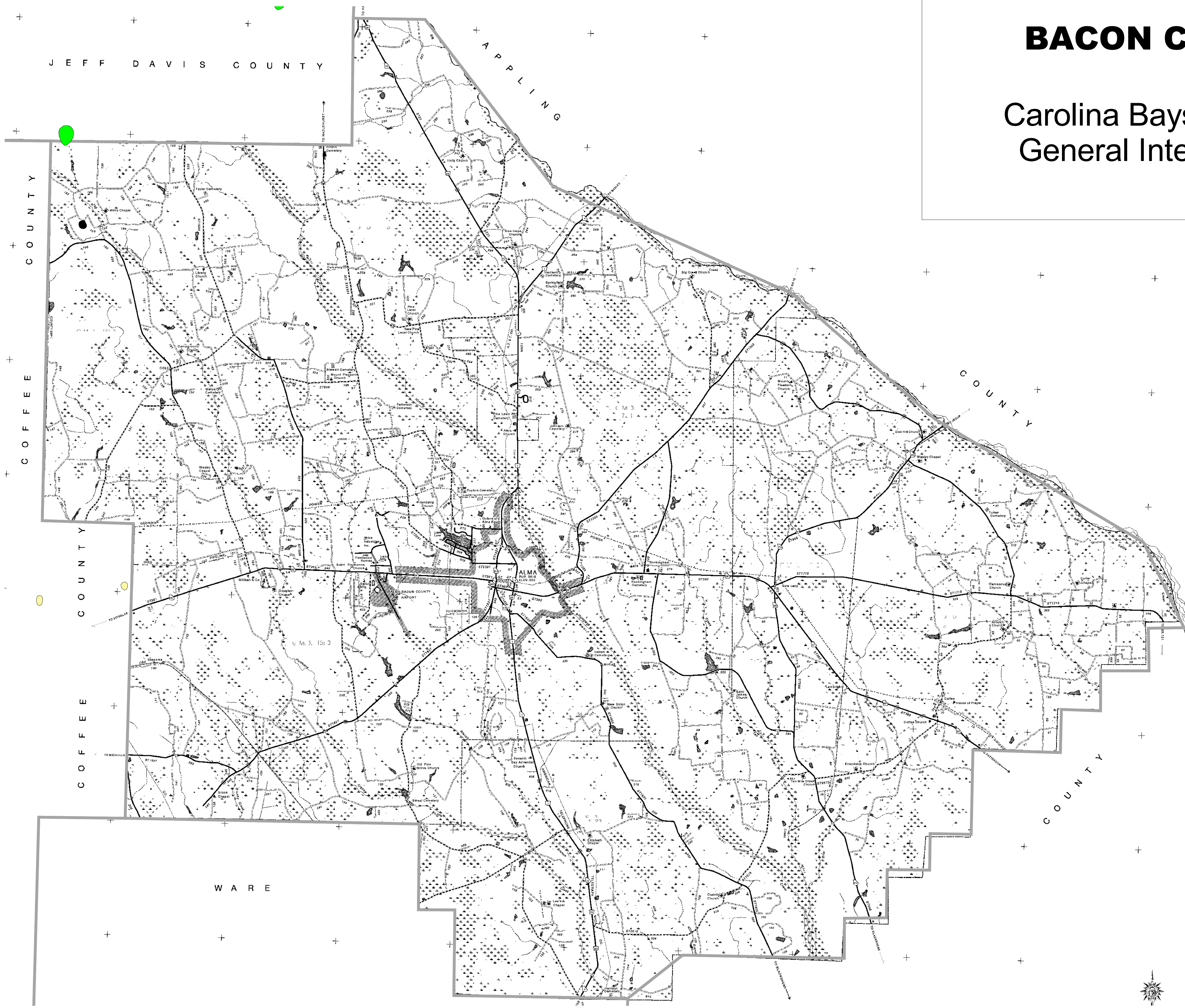


General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

BACON COUNTY

Carolina Bays Ranked by General Integrity Rating



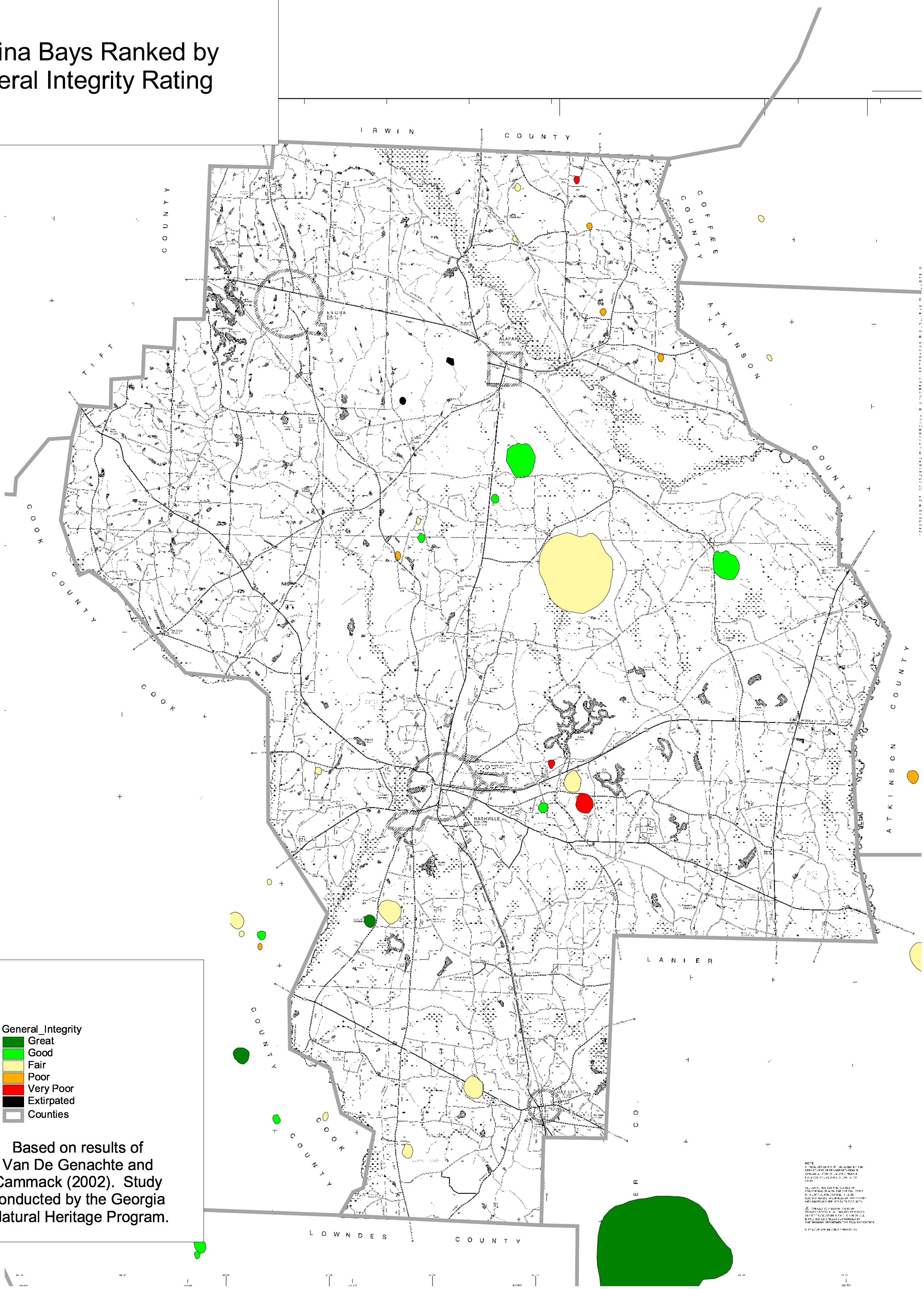
General_Integrity

- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

BERRIEN COUNTY

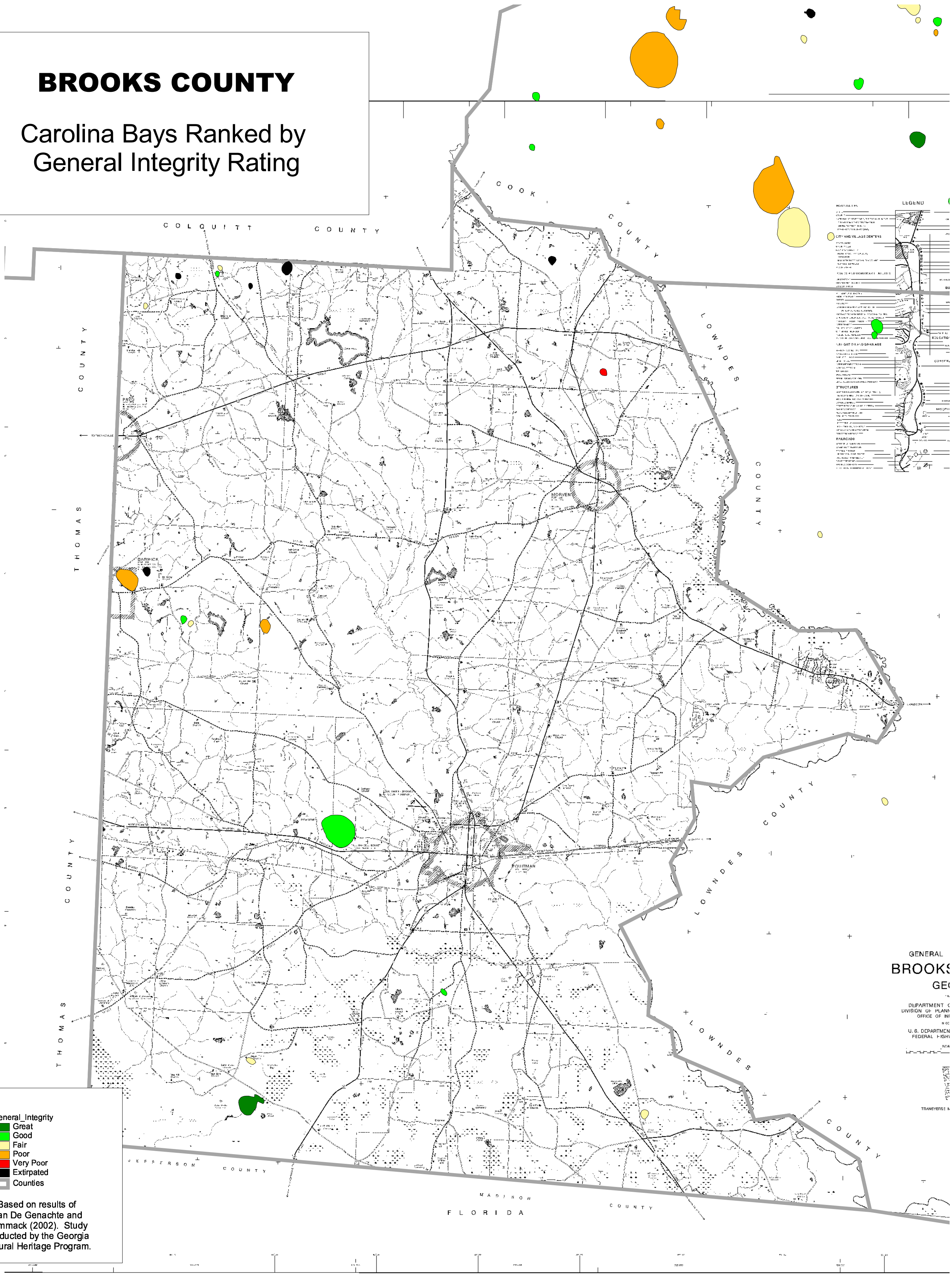
Carolina Bays Ranked by General Integrity Rating



Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

BROOKS COUNTY

Carolina Bays Ranked by General Integrity Rating

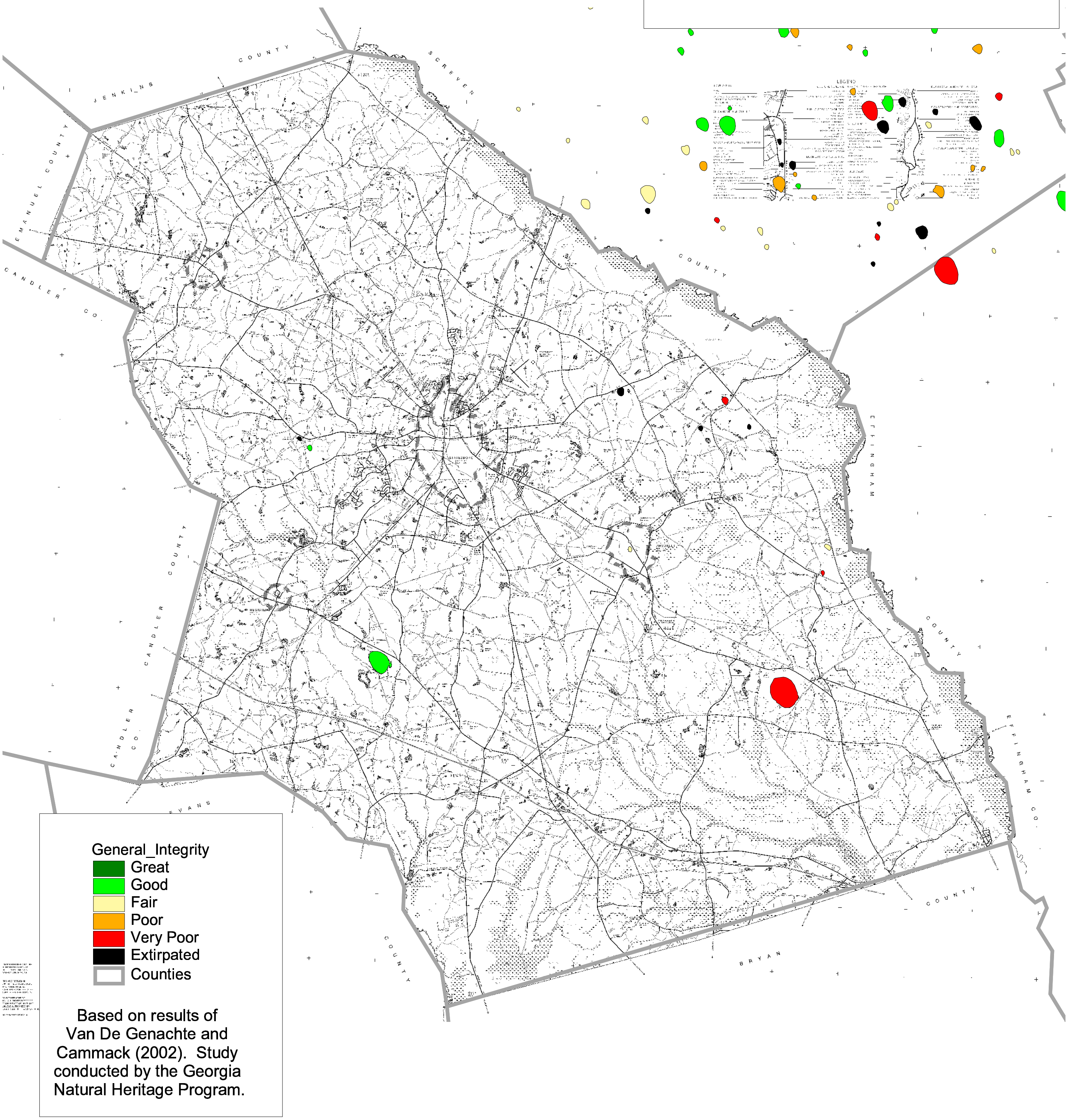


General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

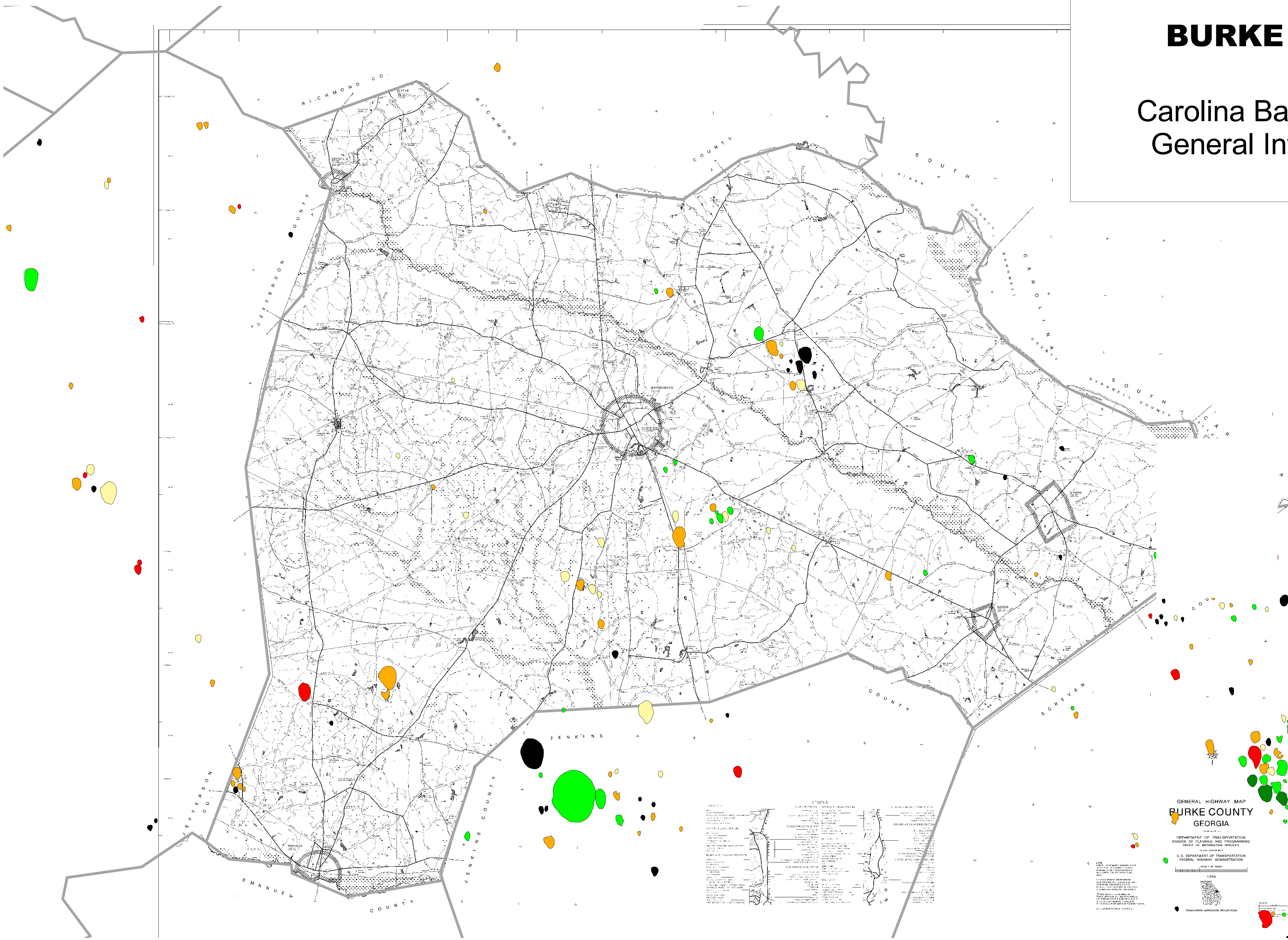
BULLOCH COUNTY

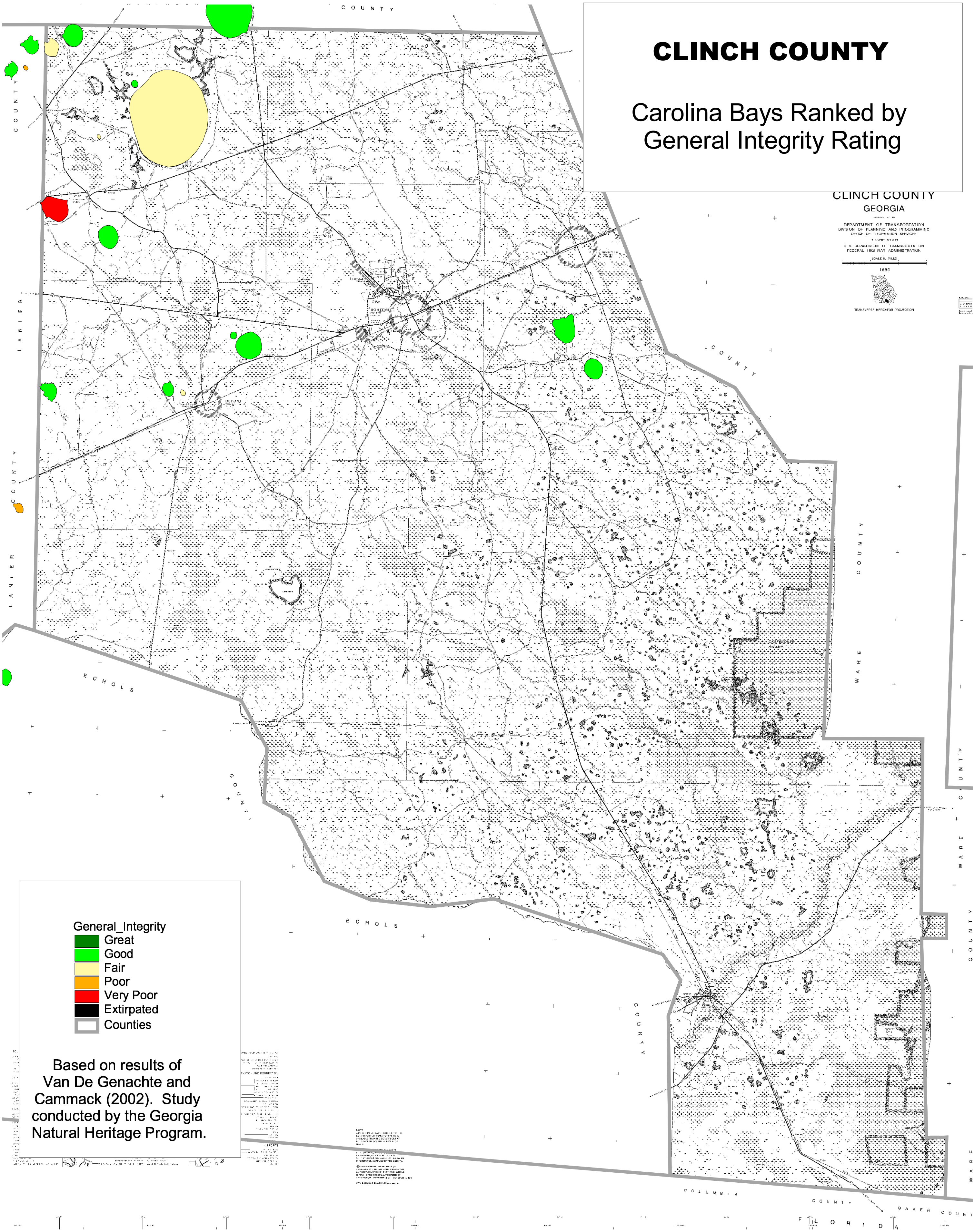
Carolina Bays Ranked by General Integrity Rating



BURKE COUNTY

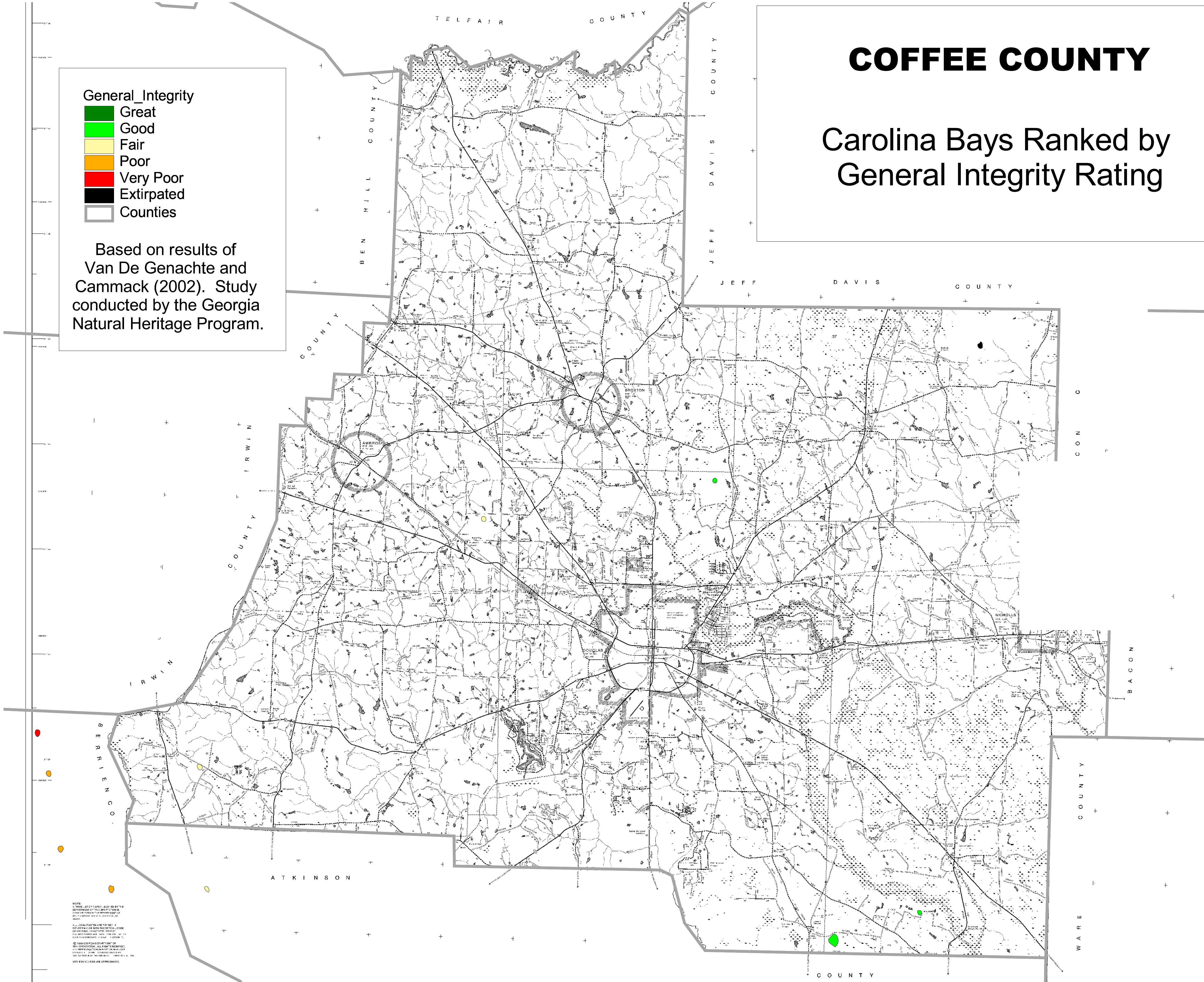
Carolina Bays Ranked by General Integrity Rating

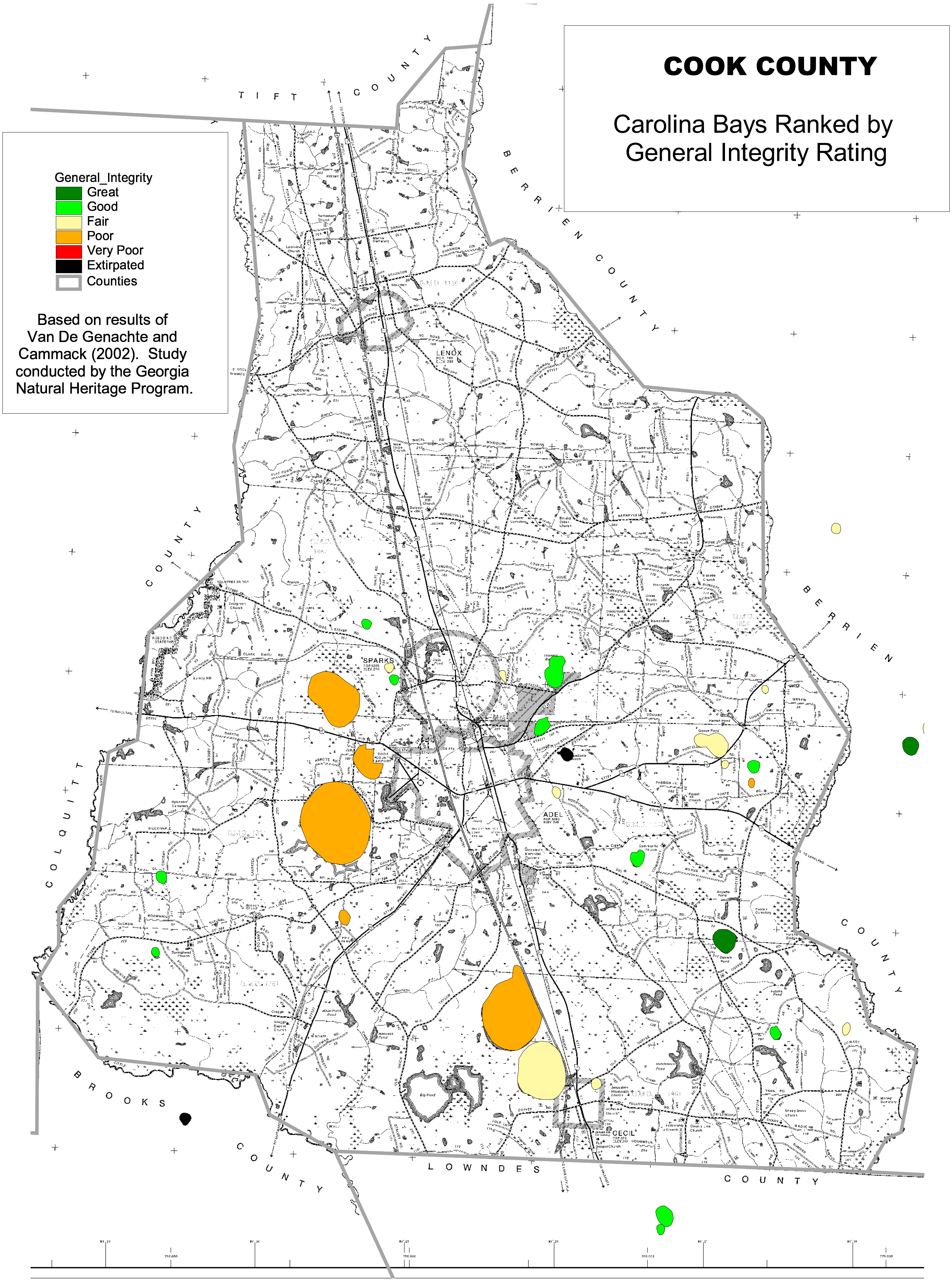



CLINCH COUNTY
Carolina Bays Ranked by General Integrity Rating
CLINCH COUNTY
GEORGIA
General_Integrity
Great
Good
Fair
Poor
Very Poor
Extirpated
Counties
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.
LANIER COUNTY
ECHOLS COUNTY
WARE COUNTY
COLUMBIA COUNTY
BAKER COUNTY
FLORIDA

COFFEE COUNTY

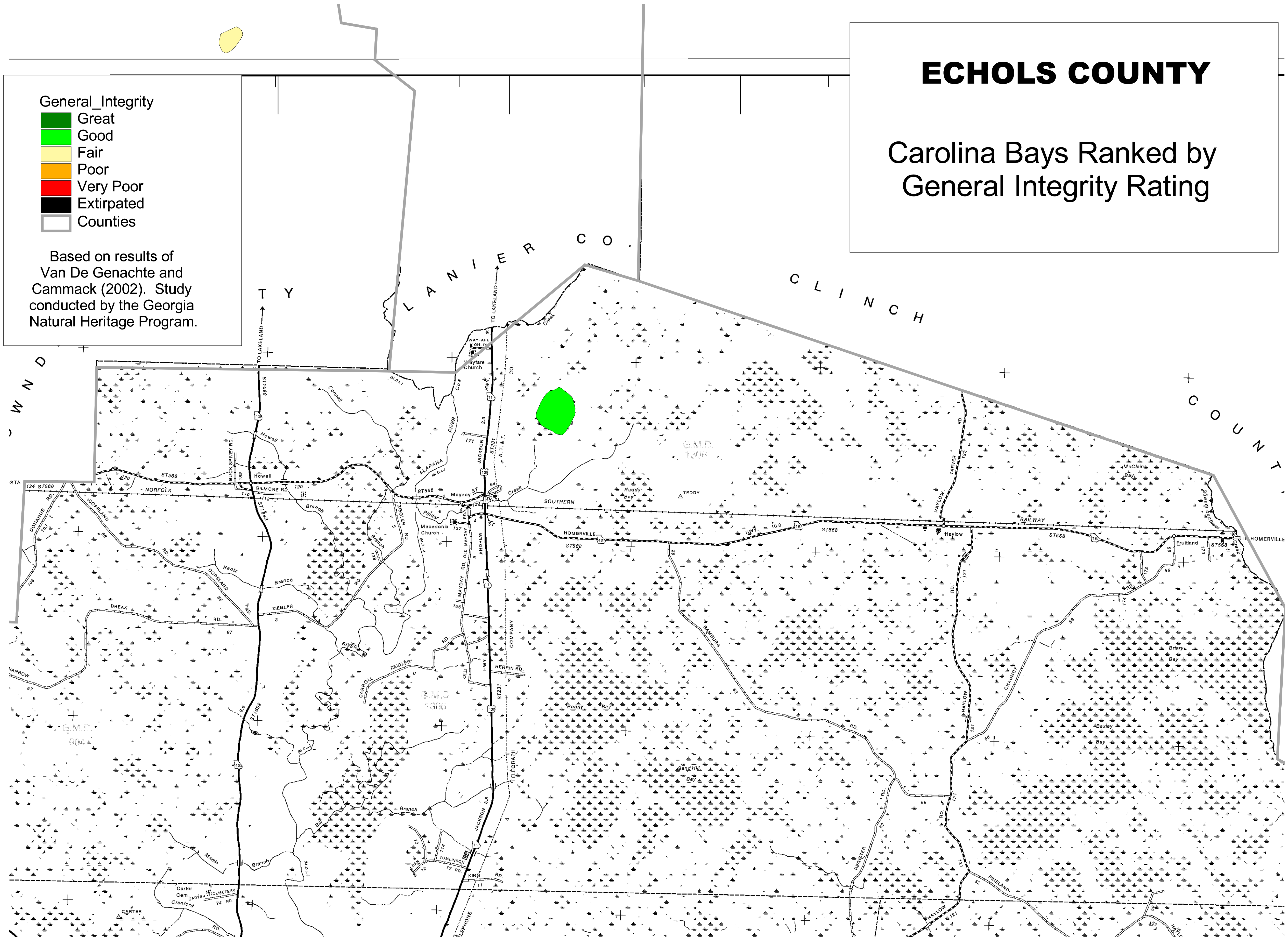
Carolina Bays Ranked by General Integrity Rating




COOK COUNTY
Carolina Bays Ranked by General Integrity Rating
General_Integrity
Great
Good
Fair
Poor
Very Poor
Extirpated
Counties
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.
TIFT COUNTY
BERRIEN COUNTY
BERRIEN COUNTY
COLQUITT COUNTY
BROOKS COUNTY
LOWNDES COUNTY
LENOX
SPARKS
ADEL
CECIL

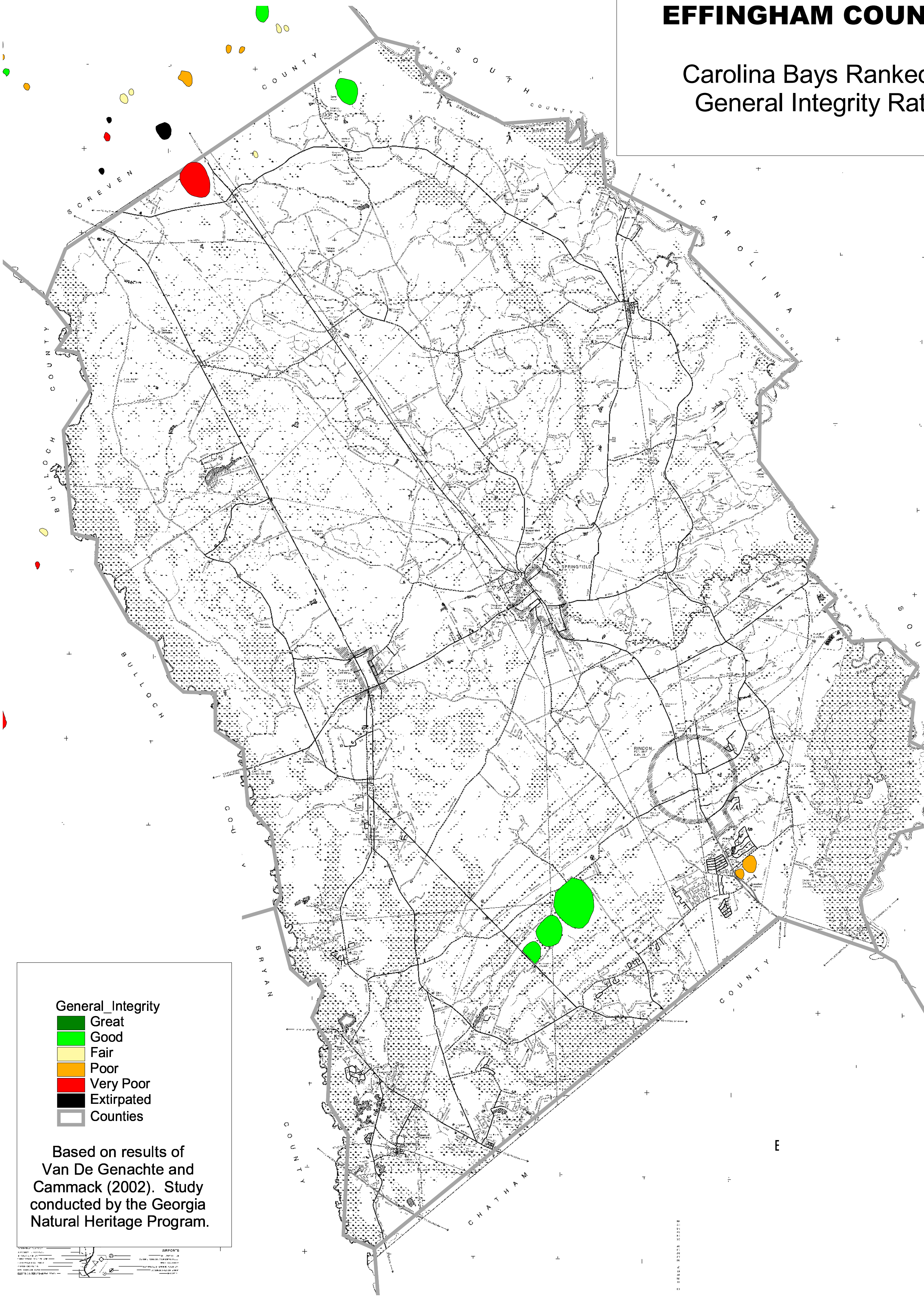
ECHOLS COUNTY

Carolina Bays Ranked by General Integrity Rating



EFFINGHAM COUNTY

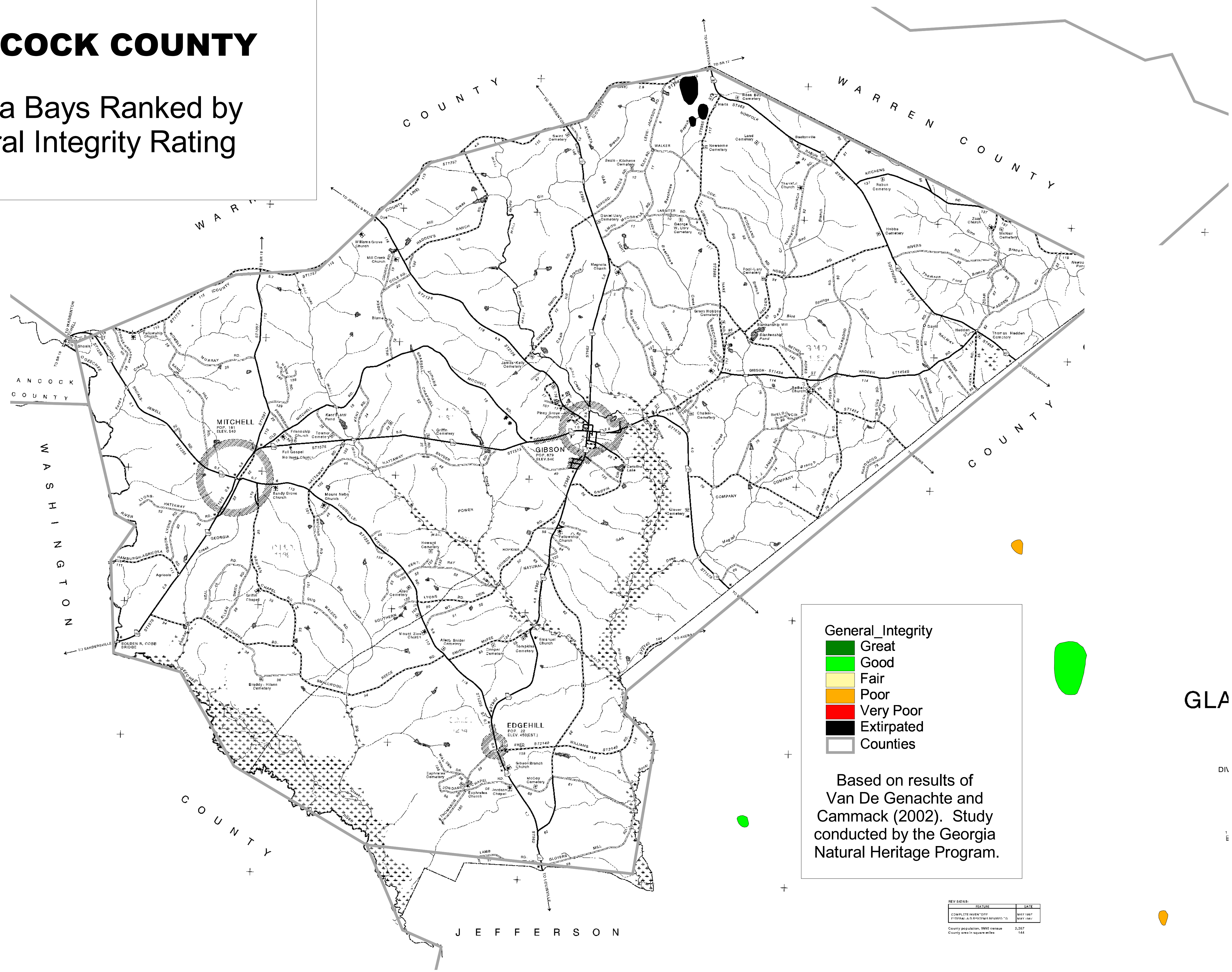
Carolina Bays Ranked by General Integrity Rating



Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

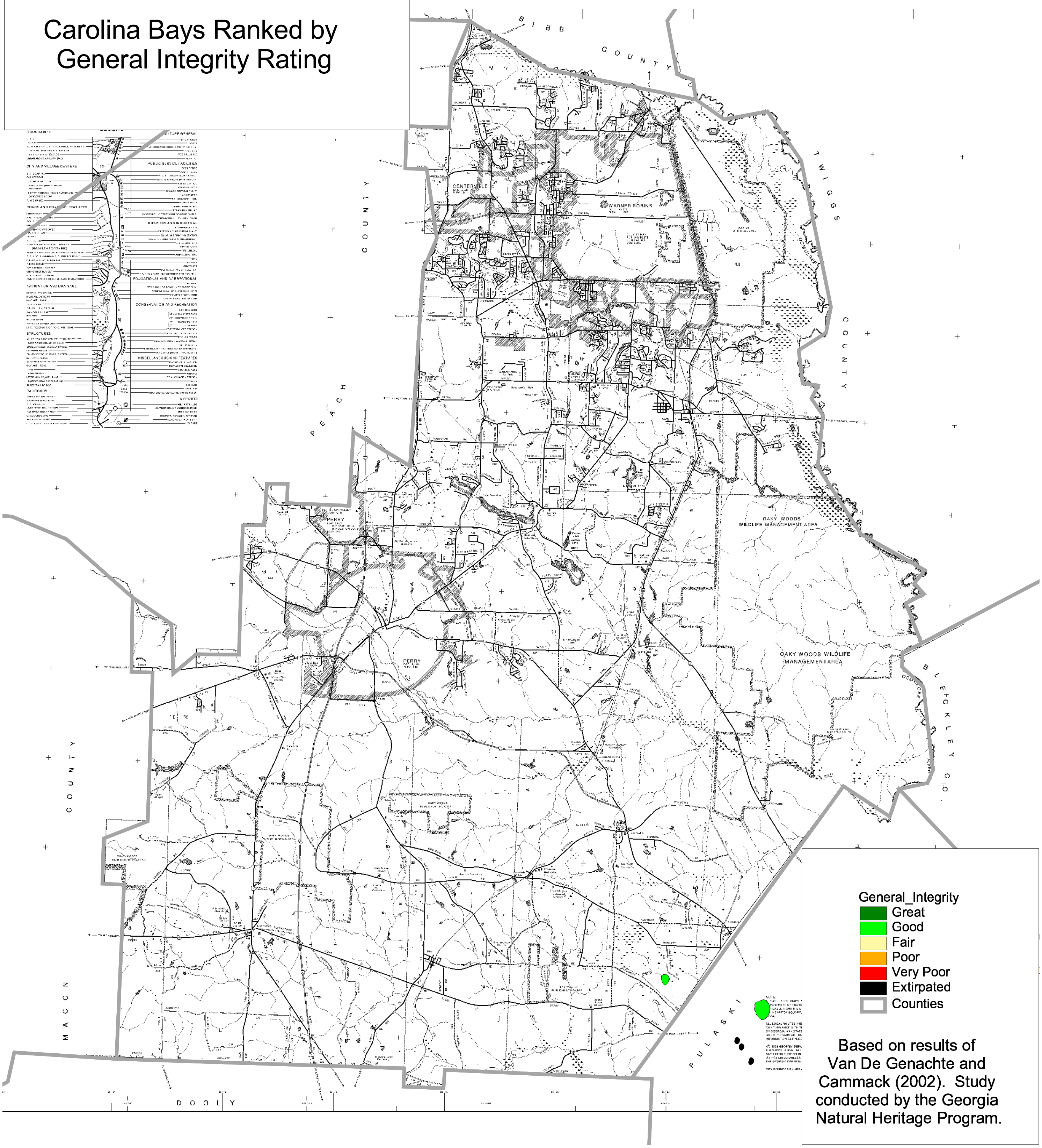
GLASCOCK COUNTY

Carolina Bays Ranked by General Integrity Rating



HOUSTON COUNTY

Carolina Bays Ranked by General Integrity Rating

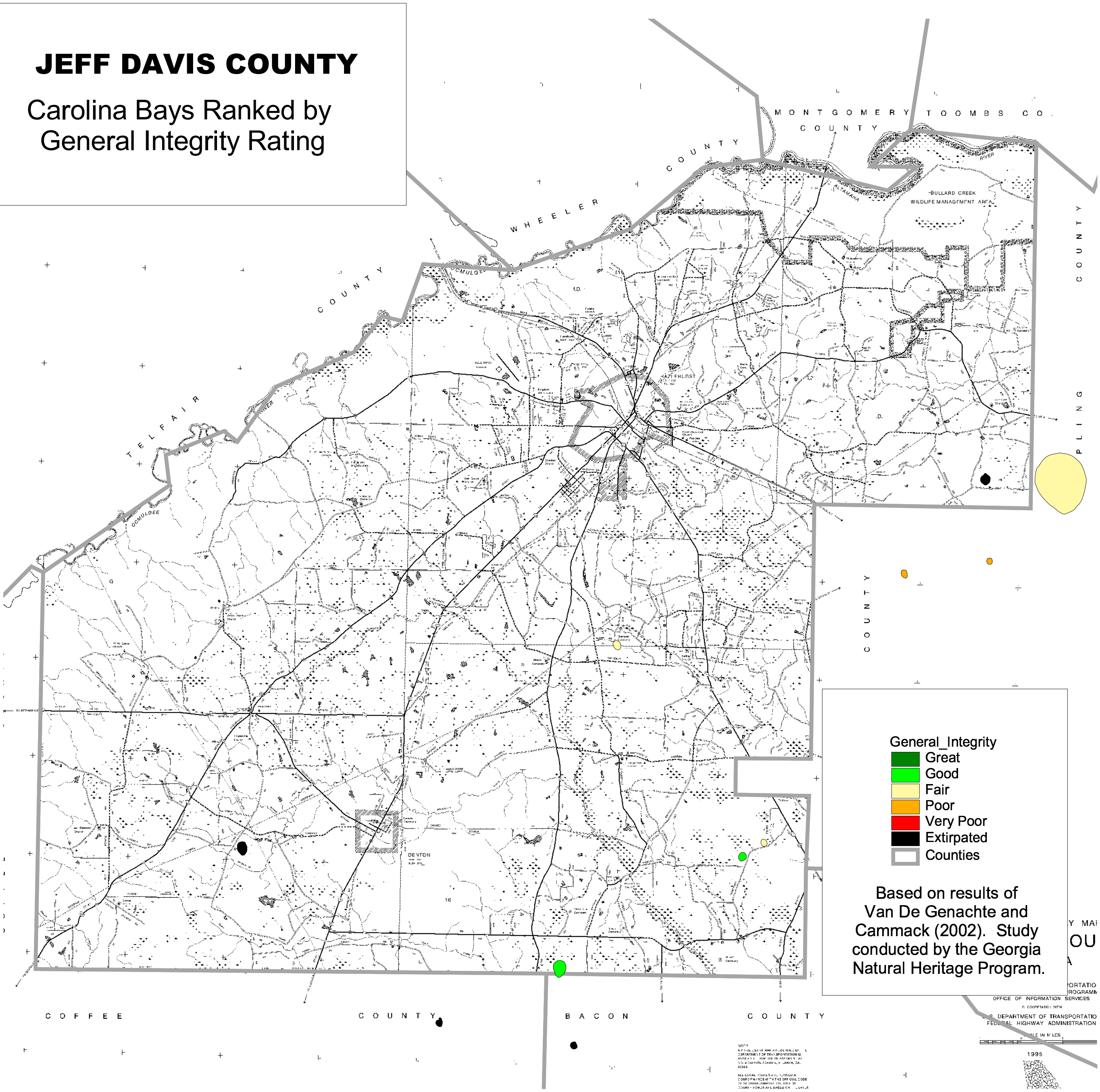


General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

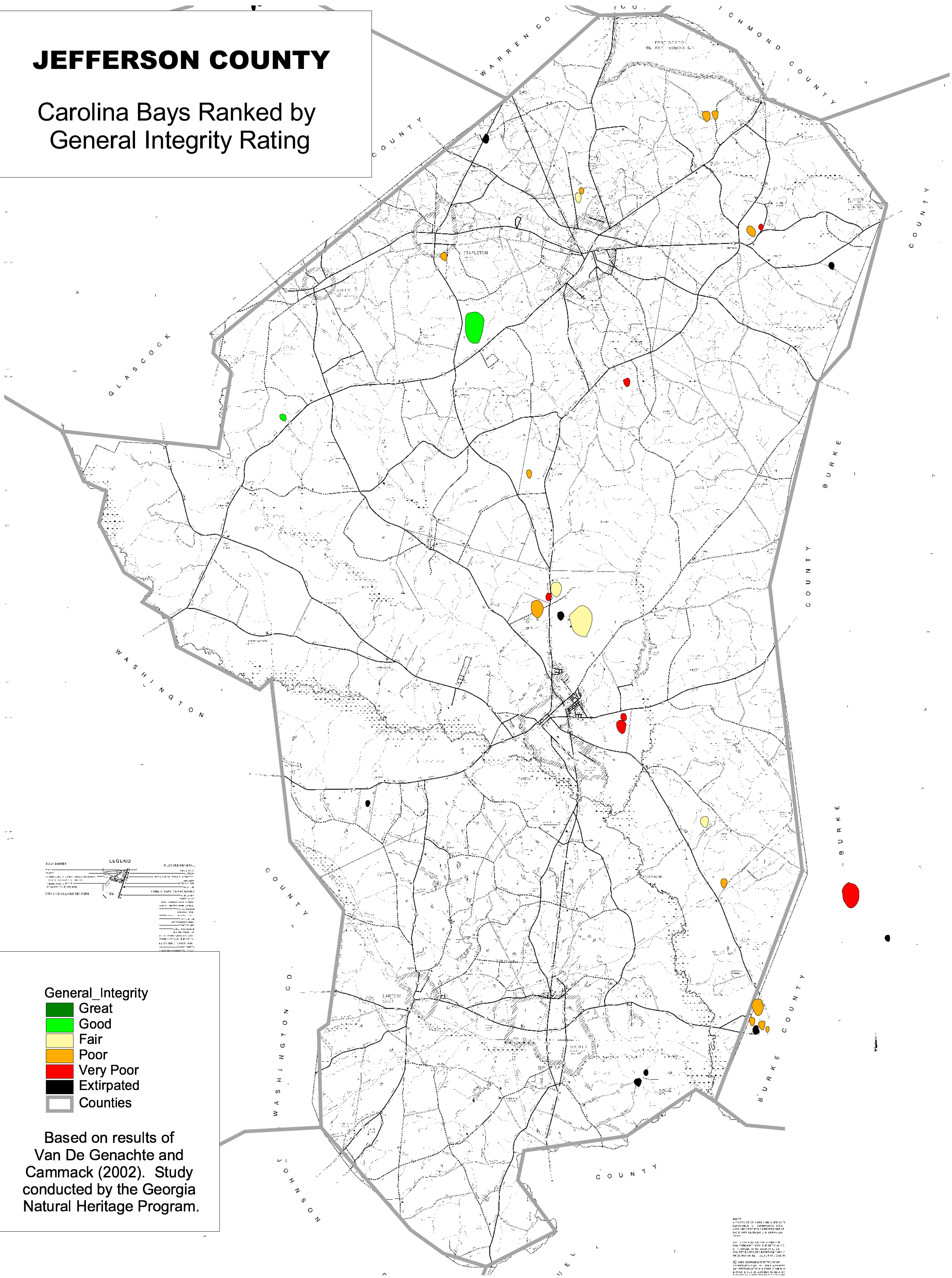
JEFF DAVIS COUNTY

Carolina Bays Ranked by General Integrity Rating



JEFFERSON COUNTY

Carolina Bays Ranked by General Integrity Rating



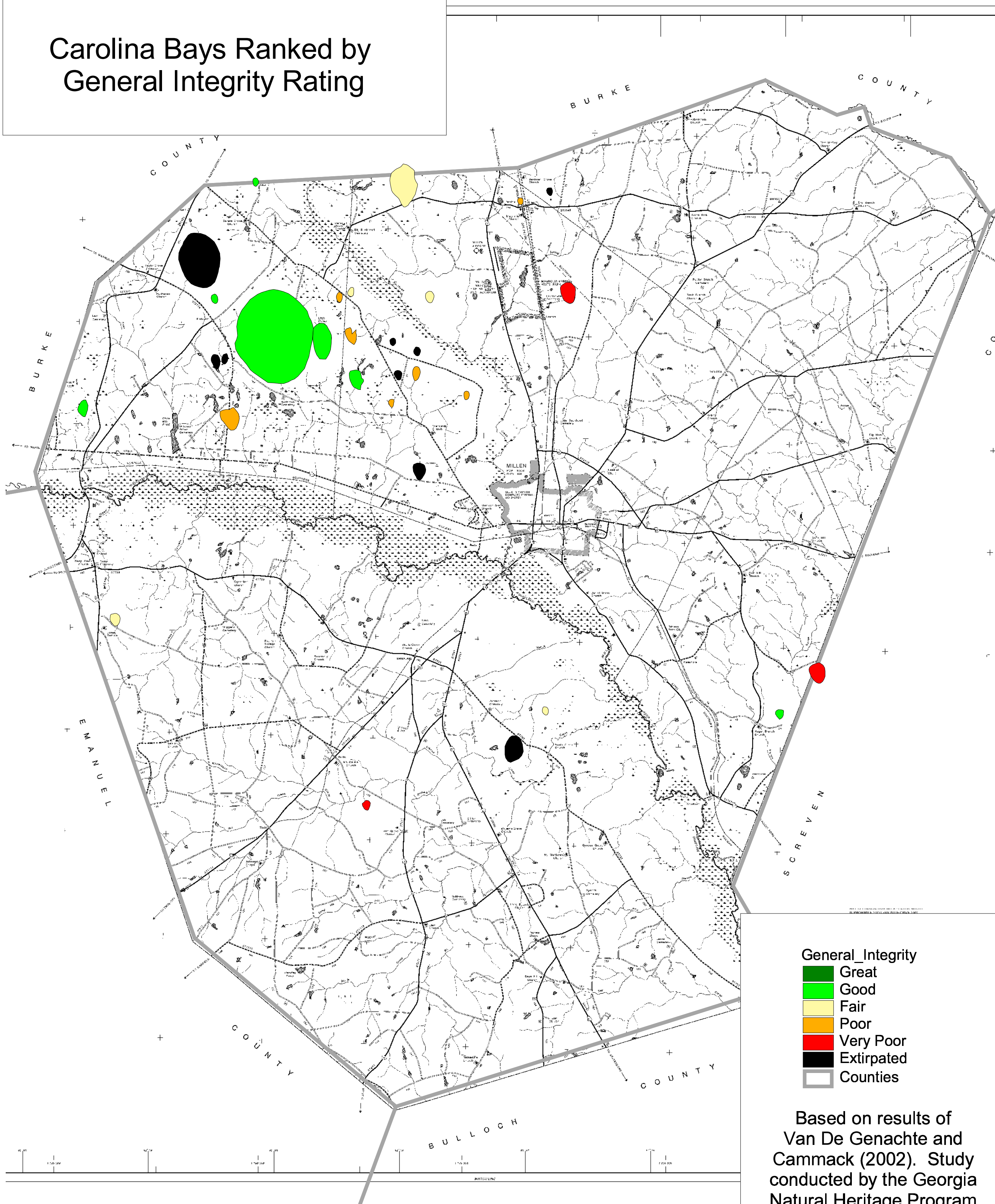
General_Integrity

- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

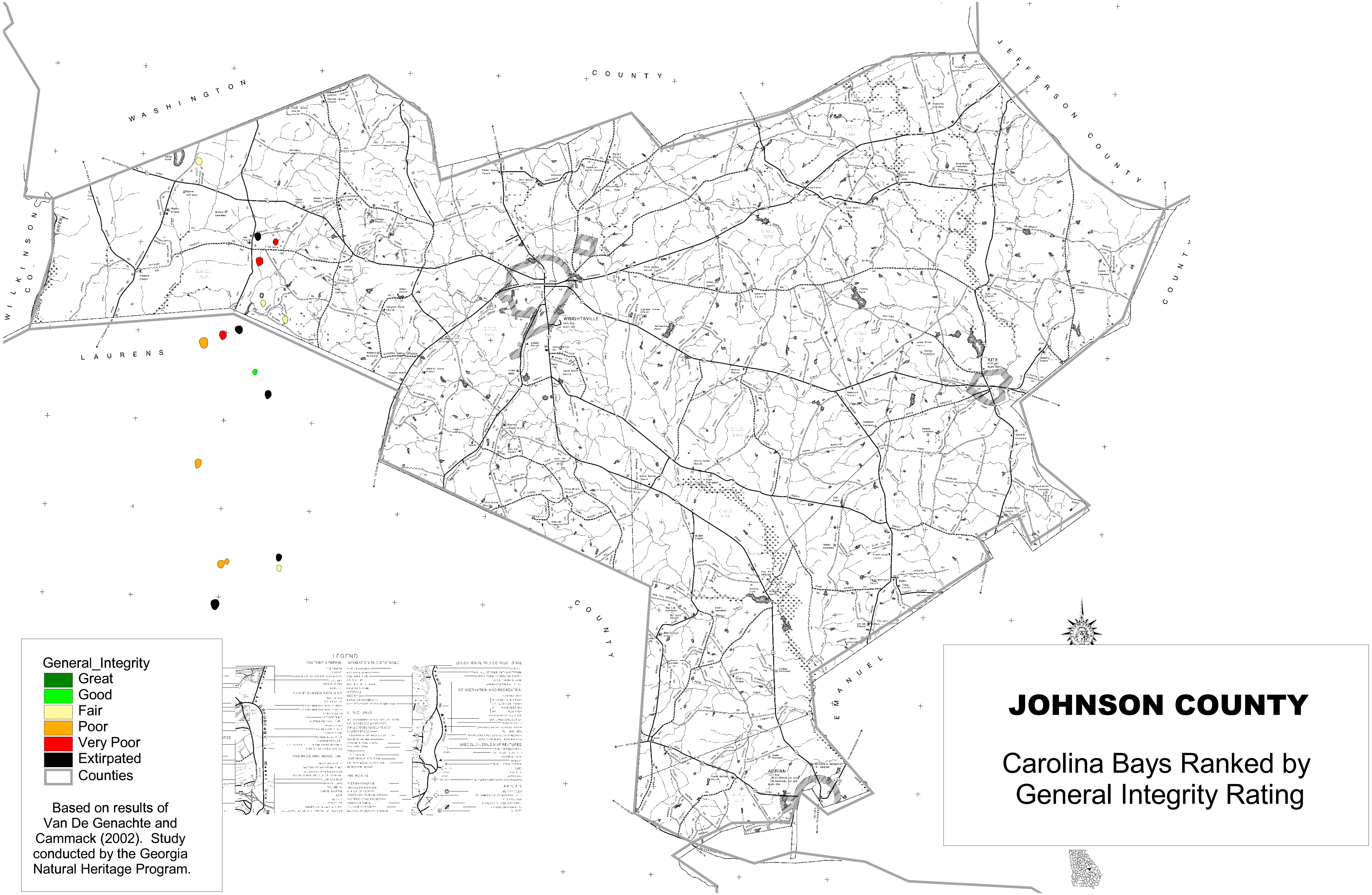
JENKINS COUNTY

Carolina Bays Ranked by General Integrity Rating



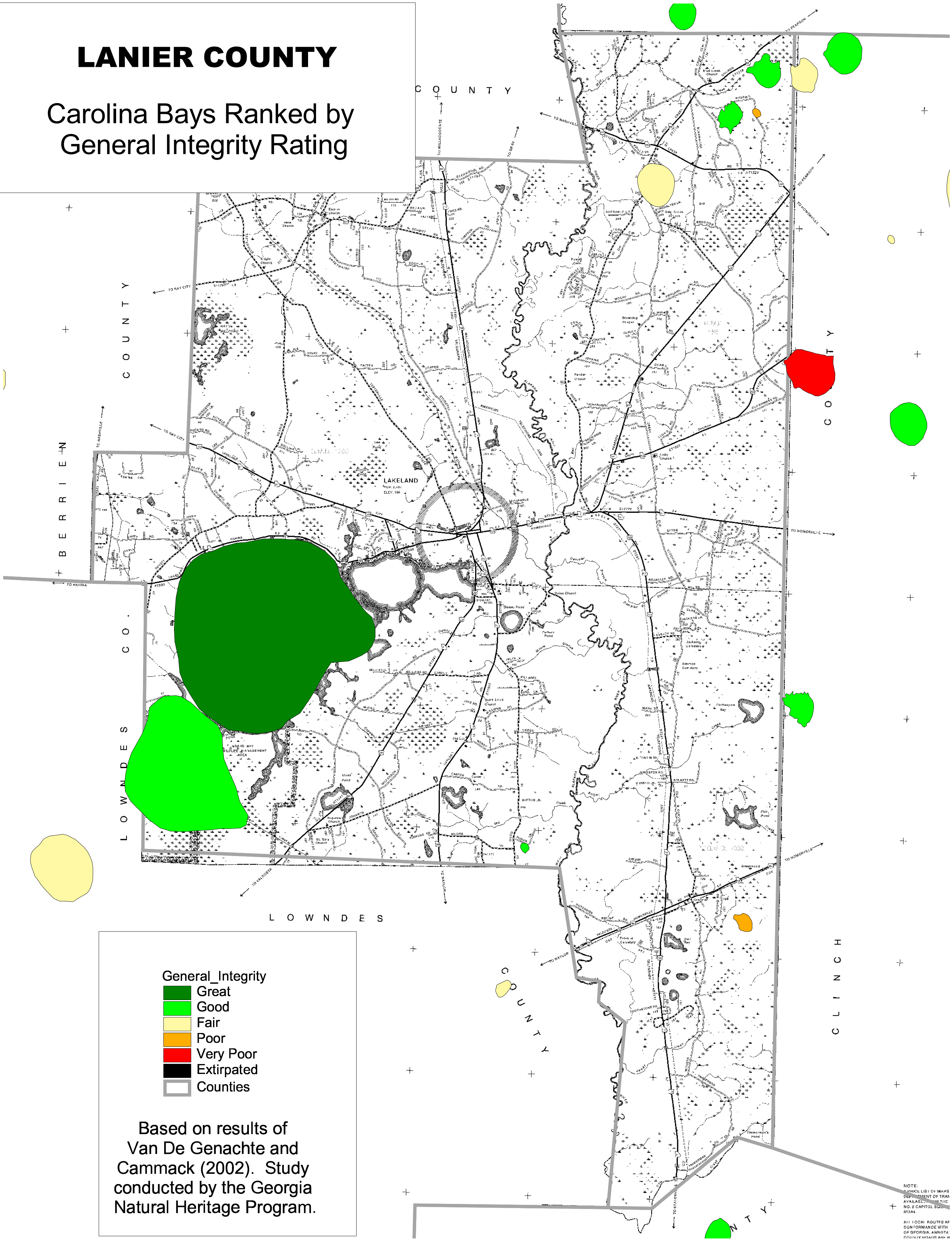
General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.


JOHNSON COUNTY
Carolina Bays Ranked by General Integrity Rating
General_Integrity
Great
Good
Fair
Poor
Very Poor
Extirpated
Counties
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.
WASHINGTON
COUNTY
JEFFERSON COUNTY
COUNTY
WILKINSON CO.
LAURENS
COUNTY
EMANUEL
WRIGHTSVILLE
KITE
ADRIAN
LEGEND

LANIER COUNTY

Carolina Bays Ranked by General Integrity Rating

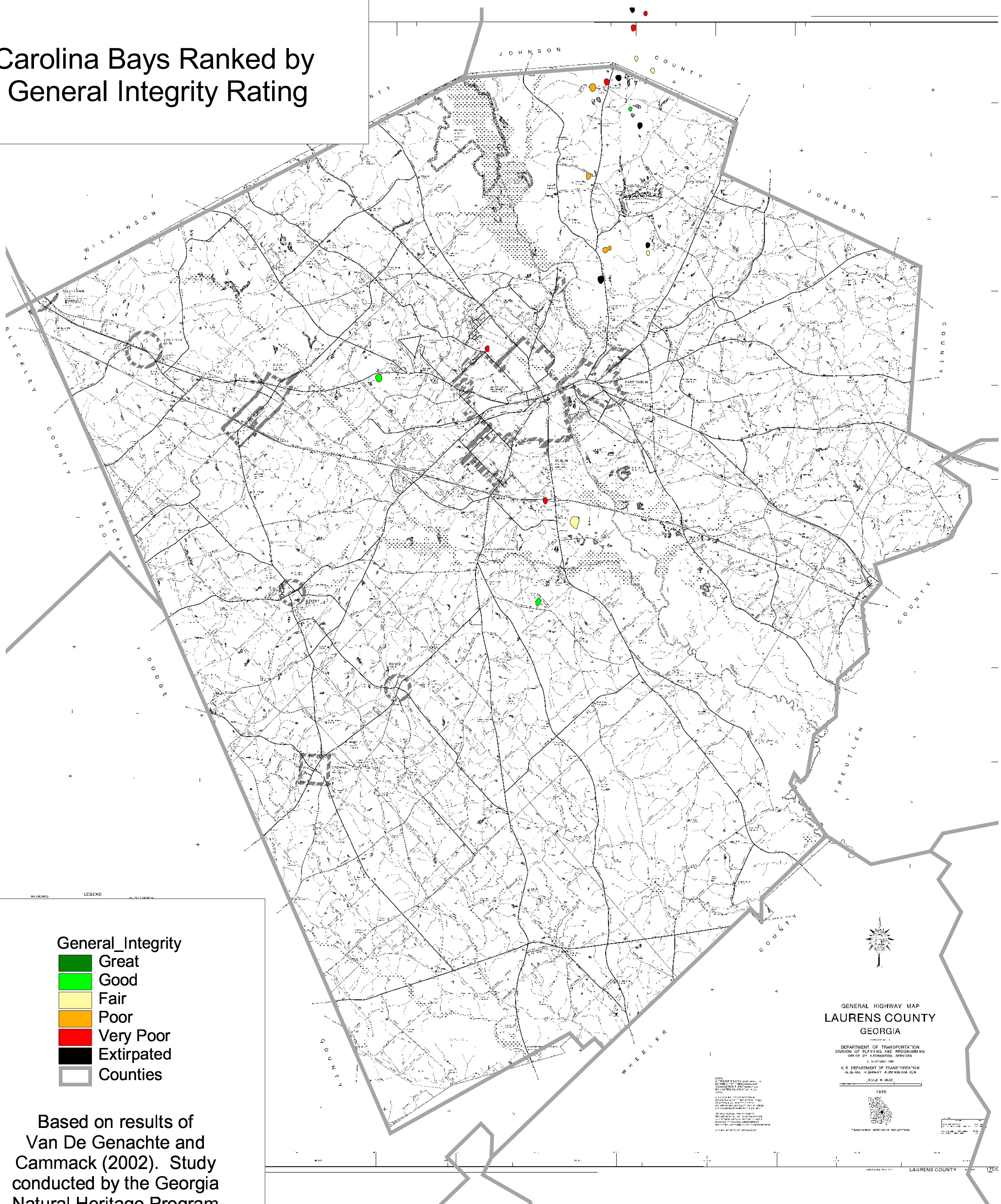


General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

LAURENS COUNTY

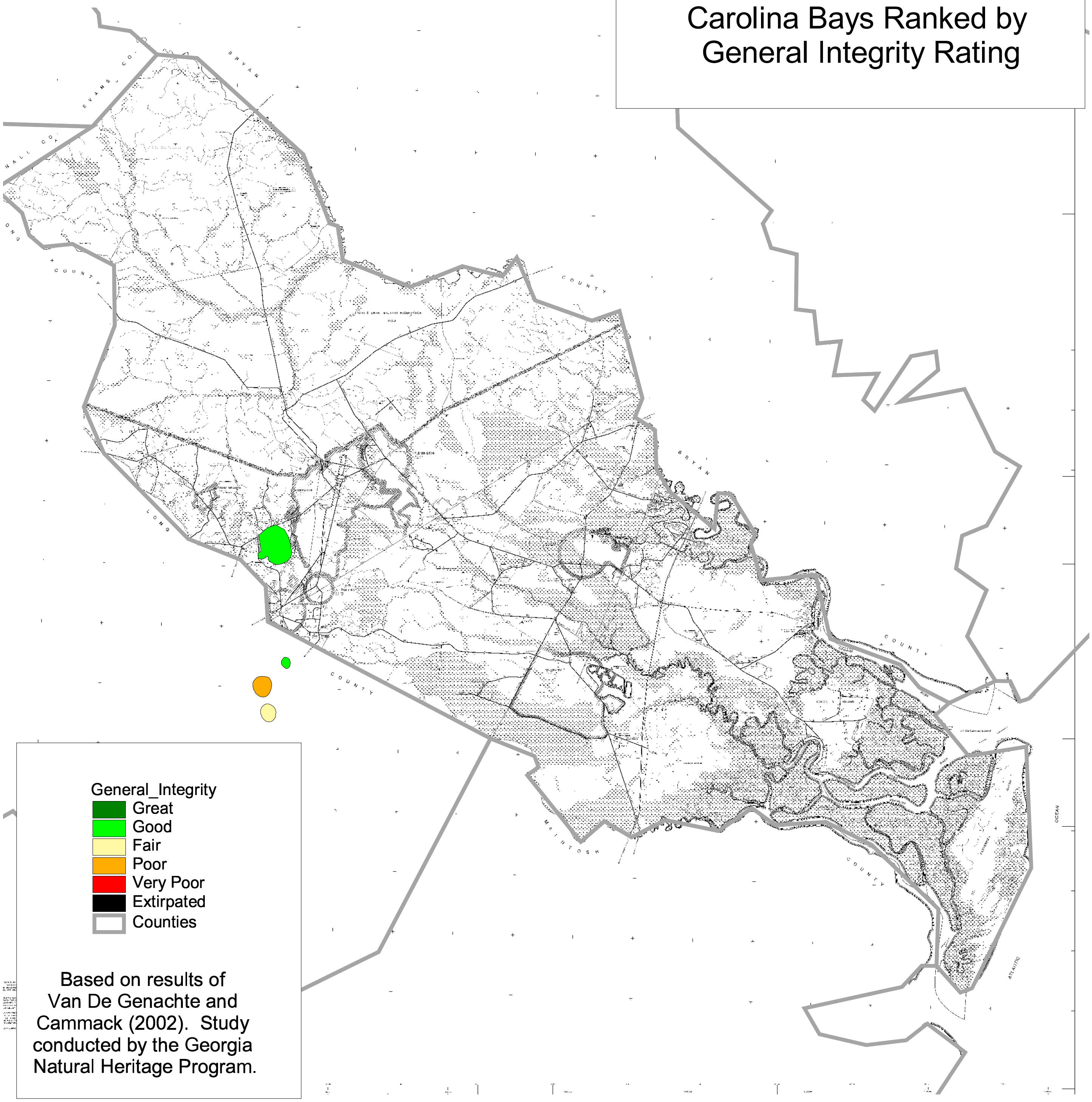
Carolina Bays Ranked by General Integrity Rating



Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

LIBERTY COUNTY

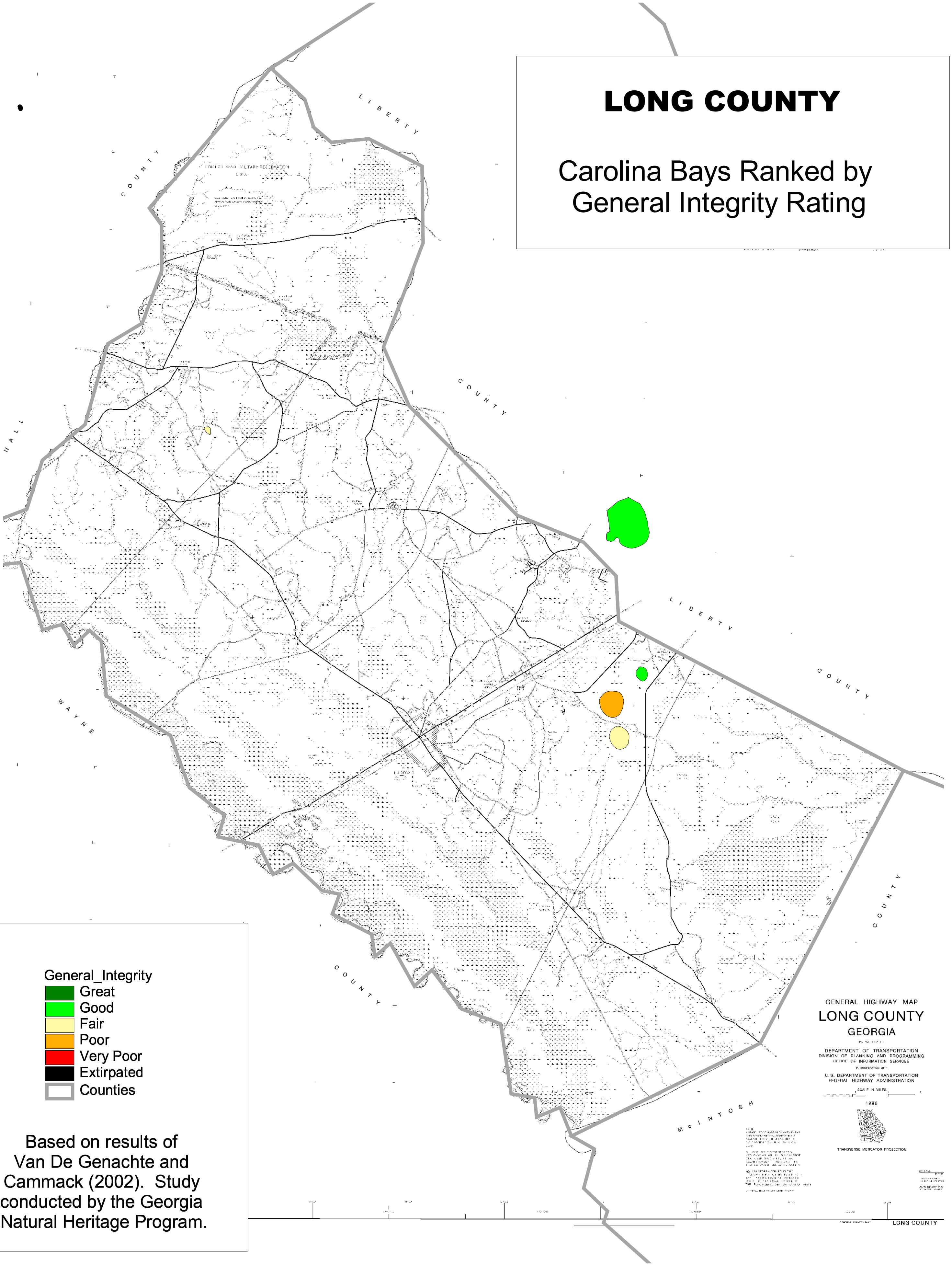
Carolina Bays Ranked by General Integrity Rating



Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

LONG COUNTY

Carolina Bays Ranked by General Integrity Rating

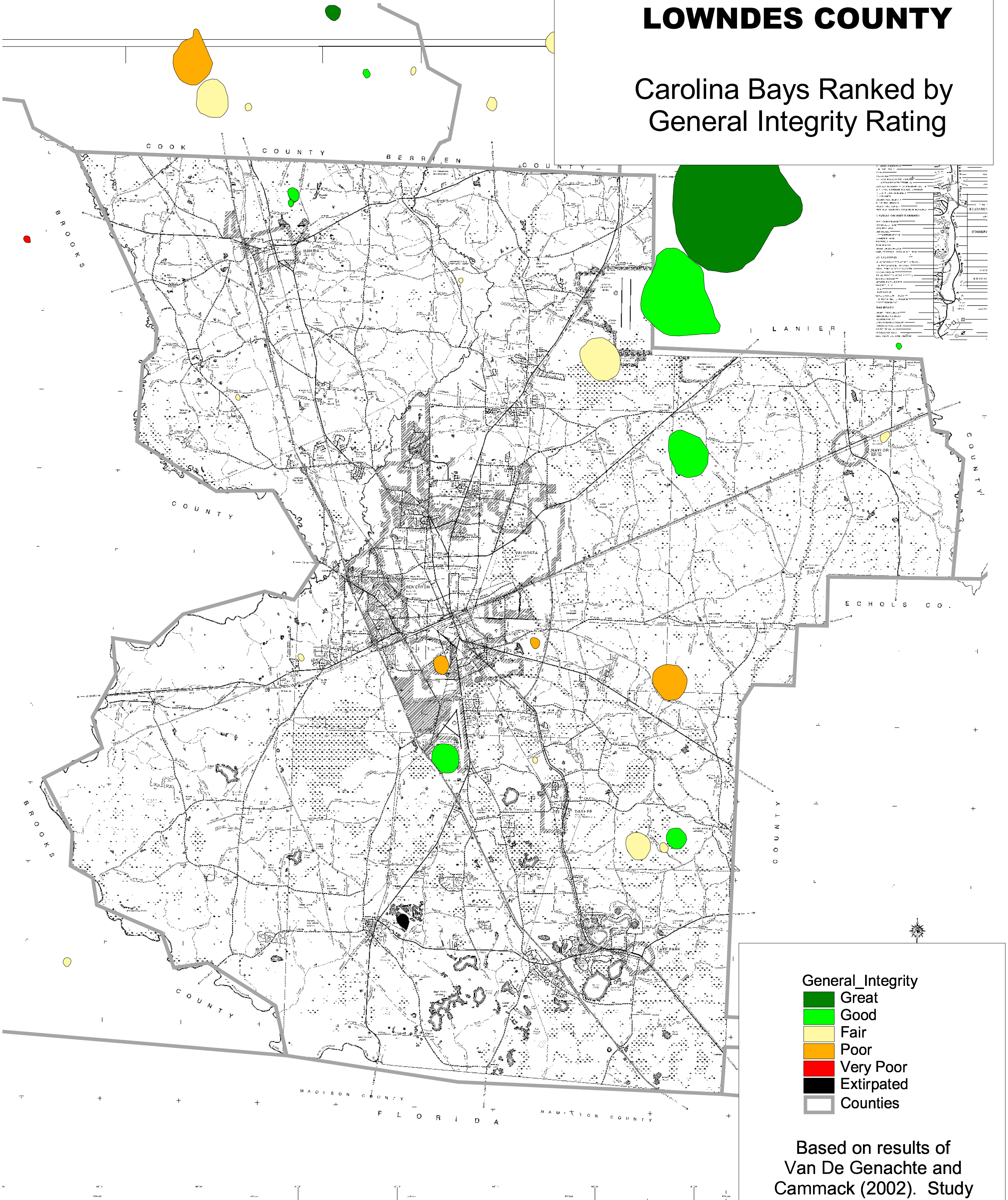


General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

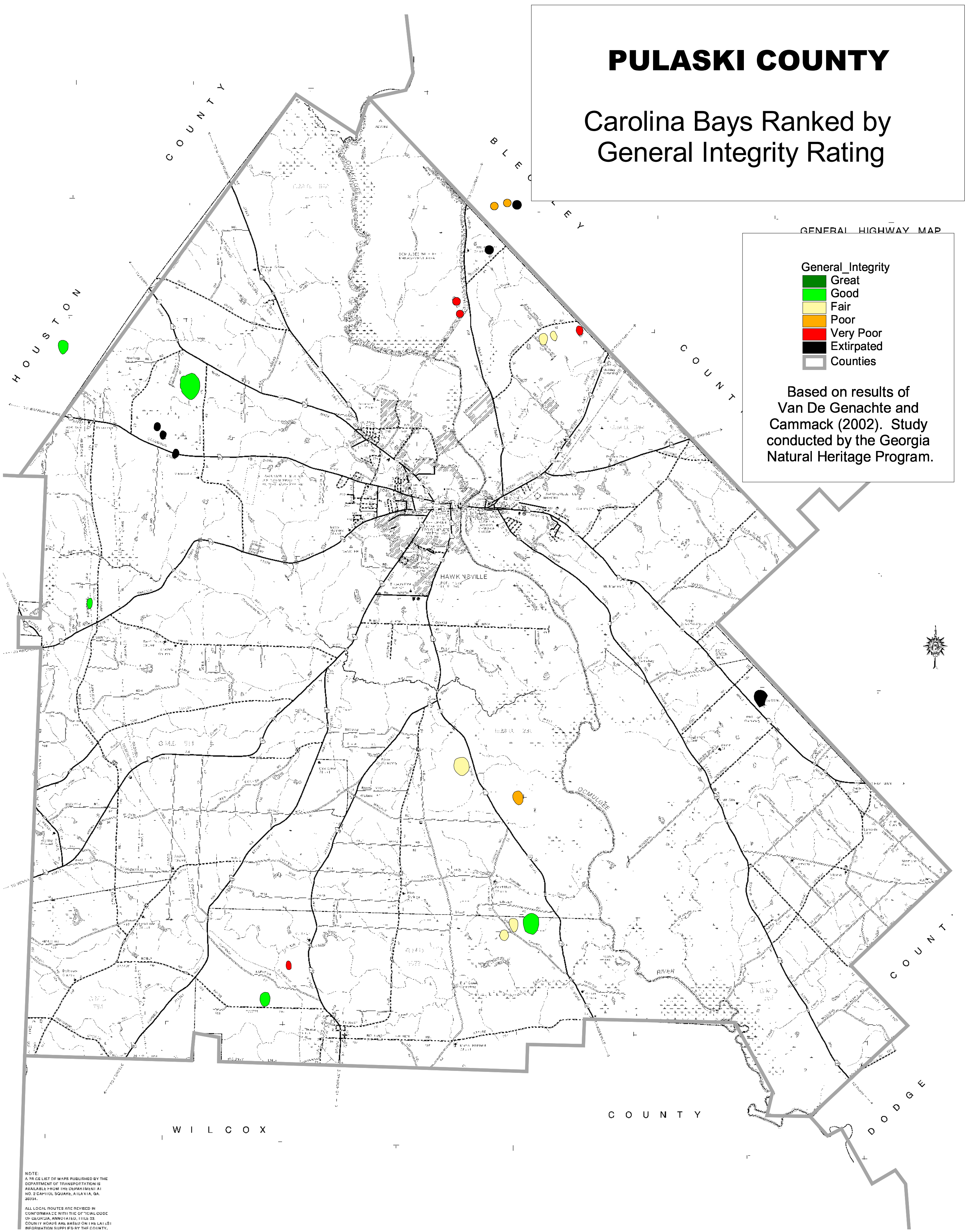
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

LOWNDES COUNTY

Carolina Bays Ranked by General Integrity Rating

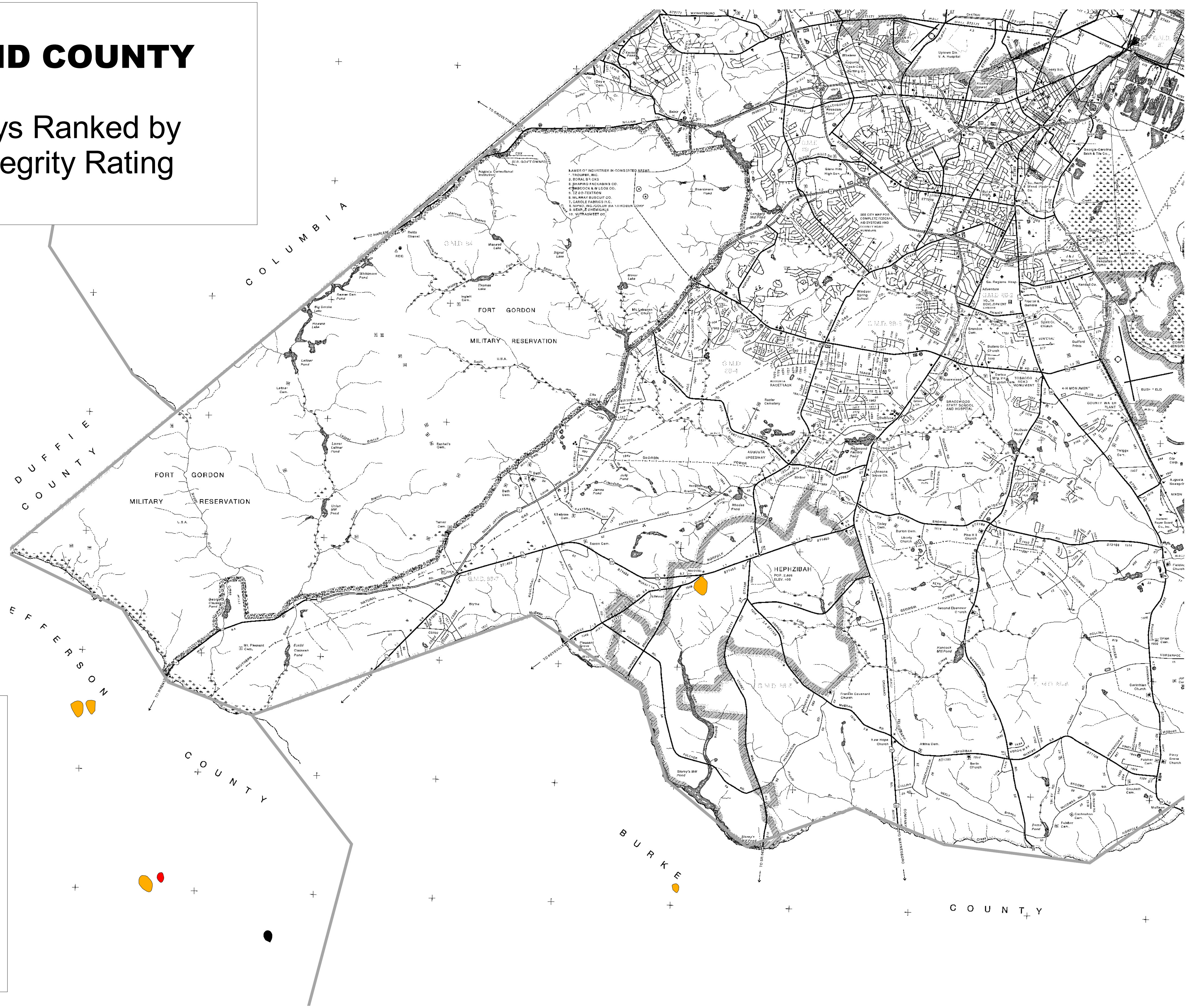


Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.


PULASKI COUNTY
Carolina Bays Ranked by General Integrity Rating
GENERAL HIGHWAY MAP
General_Integrity
Great
Good
Fair
Poor
Very Poor
Extirpated
Counties
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.
HOUSTON COUNTY
BLECKLEY COUNTY
DODGE COUNTY
WILCOX COUNTY
HAWKINSVILLE
OCMULGEE
RIVER

RICHMOND COUNTY

Carolina Bays Ranked by General Integrity Rating

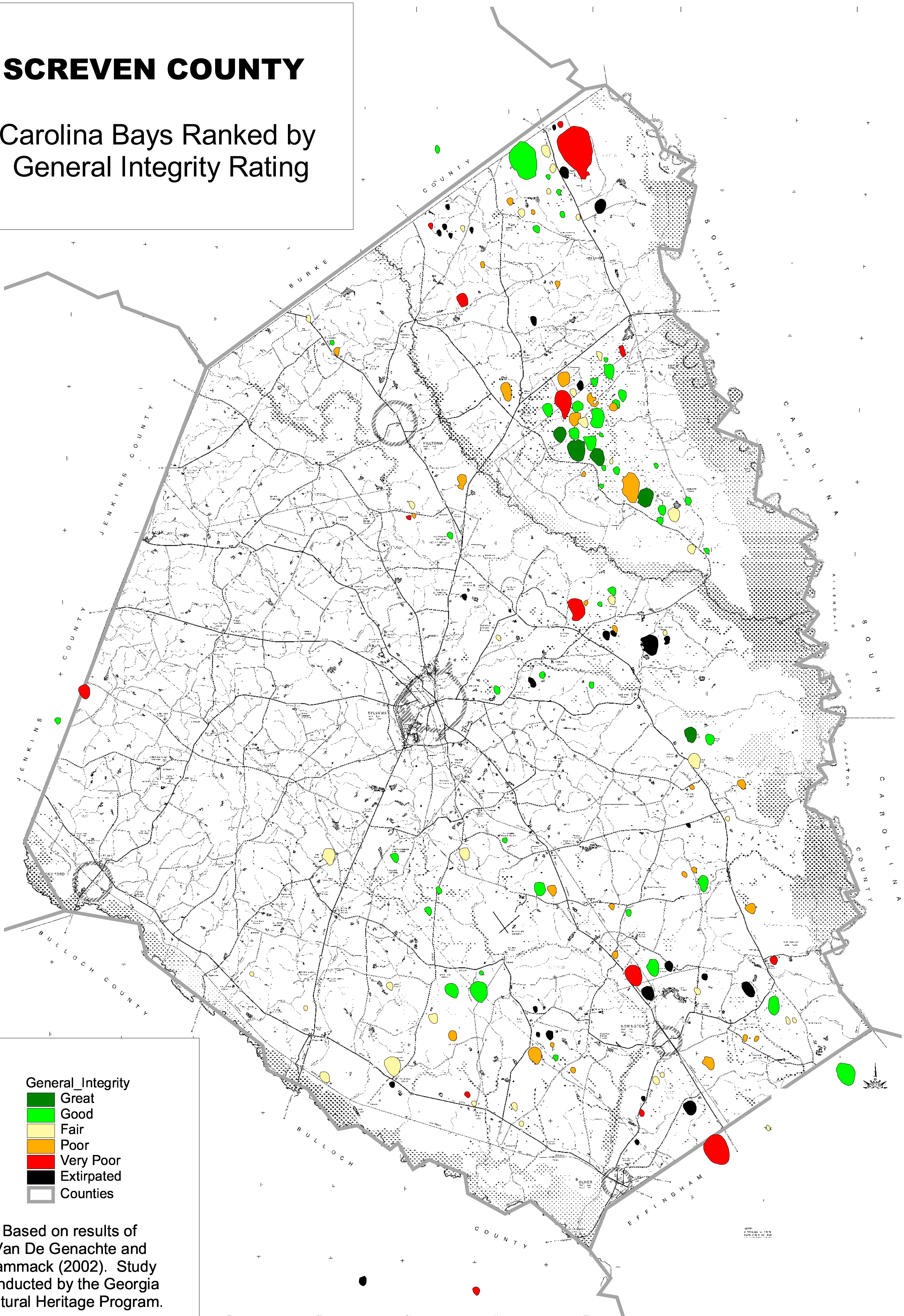


General_Integrity
- Great
- Good
- Fair
- Poor
- Very Poor
- Extirpated
- Counties

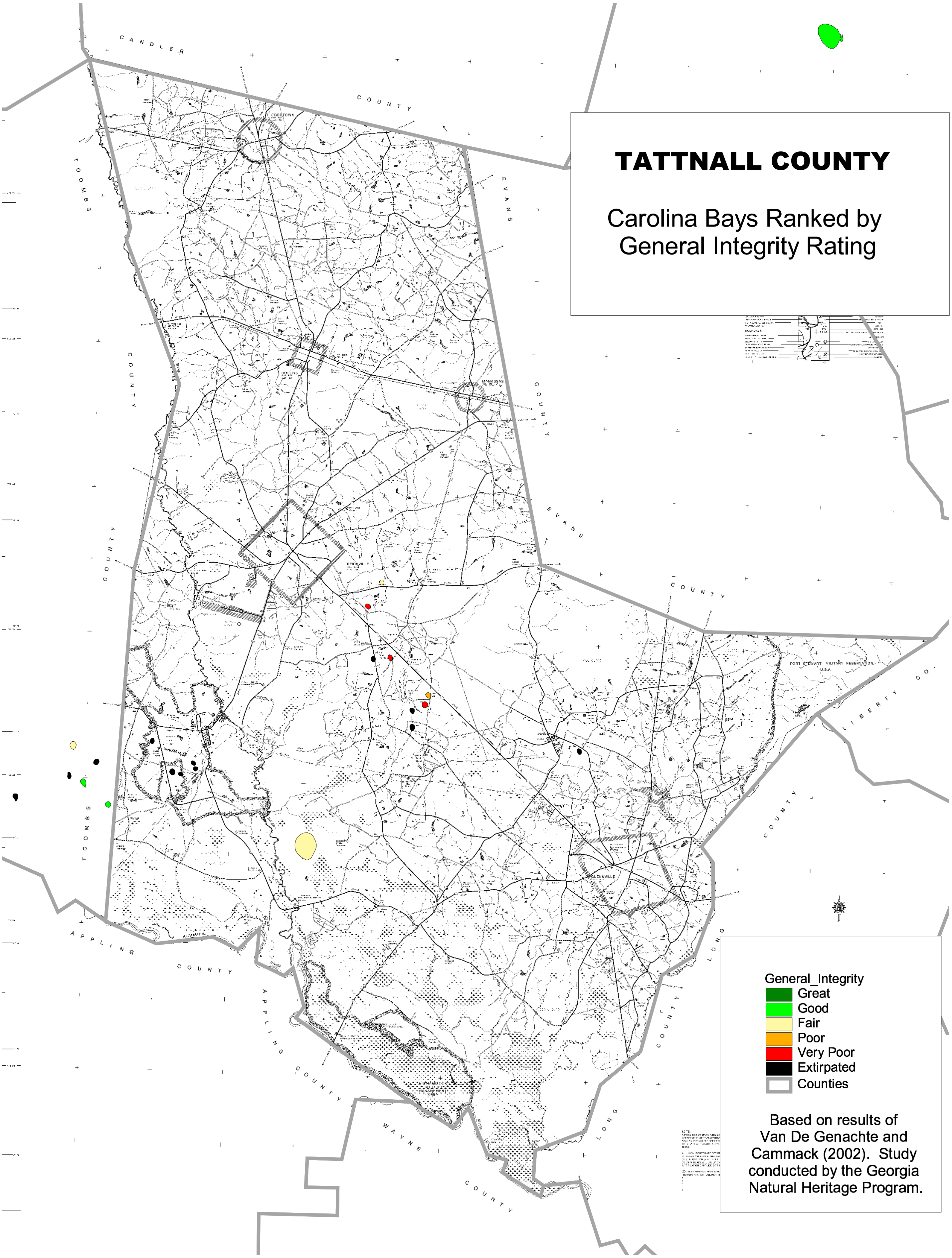
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.

SCREVEN COUNTY

Carolina Bays Ranked by General Integrity Rating

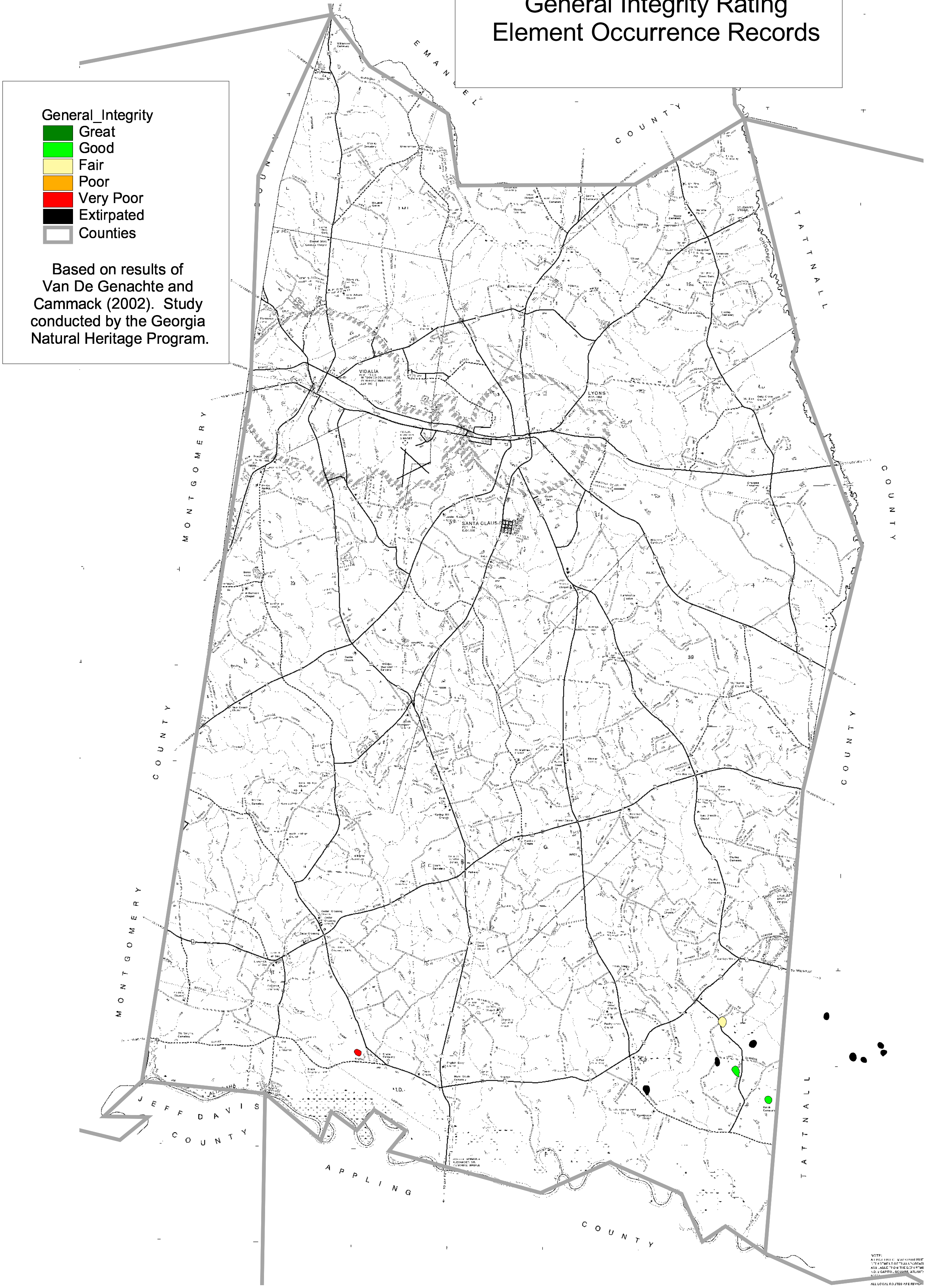


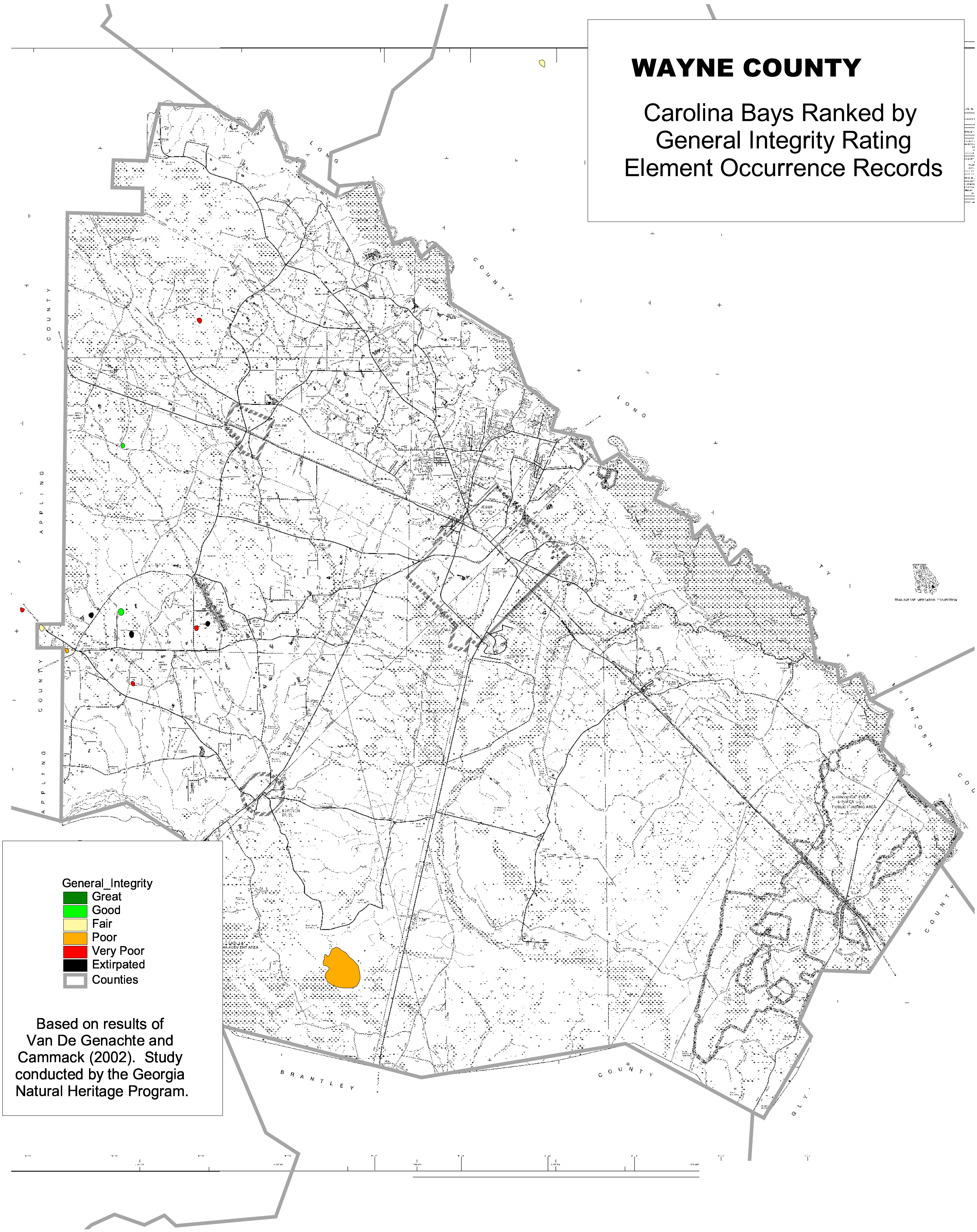
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.


TATTNALL COUNTY
Carolina Bays Ranked by General Integrity Rating
General_Integrity
Great
Good
Fair
Poor
Very Poor
Extirpated
Counties
Based on results of Van De Genachte and Cammack (2002). Study conducted by the Georgia Natural Heritage Program.
CANDLER COUNTY
TOOMBS COUNTY
EVANS COUNTY
LIBERTY CO
LONG COUNTY
APPLING COUNTY
WAYNE COUNTY
COBBTOWN
MANASSAS
REIDSVILLE
GLENNVILLE
FORT STEWART MILITARY RESERVATION U.S.A.

TOOMBS COUNTY

Carolina Bays Ranked by General Integrity Rating Element Occurrence Records

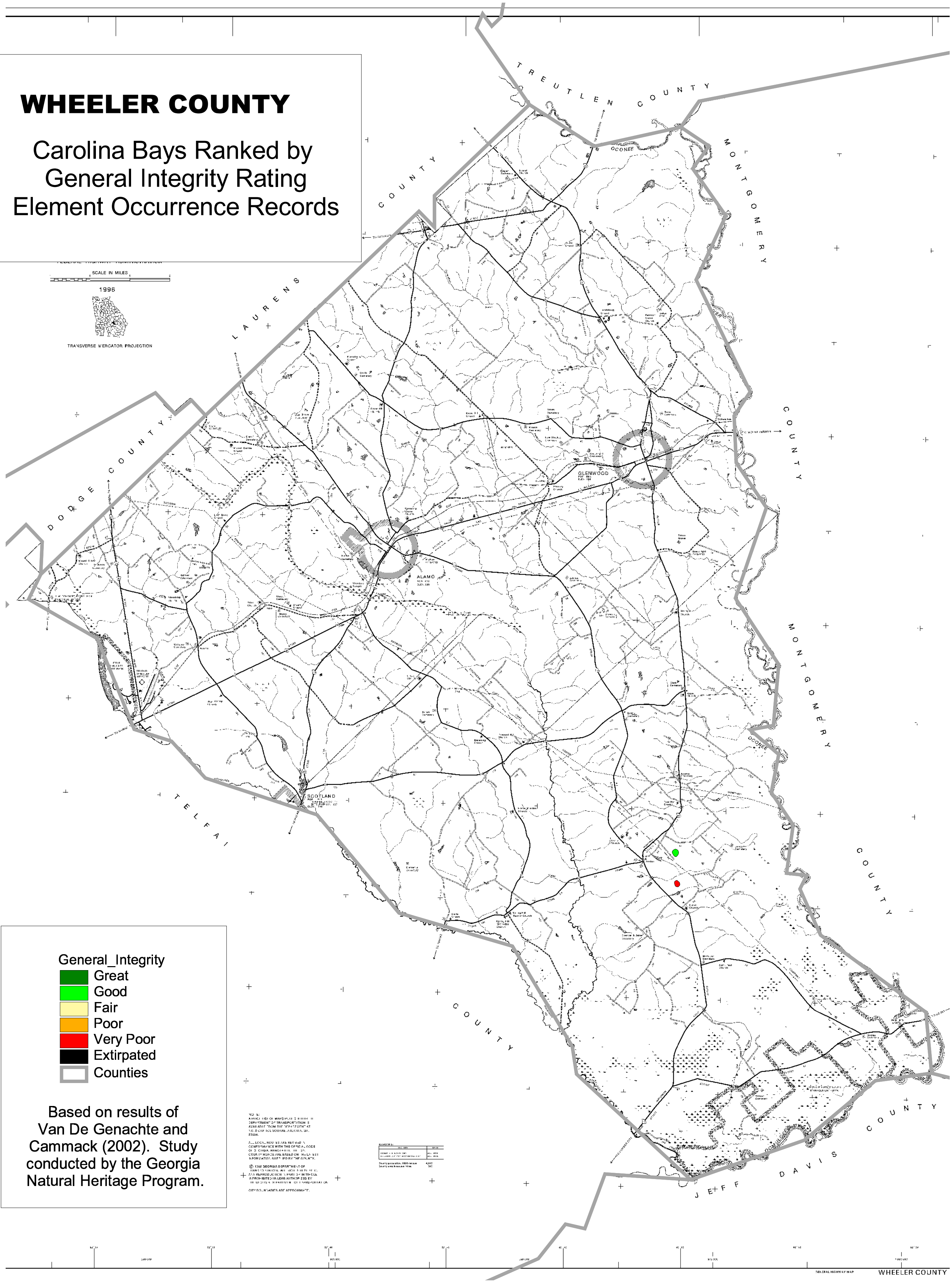




WAYNE COUNTY
Carolina Bays Ranked by
General Integrity Rating
Element Occurrence Records
General_Integrity
Great
Good
Fair
Poor
Very Poor
Extirpated
Counties
Based on results of
Van De Genachte and
Cammack (2002). Study
conducted by the Georgia
Natural Heritage Program.
LONG
COUNTY
APPLING
COUNTY
BRANTLEY
COUNTY

WHEELER COUNTY

Carolina Bays Ranked by
General Integrity Rating
Element Occurrence Records



Based on results of
Van De Genachte and
Cammack (2002). Study
conducted by the Georgia
Natural Heritage Program.

WILCOX COUNTY

Carolina Bays Ranked by General Integrity Rating